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FARM MACHINERY AND PROCESSES MANAGEMENT IN SUSTAINABLE AGRICULTURE 2017

IX International Scientific Symposium

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Edmund Lorencowicz, Jacek Uziak, Bruno Huyghebaert

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INTRODUCTION

It is already the ninth time we publish proceedings of the International Scientific Symposium "Farm Machinery and Process Management in Sustainable Agriculture". And once again, the Symposium is the result of an effective and satisfying collaboration between the University of Life Sciences in Lublin and the Walloon Agricultural Research Centre. As in previous years, the event received the support from the European Society of Agricultural Engineers (*EurAgEng*), an organization which promotes the development of Agricultural and Biosystems Engineering and its people. The Symposium also received generous encouragement and backing from sponsoring institutions, which assistance is gratefully acknowledged.

Sustainable agriculture, which integrates system of plants and animals' production practices, with long term view of not depleting the Earth's resources or polluting its environment, has a lot of different facets. As a concept, it requires understanding of the ecosystem and its functions. As a research subject, it requires interdisciplinary approach. In that respect, we are happy to recognize contributions, to this year Symposium, from academics and practitioners from several disciplines representing 19 countries. We are sure that during the event a variety of ideas, thoughts, beliefs and values will be shared and will contribute to the development of sustainable agriculture.

These proceedings contain 82 reviewed research papers, which were presented during the Symposium. The publication has an International Standard Book Number (ISBN), and additionally, each paper has an individual Digital Object Identifier (DOI).

Editors

Edmund Lorencowicz, Jacek Uziak, Bruno Huyghebaert

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AN OVERVIEW OF DEVELOPMENT OF A RICE PROCESSING PLANT FOR RURAL USE

Alex F. ADISA[1], Ibukun A. OLA[1], Ezekiah S. A. AJISEGIRI[1], Babatunde A. ADEWUMI[1], Salami O. ISMAILA[2], Nurudeen O. ADEKUNLE[2], Sunday O. ADIGBO[3]
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Keywords: overview, development, sustainable agriculture, rice processing plant

ABSTRACT

The short fall in capacity and quality between locally produced rice for example in developing countries like Nigeria (2.8 million tons) and domestic consumption (5.9 million tons) called for developing a low cost and efficient rice processing machine for improved capacity and quality for sustainable agricultural production. Rice processing plant development was carried out to the point of production at Federal University of Agriculture, Abeokuta, Nigeria for rural farmers. Out of locally available materials searched for, industrial rubber roller material performed best with coefficient of dehulling, coefficient of wholeness, dehulling efficiency and cleaning efficiency of values 66.00%, 0.77, 0.88 and 97.00% respectively.

INTRODUCTION

In developing countries, most of rice crop is produced on small scale farms in rural areas, where rice sale faces competition from imported rice which is favoured for it long white grains. The short fall in capacity and quality between locally produced rice (2.8 million tons) and domestic consumption (5.9 million tons) in Nigeria (USDA, 2012) called for developing a low cost and efficient rice processing machine for improved capacity and quality. Imported rice, although widely considered less tasty, demands less preparation as it contains no dirt and stones. Eliminating stones and dirt from rice produced by using a dehuller/destoner made from locally available materials at low cost when compared with expensive imported parts would allow rice produced from rural areas to compete favourably with imported rice. Raising the quality of local rice might discourage rice importation and boost local production.

Rice Dehusking Technology

Rice dehusking is the process by which it grain is separated from the glumes that enclose it. Apart from the labour intensive type of small scale rice dehusking by pestle and mortar, there are generally two major principles of mechanical dehusking of paddy rice which are shearing and impact types. According to International Rice Research Institute (IRRI, 2009), three different husking technologies are commonly used which are steel husker, under runner disk husker and rubber roller husker. Roller husker method of hulling can achieve hulling efficiencies of 85% to 90% with minimum broken or cracked grain. Many simple and sophisticated machines have been developed to carry out these processing operations in developed countries. There is need to move from making use of hand tools and develop more efficient simple rice processing machines to meet rural farmers' need in food production.

METHODOLOGY

Overview Development of Rice Processing Plant

A team of researchers in March 2010 commenced work on rice dehusking/destoning machine project at Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) of Federal University of Agriculture, Abeokuta, Nigeria for use in rural areas where most of the rice production comes from, Adisa *et al* (2016). The machine prototype was developed from locally available materials, a continuation of past work done earlier and now to production stage.

Design and development of roller rice dehusking and destoning prototype machine was carried out which include design of small capacity roller rice dehusking machine, assessment of power demand, minimized the power requirement, incorporated a destoning unit, grain metering unit and selected suitable roller material and found alternative sources of power like petrol engine and electricity. Rice hulling operation is shearing principle of the roller huller where paddy passes between two horizontal rollers that revolve in opposite directions at 30% difference in speeds.

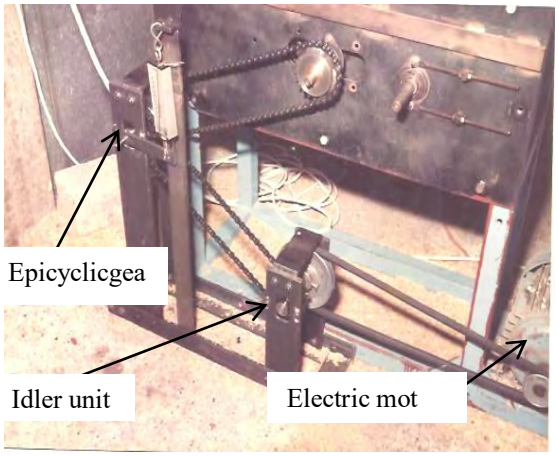

Figure 1. Epicyclic Torquemeter on the first huller

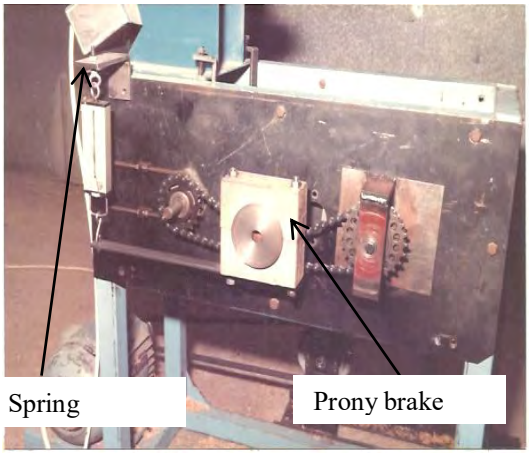

Figure 2. Prony brake assembly on the first machine huller machine

The total power required was found to be 110 watts while 41 watts was absorbed by the machine to dehusk 49 kg/h of paddy rice, Adisa and Inns (2012). Figures 1 and 2 shows the epicyclic dynamometer, while Figure 3 is the first dehusker produced which was further worked upon.

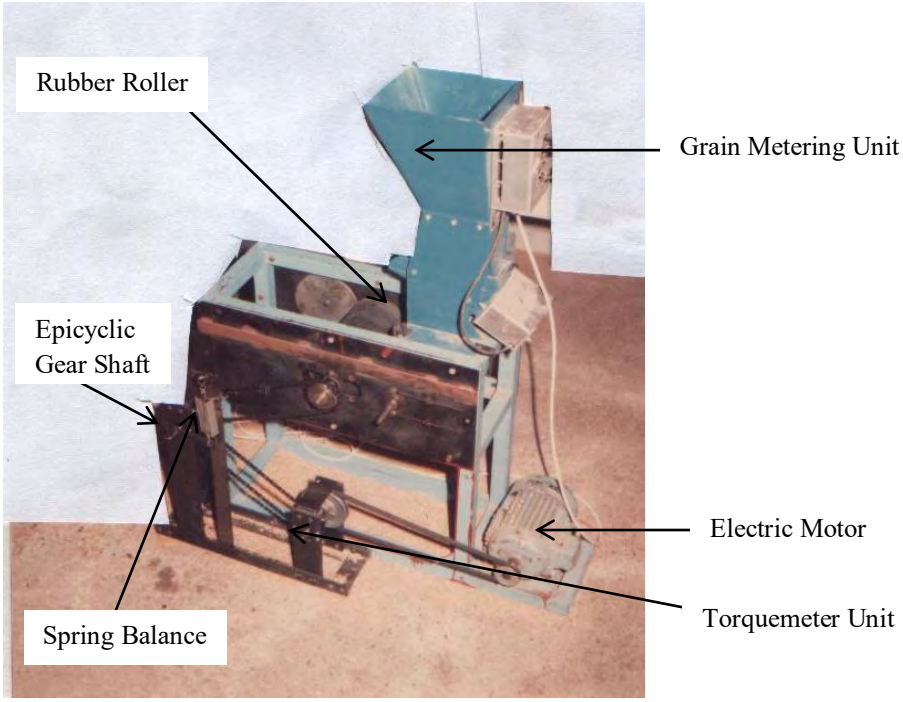

Figure 3. Electric motor, prony brake, grain metering unit and huller of first machine assembly.

Figure 4 is a picture of one of the peeled up shoe leather cover on roller which was the case for four types of them that was tried. About 4.5 kg was used for trial run which began to peel off during dehulling and got worn out as a result of friction. About 15% of paddy was dehulled with 50% wholeness which then resulted in the search for alternative roller of more superior property, knolled *Teflon* rollers as shown in Figure 5 and Figure 6 is the second prototype with destoner.

Aerodynamic Mechanism Consideration

Fluid flow occurs around the solids and the problem involves the action of the forces exerted by the fluid on these solids. Determination of some physical properties such as drag coefficient, terminal velocity and Reynolds number were considered in the design, Mamah *et al.* (2016). The air velocity, air volume and relative humidity were measured by digital air flow meter. Moreover, a number of parameters were identified to influence the separation of particles in fluid medium. Such parameters are: (i) fluid velocity (ii) particle direction in air flow (iii) particle feed rate (iv) loading ratio (v) direction at which particle is injected (vi) resilience time of particle in the separation chamber, the ratio of grain to material other than grain (MOG) and air turbulence intensity (Hamilton and Butson, 1979).

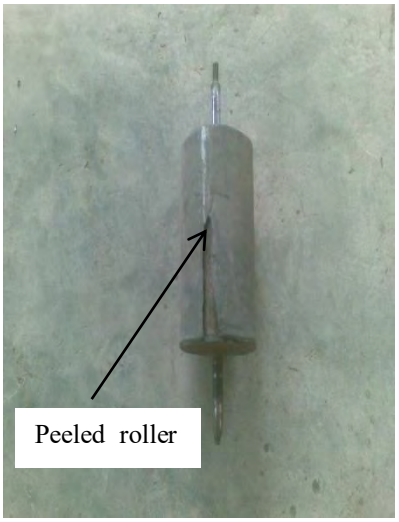

Figure 4. Peeled shoe leather on roller

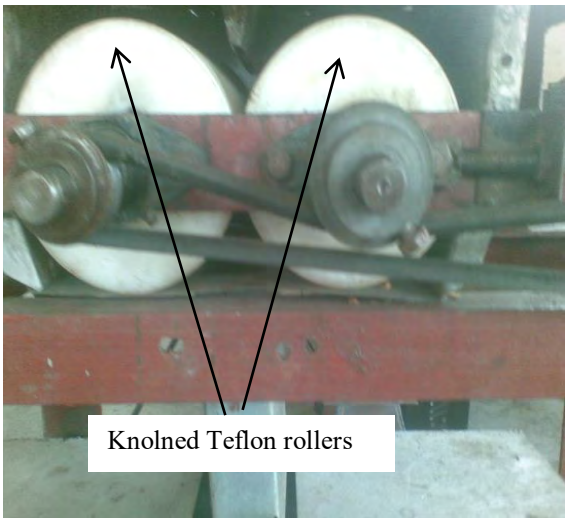

Figure 5. Teflon rollers on the second machine

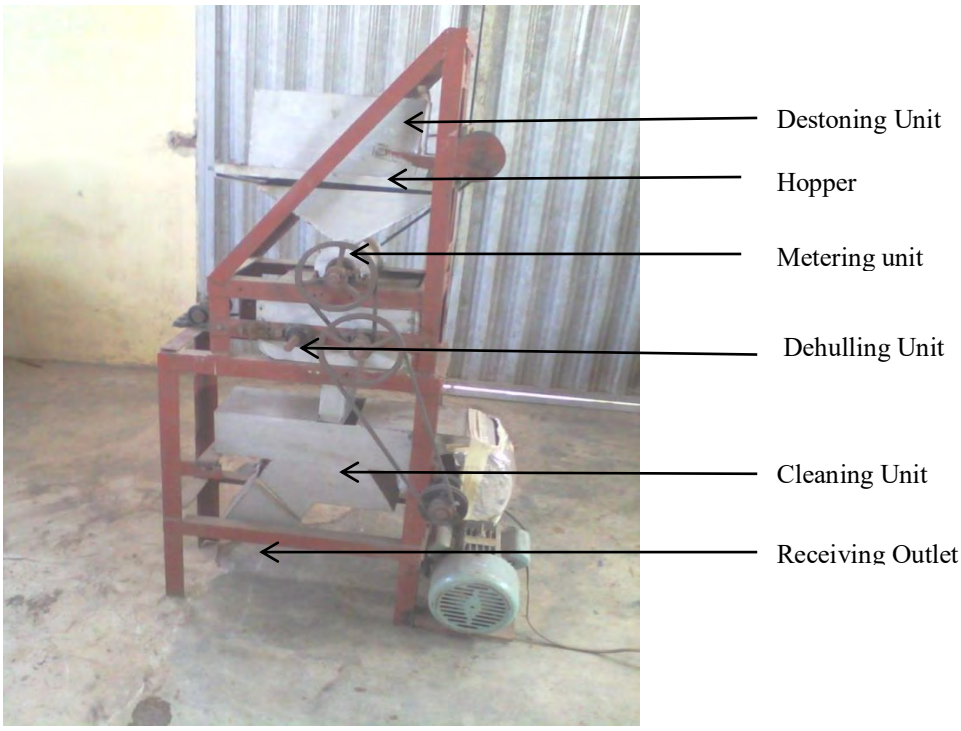

Figure 6. Second prototype rice dehusking / destoning machine with Teflon rollers.

A large amount of air was blown from cleaner blower unit which separates dehulled samples into three items viz. chaff, hulled rice and stones which comes from three different outlets. Figure 7 shows the final prototype dehuller/destoner. Table 1 shows the critical operating parameters with coefficient of dehulling of 0.77, coefficient of wholeness of 0.88, cleaning efficiency of 97% and capacity utilization of 97% which cannot be compared with any known rice processing traditional nor hand tools.

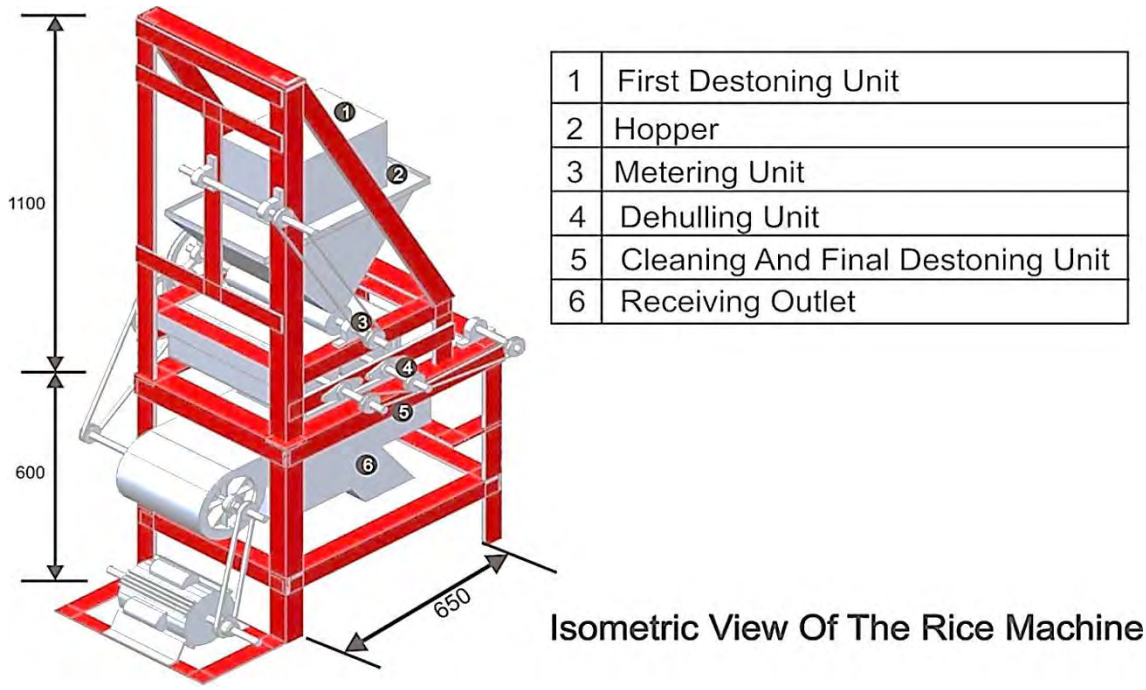

Figure 7. Isometric view of the final rice dehusking and destoning machine

Table 1. Operating parameters of the prototype dehuller

S/No	Performance Parameters	Maximum Values
1	Coefficient of dehulling	0.77
2	Coefficient of wholeness	0.88
3	Dehulling efficiency, %	66
4	Dehulling recovery, %	76
5	Cleaning efficiency, %	97
6	Output capacity, kg/h	18.12
7	Hulling capacity, kg/h	10.86
8	Capacity utilization (CU), %	97
9	Air velocity	9.8m/s
10	Air volume	0.25m³/s

CONCLUSIONS AND RECOMMENDATION

This research work shows that the milling efficiency was affected by the machine adjustment due to excessive breakage recorded when the machine was operated with single adjustment for all the paddy varieties. The optimum moisture content on wet basis for all the paddy varieties was in group A (12%). The dehulling efficiency of the rubber roller dehusker was 63.75%, Coefficient of hulling was from 0.44 to 0.77, coefficient of wholeness was from 0.55 to 0.88 and the cleaning efficiency obtained for the rice varieties was 82 to 97%. The terminal velocity of the rice grain was 7.5 m/s while the air velocity of blower was 9.8 m/s. The rubber rollers maximum coefficient of

dehulling, coefficient of wholeness, dehulling efficiency and cleaning efficiency for the rubber roller dehusking machine were of higher values than using Teflon rollers on the same machine. The introduction of this machine with coefficient of hulling of 0.77, cleaning efficiency of 97% and coefficient of wholeness of 0.88 in Countries where majority of rice processing is done with pestle and mortar will go a long way to contribute and sustain and improve agricultural production.

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THE INFLUNCE OF WHEAT HARDNESS ON ENERGY CONSUMPTION DURING THE WHEAT MILLING

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Keywords: hardness, milling, specific energy, efficiency

ABSTRACT
Wheat is generally used for a food after converting grain components into different degrees of flour. The perfect milling operation needs to get enough knowledge about kernel mechanical properties and mainly hardness, to estimate correctly its effect on grinding performance. This study determined the influence of wheat hardness on milling energy and efficiency. The results showed great effect of wheat hardness on milling performance. The lowest values of specific energy were recorded in the case of cultivar Katoda. This cultivar is characterised by the lowest value of hardness index. The study indicates that, it is possible to select cultivars with low specific energy and high efficiency during milling, which in effect will cause a reduction of production costs.

INTRODUCTION

Since the dawn of agriculture, wheat has been the major source of food and calories for mankind worldwide (Krasileva, Vasquez-Gross, Howell, Bailey, Paraiso, Clissold, Simmonds, Ramirez-Gonzalez, Wang, Borrill, Fosker, 2017). It is a leading source of protein in a human diet for its high protein content (Bhat, Wani, Hamdani, Gani, Masoodi, 2016). Examining the mechanical properties of wheat grain shows the way to optimize the machine designs and helps us determine the forces endured by wheat grains through milling process and leads to advance improvements make possible for us to drive an innovation process, (Ahmed, Nadulski, Kobus, Zawiślak, 2015). Grinding wheat is one of the oldest techniques of food processing, (Hourston, Ignatz, Reith, Leubner-Metzger, Steinbrecher, 2017), in which wheat endosperm is gradually grinded to a particular size range of flour through a progressive size-reduction process, (Patwa, Malcolm, Wilson, Ambrose 2014). Although several types of milling machines are used now, but, the most common is roller mill which grind by share and compression forces to get wide reduction of particle size (Dziki, 2011). The energy consumption through wheat milling operation has attracted a lot of scientist attentions. Consuming energy during wheat grinding operation is the highest in whole cereal industry processing (Dziki, Laskowski, 2005). Grinding energy and flour yield are affected extensively by tempering [Warechowska, 2014) and hardness (Dziki, Cacak-Pietrzak, Miś, Jończyk, Gawlik-Dziki, 2014). On the other hand, energy consumption of grain grinding depends mainly on kernel hardness, which defined as the ratio of rupture force to the deformation at the rupture point of the grain that achieved by Instron machine test (Başlar, Kalkan, Kara, Ertugay, 2012), and influenced by different factors such as moisture content (Clarke, Rottger, 2016). The energy consumption and final product specification are the main indicators for both producer and consumer (Raigar, Prabhakar, Srivastav, 2017). Thus, specific grinding energy in the milling operation is calculated as the ratio of the grinding energy to the mass of the wheat used to grind (Dziki, Laskowski, 2010). The milling efficiency is an important indicator to define wheat milling performance, (Warechowska, Warechowski, Skibniewska, Siemianowska, Tyburski, Aljewicz, 2016). The values of milling efficiency index are decrease with medium-hard wheat, but

increase with hard wheat but Warechowska, Markowska, Warechowski, Miś, Nawrocka (2016) and Dziki, Przypek-Ochab (2009) showed a significant effect of the hardness for seven bread wheat grain on grinding efficiency index, and concluded that increasing the grain hardness leads to decrease the grinding efficiency index.

The aim of this study was to reflect more information about the influence of wheat hardness on milling performance. The parameters used to determine machines performance during milling operation were specific energy and milling efficiency.

MATERIAL AND METHODS

The investigations were carried out on three Polish spring wheat cultivars (*Triticum aestivum, ssp. Vulgare*): Arabella, Kandela and Katoda, harvested in 2016, acquired from the plant breeding station DANKO Hodowla Roślin Sp. z o.o. in Chorynia. An analyser of single seeds (SKCS 4100, Perten, Sweden) was used to determine moisture content, mass, substitute diameter and hardness index of single seeds. In this study, three levels of moisture content of wheat kernels were determined: 12%, 14%, and 16%. In order to reach these levels, the grain was conditioned by adding specific amounts of water and mixed several times to ensure good distribution of added water for all kernels. The damped grains were isolated in separated containers for 3 days under normal laboratory temperature of 24±2°C.The grain was ground using a roller mill of the type Quadrumat® Junior (C.W. Brabender® Instruments, Inc., USA). The mill worked in conjunction with a computer system recording the power consumption. The parameters determined in the tests were the specific energy and efficiency of milling, specific energy is the energy used during the milling operation divided by the mass of the flour produced, while the efficiency was the mass of wheat divided by time required for the milling operation. Statistical analysis of the results was made using the software package Statistica 12.0 (StatSoft Inc., Tulsa, OK, USA), using the analysis of variance The significance of differences was verified using the Fisher LSD test.

RESULTS

The study demonstrated a statistically significant effect of cultivar traits of the wheat cultivars studied on hardness index. The results obtained by single kernel analysing are showed in Figure 1.

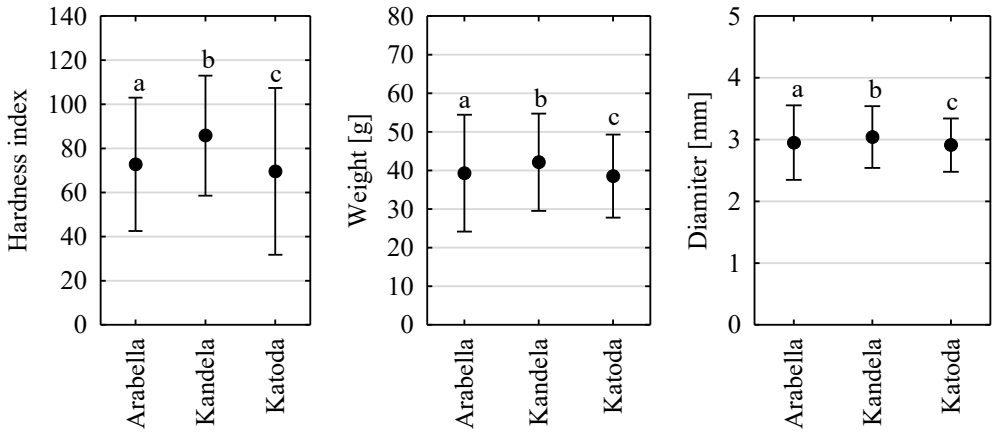

Fig. 1. Basic characteristics of kernel of the tested wheat varieties
a, b, c – values marked with the same letter are not statistically significantly different (p>0.05)

The tests demonstrated an effect of moisture content and the cultivar traits on the values of specific energy and values of efficiency of milling. The changes in the values of specific energy in relation to kernel moisture are presented in Fig. 2.

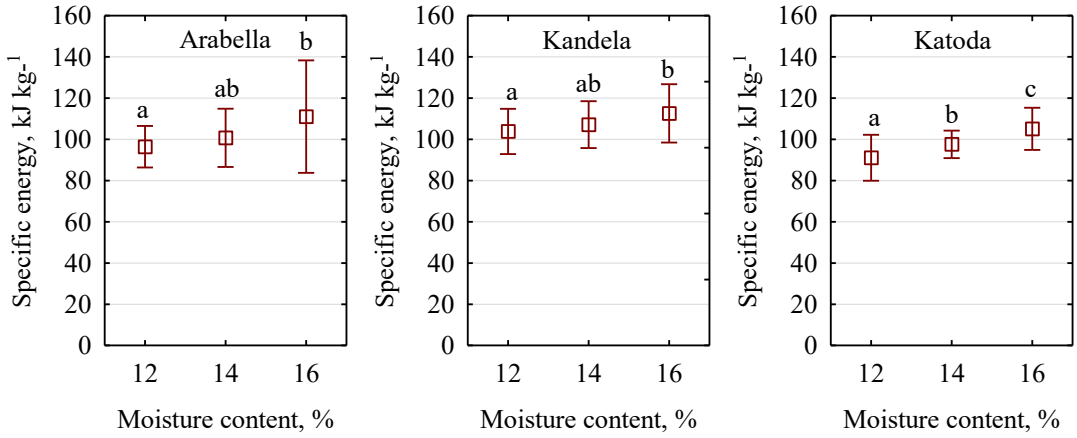

Fig. 2. Effect of kernel moisture content on specific energy for the tested wheat varieties
a, b, c – values marked with the same letter are not statistically significantly different (p>0.05)

The graph shows that in all the cases an increase of kernel moisture causes an increase of the values of specific energy. The lowest values of specific energy were recorded in the case of cultivar Katoda. This cultivar is characterised by the lowest value of hardness index. However cultivar Kandela has highest value of hardness index. Milling this variety showed the highest energy consumption.

The changes in the values of efficiency of milling in relation to kernel moisture are presented in Fig. 3. The graph shows that in all the cases an increase of kernel moisture causes a decrease of the efficiency of milling. The highest efficiency of milling was recorded in the case of cultivar Katoda.

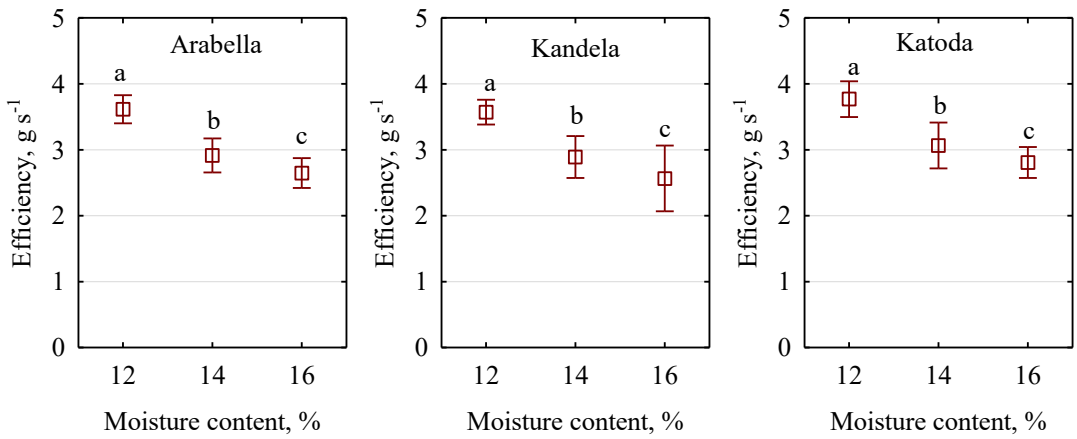

Fig. 3. Effect of kernel moisture content on efficiency of milling process for the tested wheat varieties
a, b, c – values marked with the same letter are not statistically significantly different (p>0.05)

CONCLUSION

The study demonstrated a statistically significant effect of cultivar traits of the wheat cultivars studied on hardness index. The tests demonstrated an effect of moisture content and the cultivar traits on the values of specific energy and values of efficiency of milling. Increasing the moisture content of tempering wheat leads to increase specific

energy of the milling operation for all species, while increasing moisture content leads to decrease efficiency. The lowest specific energy and highest efficiency of milling was recorded in the case of cultivar Katoda. The study indicates that, taking into account only the aspect of energy consumption, it is possible to select cultivars with low specific energy and high efficiency during milling, which in turn causes reducing the production costs, since hard wheat needs high specific energy and reduce the efficiency.

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DETERMINATION OF VOLATILE COMPOUND IN FERMENTED CAMEL MILK BY GC-MS

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Keywords: Fermented Camel Milk, volatile compounds, Lactic acid bacteria

ABSTRACT

Camel milk is important in sustainable development and in ensuring the nutritional needs of future generations. Thus, this study focuses on camel milk products. Volatile compounds were investigated for fresh camel milk and fermented camel milk using a mixture of the starter bacteria formed of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. The results showed difference in quality of volatile compounds in fresh camel milk from those found in fermented camel milk, with the presence of compounds such as -:9,12,15 Octa- decatrienoic acid, 2-[(trimethylsilyl) oxy]- 1- [(trimethylsilyl) oxy] methyl] ethyl ester, (Z,Z,Z), cis-13 Eicosenoi cac id, pyridazine2,7- Diphenyl -1,6-dioxopyr idazino [4,5:2',3'] pyrrolo[4',5'-d] ,Octa-decanoic acid,4-hydroxy-, methyl ester, Stearic acid, 3-(octadecyloxy) propyl ester, 1,2-Propanediol, diacetate, Glycine, N-[(3à,5á,7à,12à)-24-oxo-3,7,12-tris [(trimethylsilyl)oxy]cholan-24-yl]-, methyl ester, ethyl allocholate iso1.82, Octasiloxane hexadecamethyl. In fresh camel milk either the compounds that were diagnosed in fermented camel milk were included on, such as tert- Hexadecanethiol, glycerin Desulphosinigrin. The results indicated that many volatile compounds were found in fresh and fermented camel milk, with a clear difference in quality and concentration. In conclusion, the use of the starter bacteria produced an obvious change in the flavor of fermented camel milk.

INTRODUCTION

Number of camels in Iraq increased in the period 1995-2014 from 5,400 to 62,000 camel heads (FAO, 2014). Production of camel milk is one of the most important goals to achieve food and agricultural interdependence in Iraq. Moreover, camel milk substantially contributes in the sustainable development through camel milk products and dairy products. One of these products is fermented camel milk. The fermentation process is one of the most important food industry methods, especially in the field of food preservation technology. It results in desired changes in food making it more popular in terms of taste, and it has a role in preventing the growth of pathogenic microorganisms (Mufandaedza *et. al.,* 2006; Mosha& Vicent, 2004).

Naturally fermented camel milk forms a large part of the diet in the desert and semi-desert regions of East Africa (Farah *et. al.,* 1990). It is also used in the manufacture of a number of dairy products such as fermented milk, yoghurt (Elayan *et. al*., 2008) (Hashim *et. al*., 2008). Furthermore, it has a medical importance as an antidote to many infectious diseases, cancers, and diabetes. On the other hand, camel's milk maybe suitable for drinking and the remainder of it, is used to feed young camels (Yagil *et. al.,* 1984) or may be converted into fermented milk by leaving milk for several hours in pottery or leather containers (Yagil and Etzion, 1980; Ramet, 2001). One of the products of fermented milk is Suusac. It is natural yeast as it is made during self-fermentation and under room temperature for one to two days (Lore *et. al.,* 2005). In general, lactic acid bacteria (LAB), which is a substance that is added to food, is generally recognized as safe (GRAS) for human consumption (Aguirre & Collins, 1993).

Some of the plant or microbial extracts have been found to be highly effective as antimicrobial, anti-inflammatory, anti-oxidant, anti-cholesterol, anticancer, liver protection, anti-inflammatory, anti-histamine. The reason is that these extracts contain natural flavonoids, (Hexadecaonoic acid, ethyl ester and n- Hexadecaonoic acid) as well as containing unsaturated fatty acids and docosatetraenoic acid and octadecatrienoic acid (Kumar *et. al.,* 2010).

Volatile compounds are often used as an indicator of milk quality. Many studies have indicated that the estimation of these compounds gives an impression on the conditions of storage and storage temperature (Urbach, 1990). Thus, in countries with abundant of camel milk the focus has been on studying its composition. In Egypt, El-Agamy (1983) found that camel milk contained 3.7% protein, 2.9% fat, 5.8% lactose, and ash 0.7%. The changes to the flavor of milk and its products are the result of the metabolic effects of micro-organisms where secondary metabolites are introduced during the growth phase (Urbach & Milne 1987). Therefore, the aim of this study is to determine the flavor compounds found in fresh camel milk and estimated in fermented camel milk and changes during fermentation.

MATERIAL AND METHODS

Camel milk samples:

Camel milk samples were collected from central and western Iraq and transferred in sterile and cold conditions to the lab for further processing.

Culture growth and maintenance:

Yogurt starter (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* sp. *bulgaricus*) was obtained from Danisco, Denmark and was used to inoculate skim milk at 42ºC, after being incubated for 24 h and cooled after fermentation to 4ºC for short time use.

Preparation of fermented camel milk:

The fermentation process was prepared as described by Rahman *et al.* (2009). The skim camel milk was pasteurized for 30 min in a water bath in 500 ml screwed bottles at 90 C and cooled immediately to 5±1 C in an ice bath. The milk samples (500 ml) were equilibrated for one hour at the fermentation temperature (42ºC) in a water bath before inoculation with the starter cultures. Each sample was inoculated with 5% (10^6-10^7cfu/ml) of mixed yogurt culture (*S. thermophilus* and *Lactobacillus delbrueckii* sp. *bulgaricus*) at a ratio of 1:1. Samples were thoroughly mixed after inoculation and incubated at 42°C for 6h.

Water-Soluble Extracts (WSE):

The water-soluble extracts (WSEs) of fresh camel milk and fermented camel milk samples were prepared as described by Kuchroo and Fox (1982).

Extraction and determination of volatile compounds:

The extraction of the volatile compounds in fresh camel milk and fermented camel milk were performed as recommended by the liquid/liquid or liquid/solid extraction (direct extraction techniques) method (Mariaca and Bosset, 1997; Preininger *et. al*., 1994). This protocol was taken place through acetonitrile solvent for low-fat dairy products. Volatiles

flavored compounds were identified on Gas chromatography –Mass Spectrometry (GCMS) according to Agilent company's instruction manual and according to the following conditions: Column (ZEBRON ZB-FFAP 30meter x 0.25 mm I.D x 0.25 µm(. The operating conditions of the device are: sampling time: 1.00min ‹Inj. Initial temp.:250.00.C, Interface temp: 260.00ºC, Column Inlet Pressure: 56.7 kpa, Total flow: 23.0 ml/min. The oven temperature was 70ºC / 3min and the temperature is 260 ºC / 20 min and the pressure inside the column is 56.7 Kpa / 3 min and the pressure is 185.9 Kpa / 20 min.

RESULTS AND DISCUSSION

Volatile compounds, identified in fresh camel milk by using Gas chromatography - Mass Spectrometry (GC/MS), are listed in Table 1. Figure 1 shows {9,12,15-Octadecatrienoic acid, 2[(trimethylsilyl)oxy]1[(trimethylsilyl) oxy]methyl] ethyl ester,(Z,Z,Z)1.78%.cis-13-Eicosenoic acid.17% pyridazine2,7-Diphenyl-1,6 dioxopyr idazino.[4,5:2',3'].Pyrrol.[4',5'-d]pyridazin 2.10% Octadecanoic acid, 4-hydroxy, methyl.ester.2.02%,.Stearicacid 3-(octade-cyloxy) propyl ester 3.67% 1,2-Propane-diol 3, diacetate.6.59% Glycine, N[(3à,5á,7à,12à)-24-oxo 3,7,12-tris [(trimet-hylsilyl)oxy]cholan-24-yl]-, methyl ester 13.24% Ethyl isoallo.cholate 1.82% Octasiloxane hexadecamethyl 30.76%.

The results showed that there is a mixture of volatile flavor compounds and active and bioactive compounds that can be detected using GC-MS as this device has the ability to diagnose long chain hydrocarbons, alcohols, acids, esters, alkaloids, steroids, and amino and nitrogen compounds (Venkatesh *et. al.,* 2014). The process of compounds diagnosis is based on the calculation of retention time (RT), molecular formula, molecular weight, and concentration (Peak area %). Some of the substances that have been diagnosed as volatile compounds have significant efficacy and the importance as antimicrobial agents, as it found that the substance Glycine,N-[(3à,5á,7à,12à)-24-oxo-3,7,12-tris [(trimethylsilyl)oxy] cholan-24-yl]-,ester methyl is important as an anti-bacterialgrowth (Ganesh &Vennil 2011).

The volatile compounds that have been diagnosed in raw milk using solid phase micro-extraction and by using the GC/MS device are belong to different types, which include compounds in the form of aldehydes chains like hexanal, heptanal, octanal, nonanal, or methyl ketones (2-heptanone and 2-nona- none) or ketones (3-octen-2-one and 3,5-octadien-2-one). However, volatile flavored compounds can be used as a guide and indicator of the oxidizing taste of milk as in the case of the use of aldehydes and ketone compounds (Li *et. al.* 2012).It deserves to note that the materials responsible for flavor dairy products include a large number of volatile compounds (Molimard & Spinnler, 1996; Urbach, 1997). These compounds may include large amounts of free carboxylic acids, sulfur compounds and substances containing alkali nitrogen such as amines and pyridines and many neutral compounds such as carbonyl (met-hyl ketones), aldehydes, primary and secondary alcohol, esters, ketones, ethers, aliphatic and aromatic hydrocarbons (Dafflon *et. al.,*1995).

Table 1. Volatile compounds as analyzed by GC-MS in Fresh camel milk

Compound Name	RT	Molecular Weight	Molecular Formula	Area %
9,12,15-Octadecatrienoic acid, 2[(trimethylsilyl)oxy]-1-[[(trimethylsilyl)oxy]methyl]ethyl ester, (Z,Z,Z)	3.81	496	C27H52O4Si2	1.78
cis-13-Eicosenoic acid	4.52	268	C16H28O3	2.14
pyridazine2,7-Diphenyl-1,6-dioxopyr idazino[4,5:2',3']pyrrolo[4', 5'-d]pyridazine	6.19	355	C20H13N5O2	2.10
Octadecanoic acid,4-hydroxy-, methyl ester	7.12	314	C19H38O3	2.02
Stearic acid,3-(octadecyloxy)propyl ester	7.38	394	C39H78O3	3.67
1,2- Propanediol, 3-(hexadecyloxy)-,diacetate	9.54	400	C23H44O5	6.59
Ergosta-5,22-dien-3-ol, acetate, (3á,22E)-	9.87	440	C30H48O2	11.54
Glycine, N-[(3à,5á,7à,12à)-24-oxo-3,7,12-tris[(trimethylsilyl)o xy]cholan-24-yl]-, methyl ester	11.16	695	C36H69NO6Si3	13.24
Ethyl iso-allocholate	15.92	436	C26H44O5	1.82
Octasiloxane hexadecamethyl	22.31	578	C16H50O7Si8	30.76

Table 2. Volatile compounds as analyzed by GC-MS in fermented camel milk

Compound Name	RT	Molecular Weight	Molecular Formula	Area %
tert- Hexadecanethiol	4.38	258	C16H34S	7.60
Glycerin	8.42	92	C3H8O3	82.76
Desulphosinigrin	9.97	279	C10 H17 NO6S	9.64
4-Piperidineacetic acid, 1-acetyl-5-ethyl-2-[3-(2-hydroxyethyl)-1H-indol-2-yl]-à -methyl-, methyl ester	13.81	400	C23H32N2O4	3.81
Octasiloxane,1,1,3,3,5,5,7,7,9,9,11,11,1 3,13,15,15-hexadecamethy l-	22.17	578	C16H50O7Si8	3.97
Hexasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11-dodecamethyl-	22.54	430	C12H38O5Si6	5.06
Heptasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,1 3,13-tetradecamethyl-	22.74	504	C14H44O6Si7	5.69

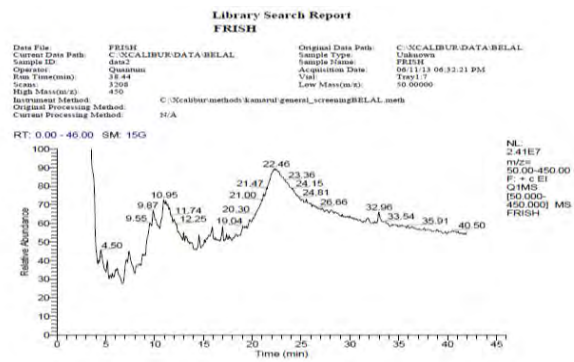

Fig.1.GC-MS analysis of Volatile compounds in Fresh camel milk

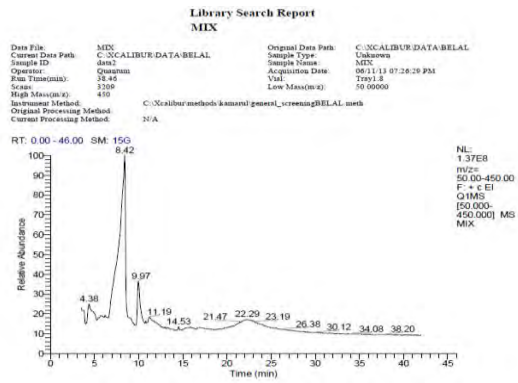

Fig.2.GC-MS analysis of Volatile compounds in Fermented camel milk

Moreover, more than 100 volatile substances, including carbonyl compounds, alcohol, acids, esters, hydrocarbons, aromatic compounds, sulfur-containing compounds, and heterogeneous ring compounds, were found in fermented milk at a low or very low concentration (Cheng, 2010). Finally, the present study showed that the process of fermentation of camel's milk by lactic acid bacteria plays an important role in the flavor of

fermented milk, while the production of most flavor compounds in milk was found to be the degradation of milk fat and microbiological shifts of lactose and citrate.

CONCLUSION

In this study, the volatile components of fresh camel milk and fermented camel milk (Lactobacillus delbrueckii subsp. *bulgaricus* and *Streptococcus thermophilus*) were analyzed by GC MS. Volatile compounds were identified. It was also identified that the major volatile components were alcohols and fatty acids, which played the most important role in imparting the typical aroma and flavor. The results indicated that there were many volatile compounds in fresh and fermented camel milk, with a clear difference in quality and concentration. This study showed that fermentation of camel milk by lactic acid bacteria plays an important role in fermented milk flavor. The use of the starter bacteria produced an obvious change in the flavor of fermented camel milk. There is still a lot of work to be done to get a more complete understanding of the formation of aroma and flavor of milk. Determining the relationship between the main aromatic compounds and the sensory properties of fermented camel milk can provide a better understanding of how milk flavor is affected by the presence of flavor compounds to make it more acceptable to the consumer.

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ANIMAL TRACTION: NEW OPPORTUNITIES AND NEW CHALLENGES

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ABSTRACT
In the last one hundred years, tractors with much more power replaced animals all over the world, except in developing countries. Besides the advantage in power, the use of tractors increases agriculture productivity and time efficiency of field operations. Despite the unquestionable advantage of tractors for agriculture performance, in recent years the interest by animal traction is growing, even in developed countries. It is important to understand why. This interest usually is linked to small scale farming, but not only. Environmental concern is one of the most significant reasons, in different aspects: use of working animals as a renewable source of energy; forest management in protected areas to protect soil physical properties related to compaction affected by tillage treatments; field operations in environment protected areas, among others. In old vineyards, but producing a high value output, plant spacing turn animal traction without alternative. The maintenance of the gene pool in domestic animals; the creation of jobs in rural areas, such as farrier, harness maker and implement manufacturer, are also important issues.
New challenges: new implements must be designed and new mechanical solutions achieved.

INTRODUCTION
Animal traction has been used by humans as draught power since the origin of agriculture. With the use of tractors, farmers get access to much more work power and gained a significant increase of productivity and time efficiency in field operations. To have the possibility to realize field operations in the most convenient period of time, is one of the most important achievements of mechanical traction, especially in industrial farms. In developed countries, the use of animal power is usually confined to specific contexts, such as in protected areas (Cerruti, A. et al, 2014). However, due to limited availability to fossil fuels, it is expected an increase of interest of animals for traction.

Other reasons can be pointed out. The use of heavy machinery in forest or agriculture operations can promote severe soil degradation, in particular in mountains regions where soils are generally poor. The most common degradation effects are soil compaction and erosion. In addition, in mountain regions, the number of small farms is significant. In these types of farms, the mechanized operations have high cost effectiveness.

In Europe, field experiments have been carried out under research programs, in order to evaluate the performance and benefits of animal traction *vs* tractors. We will refer some of them, one focusing in forest management, other in soil tillage. Others interesting conditions for animal traction will be referred.

FOREST MANAGEMENT
In forestry and in agriculture, mechanical traction substitute animals at a much lower cost and within a period of time suitable for the best conditions for the field operations.

But in certain conditions, in forest, animal systems can offer some benefits over machine systems (Spinelli, R. et al, 2013). Animals represent a clean alternative with low-impact, interesting in protected areas.

Figure 1, show looging operations using horses, during intermediate cuttings of immature pine trees in a forest managed by the Municipality of Vimioso, northeast of Portugal. Animal traction as gradually been recognized as an important tool for sustainable management of woodlands.

Figure 1. Horse skidding in forest (APTRAN)

In these conditions (forests in protected areas) operations can require surgical accuracy, such as removing wind-thrown trees with a very little damage to residual trees and causing minimal soil disturbance and compaction.

On this subject R. Spinelli, R. et al, (2013); Magagnotti N. et al, (2011a); Magagnotti N. et al, (2011b) carried out interesting research, comparing economic and environmental performance of animal systems and machine system.

It was verified that: (1) machines need more space for accessing the work place; (2) cost-effective mechanized harvesting demands a minimum intensity removal, below which machine becomes a main economic constraint, being animals less dependent on removal intensity; (3) animals (horses in the case) can skid through tight spaces with a very little damage to residual trees.

About this last issue it was concluded (Magagnotti N. et al, 2011a) that tractor skidding is cheaper than horse skidding when extraction distance exceeds 50 m if the cost of trail building is not accounted. If skidding trails must be built, skidding with one horse is cheaper than tractor skidding until distances exceeds 200 m.

Draught horses represented an advantage in low-intensity cuts, in short extraction distances or when pre-existing trails are not available.

SOIL TILLAGE

In recent years studies have been conducted in Portugal to assess the impacts on soil compaction of tillage operations with tractor pulled equipment and equipment for animal traction.

Soil compaction results from compressive forces applied to compressible soil by machinery wheels combined with tillage operations (García-Tomillo et al, 2017). Draft animal may also cause soil compaction, but a huge gap exists on experimental data (García-Tomillo et al, 2017).

Soil compaction is regarded as one of the most serious form of land degradation caused by conventional farming practices. Compaction alters soil structure by crushing aggregates or combining them in larger units, increase soil bulk density and decrease the number of coarse pores (García-Tomillo et al, 2017). The economic cost and the difficulty to be detected, make soil compaction a serious risk for food security.

The long-term use of mechanical tillage equipment, such as mouldboard ploughs and rotavators, results in a compact soil difficult to be penetrated by crop roots.

Actually, animal traction is an option seen with increasing potential to contribute to sustainable agriculture, especially in mountain areas. However, a gap of information exists in the context of mountain agriculture.

The research mentioned, carried on by García-Tomillo et al (2017), aim to compare tillage operations performed with two types of draft animals, cows (a pair) and donkeys (a pair), focusing on the effects on soil physical properties related to soil compaction, and testing the performance of Electrical Resistivity Tomography (ERT) in detecting changes in soil physical properties affected by tillage treatments.

Figure 2. Cultivator pulled by tractor (a); Roman plough pulled by cows (b) and by donkeys (c); Cultivator pulled by donkeys (d) and by cows (e)

Three different implements were considered (Figure 2): for animal traction a Roman plough and a 5 tine cultivator; for tractor a 9 tine cultivator. Tractor weight was 2745 kg; animal weight was approximately 700 kg for each donkey and 1200 kg for each cow. Weight of cultivator pulled by tractor was 360 kg. Weight of equipment pulled by animals was 30 kg each (cultivator and Roman plough).

Results also show that the reduction in soil porosity after tillage was more pronounced in tractor plots than in the animal traction ones, the lower effect being measured in donkey's plots. As well, soil moisture redistribution and retention were more affected by tillage in the former than in the latter plots. These promising preliminary results point out, however, the need for future research (Figueiredo et al, 2017).

OTHER OPPORTUNITIES

Animal traction can have an important role in other specific conditions, not yet under scientific research.

Figure 3. Animal working in vineyards

Working vines with animals never totally disappeared. It is the case of old vineyards producing a high value output with short plant spacing or in terraces or steep slopes, turn animal traction without alternative (Figure 3). That is happening in Douro River Valley (Oporto wine producer region) in Portugal, in France - Burgundy or Bordeaux regions, or in Spain - Ribeira Sacra region.

Vineyards in the School of Agriculture, Polytechnic Institute of Bragança, where animal traction has been used on a regular basis to demonstrate its potential (Figure 3). Important note: the use of a Zamorano-Leones donkey, as a way to promote local and regional breeds as working animals.

When working in greenhouses animal traction can be useful. Figure 4 show greenhouse work with horses, using light modern implements for vegetable production.

Animal traction can have a positive role in more remote regions, usually in mountains, were the creation or preservation of jobs, such as farrier, harness maker and implement manufacturer, represents an opportunity for young people, avoiding the emigration.

The maintenance of the gene pool in domesticated animals, is not a minor issue.

Figure 4. Greenhouse work (APTRAN)

CHALLENGES

These opportunities represent new challenges. Old equipment from the first half of the twentieth century is becoming hard to find, or replacement parts difficult to find.

Remanufacturing older equipment with new design, including different models of forecarts to be used with different implements made for small tractors is a challenge that has been answered by manufactures in United States and Central Europe. Some of the new forecarts have a power take-off (PTO) drive from wheels or from a motor (Figure 5).

Getting power to PTO from wheels is a better solution, but needs an additional research in order to get enough torque for the machinery used.

New solutions based on electric energy assistance are referred by Rodrigues et al (2017). The energy produced by braking friction on the downhill travel is stored in a battery and returned to electric motors to assist animals on uphill travel or when pulling heavy loads.

Figure 5. Forecart with engine PTO (Pioneer catalog 2014)

CONCLUSIONS

Animal power is usually considered as a sign of underdevelopment. A negative perception still exists regarding this source of energy (www.fectu.org). This view is changing, especially in low intensity agriculture systems, in protected areas and in mountainous regions. Development is based in economy, but also in environmental preservation, improvement of population quality of live and the sustainability of natural resources for agriculture and forest production.

This interest is growing in scientific community, which is an important step in the process. The disinterest that has been given to working animals has now negative consequences that will need to be overcome. One of them is the difficulty of finding drivers for animals and trained animals.

More research is needed on this subject, focusing for instance in costs. Costs for work and maintain animals (horses, cows, donkeys, and so on) *vs* tractors.

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OSH RISK EVALUATION WITHIN AGRO-INDUSTRIAL PLANTS: THE CASE OF AN OLIVE MILL

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Keywords: electromagnetic fields, olive mill, risk assessment, worker's health

ABSTRACT

The risk related to the presence of low frequency electromagnetic fields can be a serious OSH risk within different kind of agro-industrial plants. In this paper, an experimental analysis aimed at measuring electromagnetic fields in the productive areas of an olive mill recently built in the Bari district was accomplished. The analysis' main goal was to assess the workers' health risk level due to the presence of extremely low frequency electromagnetic fields (30 ÷ 300 Hz) mainly due to the presence of electrical distribution lines and electric motors operating at a frequency of 50 Hz with reference to a specific type of processing plants, widely spread in the Apulia region. A first analysis of the spatial layout of the electric machine was carried out, referring to their duty cycles and to workers' tasks (taking into particular account the working places) identifying 12 most significant points in which the measurements of effective value of the electrical and magnetic field would have been carried out. Effective values of the electric field (E_{RMS}) as well as effective values of the magnetic induction field (B_{RMS}) measured in each testing point, were both significantly lower than the limit values required by law. Peak values of both the electric field (E_{peak}) and the magnetic induction field (B_{peak}) measured in the different testing points at the frequency of 50Hz, were lower than the corresponding effective values E_{RMS} and B_{RMS}. The results of the tests highlight that, inside the analysed olive mill, in the period of its maximum productivity, risks for the workers' health related to their exposure to low frequency electric and magnetic fields are not relevant.

INTRODUCTION

Even if exposure to electromagnetic fields is not a new phenomenon, in the last decades the risk associated with the spread in the environment of man-made electromagnetic fields has been steadily increasing.

Everyone is exposed to a complex mix of weak electric and magnetic fields which originate from the generation and transmission of electricity, from the use of industrial equipment, from to telecommunications and broadcasting, etc. When the presence of an electromagnetic field affects a working place, workers' health and safety should be taken into proper account.

The Italian D.Lgs 81/2008, coordinated with Italian D.Lgs 106/2009 among the various risks for the health of the workers, includes the ones connected to the exposure to electromagnetic fields (0 Hz ÷ 300 GHz) during the job.

Under a sanitary point of view, an individual dipped in an electromagnetic field interacts with it creating a physical coupling between his biological system and the field, which evidently produces a deviation from the conditions of electrical balance at molecular level.

The dielectric features of biological tissues and the electromagnetic field frequency affect the physical mechanisms of coupling between electromagnetic fields and biological organisms, therefore the reaction of a human body could very different if a worker is exposed to high frequency electromagnetic field generated by telecommunications and broadcasting systems (Pascuzzi S., Santoro F., 2015) or if the same worker is exposed to a low frequency electromagnetic field.

Low-frequency electric fields influence the human body just as they influence any other material made up of charged particles. When electric fields act on conductive materials, they influence the distribution of electric charges at their surface. They cause current to flow through the body to the ground. Low-frequency magnetic fields induce circulating currents within the human body. The strength of these currents depends on the intensity of the outside magnetic field. If sufficiently large, these currents could cause stimulation of nerves and muscles or affect other biological processes.

Therefore, within the low frequency electromagnetic fields (0÷10 kHz), a person's exposure is directly bound to the values of a few electrical characteristics which establish themselves as an effect of such fields, inside the human body: such characteristics, internal or primary, are essentially the intensity of the electrical field and above all the internal current density, defined as the current which passes through a unitary section perpendicular to its direction in a conductive volume such as the human body or a part of it. These primary characteristics, however, are difficult to measure in the real exposure conditions and, therefore, a person's exposure to the electrical and magnetic fields is obtained through easier to measure outside or derived characteristics: the effective values of the inductive electrical and magnetic fields in absence of the exposed body. From these derived characteristics, thought the evaluation of the exposure conditions and of the relative characteristic of the electromagnetic field, by mean of dosimetric models the primary ones are obtained.

This paper aims to highlight the results of a survey carried out in an olive-mill located in Corato town, in the north of Bari province chosen as it was considered representative of a widely spread type of such productive plants present in the Apulia region.

The authors have already studied problems regarding the impact of electromagnetic field on workers safety and health within agro industrial sectors; this paper aims to be a further contribution in this topic.

MATERIALS AND METHODS

The considered olive-mill was organized with three independent production lines similar each other (defoliator, washer, crusher, malaxer and decanter) and, near the area occupied by one of the decanter, was located a small table with some chairs which allowed the customers to rest and manage their business. It was a family-driven business activity; during the main olive oil production period, all the three production lines work at their maximum capacity, the work is continuous over 24 hours and organized with three 8-hour shifts.

A first analysis of the spatial layout of the electric machine was carried out, referring to their duty cycles and to workers' tasks (taking into particular account the working places). This preliminary analysis identified the 12 most significant points in which the measurements of effective value of the electrical and magnetic field would have been carried out. These points are essentially located near the electric motors which drive each operating machine (Figure 1).

At these points, for the duration of a full work shift, measurements according to the CEI 211-6 Italian standard instructions for reactive near-field region were carried out.

At the height of 150 cm above the floor level, which can be considered the mean height of the human thorax, were recorded both components of electrical and magnetic fields: in the reactive near-field region, in fact, no correlation between electrical and magnetic

field exists since the first depends on the voltage present in the system or in the equipment which produces such field, the second depends on the currents in them circulating, being tensions and currents completely independent.

The low frequency electric and magnetic fields measurement system used was made by a PMM mod. EHP-50C analyser which complies both to Italian 10/09/98 D.M. 381 and to Italian 07/08/03 DPCM positioned on a non-magnetic tripod (Figure 2).

The electric and magnetic field in the frequency range 5÷100 Hz, with a 0.25 Hz scanning interval, for the three components of a global orthogonal Cartesian reference system has been measured in each of the testing points.

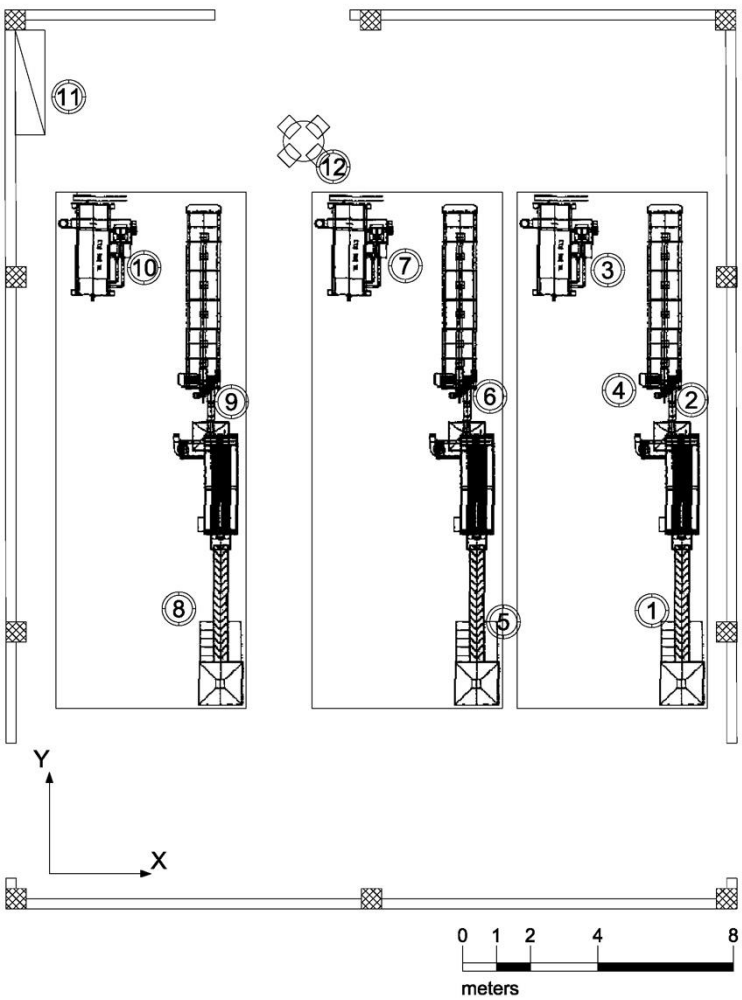

Figure 1. Oil-mill lay-out with indication of electromagnetic field measurement points.

Figure 2. Measurement system standing at test point number 12.

RESULTS AND DISCUSSION

Effective values of the electric field (ERMS) as well as effective values of the magnetic induction field (BRMS) measured in each testing point, whilst taking into account the components along each of the three axes and the whole 5÷100 Hz frequency range examined were obtained using the following two equations:

$$E_{RMS} = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} \left(E_{xi}^2 + E_{yi}^2 + E_{zi}^2\right)}$$

$$B_{RMS} = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} \left(B_{xi}^2 + B_{yi}^2 + B_{zi}^2\right)}$$

Both effective values of the electric field (ERMS) and effective values of the magnetic induction field (BRMS) were considerably lower than the action values given in the laws for the protection of the health and safety of workers currently in force in Italy as reported in Figure 3.

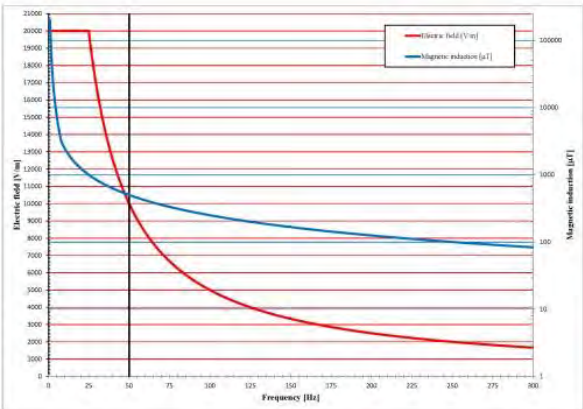

Figure 3. Effective action values of electrical field E_{RMS} and B_{RMS}.

Furthermore, peak values of both the electric field (EPEAK) and the magnetic induction field (BPEAK) measured in the different testing points at the frequency of 50Hz, were lower than the corresponding effective values ERMS and BRMS.

CONCLUSIONS

The results of the tests carried out confirms other previous surveys carried out in other Apulian olive-mills. Once again, the results highlight that, also inside the analysed olive mill in this paper, in the period of its maximum productivity, risks for the workers' health related to their exposure to low frequency electric and magnetic fields are not relevant.

It can also be generally said that the electrical field turns out significant only if there are machines, conductors or, generally speaking, tools which require high voltage to work and that the magnetic induction field produced, instead, by most electrical tools, has a low coupling with human bodies and turns out only in a very close region around its source.

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VINEYARD TREATMENTS PERFORMED WITH A RECYCLING TUNNEL SPRAYERS PROTOTYPE: PRELIMINARY ASSESSMENT

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Keywords: pesticide application, tunnel sprayer, espalier trained vineyard, crop protection

ABSTRACT

A towed single-row air-assisted tunnel recycling sprayer was developed by an Apulian Company in teamwork with the DISAAT of the University of Bari, aimed at meeting the requirements of the espaliers trained vineyards located in the Salento (Southern Apulia). Tests were then performed to assess the set up prototype with relation to the characteristic of the studied espalier trained vines. It was then necessary to point out technical solutions aimed at to reduce the size of the frame at the front of the machine, where is located the fixed shield. These actions made the prototype more suitable to the characteristics of the studied vineyards and the defined technical solutions can be considered generalizable for the tunnel sprayers employed in such trained vines of the Salento. Further tests are necessary to better assess the performance of the prototype also in different phenological stages.

INTRODUCTION

Apulia is Southern Italy's leading region for wine grape production, with an addressed area of about 8.6×10^4 ha and a yield of about 10.1×10^8 kg (ISTAT, 2014). In Apulia, the most common vine training systems used for wine grape are the espaliers with Guyot pruning system or simple/double side cordon and the "pergolato" or "tendone", an overhead canopy supported by a trellis system, also particularly employed for table grapes vines in the Region. Protection of these vineyards entail several treatments from April to November and the sprayers generally are conventional air-assisted sprayers and pneumatic sprayers, sometimes fitted with electrostatic device (Pascuzzi and Cerruto, 2015b; Pascuzzi, 2013).

A peculiar characteristic of the espalier Apulian vines, due above all to the propitious climatic conditions, is the significant development of the vegetation during the final growth stages, which at time may produce some impediments. With regard to the espaliers vines located in the Salento (Southern Apulia), the foliar development becomes considerable from the fruit set growth stage on, so producing a significant reduction of the size of the inter-row, which compromises the transit of the machines (Giametta et al., 2015). These vineyards are suitable for the employment of the recycling tunnel sprayers, which have long been recognised as an important tool to greatly reduce both soil contamination and airborne drift (Pergher et al., 2013). These machines meet also the requirements of the European Regulations concerning sustainable use of pesticides (Directive 2009/128/EC), by recovering and recycling most of the spray fraction that has not been retained by the canopy (Balsari et al., 2007).

Based on a research funded by the European Fund for Apulian Regional Development (PON02 00657-00186-2866121 Project (ECO_P4)), within a research program of the Ministry of Education, University and Research and the Ministry of Economic Development, an ad hoc towed single-row air-assisted tunnel recycling sprayer was developed by an Apulian Company in teamwork with the DiSAAT of the University of Bari, aimed at meeting the requirements of the espaliers trained vineyards located in the Salento (Southern Apulia). The objective of the present research was to assess the performance of this prototype with relation to the characteristic of the espalier trained vines of the Salento, evaluating the spray deposition on the foliage at different locations of the vine canopy.

MATERIALS AND METHODS

The tunnel sprayer

The towed air-blast tunnel sprayer (Fig.1c), manufactured by the Company Maggio with the collaboration of the DiSAAT, is specifically designed for pesticide application in espalier vineyards of the Salento. The machine is built by adopting a galvanized steel frame on which the following elements are arranged: the 1000 L tank for the mixture; the axial fan; the pump unit with its connections; valves to control and limit pressure and to control flow volume; positional hydraulic and mechanical servo-mechanisms for the motion of the shields; the piping for conveying the air flow produced by the fan to the two shields of the tunnel. One of the shield of the tunnel is rigidly connected to the frame, while the other one can slide horizontally, allowing adjustment of the distance between the shields. The machine is equipped with sensors connected to the control unit, so allowing to evaluate in real time the operating parameters: nozzle flow rate, operating pressure, sprayer velocity, volume rate.

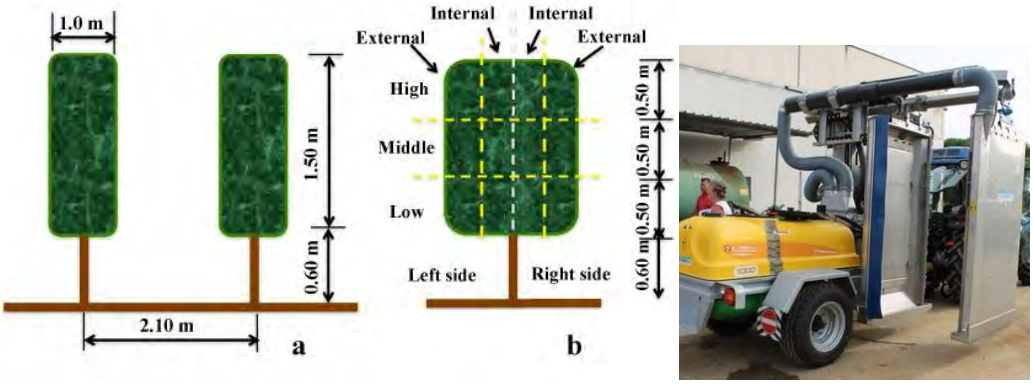

Figure 1. a: Scheme of the vineyard; b: Partition of the canopy into six zones; c: Towed air blast single-row tunnel sprayer built by Maggio Company.

The vineyard, spraying tests, foliar sampling and data analysis

Experimental spraying tests were carried out in a espalier vineyard ("Falanghina" variety") located on a farm in the territory of Cellino San Marco (Brindisi province – Apulia – Italy). The vines were planted with a layout of 2.1m x 1.0 m, giving a density of 4760 plants/ha (Figure 1a). Foliar deposits were assessed during berry touch phenological stage by spraying a mixture containing a food dye tracer (yellow tartrazine, Sigma Chemical) at a concentration of 4 g L^{-1} and measuring the volume of mixture deposited per unity of leaf surface (µL cm^{-2}). The tests were carried out by passing with the sprayer in an inter-row with the shields of tunnel straddling a row; spraying then the right and left sides of the row. Foliar sampling and deposit assessment were then carried out in the row. Particularly, foliar spray deposition was measured in different canopy locations, obtained considering the following divisions (Figure 1b): a) the vertical plane of mirror symmetry, which partitioned the canopy of the row into "Right side" and "Left side" with respect to the direction of the sprayer advancement; b) the vertical planes crossing the centre-line of the Right and Left sides, respectively, so producing the sectors "Internal" and "External"; c) the horizontal planes located respectively at 1.10 m and 1.60 m from the ground, which finally partitioned the canopy into three levels: "Low", "Middle" and "High". Therefore, twelve sampling zones were defined on each sample tree to measure foliar deposits (Figure 1b). The following operative parameters of the prototype were considered: a) speed of 5 km h^{-1}, typically

adopted by the farmer to carry out the treatments; b) volume rate of 600 L ha^{-1}; c) working nozzles 6+6, located at the middle and lower parts of the shields; d) nozzles type Albuz ATR 80°, pressure 0.75 MPa. The test was replicated three times according to a randomized block design and 4 leaves were randomly sampled in each zone, totalling 48 leaves per replication, and then 144 leaves per treatment. Each leaf was placed in a Petri dish, and the unitary deposit was measured in the laboratory by applying a spectrophotometric technique (Pascuzzi and Cerruto, 2015a). Deposits were statistically analysed by applying the factorial analysis of variance (ANOVA), using the open source software R (R Core Team, 2012).

RESULTS AND DISCUSSION

The results of the test carried out are summarized in Figure 2, which shows the average deposits obtained respectively for the considered sides ("Right" and "Left"), levels ("Low", "Middle", "High") and sectors ("Internal", "External"). The difference between the deposits registered on the left and right side of the row is not statistically significant. Conversely, the obtained values 0.46 μL cm^{-2} ("Left side") and 0.50 μL cm^{-2} ("Right side") highlight a uniform distribution of the mixture on both sides of the row. Furthermore, about the same amount of mixture was distributed at the "Low" (0.61 μL cm^{-2}) and "Middle" (0.62 μL cm^{-2}) levels of the row, whereas the deposit registered at the "High" (0.20 μL cm^{-2}) level is much lower and is approximately 1/3 of those ones of the other levels. This statistically significant difference is probably due to the absence of working nozzles corresponding the high level of the shields. Finally, the difference of the average registered deposits between the sectors "Internal" (0.29 μL cm^{-2}) and "External" (0.68 μL cm^{-2}) is statistically significant.

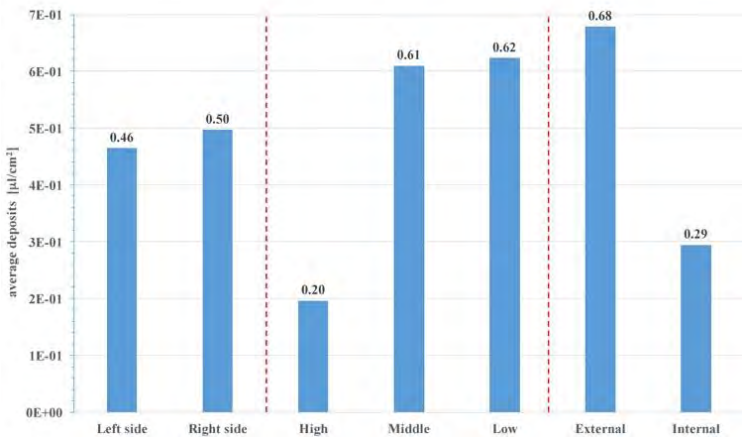

Figure 2. Average deposits concerning the considered partitions of the canopy

Altogether the results highlight that the prototype enables a good distribution of the spray on the vegetation, point out some problems. Really, starting from the phenological stage of fruit set, when the development of the canopy becomes considerable, the sizes of the machine are unacceptable, because in these conditions a proper homogeneous distribution of the product on vegetation is thwarted and the shields of the tunnel strip on the vegetation, even if their distance was the maximum allowed. Therefore, it was necessary to set up technical solutions aimed at to reduce the size of the frame at the front of the machine, where is located the fixed shield and to increase the largest between the shields. According to these actions, the prototype is become more suitable to the characteristics of the studied vineyards of the Salento.

Figure 3. Modified prototype in a full leaf stage vineyard of Salento: the machine moves easily in the short passage between the rows tree; the shields have sufficient space for transversal settings.

CONCLUSIONS

The exclusive characteristics of the espalier training vine system of the Salento is the significant development of the vegetation during the final growth stages, which creates a striking reduction of the size of the inter-row. An ad hoc towed single-row air-assisted tunnel recycling sprayer was developed to meet the requirements of these vines and tests were carried out for assessing its performance. According to the results of the experimentation, it was necessary to point out technical solutions aimed at to reduce the size of the frame at the front of the machine, where is located the fixed shield, and to raise the maximum allowed distance between the shields (Figure 3). These actions made the prototype more suitable to the characteristics of the studied vineyards and the defined technical solutions may be considered generalizable for the tunnel sprayers employed in such trained vines of the Salento.

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STAND-ALONE PHOTOVOLTAIC AND HYDROGEN PLANT COUPLED WITH A GAS HEAT PUMP FOR GREENHOUSE HEATING

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Keywords: Ground source gas heat pump, photovoltaic-hydrogen plant, Greenhouse heating.

ABSTRACT
In recent years, the increasing interest in energy production from renewable energy sources has led to stand-alone renewable energy plant being developed in agricultural land. In particular, for greenhouses heating, diesel, LPG and natural gas are the main energy sources used. Alternative solutions are represented by the integration of renewable energy plants in off grid configurations. The aims of this research is to analyzed the energy performance of a photovoltaic, hydrogen and ground source gas heat pump integrated stand-alone system during the winter season. The results showed that the system had a total energy efficiency to 13%. The performance of the system was low because the efficiency of the photovoltaic panels was the bottleneck. In fact, starting from the energy available from the PV, the system has an efficiency of 96% if the COP of the heat pump is equal to 4. Finally, the heating system increased the greenhouse air temperature about 8°C respect to the external air temperature.

INTRODUCTION

Nowadays, several research attempts are focus on the micro-generation systems based on renewable energy sources in according with the Near Zero Energy Building (NZEB) concept and the new European Directive 2010/31/CE. However, in agricultural sector, in case biomasses are not available, some attractive solutions are represented by the geothermal heating systems (Anifantis et al., 2016) and stand-alone hydrogen plant (Anifantis et al., 2017). Transforming the solar radiation surplus into electrical energy is of extreme interest due to its double benefit: it solves the problem of excess solar radiation in the greenhouse and produces electricity from renewable sources without negative environmental effects (Marucci et al., 2017). Unfortunately, the energy production and consumption of solar energy for greenhouse requests are non-simultaneity and the electric energy produced during the daylight hours must be stored and reuse in the night. Then, the surplus electricity from wind farms or solar PV farms if not used can be stored using batteries. However, the uncertainties in the cost of batteries are rather wide, even larger than difference in costs between different technologies (Zakeri & Syri, 2015). Alternatively, the electricity can be stored in the form of hydrogen gas, the surplus electricity is used for water electrolysis to generate hydrogen gas that can stored and when electricity is needed, then this hydrogen gas can be used as feedstock for the PEM fuel cells to produce electricity or can be burned in internal combustion engines (ICE) to generate mechanical or electrical energy. Other interesting technologies for energy storage are hydropower generation, flywheels and compressed air energy storage (CAES) (Ghoniem, 2011). In this paper, a photovoltaic and hydrogen stand-alone systems integrated with a ground source gas heat pump (GSGHP) for greenhouse heating was studied. The GSGHP is composed by an internal combustion engine drive shaft connected to a compressor of a geothermal heat pump. The engine was feed by the hydrogen produced by an PEM electrolyzer during the daylight hours. A performance analysis was conducted in order to define the total efficiency and the power production of the integrated system.

MATERIALS AND METHODS

The only behavior of the gas heat pump was mathematical modeled using the technical manuals provided by the manufacturer AISIN (TOYOTA group). Instead the rest of the system components have been analyzed using the data of an hydrogen plant implemented at the experimental farm of the University of Bari, located in Valenzano, Italy. In particularly, the electricity generated by 56 m^2 (A_{PV}) of polycrystalline photovoltaic panels (PV), during day time from 08:30 to 17:30, fed a electrolyzer which produces hydrogen by water electrolysis. The hydrogen was stored in a pressure tank at 30 bar. The ground source gas heat pump heated an air-inflated, double layer polyethylene film tunnel greenhouse of 106 m^2 of cover surface (A_{cf}) and 48 m^2 of area. The diagram of the plant is shown in Fig. 1 and the specifications of the plants are reported in Tab. 1. The experimental test was carried out in a winter day of February.

Table 1. Specifications of two renewable energy hydrogen plant.

Components	Specifications
Photovoltaic array	BYD 240P6-30, 34 module, 8.2 kW peak
Electrolyser	Monopolar alkaline electrolyzer 2.5 kW, 0.4 Nm^3/h – H_2Nitidor S.r.l.
H_2 storage	30 bar, 0.5 m^3
Gas heat pump	Model AXGP224E1 8HP, Aisin (TOYOTA)
Geothermal borehole	120 m vertical double U-bend ground heat exchanger
Fan-coil unit	Carisma CRC53MV, Heating capacities: 3.59 kW; air flow rate 495 m^3/h
Greenhouse	Air inflated, double layer polyethylene film tunnel greenhouse

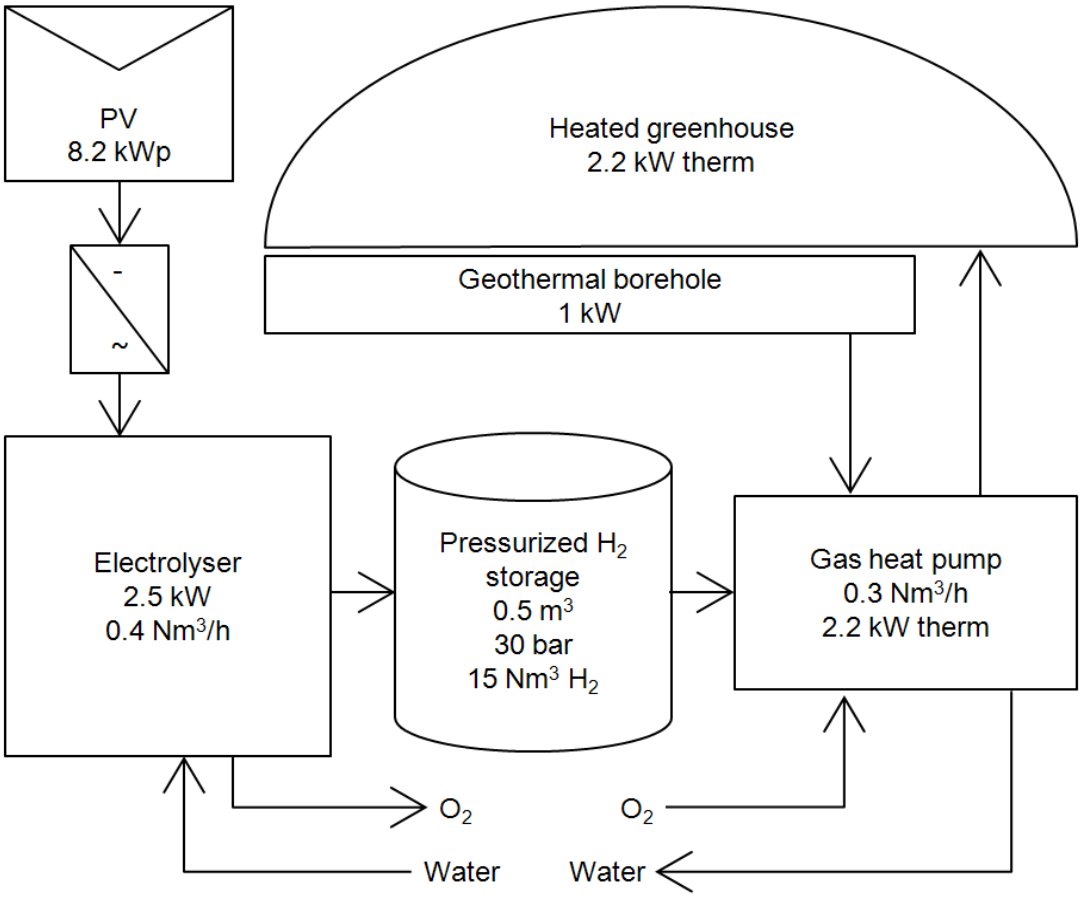

Figure 1. PV and GSGHP in a stand-alone hydrogen system for greenhouse heating.

Considering a clear day, the fraction of the instantaneous PV array power output used through electrolyzer input (P_{el}) is given by (Anifantis et al., 2017):

$$P_{el} = \Phi \eta_{vr} A_{PV} I_T \eta_r [1 - B(T_c - T_r)] \quad (1)$$

where η_r(=0.15) is the efficiency of the solar cell at a referenced solar radiation, T_c(~35°C) the solar cell temperature, T_r(=25°C) the referenced temperature of the cell and B(=0.005°C^{-1}) the temperature coefficient of a solar cell, A_{PV} the PV array surface, I_T the solar radiation, η_{vr}(=0.97) the DC/AC converter efficiency and Φ the solar radiation usability. Φ was necessary because the peak power of the PV array should be increased to assure enough available power to cover the needs of the electrolyzer.

Instead, the energy efficiency of the electrolysis reaction η_{el} is given in terms of the lower heating value of hydrogen (LHV_{H2}=119.96 [MJ kg^{-1}]), the overall hydrogen production rate $q_{el,H2}$ [=0.00011 Nm^3 s^{-1}] and the hydrogen density at standard condition (δ_{H2}=0.09 [kg Nm^{-3}]) by the expression (Calderóna et al, 2011):

$$\eta_{el} = \frac{\delta_{H_2} \cdot q_{el,H_2} \cdot LHV_{H_2}}{P_{el}} \quad (2)$$

Gas driven heat pumps performance was calculated by using the Gas Utilization Efficiency (GUE) given by the manufacturer (TecnoCasa Climatizzazione Sole European Distributor AISIN, 2017):

$$GUE = 0.64 + 0.32 \cdot COP \quad (3)$$

$$Q_1 = GUE \cdot Q_{1\_burner} \quad (4)$$

where, considering the overall hydrogen consumption rate of the GSGHP $q_{GSGHP,H2}$, the equivalent thermal power supplies by an ideal hydrogen burner Q_{1_burner} is given by:

$$Q_{1\_burner} = \delta_{H_2} \cdot q_{GSGHP,H_2} \cdot LHV_{H_2} \quad (5)$$

Thanks to the Q_{1_burner} is possible to calculate the thermal power supplies by the heat pump to the thermal hating system inside the greenhouse (Q_1) that is equal to the thermal power demand of the greenhouse.

The ground source gas heat pump (GSGHP) has the same coefficient of performance (COP) of a common ground source heat pump (GSHP):

$$COP = \frac{Q_1}{Q_1 - Q_2} \quad (6)$$

where Q_2 is the heat power extracted from the ground through the borehole-probe heat exchanger. Q_2 is given by:

$$Q_2 = q_r \cdot l_t \quad (7)$$

where q_r is the heat exchange rate and l_t is the total active length of the borehole. Considering the steady state and the overnight winter conditions, the thermal power demand of the greenhouse was assessed with the equation (Ozgener & Hepbasli, 2005):

$$Q_1 = \left[\frac{A_{cf}}{R}\right](f_w)(f_c)(f_s)(T_i - T_a) \quad (8)$$

Assuming 1, 0.9 and 1 for the wind factor (f_w), construction type factor (f_c) and system factor (f_s), respectively and 0.28 m^2 °C/W for the greenhouse thermal resistance (R).

RESULTS AND DISCUSSION

The results show that the use of a ground source gas heat pump unit integrated with a photovoltaic stand-alone hydrogen system allows to have a total energy efficiency of 13%, starting from the sun to the GSGHP. The major limitation to the performance of the whole system was represented by the performance of photovoltaic, in fact, starting from the energy available from the PV, the system has a 96% efficiency with a heat pump COP of 4. The heating system increasing the greenhouse temperature by about 8°C compared with the ambient conditions in a representative winter day of February.

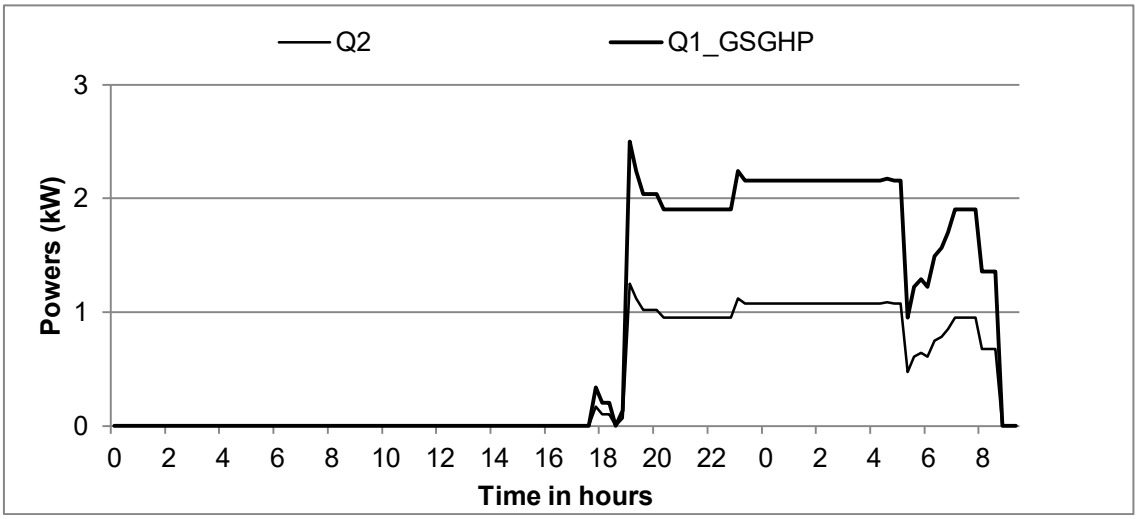

Figure 2. Equivalent thermal power supplies by the hydrogen burner (Q1_burner) and heat power extracted from the ground (Q2) during a winter day.

At night, the fuel cell and the GSHP worked from 18:30 to 08:30 and start when the temperature decreased to 10°C. The thermal power output (Q_1) and input (Q_2) of the GSGHP is 2 kW and 1 kW respectively (Fig. 2). The heat exchange rate of the geothermal borehole required (q_r) for a double U-bend pipe is 10 W m^{-1}. The difference between the indoor and outdoor greenhouse temperatures ($T_{i\ GSGHP}$-T_a) was 8°C (Fig. 3).

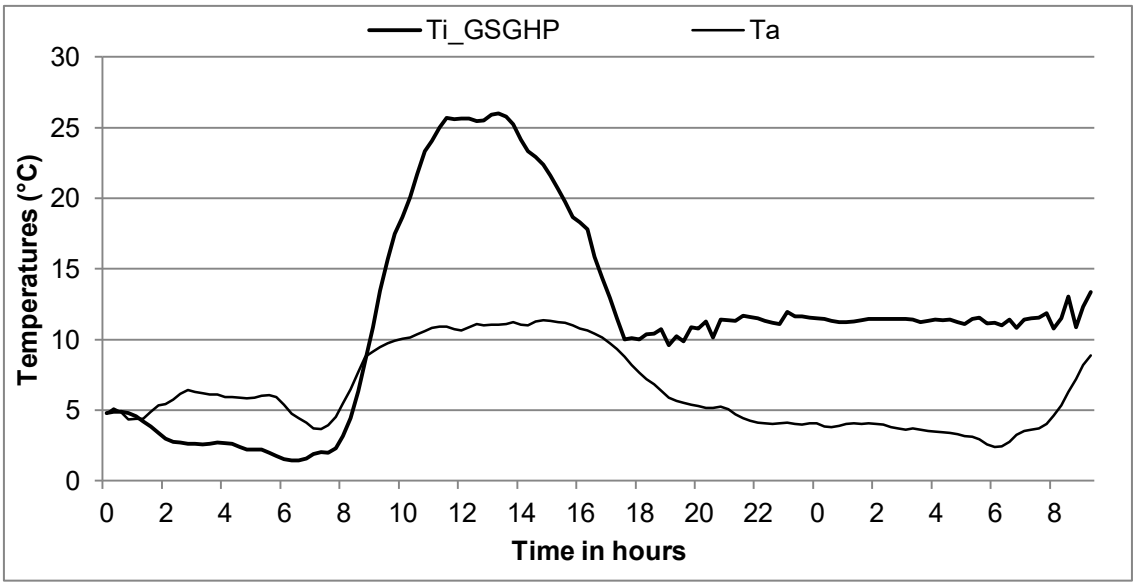

Figure 3. Internal and external greenhouse air temperature during a winter day.

CONCLUSION

The present paper analyzed the overall performance efficiency of a ground source gas heat pump integrated with a stand-alone renewable energy plant. The results obtained in these trials and the mathematical model implemented allow some remarks about the performance and efficiency of the water electrolyzer and the geothermal source gas hat pump (Aisin-TOYOTA). These trials give us a glimpse to its usage within a greenhouse-integrated heating system comprised of photovoltaic panels, alkaline barometric water electrolyzer, hydrogen storage and geothermal source gas heat pump even if experimental tests are required to better assess the GSGHP's achievement. The electrolyzer worked non-stop during the days characterized by clear skies but the electrical power supplied by the PV modules was greatly affected by the very unstable solar radiation during the partial cloudy day. In these cases, the electrolyzer overall operation was disjointed sometimes for many hours due to intemperate weather conditions in which the hydrogen production was cut off. The energy efficiency of the plant is strongly affected by electrolyzer and gas heat pump management. Considering the energy efficiency of photovoltaic panels of 13%, an electrolyzer energy efficiency equal to 50%, a ground source gas heat pump GUE of 192% respectively, the overall system efficiency is 13%. Finally, the heating system increasing the greenhouse temperature by about 8°C compared with the ambient conditions in a representative winter day of February.

ACKNOWLEDGMENTS

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USE OF DRONES IN CROP PROTECTION

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Keywords: management in precision agriculture, plant protection management, UAV, liquid spraying, crop protection

ABSTRACT
Modern management in sustainable agriculture requires the fast information about condition of cultivated plants and the quick response to undesirable phenomena such as appearance of pests. The use of drones for spraying plants will allow for rapid application of plant protection agents on the growing areas. In this paper were presented results of research into the impact of rotors rotary speed of moving drone on the spray deposition on plant surfaces. The liquid was sprayed from the drone with the use of the XR 11002 flat fan nozzle at the pressure 0.2 MPa. The drone moved on a track with the permanent speed of 1.3 $m \cdot s^{-1}$. The liquid sprayed, which was water coloured with nigrosin, settled on foil testers that were secured on three levels (the upper leaf surface, the middle part of the plant, the level of soil under plants) in mustard plants. The height of the sprayer nozzle mounted on the drone over the plants was 0.6 m. The tests were conducted at the zero speed of the rotors and at rotations of 1500 and 4000 $revolutions \cdot min^{-1}$. The impact was found of the rotational speed of the drone rotors on the change of the distribution of liquid settling on the testers.

INTRODUCTION

The present constructions of drone, called also unmanned aerial vehicle (UAV), are divided into drones with electric drives, where electric batteries constitute the source of energy, and drones that are driven with the use of internal combustion engines. They are remotely controlled by the operator with the use of a transmitter or independently according to the programmed route. The use of unmanned aerial vehicles in agriculture can contribute to the efficient management of agricultural farms. They have already found applications in precision agriculture, where they are replacing planes and satellites in the remote sensing of crops (Pinter et al., 2003; Primicerio et al., 2012). Apart from the use of drones in activities that provide information in agriculture, they can also become part of agricultural machinery. At present, efforts are being undertaken to use them to perform spraying of crops with pesticides.

Due to their small range, which is mainly caused by the battery capacity, electric drones are chiefly used in operations on the small surfaces of fields situated on different heights or in locations that are hard to access (Berner & Chojnacki 2017a). The advantages of the use of drones in the fight against pests include the possibility to quickly reach the place where the operation is to be performed and a short time of its performance; there are no problems connected with soil compaction or crumpling of plants. They can be particularly useful in the case of spot spraying over a large surface. Owing to replacing manual, backpack and tractor sprayers with them, the risk is reduced of poisoning of people who perform spraying with pesticides because the spraying drone operator is at a considerable distance from the place of the operation. The following are mentioned as the disadvantages of the use of drones to spray pesticides: a relatively high cost of the equipment as compared to possibilities offered by it, a small volume of the liquid tanks, a short flying time, the unreliability of the equipment and the uncertainty of the quality

of operations (Sizhe et al., 2017). Because the operations with drones constitute an element of aerial application, the following pose additional problems: the risk of the liquid sprayed being carried away; the fact that the flights of unmanned airships are covered by aviation law.

Exchangeable pressure flat fan nozzles: narrowband and broadband are most frequently used to spray liquid (Giles & Billing, 2015; Wei-Cai et al., 2016). Rotary atomizers can also be used (Huang et al., 2009). In the advanced designs of drones used in spraying, a computer with a GPS and a digital map of the field controls the operation of the spray gun (Huang et al., 2013). The flight of the drone is programmed taking into consideration the area covered by the operation.

The deposition of pesticides on plants with the use of unmanned aerial vehicles involves first of the combined effect of the jet of the liquid sprayed and the stream of air generated by the rotors, which must generate an air stream that is strong enough for the drone to fly at a specific height over plants and to move. A strong stream of air coming from the turning drone rotors is able to change the shape of the jet of the liquid sprayed. The research carried out into the impact of the stream of air generated by drone rotors on the distribution of the liquid that settles on the slot table demonstrates a possibility of an increased concentration of the liquid settled under the central part of the jet (Berner & Chojnacki 2017b).

Attempts are taken to assess the impact of liquid spraying parameters, such as the working height and the operating speed of unmanned aerial vehicles on the settlement of drops on the plant. Tests are most frequently performed on plant crops. Water sensing papers placed on different heights in plant crops are used as the quality markers of the operations carried out. Research is also conducted related to biological effectiveness. The control of insects was studied on rice crop with the use of a drone (Wei-Cai et al. 2016). Tests of the effectiveness of spraying performed with the use of drones are also carried out in garden crops in relation to trees and shrubs (Giles & Billing, 2015; Zhou & He, 2016). The results obtained until now demonstrate that the area of testers covered with liquid and the density of drops that settle on them decreases with a rise of the drone flying speed (Zhou & He, 2016). The research furthermore demonstrates that the quality of spraying performed with the use of drones in comparison with the quality of operations performed with the use of ground equipment may give similar results (Giles & Billing, 2015). The research carried out until now has not provided an exhaustive answer as to the influence of essential factors on the quality of operations performed in relation to pesticides with the use of drones. As there is no fundamental knowledge on the quality of the operations performed of depositing pesticides, the organization of the field spraying process is not possible.

An assessment of the influence of air stream coming from the rotors of the spraying drone on the disposition of the liquid settled on plants was the purpose of the research.

MATERIAL AND METHODS

The test stand was built in a laboratory to avoid the impact of external conditions, particularly that of wind breezes, which may have an influence on the shape of the stream of drops and on carrying the drone off. The test stand is presented in Fig. 1.

The research was carried out with the use of a DJI S 900 drone: with six symmetrically positioned rotors. To ensure the repeatability and precision of the trajectory of the

drone, it was secured to a horizontal cart moving along a frame with a track that was rigidly fixed to the ends on the stands. The cart was dragged with the use of an electric engine. Its rotations were controlled with the use of a current frequency converter. The drone was equipped with double propellers sized 15x5,2". Between the two rotors, in the connecting axis going through the middle of the rotors, a vertical bar was mounted symmetrically between the rotors. At the end of this bar, an XR 11002 flat fan nozzle manufactured by TeeJet company was mounted. The mouth of the spraying nozzle was below the bottom edges of the propellers of drone at the distance of 0.40 m.

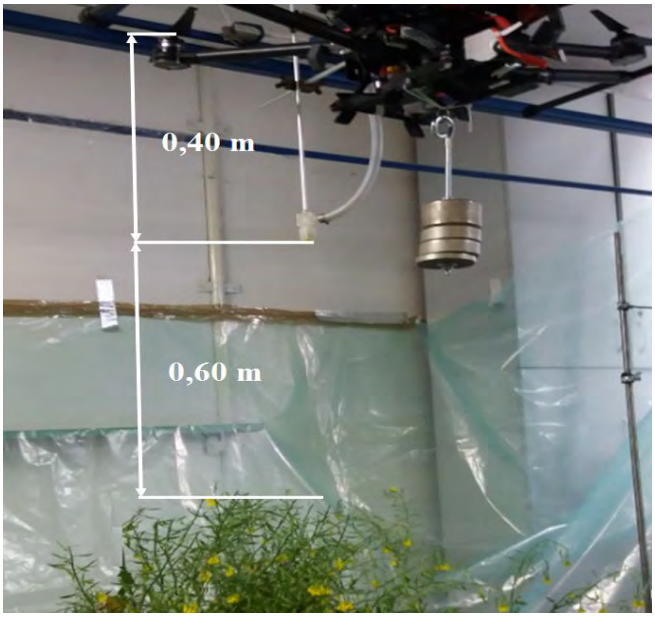

Fig. 1. View of test stand

Liquid to the spraying nozzle was delivery from a wheelbarrow sprayer. The pressure of the liquid before it accessed the nozzle was 0.2 MPa. Water mixed with water nigrosin constituted the liquid sprayed. The nigrosin concentration in the water was 0.38%. No influence was assumed of the chemical composition of water and nigrosin on the size of drops generated by the spray gun (Parafiniuk et al. 2015). The research related to the settlement of the liquid was carried out on natural mustard plants that had been replanted from a field to boxes and placed under the drone. Testers were placed on the plants on three heights: the upper surface, the middle of the plant and on the ground level under the plant. The testers were mounted on handles fixed permanently to the plants in a such way that the place of the arrangement of the testers was not to be changed when repeating the experiments. The handles of the testers were under the symmetry centre of the nozzle, and they were moved in relation to one another by ca. 25 cm. The testers were made from colourless polyethylene foil sized 37.2 x 21 mm. Each measurement was repeated three times. The height of the nozzle over the upper surface of the plants was 0.60 m.

The rotational speed of the rotors over the flat fan nozzle was controlled with a DT-2259 optical tachometer fixed rigidly over one of the rotors. The drone with the cart moved along a track over the plant with a constant speed of 1.3 $m \cdot s^{-1}$ which corresponds to 4.7 $km \cdot h^{-1}$. The rotational speed of the drone rotors was set to: 0, 1500 and 4000 $revolutions \cdot min^{-1}$. The speed of "0" denoted the ride of the cart with the drone without any

rotation of the rotors. A certain load was attached to the drone so that it could not ascend under the influence of the thrust coming from the rotors turning with a high speed.

After it had dried, nigrosin from the testers covered with the liquid sprayed was washed off with distilled water, and the liquid was subjected to a photometric analysis: 5 ml to establish the extinction of the dye. Based on conversion formulae, the concentration of nigrosin in the liquid was determined from the values of the extinction measurement; then, the volumes of the liquid that settled on the individual testers were determined.

RESULTS AND DISCUSSION

On the basis of the data obtained from the measurements, a diagram was prepared of the percentage distribution of the liquid settled on the individual levels of the plants according the following formula (Fig. 2):

$$P_i = 100 \cdot \frac{v_i}{\sum v_i} \, [\%] \tag{1}$$

where:

P_i - share of the volume of the liquid settled on the tester on i-th level in relation to the volume of the liquid settled on all levels, %

vi - volume of the liquid settled on the testers on i-th level.

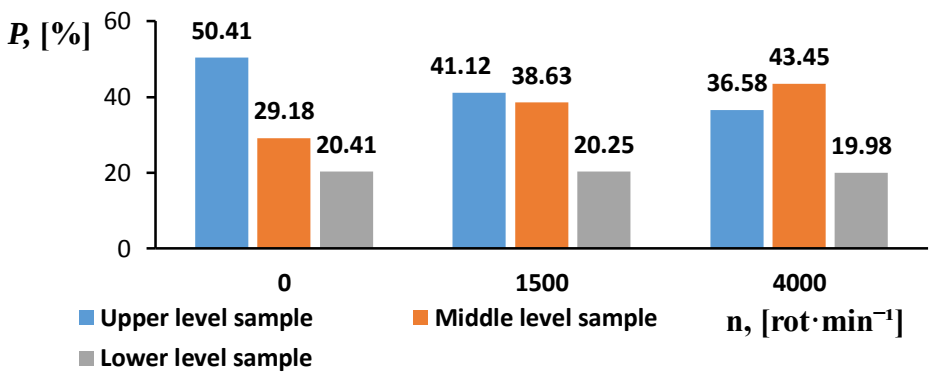

Fig. 2. Covering of testers with liquid depending on the rotation speed of drone rotors

A diagram of the coefficient of variation, as an inequality distribution index: CV, was performed for the liquid settled on the testers in relation to the speed of the rotors with propellers according to formula 2 (Fig. 3). There also was counted the average volume of the liquid settled on all testers at a given rotational speed of the propellers: *Vp* - presented in Fig. 4.

$$CV = \frac{100}{v_{sr}} \sqrt{\frac{\sum (v_i - v_{sr})^2}{3}} \, [\%] \tag{2}$$

where:

CV - the inequality distribution index of the settlement of the liquid on the testers, %,

v_{sr} - average volume of the liquid settled on the testers determined for testers from three level.

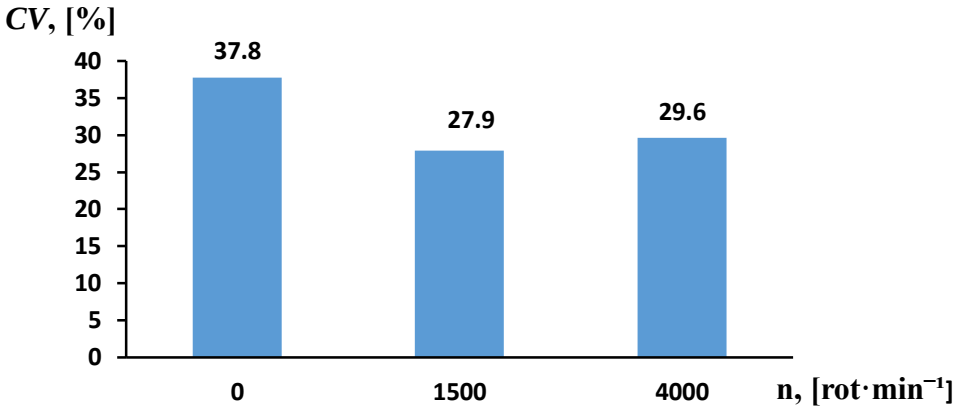

Fig. 3. Impact of the rotational speed of rotors on the inequality index CV of liquid that settled on testers

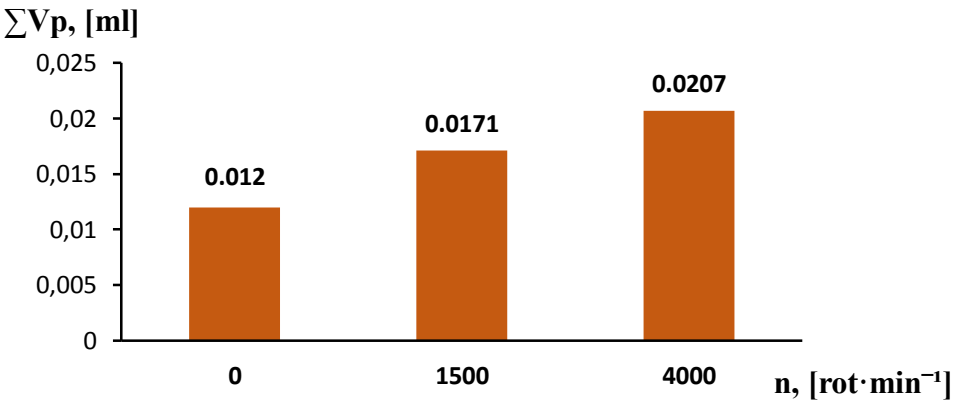

Fig. 4. Average volume of the liquid settled on the testers depending on the rotation speed of drone rotors

It can be observed from the diagram presented in figure 2 that the percentage share of covering the upper testers placed on the plant with the working liquid fell with a rise of the rotational speed of the drone rotors. The share of the liquid settled on the testers on the average level of the plants increased. No change to the share of the liquid settled on the bottom testers was observed.

It is evident based on the diagram in figure 3 that an increase of the speed of the drone rotors reduces the inequality index of the distribution of the liquid on the testers. It may be concluded that it is the effect of the increasing speed of the air stream, which blew the liquid sprayed into the inside of the plants. The average volume of the liquid settled on all the testers for a given rotational speed of the rotors increased with the rotations of the drone rotors. The testers were under the axle of the symmetry of the spray gun. This is the result of a change in the shape of the liquid jet and the thickening of the drops in the central part of jet under the influence of the air stream (Berner & Chojnacki 2017b).

CONCLUSIONS

The rush of air from the drone rotors, where the liquid is sprayed from, may change the concentration of drops in the air stream causing their greater concentration in relation to the area which the drops fall on. An increase of the average volume of the liquid settled on the testers may be an effect of this phenomenon.

The rotational speed of the drone rotors that performs spraying of the plants has an influence on the volume of the drops settled on the different levels of the plants. The stream of air coming from the drone rotors can cause a penetration of the stream of drops into the internal structure of the plants. The greater the rotational speed of the rotors is, the lower location is of water deposited on the plants. As a result of this, the rush of air may change the inequality index of the volume of the liquid settled on the different levels of the plants. The tank with the liquid sprayed mounted on the drone which gradually becomes empty during the operation will cause a change in the load of the drone. This will be the reason of a reduction of the rotational speed of the drone rotors. Its controlling system will be trying to maintain the required flying height. This means that during spraying the air stream which is required to create the appropriate lifting force of the drone may cause a change to the sedimentation of the liquid on the surface of the plants and its penetration into the deeper levels of the plants.

The knowledge obtained will offer an opportunity to plan plant protection operations with the use of drones. When preparing the technological process of pesticide applications by means of unmanned aerial vehicles should be considered that conditions of UAV using may be different than typical sprayers.

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CLOTHOID AS A TRANSITION CURVE OF THE MANIPULATOR END-EFFECTOR TRAJECTORY FOR HARVESTING TOMATOES IN A GREENHOUSE

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Keywords: precision harvest, trajectory planning, clothoid, tomatoes, greenhouses,

ABSTRACT
The article presents the way of using the clothoid as a transition curve when planning the trajectory of the tomato manipulator end-effector during harvesting in a greenhouse. Three variants of end-effector motion trajectory were planned. The first path consists of two rectilinear segments connected by a circular arc. The second path is composed of a rectilinear segment – clothoid – circular arc – clothoid and a rectilinear segment. The third option consists of two rectilinear segments connected by a biclothoid. For the analysed variants of the manipulator gripper trajectories, the motion parameters were determined and compared, and the results were presented in the graphical form. The algorithm with the use of clothoid, proposed in the paper, ensures the continuity of the displacement, velocity and acceleration for the planned trajectory of the end-effector. This is particularly important for the dynamics of the manipulator arm movement.

INTRODUCTION

The use of robots in greenhouses and orchards, for example for fruit or vegetable harvesting and spraying applications is an important issue for precision agriculture. The first stage of designing technological operations using agricultural manipulators is planning the motion trajectory. The issue concerns two questions: determination of the trajectory of aggregates or mobile robots movement in the area plane as well as that of the end-effector towards a chosen object e. g. a fruit, a vegetable or a stem etc. The paper by Sabelhaus et al. (2013) presents the way of determining the trajectory of recurrent turns whose main construction element is a clothoid. The authors analysed seven different manoeuvres useful from the agronomic point of view and proved that all motions can be executed using the proposed method. Wilde (2009) presented a simple and fast method for calculation of sharpness and curvature of the clothoid for the trajectory of continuous profile. He used the fragments of clothoid to combine rectilinear segments with the circular arc. The algorithm generates smooth, natural, drivable paths using a minimal amount of steering to reach a desired end position. In the case of planning the arm motion, Baur et al. (2013) proposed two approaches to automation determination of the end-effector, trajectory in the working space of the manipulator – heuristic as well as that exploiting an artificial function of the potential. The experimental results are presented and discussed based on harvesting one fruit and one stem. Schuez et al. (2015) proposed a two-stage solution of trajectory planning the redundant manipulator. Motion trajectories are established using the reverse algorithm of kinematics and optimized by the direct method. The paper by Zhang et al. (2016) presents the optimized structure of manipulator with four degrees of freedom. Moreover, the authors stated that the planned cycloidal trajectory of the end-effector motion allows to avoid collision with the obstacle such as a stem, a leaf or other fruit etc. In the paper by Boryga and Graboś (Graboś and Boryga 2013, Boryga 2014) the authors used higher degree polynomials for planning manipulators motion trajectories. Their advantage is the zero value of jerk in the initial and final motion phases which is decisive, any others, for positioning accuracy, dynamic load of driving units and steering the arm motion. In addition, in the paper by Boryga et al. (2015) there was

applied the PR-APT (Planning Rectilinear-Arc Polynomial Trajectory) method for planning the end-effector motion trajectory during harvesting tomatoes in a greenhouse. This paper presents the way of using the clothoid as a transient curve in planning the manipulator end-effector motion trajectory for harvesting tomatoes in a greenhouse. Three variants of end-effector motion trajectory were planned. The first path was composed of two rectilinear segments combined with the circular arc. The second was a rectilinear segment-clothoid-circular arc-clothoid and a rectilinear segment. The third path includes two rectilinear segments combined with the biclothoid (Kobryń 2017). The end-effector motion trajectories defined in this way can constitute partly fragments of obstacle profile to be avoided e. g. tomatoes stem with unripe fruit. For the analysed variants of the manipulator end-effector trajectory the motion parameters courses were determined and compared. Their results are presented graphically.

PLANNING OF MOTION TRAJECTORY

Assumptions

For all trajectories acceleration on the rectilinear segments is described by the 9th degree polynomial (Boryga 2015):

$$a(t) = -p_{252} \cdot t^2 \cdot (t - 0.5t_e)^5 \cdot (t - t_e)^2 \tag{1}$$

where: p_{252} - the polynomial coefficient, t_e - the time of motion end.

On the segment BT_1 the end-effector moves with the positive acceleration (the first part of the polynomial for which $0 \le t < 0.5t_e$), however, for the segment T_2E with negative acceleration (the second part of the polynomial for which $0.5t_e < t \le t_e$).

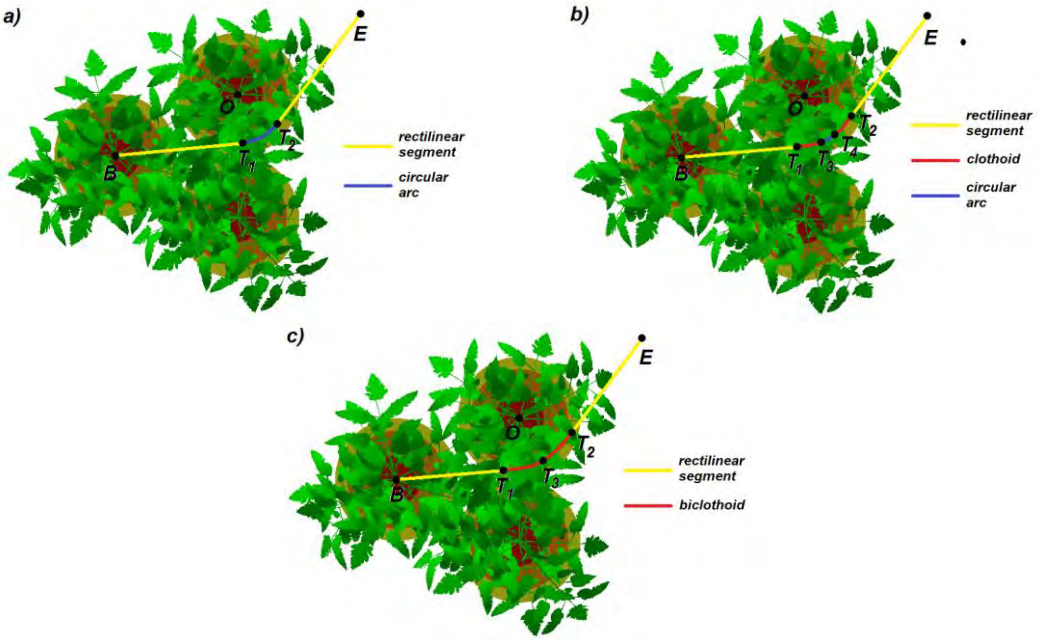


Fig. 1. Planned motion trajectories: a) *Path 1* (rectilinear segment – circular arc – rectilinear segment), b) *Path 2* (rectilinear segment – input clothoid – circular arc – output clothoid – rectilinear segment), c) *Path 3* (rectilinear segment – biclothoid – rectilinear segment)

For all trajectories, the constant variables are:

- The initial point *B* and final point *E* coordinates of the trajectory.
- The arc midpoint *O* and arc radius *R* coordinates constituting a fragment of obstacle outline to be avoided.

- The global coordinates system *xyz* whose origin is in the initial point of trajectory.
- The local coordinates system $x_O y_O z_O$ whose axes are parallel to those of the system *xyz* but the origin is in the point *O*.
- The maximum velocity on the rectilinear segments and the steady velocity of the end-effector on the curvilinear fragments of trajectories - v_{max}.

Calculations for the clothoid segments

The clothoid is a curve whose curvature κ is proportional to the arc length L, expressed by the equations:

$$L = A^2\kappa = \frac{A^2}{R} \quad and \quad \tau = \frac{L^2}{2A^2} = \frac{L}{2R} \tag{2}$$

where: A^2 - the proportionality coefficient (clothoid parameter), τ - arc tangent direction.

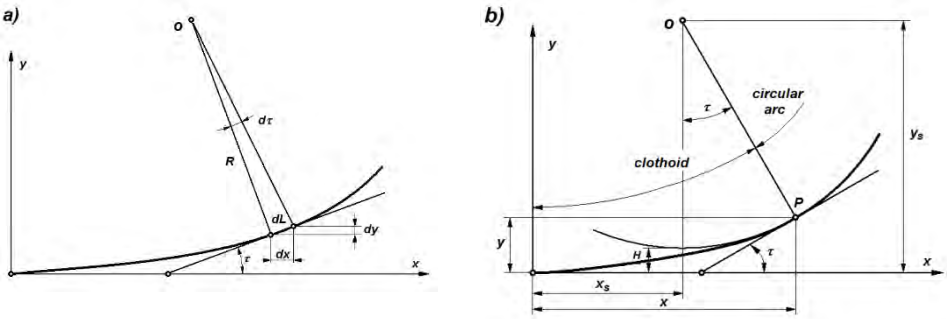


Fig. 2. Construction of an elementary clothoid: a) elementary triangle of clothoid, b) clothoid as a transition curve between rectilinear segments and circular arc

Rectangular coordinates of clothoid (Koc 2015):

$$x = \int_0^L cos\frac{L^2}{2 \cdot A^2} \cdot dL \qquad y = \int_0^L sin\frac{L^2}{2 \cdot A^2} \cdot dL \tag{3}$$

The sequence of steps during calculation procedure of the clothoid segments is as follows:

Step 1. The assumption (*Path 2*) or determination (*Path 3*) of clothoid length as well as calculation of curvature circle distant *H* stand-off from the main tangent, time in the motion along the input and output clothoid and clothoid parameter.

Step 2. Introduction of the coordinate system $x_{T1}y_{T1}z_{T1}$ whose axis x_{T1} is the direction of the motion on the segment BT_1 and its origin is in point T_1 as well as the system $x_{T2}y_{T2}z_{T2}$ whose axis x_{T2} is the direction of the motion on the segment T_2E and the origin is in point T_2.

Step 3. Determination of shifts in time for the motion along the clothoids.

Step 4. Determination of coordinates of the position of the end-effector in motion along: the input clothoid in the system $x_{T1}y_{T1}z_{T1}$, the output clothoid in the system $x_{T2}y_{T2}z_{T2}$, the input and output clothoid in the global coordinate system *xyz*.

Calculation for rectilinear segments

Step 1. Determination of coordinates of tangency points: T_1, T_2 of straight lines crossing points *B* and *E*, respectively as well as tangents to the arc of midpoint in *O* and the radius *R+H* (for the *Path 1 H=0*).

Step 2. Calculation of way increment on the rectilinear segments BT_1 and T_2E denoted Δs^{BT1} and Δs^{T2E}.

Step 3. Determination of motion time on the segments BT_1 and T_2E.

$$t = \frac{\alpha \cdot \Delta s}{\beta \cdot v_{max}} \tag{4}$$

whereby $\alpha = 1/61440$, $\beta = 1/88704$ for the segment BT_1 it is assumed: $\Delta s = \Delta s^{BT1}$, $t = t^{BT1}$ however, for the segment T_2E: $\Delta s = \Delta s^{T2E}$, $t = t^{T2E}$.

Step 4. Determination of polynomial coefficient describing the acceleration course on the BT_1 and T_2E segments:

$$p_{252} = \frac{\beta^{10} \cdot v_{max}^{11}}{\alpha^{11} \cdot (\Delta s)^{10}} \tag{5}$$

For BT_1: $\Delta s = 2 \cdot \Delta s^{BT1}$ and $p_{252} = p_{252}^{BT1}$, for T_2E: $\Delta s = 2 \cdot \Delta s^{T2E}$ and $p_{252} = p_{252}^{T2E}$.

Step 5. Determination of the time shift for the motion on the T_2E segment and coordinates of position of the end-effector in motion along the rectilinear segments.

Calculations for the arc

Step 1. Determination of time of motion along the arc, dependences for calculation of the angle displacement in the local coordinate system $x_O y_O z_O$ and determination of the coordinates of the end-effector position during the motion along the arc in the global coordinate system *xyz*.

Step 2. Determination of time shift for the motion along the arc.

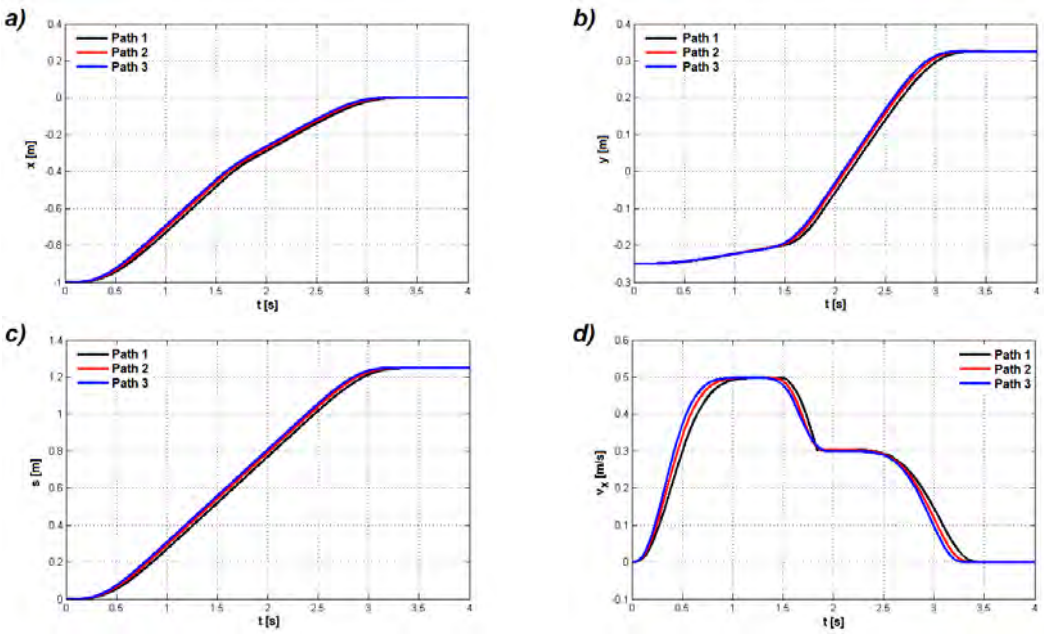
Final calculations

Step 1. Determination of total end-effector dislocation along the trajectory and determination of first and second derivatives of dislocation in relations to time.

Step 2. Determination of total time of motion along the trajectory.

RESULTS OF THE SIMULATION

The path presented in Fig. 3 as a result of simulation refer to the motion in the plane *xy*.



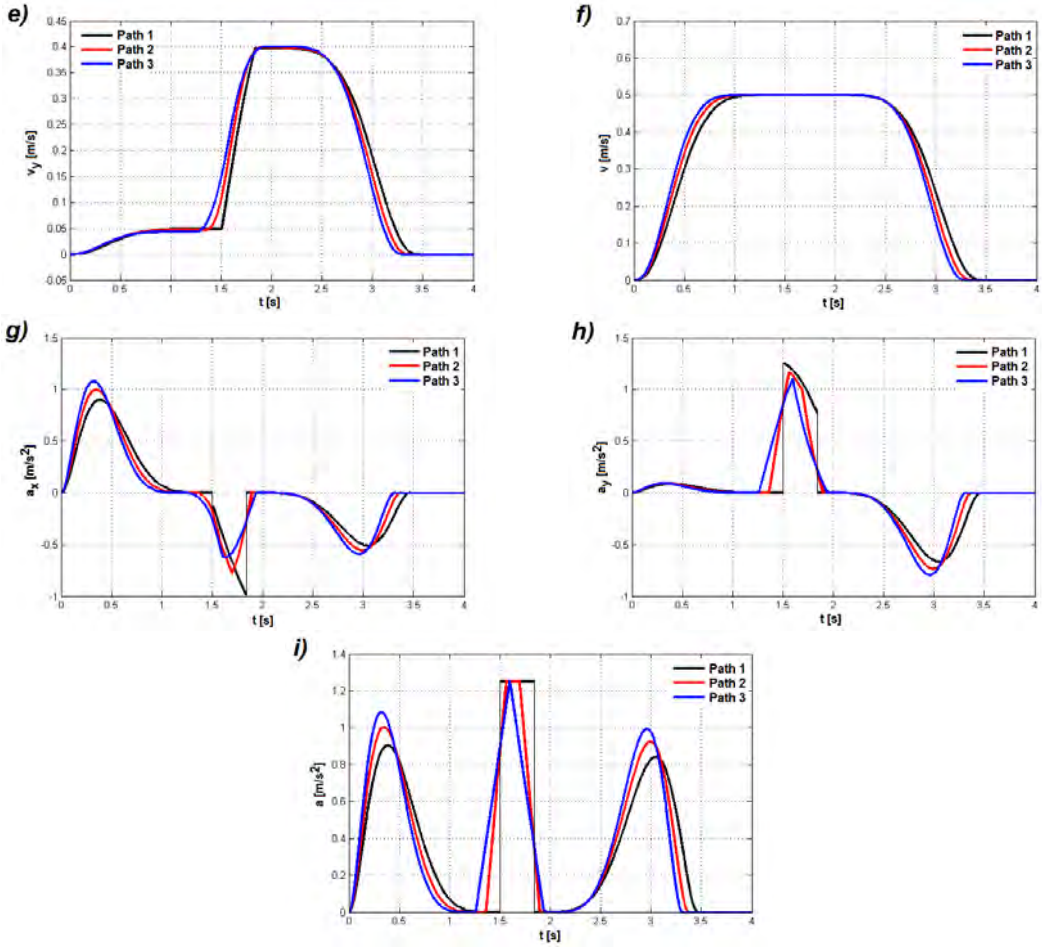


Fig. 3. The courses of kinematic quantities of the end-effector: a) dislocation towards the axis *x*, b) dislocation towards the axis *y*, c) resultant dislocation, d) velocity oriented towards the axis *x*, e) velocity oriented towards the axis *y*, f) resultant velocity, g) acceleration oriented towards the axis *x*, h) acceleration oriented towards the axis *y*, i) resultant acceleration.

Table 1. Comparison of the length of path and time of the motion for individual trajectories

Path denotation	Construction of the path	Length [m]	Motion time [s]
Path 1	Rectilinear segment - BT_1	0.522015	1.507
	Circular arc - T_1T_2	0.164122	0.328
	Rectilinear segment - T_2E	0.561805	1.622
	Σ	**1.247942**	**3.457**
Path 2	Rectilinear segment - BT_1	0.471318	1.361
	Input clothoid - T_1T_3	0.1	0.2
	Circular arc - T_3T_4	0.065660	0.131
	Output clothoid - T_4T_2	0.1	0.2
	Rectilinear segment - T_2E	0.511165	1.476
	Σ	**1.248143**	**3.368**
Path 3	Rectilinear segment - BT_1	0.435984	1.259
	Input clothoid - T_1T_3	0.168475	0.337
	Output clothoid - T_3T_2	0.168475	0.337
	Rectilinear segment - T_2E	0.475936	1.374
	Σ	**1.248870**	**3.307**

The maximal time of motion (3.457s) referred to the shortest *Path 1* of the length 1.2479m. However, the longest equalling 1.2488m with the biclothoid (*Path 3*) was covered in the shortest time which was 3.307s. The character of dislocation courses of the trajectories being analysed for the motion along each axis was similar. Analysing the velocity courses, it was found that for *Path 1* rapid changes of velocity occur in the tangent points T_1 and T_2. In the case of the other trajectories (*Path 2, Path 3*) these changes are also observed out they are of „mild" transitions character. Discontinuities of the course in points T_1 and T_2 are observed only for *Path 1* in the acceleration diagrams. Analysing the motion along the rectilinear trajectory it can be stated, that the maximal absolute acceleration value a_x occurs in point T_2 being $0.989 m \cdot s^{-2}$. Acceleration a_y at point T_1 reaches the maximal value of $1.244 m \cdot s^{-2}$. For *Path 2*, the maximal absolute value a_x is $0.775 m \cdot s^{-2}$ (point T_4). However, the maximal value of the component a_y is $1.178 m \cdot s^{-2}$ (point T_3). For the biclothoid (*Path 3*) the maximal absolute acceleration value a_x is $0.604 m \cdot s^{-2}$ and that of the component a_y is $1.095 m \cdot s^{-2}$

CONCLUSIONS

As follows from the numerical investigations the highest values of components of acceleration in motion along the curvilinear trajectory were found for the trajectory with the circular axis and the lowest for the trajectory with the biclothoid. Translocation, velocity and acceleration for the trajectory, in which the clothoid is use, are continuous functions in the whole range of motion. Moreover, application of polynomial function for description of acceleration causes that its course is tangent towards the time axis in the initial and final points of the trajectory. The above mentioned properties, have a significant effect on increase in positioning accuracy, reduce occurrence of dynamic loads in the manipulator kinematic system, driving energy and time of operation. The algorithm can be implemented in only few steps and therefore, it is very effective.

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EXPERIMENTAL STUDIES OF A COMBINED AGGREGATE FOR APPLICATION OF MINERAL FERTILISERS AND SOWING

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Keywords: sowing, mineral fertilisers, rational parameters

ABSTRACT
The article presents the results of field experimental studies of sowing grain crops and application of mineral fertilisers by means of a combined two-machine fertiliser application and sowing aggregate on the basis of two grain seeders. A regression equation is obtained, and influence of the velocity of movement, the depth of sowing seeds and application fertilisers into the soil upon the uniformity of seed and fertiliser distribution along the row are determined. On the basis of the obtained experimental data rational parameters of sowing are justified at which the necessary quality of the execution of the technological process will be achieved.

INTRODUCTION

As one of the basic ways how to increase the efficiency of crop production may be regarded elaboration of the ways for raising the efficiency of aggregates and decreasing the costs for the execution of technological operations. An analysis shows that the most perspective way for essential decreasing the costs when growing grain crops is the use of combined sowing aggregates which simultaneously perform several technological operations of sowing (Kabakov, 1984; Behov and Djachenko, 2000; Vilde et al., 2006; Chorna, 2012). There are several variants of combined machines for application of fertilisers and sowing. The present article considers a possibility to use a combined sowing aggregate for the application of mineral fertilisers and sowing on the basis of two grain seeders. The seeders are trailed by tractor of the traction class 14 kN, which is the most widespread among the agricultural producers in many countries of Eastern Europe. The main advantage of this fertilising and sowing aggregate is to introduce the basic dose of mineral fertilisers into deeper layers of the soil, directly into the area of the future root system of the crop. Justification of the scheme, design parameters and operating modes of the sowing aggregate created by using tractors of the traction class 1.4 on the basis of two trailed grain seeders is outlined in works (Masalabov, 2016; Petuhov, 2016). However, considering the difference between the proposed aggregate and those treated in the works mentioned, a necessity arises to conduct experimental studies about the influence of the sowing parameters upon the execution quality of the process and justification of their rational values. The aim of this study is experimental determination of the influence of the working velocity of the combined sowing aggregate, the depth of sowing seeds and application fertilisers into the soil upon the uniformity of seed distribution, as well as determination of rational parameters.

MATERIALS AND METHODS

The experimental equipment (Fig. 1) consists of two seeders connected together by a special hitch which allows ensuring the necessary manoeuvrability of the aggregate during its operation. During the execution of the process the first seeder of the sowing aggregate ensures introduction of the necessary basic dose of mineral fertilisers into the soil to the depth of 7 to 9 cm with a row spacing of 25 cm but the second seeder –

sowing of the grain crops to the depth 2 to 6 cm with a row spacing of 12.5 cm with simultaneous introduction of the starting dose of mineral fertilisers. As a means of aggregation a tractor of the traction class 14 kN is used.

Fig. 1. General view of the experimental equipment

Barley seeds were used for the laboratory and field studies of the sowing process, but, for better estimation of the distribution of mineral fertilisers in the furrow, it was replaced by soya bean seeds. Besides, as quality indicators of the operation there were accepted the uniformity of seed and fertiliser distribution along the row, the coefficient of the seed and fertiliser sowing depth variation, and the deviation coefficients of the seeds and fertilisers from the axis of the row – factors which affect qualitative indicators of work – the sowing depth of seeds and fertilisers, as well as the operating velocity of the forward movement of the aggregate. The sowing depth of the seeds was accepted as 2, 4, 6 cm, the sowing depth of the fertilisers – 7, 8, 9 cm, and the working velocity of the aggregate – 1.0, 2.0, 3.0 $m \cdot s^{-1}$. The object of the experimental studies is the operating process of sowing by means of the proposed combined two-machine sowing aggregate. The conditions for the execution of the studies, fixed according to known methodologies (Dospehov, 1985; Barwicki et al., 2012). The results of the experimental studies were processed according to a well-known methodology of statistical processing of research data (Maslov, 2007) with subsequent presentation in the form of functional and graphical dependencies, as well as with the application of applied programs for the PC.

RESULTS AND DISCUSSION

As a result of the conducted experimental studies according to the accepted methodology the following dependencies were obtained. The uniformity of barley seed distribution along the row will be described as a regression equation in the form of a polynomial of the second degree, like:

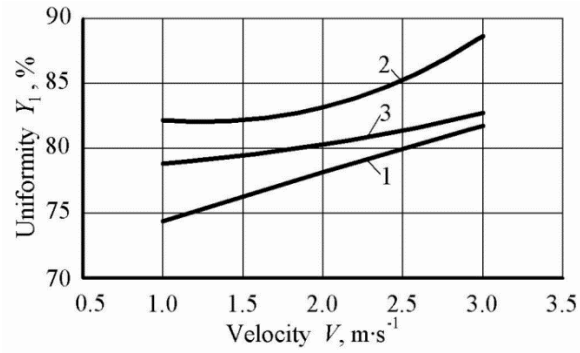
$$Y_1 = 54.33+1.21 \cdot V+12.1783 \cdot H+0.865 \cdot V^2-0.4163 \cdot V \cdot H-1.3388 \cdot H^2, \qquad (1)$$

where: Y_1 – uniformity of barley seed distribution along the row (distance between seeds), %; V –working velocity of the sowing aggregate, $m \cdot s^{-1}$; H – sowing depth, cm.

On the basis of the analysis of the obtained equation (1), as well as its graphic interpretation (Fig. 2) one can draw a conclusion about the increase in the sowing uniformity of the seeds when the velocity of the forward movement of the aggregate. But when the sowing depth of the seeds is increased from 2 to 4 cm, this quality indicator of the operation will increase; when the depth is increased further – the uniformity will decrease. For the indicator “uniformity of fertiliser (soya bean seeds) distribution along the row” the following response surface (Fig. 2) and a regression equation were obtained:

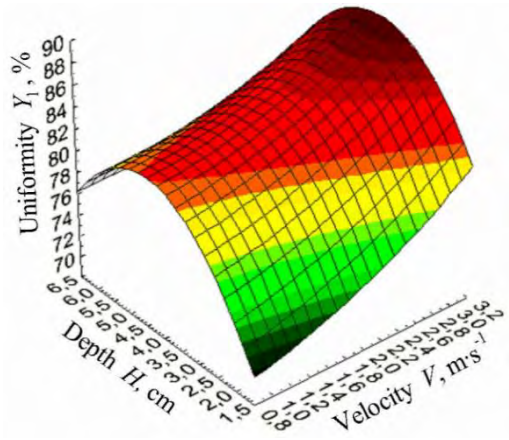
$$Y_2 = -60.6811 - 0.4867 \cdot V + 30.41 \cdot H + 0.6167 \cdot V^2 + 0.09 \cdot V \cdot H - 1.6633 \cdot H^2, \quad (2)$$

where: Y_2 – uniformity of fertiliser (soybean seeding) distribution along the row (distance between seeds), %.



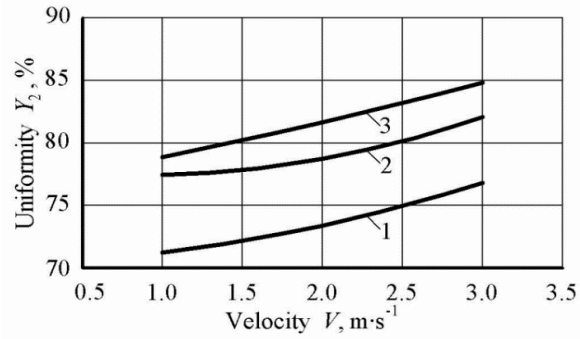
1) – H = 2 cm; 2) – H = 4 cm; 3) – H = 6 cm

a)



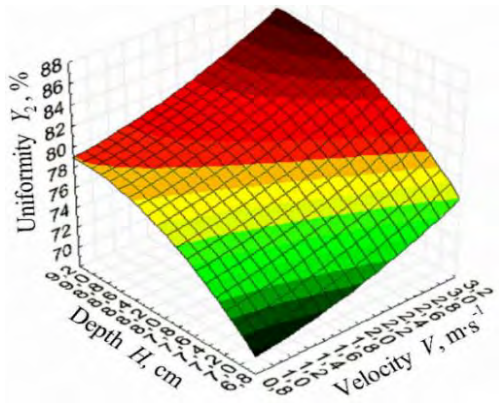
b)

Fig. 2. Dependencies of the uniformity of barley seed distribution along the row upon velocity V of the sowing aggregate and sowing depth H of the seeds (a), and the response surface (b).



1) – H = 7 cm; 2) – H = 8 cm; 3) – H = 9 cm

a)



b)

Fig. 3. Dependencies of the uniformity of fertiliser (soybean seeding) distribution along the row upon velocity V and the introduction depth H of fertilisers into the soil (a), and the response surface (b).

Increasing the working velocity of the sowing aggregate and the introduction depth of fertilisers into the soil, the uniformity of their distribution at the bottom of the furrow will increase. The analysis of the obtained research results (Fig. 3) also indicated a decrease in the variation coefficient of the sowing depth of the barley seeds when the working velocity of the aggregate and the sowing depth of the seeds increase. This is also determined by the obtained functional dependency:

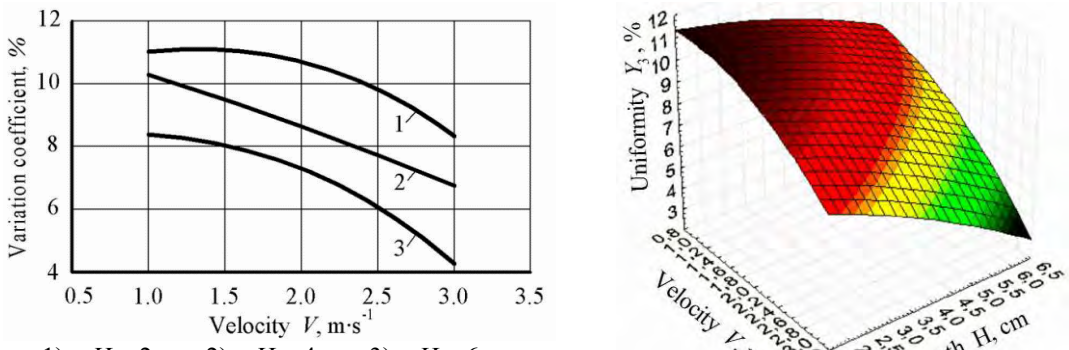
$$Y_3 = 10.79 + 1.7883 \cdot V - 0.05 \cdot H - 0.705 \cdot V^2 - 0.18 \cdot V \cdot H - 0.055 \cdot H^2, \quad (3)$$

where: Y_3 – variation coefficient of the sowing depth of the barley seeds, %.

The graphic dependency of the variation coefficient of the sowing depth of fertilisers (soya bean seeds) upon the working velocity of the sowing aggregate and the depth of the fertiliser placement into the soil is presented in Fig. 4, but the equation which will describe this dependency will have the following appearance:

$$Y_4 = 25.7444–14.89·V+2.6967·H+0.4533·V^2+1.3825·V·H–0.4417·H^2, \quad (4)$$

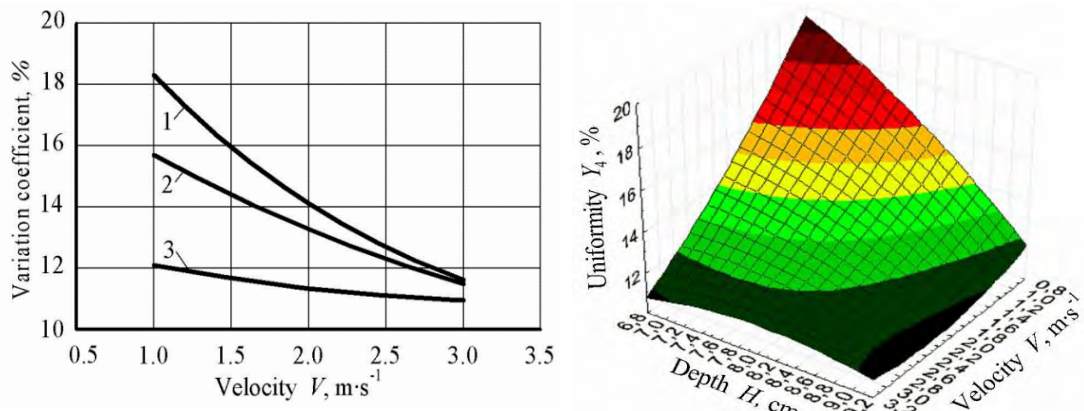
where: Y_4 – variation coefficient of the sowing depth of the fertilisers (soybean seeding), %.



1) – H = 2 cm; 2) – H = 4 cm; 3) – H = 6 cm

a) b)

Fig. 4. Dependencies of the variation coefficient of the sowing depth of the barley seeds upon velocity V and sowing depth H of the seeds (a), and the response surface (b).



1) – H = 7 cm; 2) – H = 8 cm; 3) – H = 9 cm

a) b)

Fig. 5. Dependencies of the variation coefficient of the fertiliser (soybean seeding) introduction depth upon velocity V and the depth H of placement of fertilisers into the soil (a), and the response surface (b).

The obtained results of the studies witness that decreased deviation of the introduction depth of fertilisers into the soil from the preset value can be achieved by increasing the working velocity of the aggregate and the placement depth of fertilisers. The obtained results of the experimental studies (Fig. 6) indicate also a decrease in the variation coefficient of the deviation from the axis of the row of the barley seeds when the velocity of the sowing aggregate is increased. But, increasing the sowing depth from 2 cm to 4 cm, the variation coefficient rises, but after further increase in the depth – the variation coefficient diminishes. The regression equation has the following form:

$$Y_5 = 19.5111+0.07·V+3.3433·H–1.0417·V^2+0.3987·V·H–0.5904·H^2, \quad (5)$$

where: Y_5 – variation coefficient of the deviation from the axis of the row of the barley seeds, %.

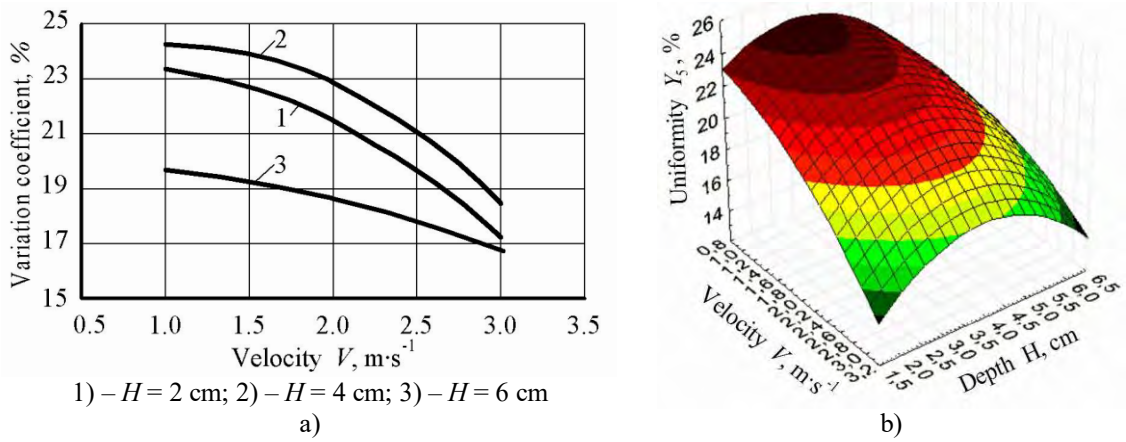


Fig. 6. Dependencies of the variation coefficient of deviation from the axis of the row of the barley seeds upon velocity *V* and the sowing depth *H* of seeds (a), and the response surface (b).

On the basis of the presented results of the experimental research of the influence of the sowing parameters upon the variation coefficient of deviation from the axis of the fertiliser row (Fig. 7) one can draw a conclusion about a decrease in its value when the working velocity of the aggregate is increased. However, when the depth of the fertiliser introduction is increased, the variation coefficient will diminish, but, when the depth is increased, it, on the contrary, will increase.

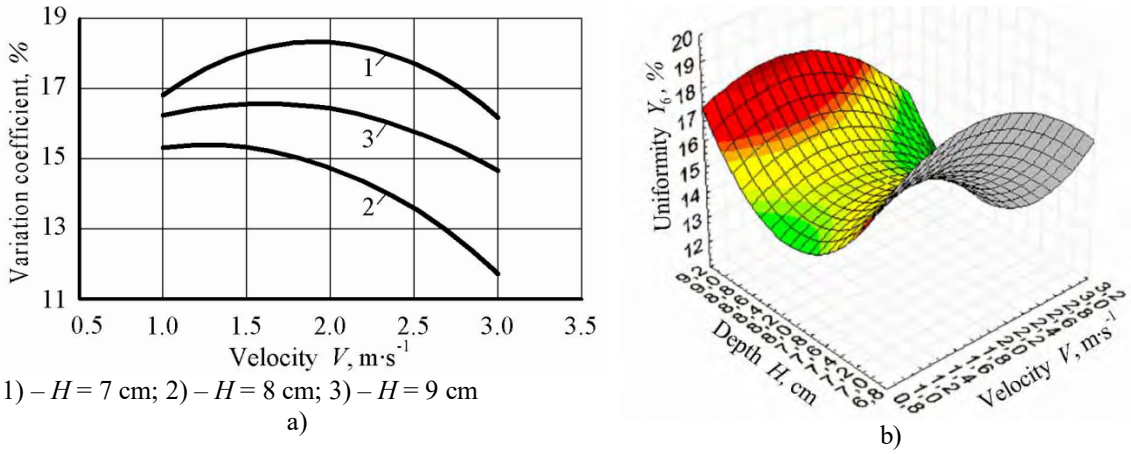


Fig. 7. Dependences of the variation coefficient of deviation from the axis of the fertiliser (soybean seeding) row upon velocity V (a), and the response surface (b).

This will be confirmed also by the analysis of the regression equation:

$$Y_6 = 175.0711+6.2817\cdot V-40.7283\cdot H-1.3517\cdot V^2-0.2325\cdot V\cdot H+2.5333\cdot H^2, \quad (6)$$

where: Y_6 – variation coefficient of the deviation from the axis of the row of the fertiliser (soybean seeding), %.

On the basis of the factor analysis of the obtained regression equations (1-6) there are determined rational parameters of sowing grain crops using a combined two-machine sowing aggregate: the working velocity of the aggregate – 2.5...3.0 m·s^{-1}, the sowing depth of the seeds – 4...5 cm, the depth of fertiliser introduction into the soil – 8...9 cm. Results of the research were given patent for construction (Adamchuk et al., 2015). The results of the conducted experimental studies made it possible to determine also the technical and operational performance indicators of the particular combined fertilising and sowing aggregate (Table 1).

Table 1. Technical and operational performance indicators of the combined fertilising and sowing aggregate

Name of the parameter	Value
Turning radius, m	6.5…8.9
Turning time, s	18.4…24.7
Average velocity on the turning strip, m s^{-1}	1.78
Average deviation of the path of the second seeder in relation to the path of the first seeder, see: -at the turn -during the working travel	 23.7 3.6
Specific fuel consumption, l ha^{-1}	3.77

As evident from the data in Table 1, the turning radius of the particular combined fertilising and sowing machine and tractor aggregate does not exceed 9 m, which ensures its «looping» turns but deviations of the path of the second seeder in relation to the first one also have an insignificant value, which is 23.7 cm and is also quite acceptable.

CONCLUSIONS

1. For a combined aggregate for the introduction of mineral fertilisers and sowing on the basis of two seeders a regression equation has been obtained and impact of the working velocity, the sowing depth of seeds and the introduction depth of fertilisers into the soil has been determined upon the distribution uniformity of seeds and fertilisers along the row.

2. Rational values of the sowing parameters of the barley seeds by a combined sowing aggregate are: the working velocity– 2.5...3.0 m s^{-1}; the sowing depth of seeds – 4...5 cm; the introduction depth of fertilisers into the soil – 8...9 cm

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MONITORING THE STATE OF AGROCENOSIS WITH THE USE OF REMOTE-SENSING GYRO SYSTEM

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Keywords: precision agriculture, gyrocopter remote sensing system, hyperspectral imaging, GHG mapping, decision support system

ABSTRACT

The aim of the project is the development of a decision support system (DSS) for precision farming. It is based on remote sensing to assess condition of agrocenoses and define requirements for cultivation operations (irrigation, fertilizing, and pest control). The remote sensing method is to be used for monitoring winter wheat and maize as well as for assessing degradation level of meadows on the basis of intensity of carbon dioxide and methane exchange between the ground surface and the atmosphere. The paper discusses application of an ultralight autogiro as an efficient carrier of remote sensing equipment. The project is co-financed by the National Centre for Research and Development, BIOSTRATEG grant no. 298782.

INTRODUCTION

Precision agriculture is a management strategy based on the assessment of local, specific soil and plant properties, which specifies appropriate timing and doses of application of irrigation, plant protection products, fertilizers, etc. or machine operating parameters in order to optimise the use of soil resources and production potential of plants with minimal hazards to the environment. Production practices are adapted to the needs and condition of plants in individual field fragments (Gozdowski at el. 2007; Dammer at el. 2015). The advantages of precision agriculture are currently widely accepted, but it is profitable mainly in large-scale farms. It is possible to increase profitability through development of novel and more cost-efficient methods for acquisition of the most complete information possible about the condition of the entire field (soil and plants) (Dąbrowska-Zielińska at el. 1998; Strachan at el. 2002). Precision farming is vital for the required sustainable intensification (Chen at el. 2011, Day at el. 2008). State-of-the-art precision farming has demonstrated yield increases of 3.7% with 7% less N-fertiliser (Hobbs at el. 2008).

So far, acquisition of data required for implementation of precision agriculture is mainly achieved by ground-based examinations of soil and plants (Bereś 2013, Bieganowski at el. 2013; Lamorski at el. 2014; Rook at el. 2014). However, this approach involves expensive chemical and biological analysis and is work- and time-consuming. A solution may be aerial data acquisition. However, the use of aircraft for these purposes has substantial drawbacks: operating costs (the need of flights to and from the airport and the high consumption of the expensive aviation fuel); high speed of the flight, resulting in a lower resolution of recorded images. When using unmanned aerial vehicles, there are other important limitations: the prohibition of the use of drones

heavier than 25 kg imposed by law (Regulation of MTBiGM from March 26, 2013; Communication from the Commission to the European Parliament and the Council. April 8. 2014) which substantially reduces the capacity of drones, e.g. mounting of the hyperspectral high-resolution system designed in this project, and impairs stability (particularly at stronger gusts of wind); the prohibition of flights above the altitude of 300 m, which makes it impossible to increase the imaging band at the constant focal length of the scanner, thereby causing its low efficiency; the prohibition of flights out of pilot's sight, which impedes and prolongs the measurement in the case of high crops (maize) and large fields.

A solution, which seems to be the most optimal, is the use of an ultralight aerial vehicle - the gyrocopter. The gyrocopter is an ultralight aerial vehicle (from the family of rotorcrafts) equipped with a rotor and a push propeller (Fig. 1, 2) (Bzowska et al. 2015). Unique ultralight gyrocopter features became an origin of selection of this type of aircraft as a remote sensing system carrier. In order to assure sufficient lift and space for the equipment the three sided version of the gyrocopter was selected. A gyrocopter can operate from grasslands not specially prepared, located in the direct neighbourhood of an object to be scanned.

Fig. 1. Gyrocopter equipped with hyperspectral scanners (photo P. Turos)

In comparison to aircrafts, gyrocopters are cheap to operate; they can land on the field and burn car petrol (much cheaper and much more easily available) in amounts lower than are used by a plane. Simultaneously, their carrier capacity is sufficiently high to have no limitations on the requirements of camera sets and other sensors designed in this project.

Fig.2 Gyrocopter flying over the maize (photo P. Grzybowski)

Fig 3. Hyperspectral cameras inside the gyrocopter (photo M. Bzowska)

OBJECTIVES AND METHODOLGY

In contrast to the majority of hitherto applied solutions based on multispectral imaging (selected spectral channels of the spectrum are recorded and interpreted), this project is based on hyperspectral recording (i.e. in a wide spectral range from 400 to 2500nm with a high spectral resolution of 2-10 nm). Spectral characteristics are recorded by two complementary-scope cameras (Fig 3). The use of a hyperspectral set allows application of a greater number of available interpretation techniques in the analyses of vegetation and soil and development of novel techniques through recording in a wide spectrum range.

The primary objective of the project GYROSCAN is to develop a Decision Support System (DSS) based on an analysis of hyperspectral images in order to identify the needs for agricultural treatments (irrigation, fertilisation, and chemical pest and disease control) in the context of the requirements and objectives of precision agriculture. Remote sensing methods will be employed for:

- evaluation of the meadow degradation degree (the level of biodiversity of vegetation occurring on the analysed meadow will be a measure of degradation)
- assessment of the intensity of carbon dioxide and methane exchange between the active surface and the atmosphere

The objectives of this project complement the tasks realised under the project Advanced Sustainable Agriculture Production (ASAP) .The concept of this project is presented in Fig. 4.

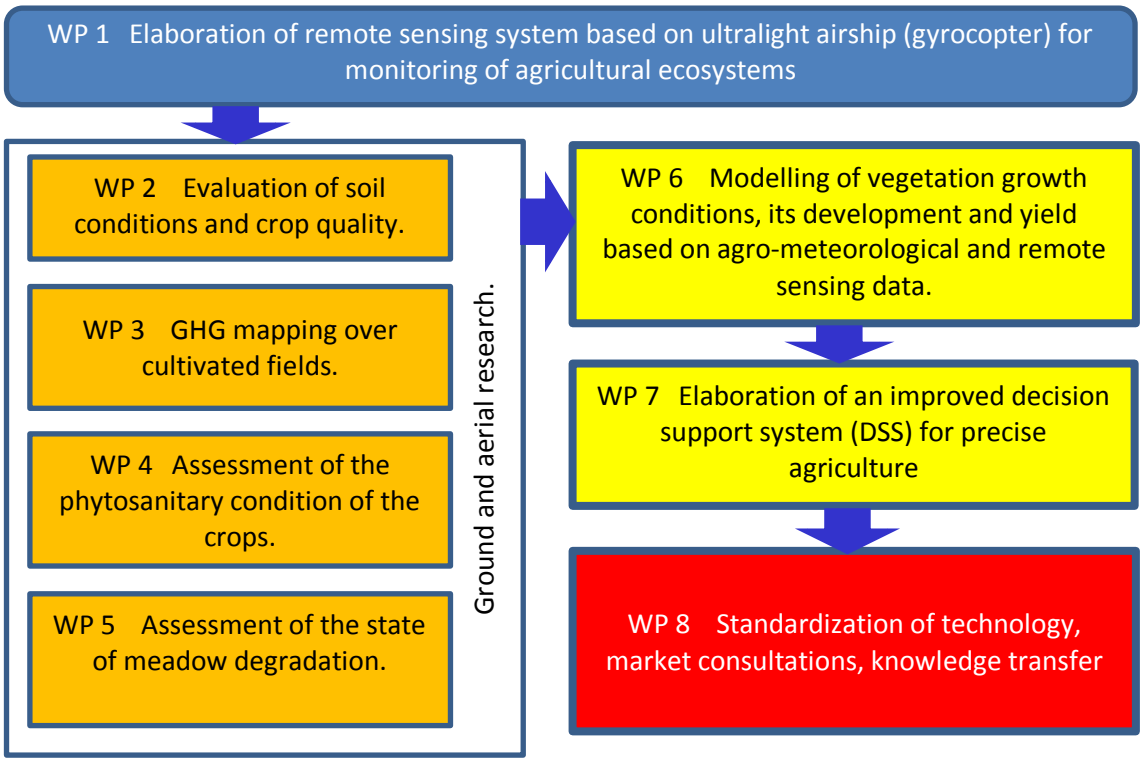

Fig. 4. Project scheme

A major advantage of the project is the consortium consisting of four scientific units such as the Institute of Agrophysics, PAS (leader), Institute of Geodesy and Cartography, the Institute of Plant Protection - National Research Institute, the

University of Life Sciences in Lublin and three companies: Aviation Artur Trendak, Geosystems Polska Ltd. and Lesaffre Polska S.A. The consortium has been design in such a way that the qualifications and capabilities of all partners complement each other. Among the enterprises each one has great experience in a field of its business profile. **Aviation Artur Trendak** firm is an important (in Europe and globally) manufacturer of gyrocopters. It has extensive experience in flight services, also offered to farmers. **Geosystems Polska** is one of the leading companies in recording and interpretation of the hyperspectral spectrum. It has vast experience in operation of this type of systems and good knowledge of the market. **Lesaffre Polska** is experienced in ecological crop cultivation and is an excellent representative of potential recipients of the project results. Also, scientific units are leading in their field of expertise. **Institute of Agrophysics, PAS,** has substantial experience, proven by many reckoned publications, in physicochemical research of soil and plant properties, modelling of mass and energy transport processes in the soil-plantatmosphere systems, and use of multi- and hyperspectral systems, including measurements and interpretation of results. The renowned **Institute of Geodesy and Cartography** is a strong scientific partner as well. This is confirmed by the experience derived from the involvement of the Institute in projects (also international). In the project, the experts from the **Institute of Plant Protection - National Research** Institute is assessed the degree of pest and disease infestations in the crop plants. Realisation of the full scope of the project would not be possible without a team specialised in meadow studies. This is provided by the team from **the University of Life Sciences in Lublin**, who specialise not only in identification of plants in meadow communities but has good knowledge of the study area.

Methodology is based on two main pillars: gyrocopter-based measuring system and field experiments (ground-based and aerial analyses). The measuring system consists of a set of cameras (hyperspectral imaging system) and the device for remote measurements of the concentration of greenhouse gases (GHG emission monitoring system) which are installed on board of the gyrocopter constructed and adapted for the purposes of the measurements. The whole measuring system is validated in a way that it is possible to record a spatial map of fields/meadows in the context of the hyperspectral properties of plants and soils, taking into account the parameters of the gyrocopter flight (Fig. 5, 6).

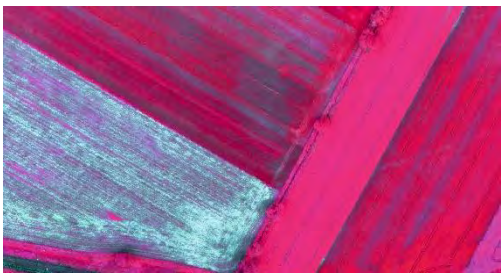

Fig. 5. Example of image recording in the infrared band

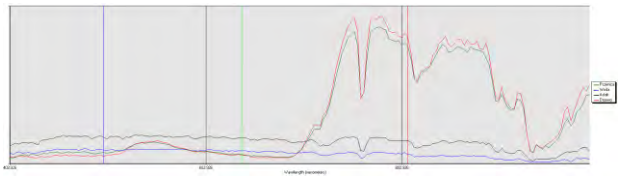

Fig. 6. Spectral characteristics representing different types of objects

After successful completing and the measuring system validation, the next stage of the project consists of a series of ground-based and aerial field analyses.

An important value of the project is the diversity of the scanned objects (agrocoenoses) investigated with the aim of calibration and validation of the model and DSS The crop plants (two most important Polish crops in large-scale farms, i.e. wheat and maize) are

examined on the fields of a private large-scale farm in Rogów, Lublin Province, and fields located near Wołczyn, Opole Province. On the Rogów farm, reduced tillage is mainly applied (elimination of ploughing, as the treatment is energy-intensive and, according to many reports, does not bring positive results).

Lesaffre Company manages waste from yeast production (Lesaffre is a major world producer of yeast) by utilising it as organic fertilisers, in accordance with the aquatic legal documentation. Additionally, the company makes use of a developed fungicidal formulation (yeast-based fungicide). Hence, we decided to include investigations of crop plants cultivated on this farm as part of the proposed project.
The assessment of the degree of meadow degradation is carried out in a naturally and economically valuable area of the middle section of the Wieprz River (Lublin region), characterised by high habitat diversity.

The aim of ground-based research tasks is to acquire data about the soil conditions and plant status as well as for evaluation of the degree of meadow degradation. Many measurements and analyzes are made on soil, plants and atmospheric conditions. The seven measurement campaigns are conducted (once a month between April and November) during each of the vegetation seasons. Spectral characteristics (in the range of 400-2500 nm) of the plant cover will be obtained for all the variants of the field experiments (32 variants in Rogów and 22 variants in Wołczyn) for various crop growth conditions.

The collected aerial data will be used to create high resolution maps which will support the DSS. Furthermore, on the base of the gathered hyperspectral data, the most suitable spectral bands/ranges and appropriate indices of plant water status, and phytosanitary status of plants are selected and evaluated. The actual crop water requirements, fertilization status, phytosanitary status is evaluated for all the growing stages on the base of the relations between the plant spectral characteristics and plant environment, including meteorological historical and prediction data, soil database information.
The data gathered from ground-based and aerial analyses will be used for development, calibration, and validation of the yield prognosis model and directly for development, calibration, and validation of the DSS. The added value of the solution will be a reduction of the amount of pollutants and GHGs emissions in the regional/national scale. Thus, this will contribute to an overall better life quality and human health.

CONCLUSIONS AND PLANNED RESULTS

The GyroScan project will deliver a comprehensive solution for an overall precision farming approach including a comprehensive DSS, reflecting both ecologic and economic costs. Its use will lead to reduction of the amount of fertilisers to the exact amount needed by the plants.

The final stage of the project will include development of the key project product, i.e. a calibrated and validated Decision Support System which will be composed of a gyrocopter-mounted hyperspectral registration module. The module will be fully coupled with the gyrocopter in a way allowing recording of the altitude as well as speed and direction of flight. This will contribute to precise mapping of the condition of the soil surface/plants and indication of areas where there is a need for undertaking specific agrotechnical treatments. Together with treatment recommendations (recommended doses of water and/or chemicals), the digital map will control the operation of the system. Downloaded to the module mounted on the area and/or on a tractor, the map will facilitate undertaking of recommended actions. Additionally, the yield prognosis

model will contribute to specifying the terms of application of the required treatments for several days ahead, which will significantly help the farmer to optimize the time and use of the available infrastructure.

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EMISSIONS FROM THE COMBUSTION OF SOLID BIOFUELS

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ABSTRACT

Owing to the use of excess straw and unsold grain that has gone bad as a biofuel for heating boilers, farmers may save money to be spent on fuel and it allows them to gain additional profits from the sale of biomass that has not been used. In order to assess the usability of waste biomass as a fuel, tests were conducted related to the emission levels of particulate matter (PM), carbon oxide and nitric oxide that are emitted during combustion in the heating boiler of pellets from pine wood and from rape straw as well as a mixture of pine and rape pellet with lentil grain. The values of the emissions of the agents examined from the combustion of crop-based biomass exceeded by many time the values of emissions that occur as a result of the combustion of pine wood pellet only. The high levels of the emissions of particulate matter, carbon oxide and nitric oxide connected with the combustion of waste crop-based biomass may in the future discredit this material as a fuel for low emission boilers.

INTRODUCTION

In agricultural farms, there is an overproduction of waste biomass, i.e. unused straw and spoiled, damaged or unsold grain. An excess of biomass may be used by farmers as an energy material. Present-day heating boilers that use biomass granulate as a fuel are chiefly used with wood pellet, yet granulates from straw or hay as well as grain can be incinerated in these boilers. Owing to the use of energy materials from their own waste biomass to heat rooms, farmers may have significant savings in spite of the fact that farmers bears additional costs to process biomass into the pellet form (Kraszkiewicz et al., 2015). Another advantage of straw pelleting and storing it in the form of granulate is the high bulk density of this form of material; hence, the storage space in farms can be reduced (Niedziółka et al., 2015).

During the incineration of solid fuels, including crop-based fuels, there occurs an emission of substances into the atmosphere that are harmful to human health and to the natural environment. These are chiefly emissions of particulate matter and gases (e.g. Demirbas, 2005). The primary undesirable gas emissions include carbon monoxide: CO and nitric monoxides: NO_X as well as polycyclic aromatic hydrocarbons (Olsson, 2006). The particulate matter contained in exhaust gases is related to liquefied fluid, incomplete combustion products and ash particles. These may also be fine underburnt biomass particles and ash particles that are removed from the boiler into the atmosphere by the rush of gases. Particulate matter suspended in air is divided into three subclasses, i.e. PM10, PM2.5 and PM0.1. The emission levels of pollutants contained in fumes from the incineration of biomass may significantly vary depending on the composition and type of fuel, fuel humidity, boiler capacity, incineration technology, the course of incineration and the thermal processes that occur there as well as the software that is used to control boilers (Bignal et al., 2008; Chojnacki at al., 2017; Hays et al., 2003; Johansson et al., 2003).

In modern heating boilers, with the aid of the control system installed in these and appropriate software, by dosing air and fuel that is fed into combustion chambers, it is possible to control the composition of emissions contained in exhaust gasses and to

modify and control thermochemical processes (Romeo & Gareta, 2006; Valíček et al., 2017). Dosing of fuel and air is done depending of the data obtained from sensors (e.g. temperature in the combustion chamber, oxygen excess ratio as well as the temperature of water in the water jacket, the temperature of fumes as well as CO_X and NO_X emissions). Permissible emission levels for boilers including a division into classes are contained in the PN-EN 303–5:2012 Standard. Following this Standard, the Ecodesign Directive will come into force starting from the year 2020. With regards to emissions, its requirements are the level of Class 5 of the PN-EN 303–5:2012 Standard. Those farmers who will purchase modern boilers that guarantee emission levels according to this class will qualify for financial support from government anti-smog programs. Boilers including the software that controls their work are designed taking into consideration combustion of a selected fuel, e.g. pine wood pellet, so that the minimum emission levels as per Class 5 could be maintained while making a maximum use of the calorific value. Unfamiliarity with the level of emissions from the combustion of crop-based waste biomass from the farmer's own farm and replacing the fuel dedicated to given boilers with this biomass may lead to the levels permitted by the Standard being exceeded. This may result in the loss of the subsidy connected with the purchase of the boiler. To prevent this, emissions need to be determined from the combustion in "anti-smog" boilers of crop-based waste biomass of various type; investigations need to be initiated to create a composition of low emission fuels from this biomass that conform to the conditions related to fuels dedicated to boilers. Emissions of some substances during the combustion of biofuels may be reduced by the use of fuel additives and production of mixed fuels. The authors of the paper (Bäfver et al., 2009) investigated the impact of a calcium and kaolin additive to the fuel on changes in the emissions of particulate matter during the combustion of oat grains. It was found that a kaolin additive to oat grain may limit the emissions of particulate matter during its combustion. The research demonstrated that a two-percent share of kaolin in the fuel reduced particulate matter emissions by 31 per cent, while a four per cent additive reduced particulate matter emissions by 57 per cent. The authors of the paper (Fagerström et al., 2010) described examples of a reduction of the emissions of potassium and particulate matter by adding peat to the biofuel.

The purpose of the present research is an assessment of the level of the emissions of particulate matter, carbon monoxide and nitric monoxides in waste gases from the combustion of a composition of solid fuels from crop-based waste biomass in a heating boiler.

MATERIAL AND METHODS

Lentil grain, pine wood pellet and rape straw pellet were used as fuels in the investigations related to the emission levels of biofuels during incineration in a boiler. The diameter of the pellet used was 6 mm. Lentil grain came from a cleaning plant and this was waste with mechanical damage. The compositions of the fuel inputs used were as follows: pine wood - 100%, pine wood 80% lentil grain 20%, pine wood 20% lentil grain 80%, rape straw 50% lentil grain 50%, rape straw 100%. The relative humidity of the fuels prepared did not exceed 6 per cent. The fuel was combusted in an automatic 25 kW heating boiler manufactured by Froling, type: P4 Pellet. This boiler possesses a double ash collector; the purpose of the other ash collector is to remove ash particles from fumes. It also possesses a condensation chamber that collects heat from the fuel

that goes from the boiler to the stack. Pine wood pellet is the fuel that is dedicated to this boiler.
A Testo 380 fine particle analyser connected to a Testo 330-2 LL fumes analyser was used in the measurement of particle matter emissions as well as carbon monoxide and nitric monoxides in fumes. The analyser probe was installed in the stack over the boiler condensation module. The fume analyser made an automatic measurement over a period of 15 minutes. Additionally, with the aid of this analyser, the measurements were made of the fume temperature, fume humidity and oxygen share in the fumes. The test stand is presented in Fig. 1. The boiler was connected via pipes with a warm water tank. Heat from the boiler was collected indirectly by heating cold water that flowed through it which, once heated, was removed to a sewage system. The flow rate of water that chilled the tank was selected in such a manner so that water coming from the boiler to the tank and that heated it could maintain a constant temperature of 60°C.

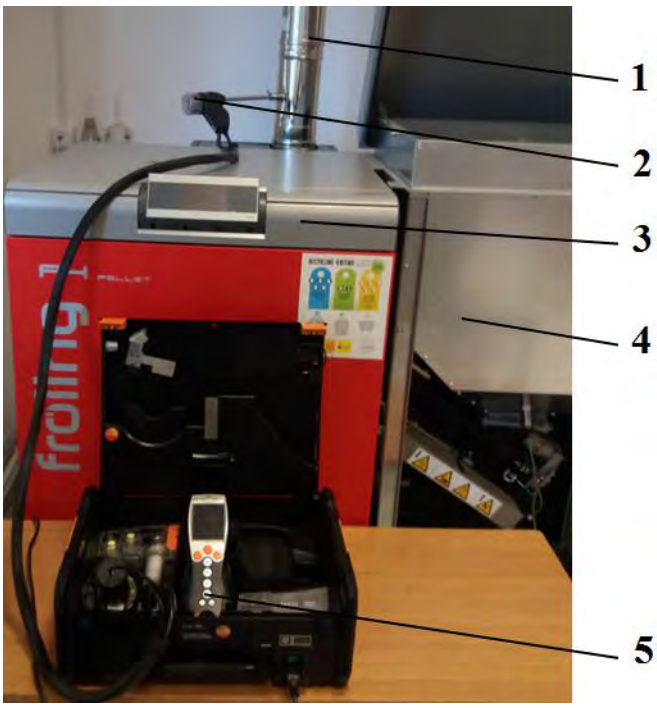

Fig. 1. Test stand: 1 - stack, 2 - probe, 3 - boiler, 4 - pellet container, 5 - analyser

RESULTS AND DISCUSSION

The values of the parameters of exhaust gases measured with the probe, such as: relative humidity, temperature and oxygen contents in exhaust fumes are presented in Table 1.

Tab. 1. Parameters of exhaust gases

Name of parameter	Pine wood 100%	Pine wood 80%, lentil grain 20%	Pine wood 20%, lentil grain 80%	Rape straw 50%, lentil grain 50%	Rape straw 100%
Humidity of exhaust gases, [%]	11.3	11.6	10.7	11.2	10.7
Temperature of exhaust gases, [C]	54.9	54.9	55.5	56.3	54.9
Oxygen cont. in exhaust gases, [%]	15.2	15.2	15.2	15.2	15.1

The results of the following measurements: particulate matter, carbon oxide and nitric oxides contained in exhaust fumes are presented in Figures 2, 3 and 4. The diagrams present the mass of the substances emitted that are contained in the mass of exhaust gases.

It is evident based on the diagrams that the combustion of a mixture of pellet from pine wood and lentil grain caused emissions that are by many times higher than the level of emissions from the combustion of pine wood pellet only. The results demonstrate that even a small addition (20 per cent) of lentil grain to pine wood pellet could cause a growth of the values of the emissions under investigation even by 100 per cent. The levels of emissions from the combustion of rape straw pellet only and mixed with lentil grain pellet also exceeded by many times the levels of emissions from the combustion of pure pine pellet.

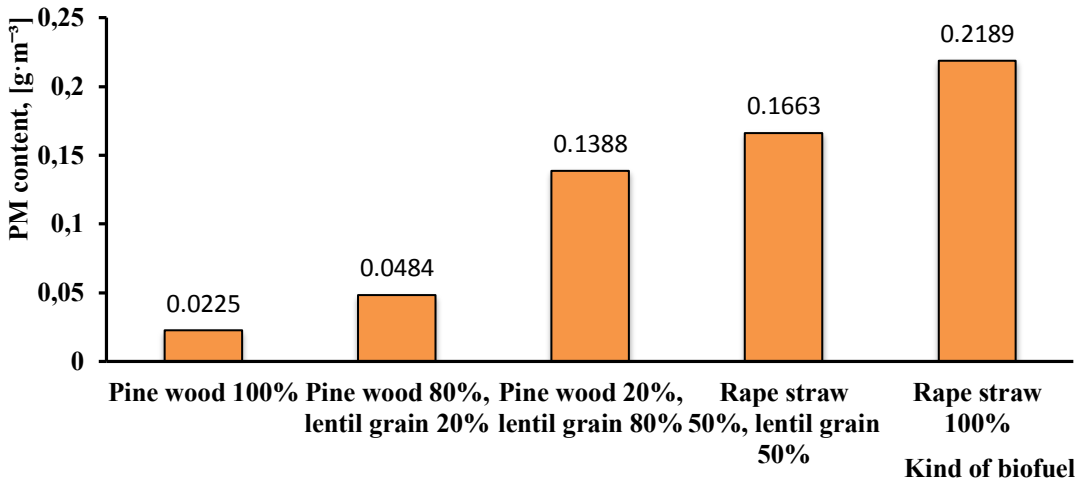

Fig. 2. Particulate matter content in fumes

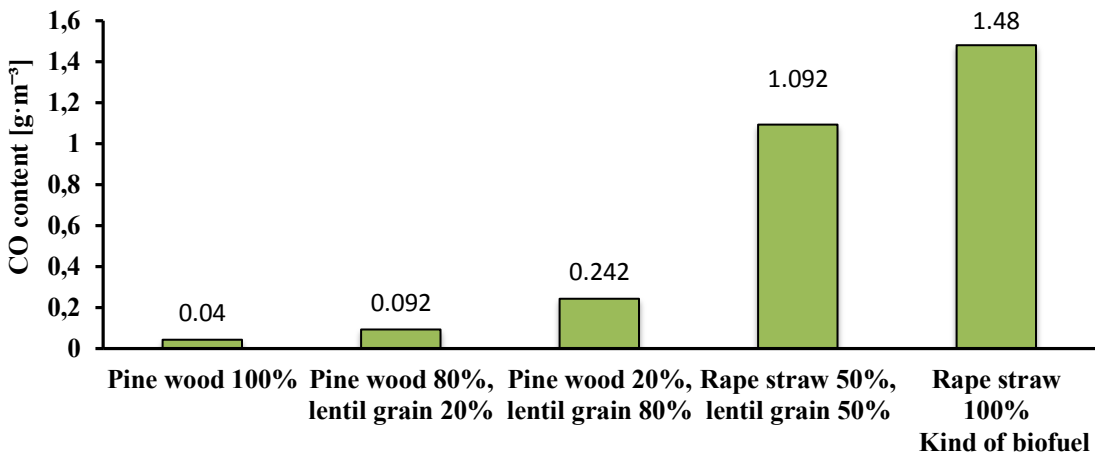

Fig. 3. Carbon oxide content in fumes

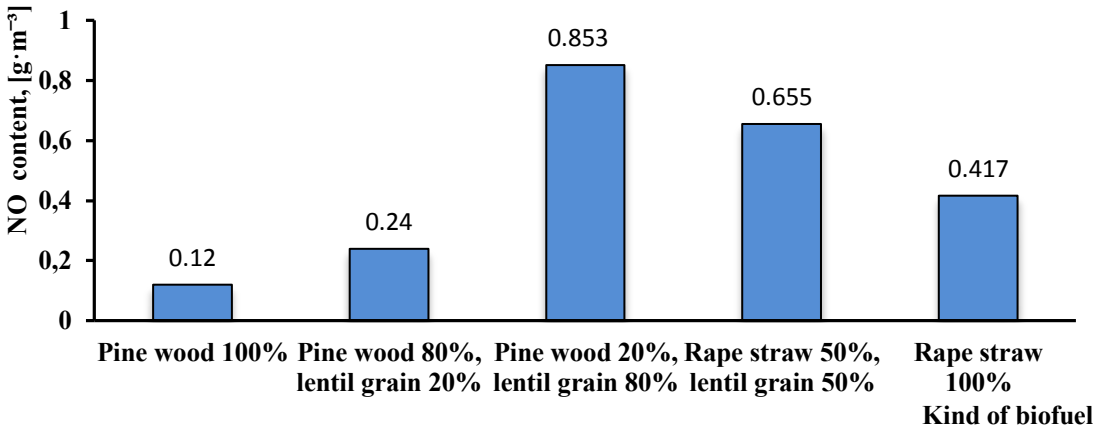

Fig. 4. Nitric oxide content in fumes

During combustion, nitric oxides may form as a result of the reaction of atmospheric nitrogen with atomic oxygen in high temperatures, yet it is also oxidation of nitrogen compounds that are chemically bonded with the substance that is the main factor that has an impact on their value in exhaust fumes (Kraszkiewicz et al., 2015; Mitchell et al., 2016). According to the data contained in the articles (Chojnacki et al., 2017; Gulmezoglu & Kayan, 2011; Komorowicz et al. 2009), the average nitrogen content in pine wood is from 0.13 to 0.5% of dry matter; in rape straw, this is ca. 0.8% and in lentil grains: from 3.4 to 4.4%. When comparing this data with the results of tests related to nitric oxygen emissions, it may be stated that it is nitrogen contents in the biofuels under examination that had a major impact on the value of these emissions.

CONCLUSIONS

The following was established in the research:

- combustion in low-emission boilers of fuels from waste crop-based biomass such as rape straw or lentil grain may cause the occurrence of the emission levels of particulate matter, carbon oxide and nitric oxide that substantially exceed the emission levels that are permissible for this type boilers,
- co-combustion of crop-based products, like lentil grain in the experiment, with fuel dedicated for low-emission boilers (in this case, pine wood pellet) may also cause a significant increase of the level of the following emissions: particulate matter, carbon oxide and nitric oxide.

When relevant services find that permissible emission levels have been exceeded, those farmers who have used preferential credits or dedicated programs that support the purchase of low emission boilers may lose their financial privileges.
In order to utilize the unused potential of waste crop-based biomass as an energy material for low emission boilers, there is a need to develop and test formulas for low-emission fuels produced based on these materials.

ACKNOWLEDGMENTS

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SELECTED PHYSICAL PROPERTIES OF EXTRUDED FOAMED MATERIALS BASED ON STARCH

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Keywords: starch, foams, extrusion-cooking, physical properties, sustainability

ABSTRACT
Starch-based foamed materials were processed with extrusion-cooking. Potato starch was used as a basic raw material. Plastronfoam PDE and poly(vinyl) alcohol were added in the amount of 1, 2, and 3% of starch mass. Directly expanded foams were produced with the extrusion-cooking process at 80-110°C with 19% of initial moisture of blends. The processing was carried out at 100 and 130 rpm with two types of forming dies: round and ring of 3 and 5 mm of internal diameter, respectively. The obtained foams were put to cutting test to evaluate the durability of samples expressed in the maximum force needed to break the sample. The increasing amount of additives had a different influence on the foams' hardness. Plastronfoam PDE lowered the cutting force of foams independently of the screw speed and forming die applied. An opposite trend was observed when poly(vinyl) alcohol was used as an additive. The samples shaped with the round forming die exhibited a higher hardness and better durability than the foams shaped with a ring die. The results could be helpful in management of optimum composition and treatment conditions to achieve desirable and sustainable products with desired properties.

INTRODUCTION

Polymer foams are polymers with bubble pores but are also known as materials with a reticulated structure (Mittal 2013; Pu et al. 2017; Zhang and Li 2000). Such foams are usually made from conventional polymers, such as polyethylene (PE), polypropylene (P), polystyrene (PS), polycarbonate (PC), hard poly(vinyl) chloride (PVC) with some foaming agents added as powders, liquids or gas (Peisheng and Guo-Feng 2014; Siva et al. 2017; Wu and Xu 2002). Due to their cellular structure, foamed materials are very popular across industries, such as the building and construction, cooling and freezing, and, mostly, packaging industry. They are resistant to heat and cold and, most importantly, to mechanical damage. Foamed loose fillers, next to film and rigid forms, are widely used for packaging (Machade et al. 2017; Zhou et al. 2006). Due to the limited resources of petroleum and stricter environmental requirements, polymers, including foamed materials, need to be replaced by environmentally friendly composites with some addition of renewable plant materials (Bhatnagar and Hanna 1996; Bryśkiewicz et al. 2016; Wójtowicz et al. 2009; Zhang and Sun 2007). Intensive research has been going on for many years to find natural renewable raw materials for biopolymers as sustainable solution. Starch-based biopolymers have been found suitable for various applications, such as packaging materials and fillers, and are the prevailing group of biodegradable materials available on the market (Gáspár et al. 2005; Mitrus et al. 2009; Patel et al. 2005). There are many methods suitable for the processing of biopolymers and, among bioreactors, the extrusion and reactive extrusion can be applied. The extrusion of porous materials gives the material a specific two-phase structure based on plant polymer chains and gas where small gas bubbles are evenly distributed in the internal structure (Garbacz and Tor 2007, Gendron 2004; Peng et al. 2016). Plant starches (potato, maize, wheat, tapioca) are the most promising biopolymers as they fit various biodegradable

thermoplastic material applications (Cunningham et al. 1991; Combrzyński et al. 2015; Mitrus and Moscicki 2014; Wang et al. 2005). Biopolymers, such as starch and cellulose, are suitable for composting and decomposition in the soil without generating any waste. So, these raw materials are sustainable both as renewable and environmentally friendly. Much effort has been taken to investigate the options of improvement of the physical, mechanical and functional properties of biopolymers aimed to find the proper quality of final products (Cha et al. 2001; Lui and Peng 2005; Mitrus et al. 2016). The aim of the study was to determine selected physical properties of extruded starch-based foamed materials processed using a single screw extrusion-cooker with the addition of selected functional components.

MATERIALS AND METHODS

Potato starch (purchased from PEPEES S.A., Łomża, Poland) was used as the basic raw material. Plastronfoam PDE and poly(vinyl) alcohol AP in the amount of 1-3% were used as additives. The ready blends of potato starch and additives were moistened with a proper amount of water to reach the target blend moisture of 19%. The extrusion-cooking process was performed with the single screw extruder TS-45 (Metalchem, Gliwice, Poland) with the configuration of L/D = 12:1 and the compression ratio of 3:1. The processing temperature ranged from 80 to 110°C and two screw speeds were used: 100 and 130 rpm. Two types of forming dies were applied as shapers: a round die with the diameter of 3 mm (M1) and a ring die with the internal diameter of 5 mm (M2). The produced samples were dried at 40°C for several hours to reach the final moisture content of 6% of snacks. A cutting test was used to evaluate the hardness of obtained foams. The universal testing machine Zwick BDO- FB0.5TH (Zwick GmbH & Co., Ulm, Germany) was used according to the method proposed by Jin et al. (1995) with some minor modifications. A 20 mm-long sample was cut on the testing table at an angle of 90° with a cutting knife. The cutting force (F_{max}) was measured with a Warner-Bratzler steel blade with the test speed of 8.33 $mm \cdot s^{-1}$; the initial force was set at 0.1 N. Force–displacement curves were recorded and analyzed with the testXpertIIv3.3 software based on the data from 10 replications. Statistica (version 6.0, USA) was used for the analysis of the results.

RESULTS AND DISCUSSION

Some extrusion-cooking processing parameters, as the temperature, screw speed, feeding rate and the moisture content as well as the rheological characteristics of starch, have an effect on product density, expansion, and many other physical properties, including the hardness of foamed loose extrudates (Nabar and Narayan 2006). The measurement of resistance to break is one of the most important features of foamed materials because of their application as protective fillers for sensitive products. The additives used in the experiment revealed various durability qualities of the tested foams.

The effect of cutting force on starch-based foams processed, with the addition of Plastronfoam PDE, are presented in Fig. 1. An increased amount of this additive lowered the cutting force results independently of the screw speed and forming die applied. The samples processed with the application of a ring forming die demonstrated higher resistance to cutting than the samples shaped with a round die. The cutting force in the ring-shaped foams was at least twice as high as in the round-shaped samples (Fig. 1a). Significantly lower cutting force values were reported for foams with the addition of Plastronform PDE compared with the control samples processed without any additives.

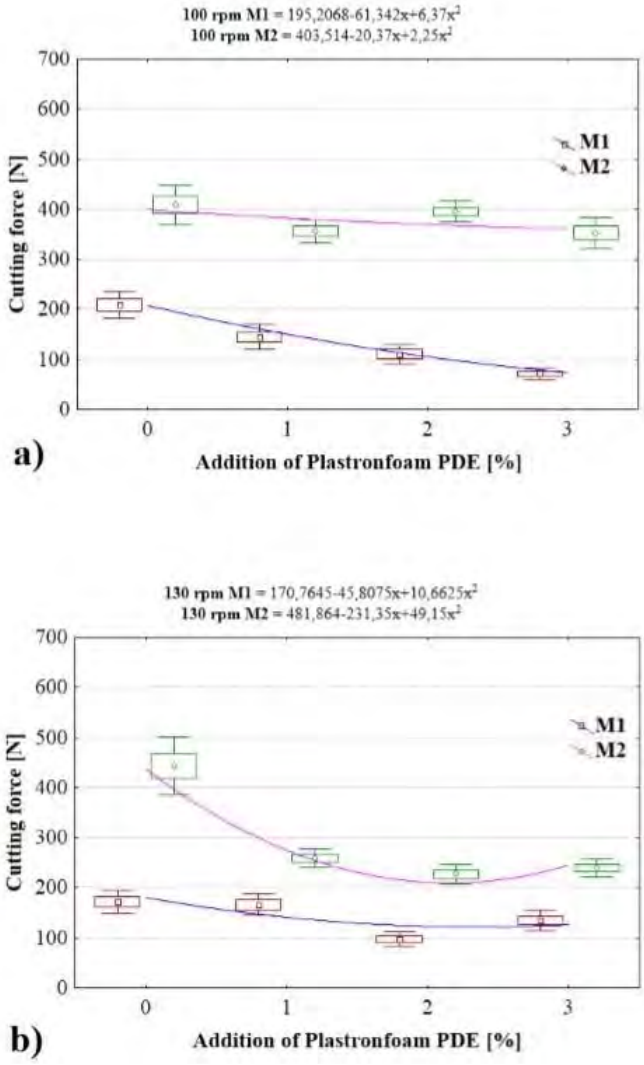

Fig. 1. The cutting force of starch-based foams processed with the addition of Plastronfoam PDE with various forming dies: a) 100 rpm, b) 130 rpm.

Correlation coefficients showed diverse dependencies depending on the shape of the forming die and the screw speed applied during processing. Fig. 1b shows the results of the applied cutting force on foams shaped at screw speed of 130 rpm with round M1 and ring M2 forming dies. The highest correlation was observed when the M1 die was used and the processing screw speed was set at 100 rpm (R2=0.994) and when the M2 forming die was used at the speed of 130 rpm (R2=0.98).

A different trend was observed when poly(vinyl) alcohol was applied as an additive. An increased amount of the additive in blends raised the value of cutting forces (Fig. 2). Higher values of F_{max} were reported for samples processed with poly(vinyl) alcohol v. the control samples. Additionally, the shape of the forming die had a significant effect on the sample's hardness (Fig. 2a). A more rapid increase of hardness with the addition of poly(vinyl) alcohol was observed when the speed of 130 rpm instead of 100 rpm was applied during the processing (Fig. 2b), especially when the ring forming die was used for shaping. A significant effect on hardness ($p_{\text{-value}}$=0.000) was observed after the increasing of the quantity of poly(vinyl) alcohol coupled with positive correlation coefficients (R^2=0.999 and 0.992, for M1 and M2, respectively) when processed at 100 rpm.

Similarly, a positive effect was reported when the speed of 130 rpm was applied during the processing with the correlation coefficients of 0.976 when shaped with the M1 die and 0.967 when the M2 ring die was used.

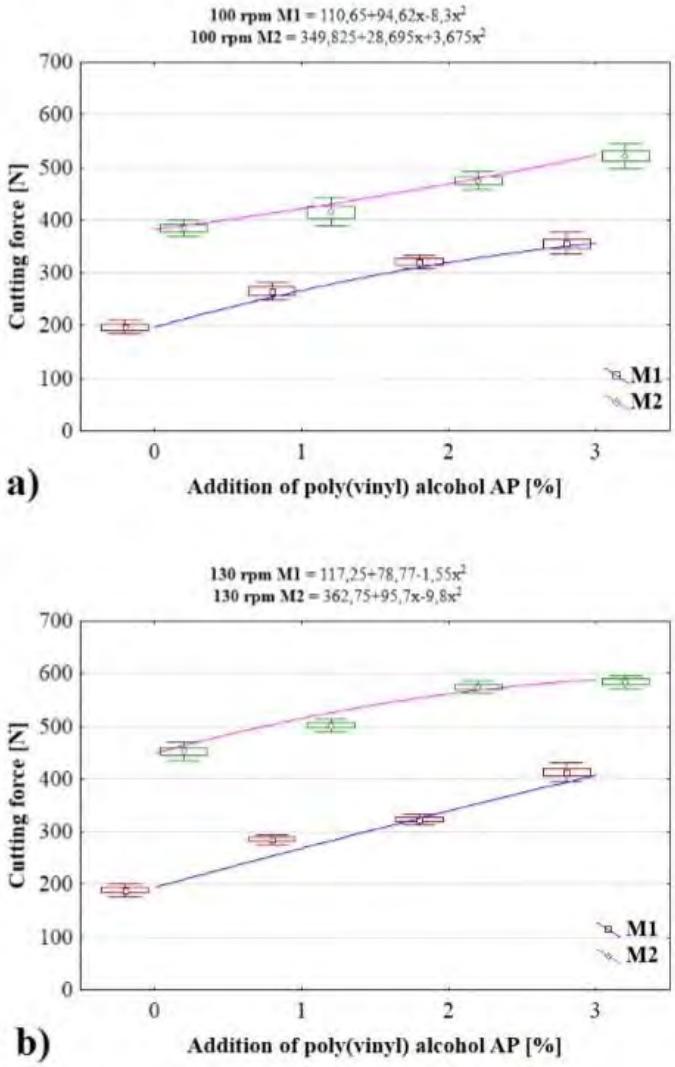

Fig. 2. The cutting force of starch-based foams processed with the addition of poly(vinyl) alcohol with various forming dies: a) 100 rpm, b) 130 rpm.

CONCLUSIONS

Potato starch with selected additives enables the production of foamed starch-based loose fill materials with different characteristics. The addition of Plastronfoam PDE lowered the maximum force needed to break the sample. An opposite trend was observed when poly(vinyl) alcohol was applied. The samples with this additive showed greater hardness and higher durability of foams as the amount of the additive was increasing. The results regarding the durability and resistance of foam to break can be useful in selecting the proper processing conditions to obtain starch-based biopolymer foams with the desired properties. Starch-based biopolymers could be a sustainable solution to waste management issues compared with conventional polymers which are becoming an environmental protection challenge. This makes the extrusion-cooking a suitable technique for the sustainable use of plant raw materials – among them environmentally friendly foam products.

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CONCEPT OF A SYSTEM OF PLANT PROTECTION SUPPORT BASED ON THE ERP SYSTEM

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Keywords: IPM, plant protection products, decision support system, agricultural advice

ABSTRACT
The paper presents a concept of utilising existing IT systems supporting shops supplying plant protection products to farmers in order to assist chemical protection of plants. The method implies use of sales alerts to generate messages intended for agricultural producers. The system created on this basis may supplement the existing systems signalling threats from pests. Implementation of the proposed solution does not require high financial outlay providing at the same time the possibility of reaching a large number of recipients, also at small farms. A disadvantage of the proposed solution is its lower effectiveness compared with the advanced warning systems.

INTRODUCTION

Protection of cultivated plants against pathogens is becoming an increasingly important task for the farmer. These actions are very essential in sustainable and integrated agriculture. The existing crops require using appropriate chemical agents, applied in the appropriate dose and at the appropriate time. Correct use of plant protection products requires not only extensive knowledge and skills but also access to up-to-date information (Stenberg, 2017). Lack of application of adequate protection, application of inappropriate products and doses or implementing protective measures at the wrong time may cause considerable losses to the farmer (Królczyk, et al. 2014; Niemiec, et al. 2017). These losses can include not only the loss of crops (its quantity and quality) but also damage to the plantation. Incorrectly managed plant protection may lead to the development of resistance of pests, which may cause insensitivity of pathogens to the agents used in the future (Dent, 2000; Martinez-Medina, et al. 2016).

Although the list of chemical agents authorised for use often changes, it is currently relatively easy for the farmer to acquire information on the kind of product that they should apply. Information on the dosing of preparations for particular plants is also readily available. It is significantly more difficult to determine the optimal time for carrying out the procedure. Also, farmers are not always able to correctly identify the pest that they need to combat.

Present consultancy systems supporting plant protection are focussed on providing agricultural producers with information on the potential or observed threat (Walczak, et al. 2010). The recipient obtains information on the suggested time and type of protective measures that they should apply. The functioning of such systems is based on observations of occurrences of pathogens (mainly insects and plant diseases) and on threat prediction algorithms. These algorithms, dedicated to the individual plants and pests, calculate the risk of occurrence of the particular threat based on above all weather data, such as temperature and humidity. In these systems, an alert appears when the calculated risk of pest occurrence exceeds the permissible value (Bajwa, et al., 2003; Di Guardo, 2017; Murali, et al., 1999).

Such systems prove themselves in fruit farming (Agrosimex), they are implemented at horticultural farms as well as for selected field plants (cereals, potatoes, sugar beets) (Piorin, IUNG, Target, IOR). Availability of such information is limited to some selected areas (Nieróbca, Zaliwski, 2014).

Currently, the majority of farms in Poland do not use any warning system for pests. Small farms, which cannot or do not want to invest money in the purchase of a commercial system, apply plant protection using their own knowledge and observations of the plants they grow. This kind of approach is ineffective and may lead to the spread of pests.

INPUT DATA

Within the framework of the plant protection support system being designed, the fundamental assumption that was made concerns the possibility of taking advantage of the available data. It was assumed that the majority of farmers are currently not interested in having their data regarding their own observations of diseases and pests in plantations entered into the network. Due to the lack of time, these data will be difficult to acquire from vendors of plant protection products. However, at the time when such information will be possible to obtain, the efficiency of the system will increase substantially. These assumptions were confirmed in interviews with interested persons (farmers, vendors).

Data that can possibly be used include information on the sales of plant protection products coming from the ERP system deployed at shops in rural areas. For the research, the existing system Comarch ERP Optima was used (Comarch). This software uses the Microsoft SQL Server. Useful information can be retrieved from the database to the decision support system by means of appropriate SQL queries. Similar architecture is used by other popular programs for sales management (e.g. the Subiekt ('shop assistant') by the Insert Company).

When a threat is looming, farmers start buying appropriate plant protection products. As a rule, these products are not stocked up for later use. Thus, it can be assumed that such an increase in the sales is caused by the occurrence of a pest threat. Even though this signal comes already after the occurrence of the pest, for many farmers the information appears early enough for the losses to be prevented. It can also be observed that increased purchases appear at the time when the weather is appropriate for the sprays.

The minimum necessary scope of data that should be downloaded from the ERP system are: the date of sale, the type of plant protection product and its quantity. Additionally, due to the different sizes of packages and types of products the desirable data also include the size of the package and the unit of measurement. A good indicator can be the unit price. With the use of such data, it is possible to automatically obtain information on when sales of a particular product rises rapidly.

Fig. 1 and Fig. 2 present examples of data from two consecutive years with months marked on the horizontal axis. The data has been compiled with an accuracy of one day (the ERP Optima system can provide the hour and minute of the sale).

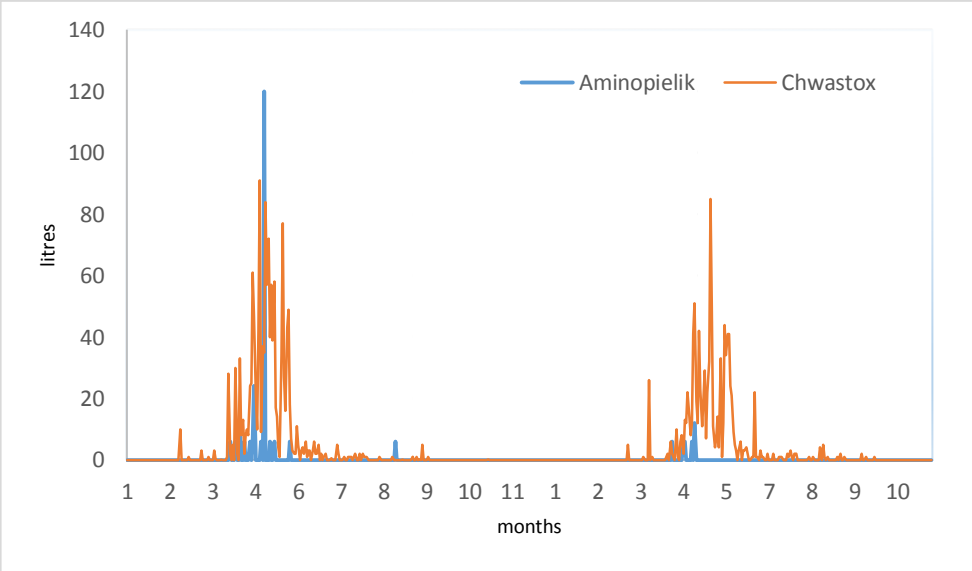

Fig. 1. Example of herbicide sales [litres]

The graphs present examples of plant protection products (herbicides: Aminopielik and Chwastox, insecticides: Actara and Decis). As of the final day of the study, the database of the shop contained 3,728 products, of which 741 were chemical agents. In order to generate alerts that signal the occurrence of pests, it is necessary to arrange the products into groups. In the database concerned, the groups of products were defined according to the sales criteria; there was no breakdown into herbicides, fungicides, insecticides, etc. For the needs of the system being created, it is thus necessary to develop an additional database containing rules for grouping products together.

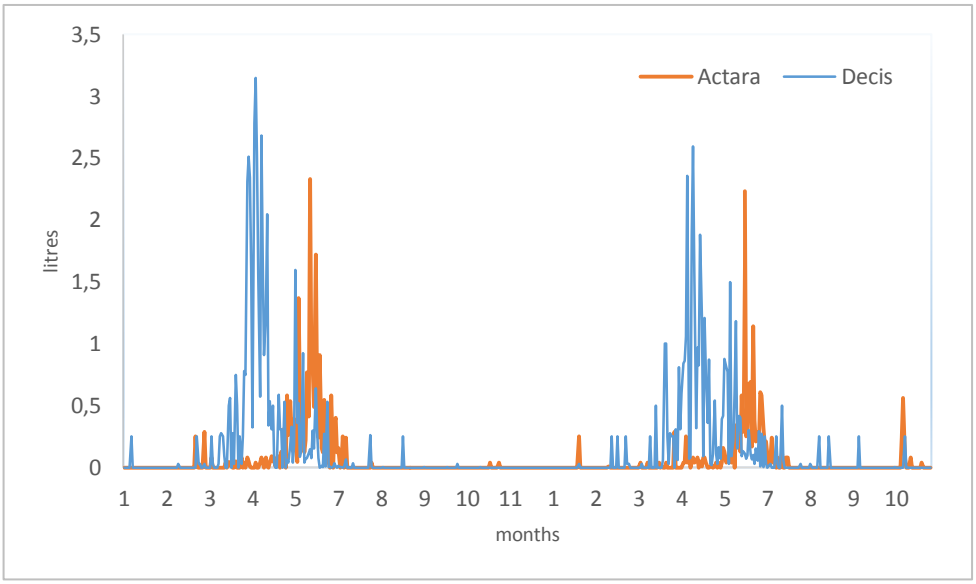

Fig. 2. Example of insecticide sales [litres]

In the graphs, the days when the sales of the particular chemical agents rises can be clearly noticed. This is visible with regard to both insecticides (Fig. 2) and herbicides (Fig. 1). These correlations occur in the successive years. Graphs illustrating the sales of other chemical agents are similar.

SYSTEM DESCRIPTION

Fig. 3 presents a simplified scheme of the system of plant protection support. Data loaded from the SQL database of the ERP software are filtered and then the sales increase is detected.

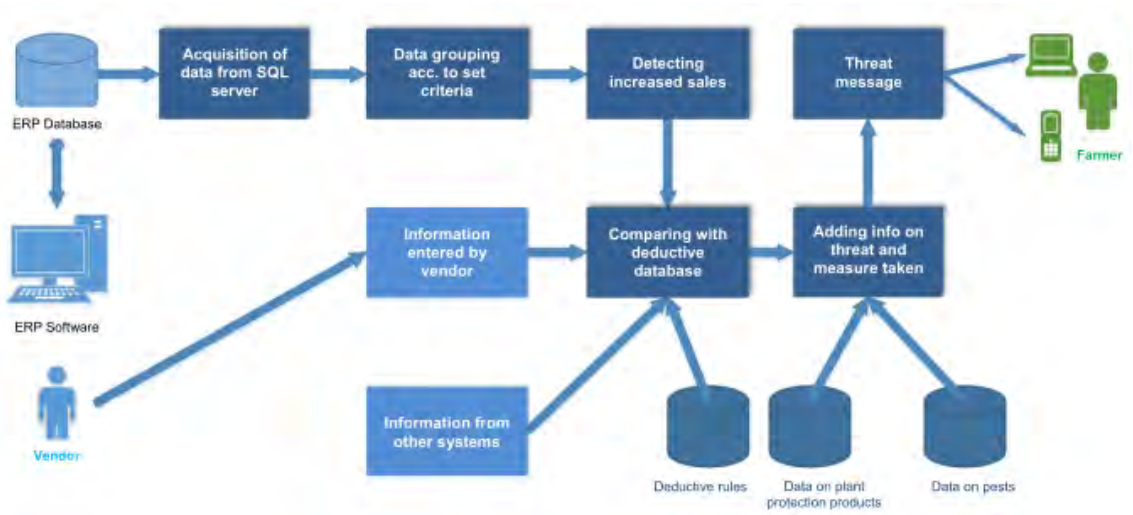

Fig.3. Simplified scheme of the system

If an increase in the sales of a particular product is detected, this information is checked using a set of deductive rules (deductive database) and then the information on the current threat and the necessity of applying an adequate chemical agent is added. An appropriately formatted message is sent to the recipient. The message can be delivered in the form of an email or a short text message, or it can be displayed on the vendor's monitor or banner, etc.

Due to the fact that the increase in the sales of selected plant protection products may be in some cases insufficient information, it is advisable to extend the system with two additional elements. The first of them is additional information entered into the system by the vendor, such as the type of threat, the type of cultivation and also the farmer's details (farmer's details can be obtained from the ERP system). This information is available to the vendors because farmers often seek advice from them. An additional functionality is integration with other alert systems (freely available or commercial). Such integration will not only increase the availability and reach of the alert systems but it will also increase their effectiveness.

In the simplest version, the system may be an application installed on the vendor's computer. In a more extended version, it might be a network application aggregating data from multiple shops and other points of sale. While the functionality of the extended version is considerably greater, there is still the risk that vendors will not make their sales statistics available due to competition concerns. Implementation of the application at a company requires acquisition of information on the structure of the ERP database as well as user authentication on the SQL server.

CONCLUSIONS

The proposed method is not intended to replace the extended consultancy systems in the scope of plant protection but to be a supplement to them. Its effectiveness does not

match the existing solutions; however, the ease of implementation and the possibility of using available data might ensure that it will be used by a large number of farmers who do not use the existing commercial solutions. The method implies taking advantage of sales alerts to generate messages intended for agricultural producers and, in some situations, it may fail to ensure that the alert is delivered on time. This disadvantage of the system may render it useless in the view of some agricultural producers. Implementation of the proposed solution does not involve any high financial outlay; at the same time, it provides the possibility of reaching a large number of prospects, also at small farms. The system does not require entering any additional data either on the part of the vendor or the user. The effectiveness of the system can be substantially improved when information concerning the possible threats is entered by the vendor. This sort of information usually comes from farmers buying plant protection products – vendors commonly give advice to their customers. However, this requires entering additional data at the time when a greater number of customers appear in the shop. But some vendors do notice possible marketing advantages of such a solution. Integration of the proposed system with the consultancy systems already available in the market will allow achieving high effectiveness of alerts with retained availability for agricultural producers.

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SETTINGS PARAMETERS FOR AERIAL PESTICIDES APPLICATION USING GYROPLANE

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Keywords: aerial spraying, spraying characteristics, drift control, forest protection, gyroplane

ABSTRACT
The operational effectivity of pesticide application on small areas of forests (<5 ha) could be improved e.g. by using gyroplanes. The gyroplane is powered by standard automotive fuel, and can be operated without airport infrastructure. For safe and efficient use of such technology an elaboration of working settings is needed. Three most widely used insecticides for protection of Polish forests were tested. In the conducted study new applications parameters (forward speed, flow rate) adapted to gyroplane were used. The rotating atomisers AU 7000 were adapted to gyroplane, to receive the application of insecticides, similar to quality received by aircraft. Additionally, the same dose rates of tank mixes were tested, but for application speed optimized for gyroplane (100 km/h).

INTRODUCTION

In Poland, each year hundred thousands of hectares of forest need insecticide application. The areas for spraying have very different sizes and mostly irregular shapes. As reported Majewski (2015) it influences the operational efficiency of aerial application which depends also on meteorological situation and phenology of pests. Because in the last decades, as reported Bungescu *et al.* 2011), Giles & Billing (2014), Xiongkui He *et al.* (2014), Bzowska-Bakalarz *et al.* (2015), new options of aircraft in crop protection were adapted: ultralight trike, gyroplane (both operated by pilot), and unmanned aerial vehicles (UAV), or unmanned aerial systems (UAS): drones and helicopters (operator working from the ground).

These ultralight aerial vehicles are easier to control, are powered by standard automotive fuel (not aviation fuel), and can work without accredited airport (infrastructure). Any airport and airstrip should have permission from the applicable civil aviation authority.

When making any agrochemical spray application, the primary concerns are ensuring maximum biological efficacy while minimizing any off-target movement and adverse environmental impact or other non-target biological harm. One of the principal factors to consider when setting up any sprayer prior to an application is droplet size, which has long been recognized by many researchers (Teske & Barry 1993, Hewitt 1997, Miller & Butler Ellis 2000, USDA 2006, Czaczyk 2014, Matthews *et al.* 2014) as one of the primary parameters influencing overall spray deposition, efficacy, and drift.

For aerial application of the most common insecticides in Poland, an ultra-low volume (ULV) technology is used. It allows spraying with oil based tank mixes - not sensitive to fast evaporation during application. Woziński (1995) and Rowiński (2009) reported on how to operate with applications by planes and helicopters under Polish conditions. Also other sources are available - e.g. USDA (2006), Matthews *et al.* (2014) with descriptions of spraying setting selection. Majewski (2016) reported significant progress when using e.g. gyroplane on small areas (<5 ha) of forests. The cruise speed range for

gyroplanes is between 50 and 170 km/h. The range of working speed for AU 7000 rotating atomiser determined by Micron Group (2016) result in between 64 and 160 km/h. The liquid output variable: 0 - 10 l/min, and spraying characteristics variable described by volume median diameter (VMD) is between ∅60 - 750 µm.

For an optimisation of economic efficiency, a special algorithm was elaborated by Majewski (2016). For the purpose of national forests protection, three original tank mixes were used in the conducted study, similar to those used with typical aircraft.

The objective of this study was to develop and evaluate application settings for gyroplane associated with application by typical aircraft.

MATERIAL AND METHODS

Liquids tested in the study

The key and mixing rates for the products used in conducted study (tab. 1.):
Product 1: Water Only (control);
Product 2: Bt Solution 200 ml/4 l;
Product 3: Dimilin 480 SC 100 ml + 1.7 l of Ikar 95 EC in a total solution of 4 gal;
Product 4: Tristar 30 SG (acetamiprid as the active ingredient) at 80 ml + 2 l of Ikar 95 EC in total solution of 4 gal.

Application Parameters

The application speed for conducted study was 100 km/h;

The working pressure of tested tank mixes was 276 kPa (40 psi).

Figure 1. View of rotating atomiser in testing position. (photographed by Zb. Czaczyk).

Droplet Size Measurements

Droplet sizing measurements were conducted at the United States Department of Agriculture (USDA), Agricultural Research Service (ARS) Aerial Application Technology Research Unit's (AATRU) laboratory located in College Station, Texas. Testing Procedure All tests were conducted at the high-speed wind tunnel (HSWT), at USDA–ARS in College Station, TX. The USDA-ARS HSWT consists of a high speed centrifugal blower powered by a 48.5 kW (65 hp) gasoline engine. The blower speed is controlled by adjusting the engine's throttle. The high-speed air generated by the blower, exhausts through a 50.8 × 50.8 cm outlet. The air velocity is measured directly at the outlet, using a Pitot tube attached to an airspeed indicator. A 30 cm section of aircraft boom was mounted directly at the tunnel's outlet.

Spray solutions were fed from 19 l stainless steel pressure tanks which were pressurized using an air compressor. A pressure regulator was used to change pressure, which was measured using an electronic pressure gauge (PX409-100GUSB, Omega Engineering, Stamford CT) positioned within 20 cm of the atomiser outlet. A Sympatec HELOS Vario® laser diffraction system (operated with the manufacturer denoted R5 lens, dynamic size range of ∅0.5 - 875 µm across 32 bins) was positioned downstream of the nozzle such that the area of measurement was 45 cm from the exit of the tested atomiser. Evaluation of each treatment (Table 1) consisted of a series of replicated measurements. Sufficient replications were made to ensure that the standard deviations of $D_{v0.1}$, $D_{v0.5}$, and $D_{v0.9}$ according ANSI/ASAE (2009) were within ±5% of the means as well as the Relative Span (RS). Additionally, the percentage volumes of characteristic droplet size fractions of the spray $V_{<x}$ ($\%_{vol}$) contained in droplets less than (x size): ∅50, 80, 100, 141, 150, 200 and 730 µm was also recorded.

RESULTS

Table 1. Spraying characteristics for four tested tank mixes at 276 kPa liquid pressure, simulated flight speed 100 km/h, for rotating atomiser AU 7000. (source – own study)

Product	Rep	D_{v10}	D_{v50}	D_{v90}	RS	$V_{<50}$	$V_{<80}$	$V_{<100}$	$V_{<141}$	$V_{<150}$	$V_{<200}$	$V_{<730}$
1	1	17.11	53.44	173.72	2.93	47.37	64.09	71.67	83.47	85.72	93.31	100
1	2	17.10	53.47	176.35	2.98	47.35	64.12	71.66	83.20	85.39	92.78	100
1	3	17.19	54.04	177.16	2.96	47.00	63.74	71.32	82.96	85.17	92.69	100
2	1	16.79	52.17	166.99	2.88	48.18	66.42	74.47	85.45	87.42	93.82	100
2	2	17.24	53.49	169.26	2.84	47.21	65.56	73.75	84.98	86.99	93.57	100
2	3	17.19	53.61	169.02	2.83	47.14	65.49	73.69	84.98	87.01	93.64	100
3	1	17.04	49.42	144.10	2.57	50.58	72.27	80.63	89.53	90.91	94.84	100
3	2	17.04	49.49	143.66	2.56	50.51	72.24	80.62	89.59	90.98	94.92	100
3	3	17.00	49.30	144.61	2.59	50.70	72.30	80.59	89.45	90.82	94.73	100
4	1	16.91	48.93	142.05	2.56	51.08	72.85	81.11	89.84	91.19	94.93	100
4	2	17.17	49.28	143.74	2.57	50.72	72.46	80.77	89.59	90.95	94.79	100
4	3	17.04	48.62	142.94	2.59	51.40	72.99	81.12	89.71	91.04	94.77	100

CONCLUSIONS

The technologies in sustainable agriculture require adaptation of new available techniques and settings for the employed equipment. As reported Majewski (2016) on the pest control in smaller areas (especially smaller than 5 ha) of forests, a typical aerial equipment (plane, helicopter) operation is very ineffective. It was possible to compare, after pioneering use of gyroplane for pest control in the Piła region. Documented operational profits allow realisation of economical and environmentally friendly pesticide application. Selected rotating atomiser AU 7000 and settings deliver spraying characteristics presented in table 1. The received values allow looking for optimisation of atomisation quality for the applied insecticides. For further development of optimised and environmentally friendly application techniques, it is necessary to evaluate spraying characteristics of working liquids. To evaluate and confirm an operational settings of advanced application technique, the next research is needed. Using gyroplane for pest control, also for arable crops, the CO_2 emission could be reduced.

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UTILIZATION OF DIGESTATE OBTAINED FROM METHANE FERMENTATION OF CHICKEN MANURE

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ABSTRACT

Since 2012, Poland is the European leader in poultry production and one of world's key exporters of poultry meat. Poultry production is directly related with presence of droppings. Depending on the type of breeding, a by-product can be droppings or manure. The most popular solution of utilizing chicken droppings and manure is using them as fertilizer. Considering issues related with environmental protection, more often alternative methods are searched for. One of them is utilizing the discussed substrate in the process of methane fermentation. Products of the process will be biogas and digestate. The aim of the work was to present possibilities of utilizing the digestate obtained in the process of fermentation of chicken manure.

INTRODUCTION

Chicken droppings and manure are waste materials which are strenuous for human life and the environment (Hussein et al., 2017). The greatest threats are related with emission of detrimental gases (mainly ammonia), emission of leachates to soil, ground and surface waters, and with microbiological hazards. One of preferred ways of the waste management is anaerobic decomposition of them (Czekała et al., 2015). Another method of the waste management is extrusion cooking technique (Guz at al., 2011, Oniszczuk at al., 2015, Oniszczuk at al., 2016). Application of this technique allows to manage a lot of agriculture waste materials (Obidziński 2014., Obidziński et al., 2016., Oniszczuk et al., 2013)

METHANE FERMENTATION AS A WAY TO UTILIZATION POULTRY WASTE MATERIALS

Methane fermentation has a large potential in utilization of agricultural and food wastes (Czekała et al., 2017). Strongly intensified poultry production is related with production of waste, which need to be utilized (Burra et al., 2016). Waste management is an obligation of producers active in the field of animal breeding. As a result, the process of biodegradation in controlled conditions seems to be a solution meeting this criterion and offering additional benefits for producers as well as the environment (Gizińska-Górna et al., 2016; Kowalczyk-Juśko et al., 2015). Using manure for biogas aims is related with an effective limitation of emission of harmful compounds to the atmosphere, which are released during its collection or use in the form of a raw fertilizer, as well as elimination of a potential sanitary hazard (Hagos et al, 2017).

The process of methane fermentation consists in an anaerobic decomposition of organic matter with the use of anaerobic microorganisms. A product of the fermentation is biogas, composed mainly of methane (50-75%), carbon dioxide (25-50%), and trace amounts of hydrogen sulphide, hydrogen, nitrogen, oxygen, and carbon monoxide. As far as the process efficiency is concerned, chicken manure is a substrate strongly

susceptible to fermentation, due to e.g. a high content of albuminoids and organic dry matter - 63-80% of the mass. Chicken manure has also relatively high biogas efficiency, 250-450 $m^3 \cdot Mg^{-1}$ of the organic dry matter and content of methane in biogas reach 60% by volume.

However, the use of chicken manure as a substrate for fermentation is related with a significant technological challenge, i.e. a high content of nitrogen. Bacteria of the methanogenesis stage are very sensible to its excessive amount. A high content of nitrogen can act in an inhibited way on the process of methanogenesis. Nitrogen in the amount from 1,5-3 $g \cdot dm^{-3}$, at proper pH can be an inhibitor of the process, while at the concentration over 3,7 $g \cdot dm^{-3}$, nitrogen has killing effect on methane bacteria. The possibility of an efficient fermentation process is enabled by using a co-substrate which is rich in organic carbon.

DIGESTED PULP AS A PRODUCT OF METHANE FERMENTATION

Unskilful use of chicken manure in the form of a raw fertilizer is detrimental to the environment. It is necessary to develop a solution enabling its safe and effective use. Production of biogas through methane fermentation brings benefits resulting not only from efficient obtaining of gas (Deepanraj et al., 2017). It is possible also a by-product of the process, i.e. a digested pulp, which can be used as a valuable fertilizer (Hung et al., 2017). A strong concentration of minerals, elimination of odour substances, as well as pulp's pH at the level of 8, make it can be a strong competition for chemical fertilizers currently available on the market.

Digestate is a by-product of the process of methane fermentation, which is a digested residue of the substrate used in the process. Usually, it makes about 90% of mass of the substrate feed to a reactor. In case of a biogas plant of the power of 0,5 MW, there is produced about 10 000 Mg of digestate mass. This value can be significantly diversified, depending on used substrates. Counter to the common belief, digestate is not only a waste that needs to be utilized. It has a large potential as far as fertilizing and energy is concerned. Digestate is characterised by a high concentration of nitrogen, phosphorus, potassium, which are most essential for plants as far as fertilizing is concerned.

A conversion of complex compounds to inorganic compounds contributes to a reduction of pathogens or seeds of weeds contained in the digestate. In the course of the process of mesophilic fermentation, majority of viruses, bacteria and other organisms present in raw manure is being neutralised. On the other hand, in the process of thermophilic fermentation, all pathogenic organisms are neutralised. Thanks to the fermentation process, the pulp becomes a safe and environmental friendly fertilizer, in comparison to the raw manure.

Storage of natural fertilizers has a significant influence on uncontrolled emission of methane and ammonia (Dinuccio et al., 2012). An advantage of the digestate coming from natural fertilizers is a reduction of gas emissions, including methane, which is one of the most strenuous compounds of animal production. Thus, using manure for biogas aims will be related not only with a reduction of the methane emission, but also depriving a substance of odour compounds.

Raw digestate is characterised with a relatively high hydration. The content of water in the substance is 90-95%. Apart from the used process technology, in case of the utilized

chicken manure in the fermentation, also a species of poultry has an influence on the level of the pulp hydration. Usually, the pH of the digestate ranges from 8 to 8,5, thus, it is reasonable to use such form of fertilizing in soils in which a strong acidification is present. Using the digestate in the form of a fertilizer of full value is related with its proper processing, consisting mainly in the material dehydration.

DIGESTED PULP MANAGEMENT

According to the Waste Management Act of 14.12.2012 (Journal of Laws 2013, item 21), the following forms of recovery are distinguished:

- R1 process – „using as a fuel or other source of energy",
- R3 process – „recycling or recovery of organic matter, which are not used as dissolvent (including composting and other biological transforming processes)",
- R10 process – „processing on the soil surface offering benefits for agriculture or an improvement of the environment condition".

Each recovery method has individual requirements that need to be met in order that a process could be legally regarded as properly conducted. After conducting a process, a producer of the digestate has a chance to apply for a permit of marketing of products supporting growing. However, in order this was possible, requirements stated in the Article 4 of the Act on Fertilizers and Fertilizer Application and the Regulation of the Ministry of Agriculture and Rural Development of 18.06.2008 on execution of some regulations concerning fertilizers and fertilizer application (Journal of Laws item 119, point 765) should be met. 765.

This record obligates producers to satisfy a complex revision procedure and conducting test of a potential fertilizer with regard to a possible usability of fertilizing soil and plant. It is also indispensable to obtain positive results of tests of the pulp with regard to the presence of intestinal parasites and pathogenic bacteria, which exclude their presence in the obtained fertilizer.

Whole digestate pulp should initially undergo the process of dehydration or drying in order to decrease the content of water, and its volume as a result. A high hydration will result not only in problems with efficient storage but mainly with the possibility of further utilisation.

The reduction of water in digestate can be obtained using one of below methods:

- mechanical, using centrifuges or presses,
- thermal and pressure, consisting in evaporating water,
- physical, in which dehydration is done due to sedimentation or membrane filtration.

Each of the above solutions shall be characterized by different efficiencies and energy consumption, thus, it is necessary to select a solution that the whole processing process was optimised in the most possible way as far as energetic and economic issues are concerned.

After a separation into fractions, the post-fermentation pulp can be used in numerous ways. Solid fraction has a structure similar to fresh compost and is greatly deprived of pathogens. This material has dry matter at the level of 25-30% and it is loose. It can be mainly used as a fertilizer or an agent for improving the soil quality. On the other hand,

liquid fraction is characterised by a low content of dry matter, usually amounting up to 5%. Liquid fraction can be used as a fertilizer or used in the process of fermentation for a possible dilution of the substrate.

CONCLUSION

Strongly developed poultry production obligates Poland to solve the issue of the utilisation of large-scale post-production wastes. Due to their good biogas features, there is a potential of their efficient utilisation, at the same time having benefits resulting from the biogas production. A high content of ammonia nitrogen present in chicken excrements forms a certain type of a technological barrier, potentially hazardous to the fermentation process. It is necessary to develop a technology enabling a co-fermentation of chicken manure with another substrate, at the same time maintaining high biogas efficiencies, or developing a new, innovative, and economically efficient technology of single-substrate fermentation. The pulp obtained during the process of methane fermentation has also a high fertilizing potential thanks to a strong concentration of minerals and organic components. Properly processes digestate has a chance to become a fertilizer of full value, being a serious competition to artificial fertilizers.

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ASSESSMENT OF THE CAN BUS TECHNOLOGY IMPLEMENTED ON MODERN AGRICULTURAL TRACTORS TO STUDY FUEL CONSUMPTION SAVINGS

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Keywords: CAN Bus, tractor, fuel consumption, standardization

ABSTRACT
In developed countries, the mechanized agriculture is highly dependent on fuel. Unfortunately, the heterogeneity and complexity inherent to agricultural process do not help the actors (researchers, counselors, farmers) to improve fuel consumption efficiency in the farms. In order to measure precisely the use of the tractors this study proposes to rely on the embedded CAN bus technology and RTK positioning system implementing modern tractors to record fully characterized data of the engine load. This study demonstrates the feasibility of such proposition by testing specific dataloggers and software in-situ and by decoding signals to data and characterizing them.

INTRODUCTION

The increase of work intensity in the fields, the modernization of the techniques, the decrease of the qualified workforce, and the care for better working comfort lead the sector to rely increasingly on mechanized solutions. As a result, manufacturers of agricultural vehicles follow the demand and continually improve the power delivered, the steerability, the precision and automation of tasks. But the instability of the fuel markets and the announced declining oil reserves are persistent reminder that farmers should consider fuel consumption savings as an important lever to maintain farms income and competitiveness, or even sustainability. Unfortunately, the heterogeneity and complexity inherent to agricultural process complicate the production of advice by the actors (researchers, counselors, farmers) to improve fuel consumption efficiency in the farms, as experienced by Efficient20 project (2013).

The standardization of « CAN » (Controller Area Network) bus communication systems on agricultural tractors, from mid to high power range, open a wide range of opportunities for researchers in farm machinery and is considered by Grenier (2001) as a new field of data. Surprisingly, there are few examples of research valorizing these data, for example like Mattetti (2013) and Debroizze (2017). Furthermore, the manufacturers focus on the operational utility (monitoring of settings and mechanical failure, fleet management) through telematics (JDLink John Deere, PLM New Holland, etc.) without proposing analysis and Decision Support System (DSS).

Another step could be achieved if the CAN bus data were associated with the use of agricultural guidance systems by satellites. It could enhance the analysis to the agronomic level, giving context to CAN bus data (per field, per crops, pedologic and climatic conditions). Huyghebaert (2013) found that Guidance systems know an increasing demand from farmers because it largely facilitates control on field and improves comfort of the operator as well as the precision of work.

The main objective of the study was to determine the level of integration of CAN bus systems on modern agricultural tractors in Wallonia, their connectivity and their compliance to communication protocol standards.

MATERIAL AND METHOD

Five tractors used in Wallonia were selected on the basis of the following criteria:

- Equipped with electronically controlled fuel injection (common rail)
- Representative of technical specificity of various groups of manufacturers (CNH, AGCO, SDF Group, John Deere)
- Covering a wide range of power and agricultural activities.

The average power of the tractor selected, presented in Table 1, is 178hp. All tractors are considered modern and non-obsolete, for an average year of construction 2010.

Table 1: Characteristics of selected tractors

Brand	Case IH	John Deere	Deutz Fahr	Massey Ferguson	Fendt
Model	Maxxum 115	6830 Premium	Agrotron M650	7619	826
Year of construction [1]	2007	2010	2007	2013	2013
Nominal power [hp][1]	117	145	185	185	260
Transmission	Semi-Power Shift [2]	Semi-Power Shift [2]	Power Shift [3]	Power Shift [3]	Continuous variation
Options	Front hitch	Front hitch	Front hitch	Front hitch & PTO	Front hitch & PTO

[1] : brand official information
[2] : synchronous ranges
[3] : synchronous ranges and gears

Considering that the average nominal power of new tractor sold in Belgium in 2011 was 177hp (excluding tractor without CAN bus), the selection is considered as representative. The five brands concerned totalize together 57% of market share on a national scale (FEDAGRIM ASBL, 2014).

In order to record the CAN bus data, a datalogger Vector GL2000 was chosen for its ability to log simultaneously up to four CAN bus networks and to convert signals from electrical tension to bits. The datalogger has an integrated timer able to timestamp every data recorded with a 10-6 second resolution. The datalogger itself was configured to prevent any interaction with the networks, on a so called “no acknowledgement” mode (no ACK). Logging was activated on the four channels simultaneously on a standard baud rate for off-highway vehicles of 250Kbits/s (SAE, 2013). The internal timer was set to internet time and date before every recording. In an effort to record all the data at the time they are sent on the networks, the start and stop of the logging were set respectively on the “ON” and “OFF” position of the contact key.

Eventually, a multibrand diagnostic interface TEXA Navigator TXTs was used to determine the method to connect the datalogger to each tractor. Most CAN bus networks were not visible from the driver point of view in the cabs but the Navigator TXTs permitted to localize the access points to the networks and to identify the connector type installed and their active pins. These pins had to be tested to determine if there were connected either to CAN High wire of CAN Low wire. Thereafter, complete wired connections were developed to be able to connect the datalogger to each network.

The tractors were tested individually, always with the datalogger installed before electrical contact and ignition. To summarize, the datalogger was used as an embedded system, following each tractor during common use, from farm to fields. Duration of logging was not a controlled parameter, as all ECUs connected to the network must have communicated once before a limited time.

Post-treatment of the recordings was completed with CANalyzer software, primarily to compile the CAN bus bits structured in frames with three standard communication protocols for off-highway vehicles: SAE J1939 (SEA, 2013), ISO 11783 (ISO, 2017) and IEC 61162 (IEC, 2014). Consequently, standardized CAN frames, called "messages", are disaggregated in various CAN "signals", each one corresponding to a specific parameter (or data) communicated by the network. All the active CAN signals are sorted by their standard identifier and name, excluding the network diagnostic and management signals.

RESULTS AND DISCUSSION

Globally, the data retrieval had to deal with minor difficulties, except for the Deutz Fahr, in which the connections were still partially unidentified at the time this study was written. The CAN bus proved to be well integrated on the tested tractors and more importantly, predominantly in accordance with the current standards. The results are synthetized in Table 2.

Table 2: Characteristics of CAN bus communications

Brand	Case IH	John Deere	Deutz Fahr	Massey Ferguson	Fendt
CAN bus	1	1	1	4	2
Connector number/type	1/Deutsch HD10-9-1939	1/Deutsch HD10-9-1939	1/?	2/Deutsch HD10-9-1939	1/Deutsch HD10-9-1939
Total standard frames	24	44	31	54	54
Non-standard frames	22	55	63	63	25
Standardization rate [%][1]	52	44	33	46	68
SAE J1939 signals	97	103	109	194	207
ISO 11783 signals	Not implemented	34	?	54	92
IEC 61162 signals	25	Not implemented	?	25	Not implemented
Total signals	122	137	109	273	299

First of all, the majority of the CAN connectors, as provided by manufacturers, followed the J1939/13 standard specifications "Off-Board Diagnostic Connector" for trucks and tractors. The distribution of the nine pins is theoretically standardized as well, but minor adaptations were observed. The Deutz Fahr presented an unidentified connector.

The results obtained demonstrate a global trend of number of CAN, frames and signals related to the power and equipment level of the tractors.

Totals and subtotals of frames and signals number are listed in Table 2, without multiple counting. Two tractors (Case IH and Massey Ferguson) had integrated GPS devices communicating by IEC 61162 protocols. As the number of signals contained within the non-standard frames is not determined, Standardization rate of the CAN communication was calculated on basis of the frames number. It appeared clearly that an important part of the data was not usable as such, with a limited average standardization rate of 48.2% for the whole study. There are significant differences between the brands, even between Massey Ferguson and Fendt although they are both brands of AGCO Corporation. Non-standard frames are considered as "proprietary", and designed by the brands themselves.

However, in terms of absolute value, the standardization permitted the retrieval of an unexpected number of signals, mainly under the J1939 protocol, confirming that CAN bus of tractors could represent an undervalued data field in agronomical research. The amount of readable signal as formal data varied from 109 (Deutz Fahr) to 299 (Massey Ferguson). Given the quantity and the wide variety of the signals recorded, it is difficult to present these results in a more detailed form in this study. In terms of homogeneity, the five tractors had 22 signals/7 frames) in common. This short list has still great potential for energy efficiency analysis, as shown in Table 3.

Table 3: Examples of signals involved in fuel consumption analysis and common to the five tractors

Topic	Frame code	Signal name	Description
Motor configuration	EC1	EngReferenceTorque (Nm)	Theorical max. torque
Motor management	EEC1	ActualEngPercentTorque (%)	Engine torque
	EEC1	EngSpeed (rpm)	Engine speed
	EEC1	EngTorqueMode	Engine torque curve
	EEC2	EngPercentLoadAtCurrentSpeed (%)	Instant. engine load
Motor temperature	ET1	EngCoolantTemp (°C)	Coolant liquid temp.
	ET1	EngFuelTemp1 (°C)	Fuel temp.
Fuel management	LFE1	EngFuelRate (L/h)	Instant. fuel consumpt.

All resolution and range of standards signals were in accordance with the three references.

Based on the time measurement of the datalogger, average frequencies were determined for all standard signals. The Figure 1 represents the distribution of the frequencies for signals standardized under J1939.

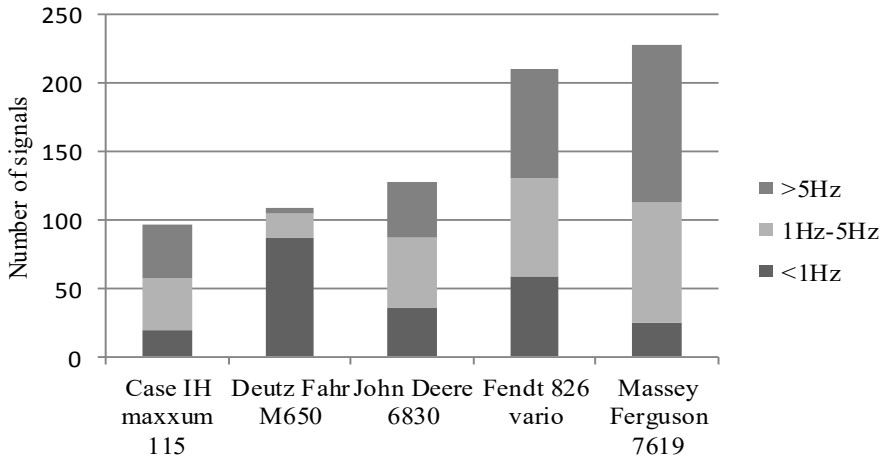

Figure 1. Distribution of the frequencies of J1939 signals by tractors

The Frequencies equal or above 1Hz were the most represented. From the agronomical and operational points of view, in the conditions of use of a tractor, we assumed that a frequency above 1Hz is adequate for most data analysis. For comparison, most guidance system used in agriculture work in the "1Hz-5Hz" frequency class (RTK DGPS have a 5Hz default set). The signals with low frequencies ("<1Hz" class) provide mostly "metadata" such as the configuration of the tractor (motor, ECUs, manufacturer ID, etc.), and they are subject to little or no variations.

Once again, the Deutz Fahr did not follow the trend of the other tractors and presented 80% of signals below 1Hz.

CONCLUSIONS

The main objective of the study was to determine the level of integration of CAN bus systems on five modern agricultural tractors in Wallonia, their connectivity and their compliance to communication protocol standards (SAE J1939, ISO 11783, EIC 61162), in order to allow more objective analysis of the fuel consumption in the farms.

First, the majority of the CAN connectors, as provided by manufacturers, followed the standard specifications for trucks and tractors. With a few adaptations, all the tractors were easily connected for recording. A large amount of data was then detected, but only half of it was standardized and readable, with significant differences between the brands. However, in terms of absolute value, the standardization permitted the retrieval of an unexpected number of signals, from 109 to 299 for the sampled tractors, mainly under the J1939 protocol. The five tractors shared 22 identical signals, comprising signals with direct interest for fuel consumption analysis. The results obtained demonstrate a global trend of number of CAN, frames and signals related to the power and equipment level of the tractors. A significant majority of signals are transmitted with frequencies equal or higher than 1Hz which is considered adequate to analyze the activities of the tractors.

To conclude, results were globally considered as very encouraging. The good quality of the data acquired in terms of quantity, variety and frequency, and the highlight of standards data for fuel consumption analysis found on all studied tractors have proven the

relevance of the approach, thanks to the well-integrated standardization. Finally the monitoring system developed during the study was selected for further research and implemented on tractors for long term recordings (1 year).

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CROPS DIAGNOSIS USING HURST EXPONENT VALUES IN FIELDS IMAGE ANALYSIS

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ABSTRACT

One of the branches of sustainable agriculture is the precision farming which assumes an individual approach to each plant. The main problem encountered by the precision agriculture is to quickly acquire and analyze good quality data assessing the condition of the crop. One of the fastest growing monitoring techniques is the analysis of images obtained from cameras placed on UAV. The studies used the chaos tools to determine Hurst exponent values received from images collected during UAV flights over the fields. The obtained results of image analysis indicated the presence of a strong dependency between the Hurst exponent values and state of crops. Images showed crops which are in good standing have been seen as strong organize objects represented by the mean Hurst exponent values from 0.8 to 0.87. Crops in which occurred the destruction of plants on the collected images were estimated by the Hurst exponent between 0.41 and 0.49 values, which indicates the presence of the characteristics of chaotic changes in the distribution of color attributes.

INTRODUCTION

The proper application of the sustainable agriculture is only possible through receive of the accurate information about the crop status and soil fertility. The reliable information on the status of the crop is the key data needed to take further action in it (Christy, 2008). For large fields or fields unable to monitoring through traditional methods, one of the most popular method recognize of the state of crops is analysis of the images, had sent from satellite or UAV (Unmanned Aerial Vehicles). Optical recognized methods are one of the most promising for evaluation both state of crops and the soil conditions (Shapira et al., 2013). The principal advantage of the optical methods is the high speed of measures not possible for traditional ground methods (Zwiggelaar, 1998). It is well known that in the sustainable agriculture the time is the major parameter beside of the accuracy. Compared to the traditional soil or crops measurement methods, optical methods can reduce of the total of the estimation costs up to 80-90% for large areas (Nduwamungu et al., 2009).The main indicator have used for crops state evaluation has been the NDVI index (Normalized Difference Vegetation Index). NDVI index is described as relative difference of the reflectance values of infrared and red color wave (Soliman et al., 2013). For the better discrimination, the Infrared images are supplemented by images captured in visual light range. Interpreting of these images, the very significant for correctively recognize and estimation state of crops (McNairn et al., 2009). The find the proper method for the image discrimination is the important challenge for manufacturers of the image analysis systems.

In order to discriminate elements contained in the image we can use its texture. A texture can be defined as the placement of individual color identifiers in the image space. In the image consisting of a set of ordered pixels with the parameters of the point A (x, y, z), where x and y represent the position of the point on the surface of the image and z is the

parameter describing the color properties of the image (Zhao & Wang, 2016). During analyses, it is possible to pick out information about generally speaking the image texture described as:

- Contrasts between pixels.
- Image coarseness - represents the size of a single pixel in the image relative to the entire image.
- Regularity - is defined as the pattern uniformity variation of the analyzed image parameters on the surface of the image.
- Anisotropy - determines the degree of regularity variation along of the different image axes.

Numerous works show the possibility of describing the texture of a picture by using fractal dimension which can be a measure of its regularity. The fractal dimension represents the degree of self-similarity variation of given quantity (Ekielski, 2013). The Hurst exponent is related to the time function of self-similarity. Hurst exponent is a dimensionless quantity to estimate the self-similarity of events occurring in time series. Hurst exponent H for white noise is H = 0, for random variable distribution Hurst exponent H = 0.5. The value of H = 1 indicates the occurrence of a high trend value in the measured value variations. The digital image can be presented as a 2-D time process in which the time equivalent is the distance between successive pixels and the measured values; pixel color parameters A (x, y). For the time series image, it is bi-directional in the x and y directions (Ekielski at al., 2015, Zhu et al., 2015).

METHODS

The research consisted in assessing the degree of image structure arrangement collected from fields. The pictures were collected by low-ceiling drones target runs. Drones were equipped with cameras to collect images in the visible light. The study was conducted with a Sony alpha 6000 camera and a flight height of 150 m. The resolution of the image at the ground level was 15 cm.

There were designated characteristic areas of the field selected from the photos area. The selected area was 256x256 pixels in size. Each of the analyzed area had an offset of 10% of the field width. Hurst exponent was calculated by Brown's fractional moves. Let X (t) be a function of Brown's fractional moves, the value variation of this function in the direction α can be described in two-dimensional space as:

$$X_H\big(x + \Delta x \cdot cos(\alpha), y + \Delta x \cdot sin(\alpha)\big) \tag{1}$$

Brown's fractional movements describe the freedom of measured quantity variations depending the environmental conditions. If the function $X_H(t)$ is a function of the partial Brown motions, then it has an average zero value of the increment with the existing variability and the variance is described by the formula 2:

$$E([X(x + \Delta x) - X(x)]^2) \propto |\Delta x|^{2H} \tag{2}$$

Where H is the Hurst exponent, H∈<0,1>. H is the Hurst exponent displacement factor of Brown and as Pentland (1984) has shown, there is a direct relationship between the fractal dimension DF and the displacement function $V_H(x)$ described by equation 3:

$$DF = DT + 1\text{-}H \tag{3}$$

where DT - is a topological dimension. If the Hurst exponent is in the range of 0.5 <H <1, then the random process becomes a process with a long memory. The coarseness parameter H varies from 0 to 1. When H is close to 0, the surface is rough (coarse), When the value of H approaches 1, the surface is relatively smooth.

When considering the two-dimensional surface of Brownian motion Fourier transform can be used (formula 4):

$$E\left(\left[V_H\left(x+\Delta x\cdot cos(\alpha), y+\Delta x\cdot sin(\alpha)\right)-V_H(x,y)\right]^2\right)\propto|\Delta x|^{2H} \quad (4)$$

The exponent H is independent of the angle α. As Voss (1986) demonstrated, if these requirements are met for a two-dimensional power spectrum, then:

$$F_H(f,\theta)\propto f^{-\beta} \quad (5)$$

Where$\beta = 2H + 2$

The Hurst coefficient was calculated using the Matlab v 2013 software, with RGB tested images, it was transformed into CieLab space (Ekielski et al., 2017). For L * (brightness) and a * (greenness) color channels, the Hurst exponent was calculated.

AIM OF THE STUDY

The aim of the study is to evaluate the use of Hurst exponent for the assessment of crop images.

RESULTS

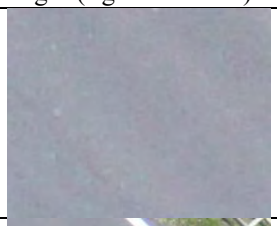
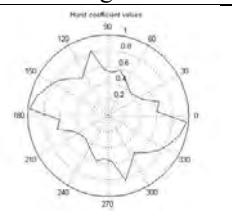
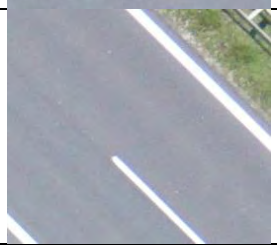
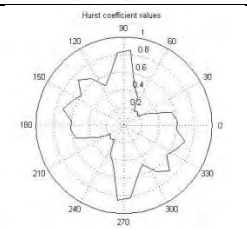
In the table 1 shown three of the analyzed RGB images (figures a, b, c).

Table 1.RGB images a, b and c captured during fields monitoring

a		b	
c			

Table 2 shows the images (figures a and b) of the studied surfaces and the corresponding directional distribution of the Hurst exponent. Of course, images showing large homogeneous areas have Hurst directional exponents near H = 0.5.

Table 2. Pictures of asphalt road surface and appropriately directional Hurst exponent values

	RGB images (figures a and b)	Diagram
a		
b		

In the case of areas covered by crops in good condition the Hurst exponent anisotropy stayed more uniformly for greenness (a*) canal, shown in the table 3.

Table 3. Images (a, b) are shown the growing wheat in the good condition

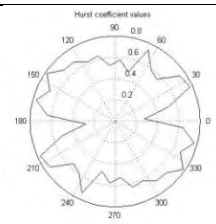
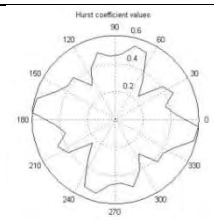
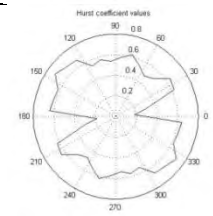
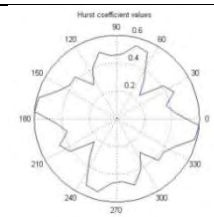
	Image (figures a and b)	Directional values for L* channel	Directional values for a* channel
a			
b			

Table 4. Changes in Hurst exponent of the diversified field surface structure

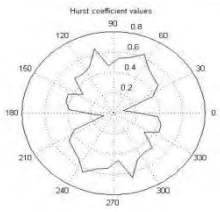
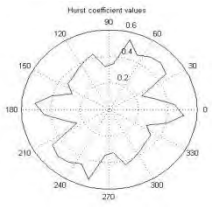
RGB image (figure a)	Directional values for L* channel	Directional values for a* channel
		

Table 5. Distribution of changes in parameter H in the case of directional mechanical damage (tractor wheels path).

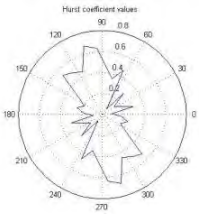
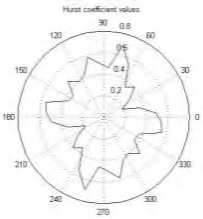
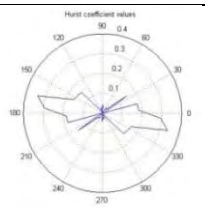
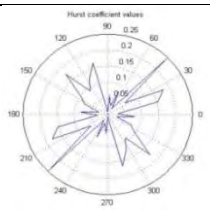
RGB image (figure a)	Directional values for L* channel	Directional values for a* channel
		

Table 6. Distribution of the H parameter on the field surface image after damages caused by atmospheric factors.

RGB surface image (figure a)	Directional values for L* channel	Directional values for a* channel
		

CONCLUSIONS

Texture description was always a difficult task when performing image analysis and automatic surface recognition. It is especially difficult in the automatic recognition of crop status, characterized by heterogeneity in color distribution. The study confirmed that nonlinear image analysis using the Hurst index as a parameter of the discontinuity of the examined texture image allows for searching. In the case of directional defects in the distribution of brightness parameters (L *) and the greenness channel (a *), the H value increases as the direction of the anisotropic distribution increases. The images of areas of continuous structure show high values of the H parameter, with their characteristic deviations in the direction perpendicular to the sowing line. Significant anisotropy of H distribution and lack of directionality of change characterize areas with poor condition caused by climatic factors. In conclusion, work has shown to have a significant effect of the image structure of moving drones on Hurst exponent. The calculated Hurst exponential directional distribution is an important additional parameter for assessing the condition of the examined area. High homogeneity areas are characterized by high Hurst values. Due in authors thought that one of the most important part of the image analysis by the Hurst's exponent is an anisotropy of its value distribution.

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DETERMINATION OF THE COEFFICIENT OF INITIAL DRYING SPEED OF SELECTED VEGETABLES

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Keywords: convective drying, carrot, beet, parsley, celery, sustainable agriculture

ABSTRACT
Efficient production of safe, high quality food is an important element of sustainable agriculture. Fruits and vegetables belong to an exceptional group of materials in food processing, and one method of preservation of growing production of fruits and vegetables is drying them. The work analyses the dependence of the initial drying speed coefficient in the first stage of drying on the initial moisture content in the process of convective drying, using cruciferous (root vegetables), namely, carrot, parsley, celery and beet. Samples of three different thicknesses (3, 5 and 7 mm) were dried at three different temperatures (50, 60 and 70°C), with the constant flow speed of the drying agent. The results were presented graphically, in the form of charts. As expected, the analysis of the results showed that the drying process is faster for materials with higher initial water content. The coefficient of initial drying speed reached lower values for thicker slices, and increased together with the temperature of the drying agent.

INTRODUCTION

Fruits and vegetables are an exceptional group of materials in food processing as nutrients they contain are indispensable for appropriate functioning of human organisms. Efficient production of safe, high quality food is an important element of sustainable agriculture. Food products with long expiry date in the form of concentrates, including dried fruits and vegetables are becoming increasingly common. Thermal processes belong to one of the most important and popular methods of food preservation, as they ensure microbiological stability, enzyme inactivation, and decrease water activity by decreasing its content or availability. Drying is one of the oldest methods used by human for food preservation (Lewicki, 2006). It involves water removal from products in order to decrease its chemical activity (Janowicz 2012). During drying, the material changes its physical properties, including drying shrinkage, which manifests in the reduction of the volume of the material being dried (Wang and Brennan, 1995)

There are numerous methods of drying, with the most popular one, used on industrial scale, being convective drying, which is also one of the most destructive methods of food preservation (Alibas, 2007, Stępień 2009).

One of the main notions that define the process of drying is drying kinetics, i.e. changes of temperature and water content in the material during drying (Strumiłło, 1983). Knowledge of drying kinetics is indispensable for optimization and management of the process of drying on the production scale. Numerous authors have conducted research on drying kinetics, e.g. Jaros 1999a (red beet, carrot), Górnicki 2000 (parsley), Zaremba 2004 (celery), Łapczyńska-Kordon and Krzysztofik 2006 (red beet), Jałoszyński and Szarycz 2011 (carrot).

Drying may be divided into two stages. In the first stage the drying speed is constant, and in the second, it decreases (Pabis, 1982, Kneule 1970). The drying speed in the first

stage depends on water content in the material being dried and the temperature of the drying gas. As experiments and observations show, the drying speed also depends on the size of particles being dried (Jaros, 1999b).

According to Jaros (1999b), changes in water content in this period may be approximated by the polynomial of the third order:

$$u(\tau) = u_0 - k_0\tau + \frac{sk_0^{\ 2}}{3u_0}\tau^2 - \frac{s^2k_0^{\ 3}}{27u_0^{\ 2}}\tau^3 \tag{1}$$

where:

u – moisture content, kg/kg
τ – drying time, min
s – drying shrinkage coefficient

Parameter k_0 in the equation ought to be interpreted as the coefficient of constant drying speed at the beginning of the process (Jaros, 1999a). In the first period, drying speed also depends on the area of mass exchange and on the difference between the temperature of the material surface and the temperature of the drying agent. In consequence, different values of drying speed coefficient may be obtained for the same raw material with different degree of fragmentation. It results from the dependence that the area of the material with the same volume increases together with the degree of fragmentation (Jaros, 1999b).

AIM AND SCOPE OF WORK

The goal of work was to determine the value of the coefficient of the initial drying speed for selected root vegetables, i.e. carrot, parsley, celery and beet.
The scope of work included:

- drying fragmented vegetables in the form of slices of three thicknesses (3, 5 and 7 mm) in forced convection conditions (at the speed of the drying agent equal 1.0 m/s) in the tunnel drier in three temperatures of the drying agent (50, 60 and 70°C)
- measurements of mass changes during drying
- determination of the initial moisture content.

RESULTS AND DISCUSSION

The coefficient of the initial drying speed was determined using linear regression method (Jaros 1999a, Golisz 2003) based on the measurements of drying kinetics of selected vegetables. As the goal was to study kinetics of the first stage of drying, the vegetables were dried to the water content of 2 kg H_2O/kg d.s. Depending on the temperature, drying time ranged from 180 to 240 min. Water content was determined based on the changes of the mass of samples M(τ) during drying, and the mass of dry substance M_s, and calculated from the following formula:

$$u(\tau) = \frac{M(\tau) - M_s}{M_s} \tag{2}$$

The results of the research on the dependence of the coefficient of the initial drying speed on the initial moisture content considering the type of vegetable, slice thickness and the temperature of drying are presented in the form of graphs.

Figure 1 shows an example graph of the dependence of the coefficient of the initial drying speed on the initial water content for carrot, considering the thickness of slices and drying temperature. Initial water content of the examined slices of carrot ranged between 5.3 and 7.4 kg H_2O/kg dry substance, and the coefficient of the initial drying speed ranged between 0.03 and 0.072 1/min. As expected, the observations confirmed that the drying process lasted longer for thicker slices, for which the coefficient k_0 had lower values than for thinner slices.

For parsley, the initial water content ranged between approx. 4 and 5.3 kg H_2O/kg dry substance, and the coefficient of the intitial drying speed reached values from approx. 0.022 1/min for 7 mm-thick slicess dried at the temperature of 50°C to approx. 0.053 1/min for 3 mm-thick slices dried at the temperature of 70°C.

The initial water content in celery ranged between 5.5 and 7.5 kg H_2O/kg dry substance, and the coefficient of the initial drying speed ranged from 0.02 1/min for 7 mm thick slices dried at the temperature of 50°C to 0.056 1/min for 3 mm thick slices dried at the temperature of 70°C.

For beet, the initial water content ranged from 6.2 to as much as 12 kg H_2O/kg dry substance. The values of the drying speed coefficient, similarly to other cases, increased together with the increase in the temperature, and the decrease in slice thickness, and it reached the values ranging between 0.024 and 0.063 1/min.

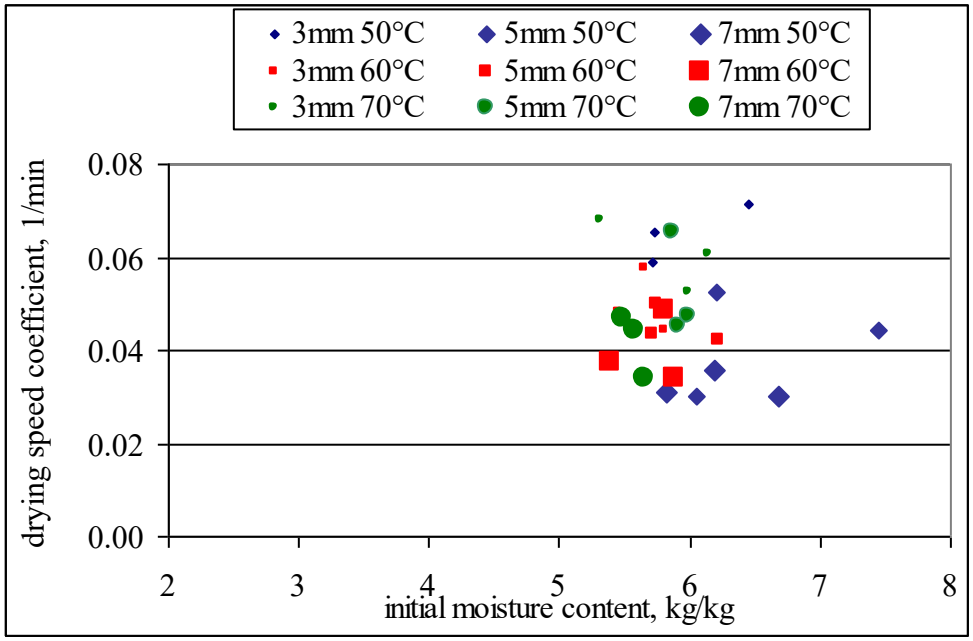

Figure 1. Dependence of the coefficient initial drying speed of carrot on the initial moisture content, considering slices thickness and drying temperature.

Next, the impact of slices thickness of the material being dried on the value of the coefficient of the initial drying speed in given drying air temperature, and the impact of the temperature on the drying speed coefficient in the first stage of drying for given slice thicknesses of the vegetables being dried was analysed. Example graphs for drying air temperature of 50°C and slice thickness of 3 mm are presented in figures 2 and 3.

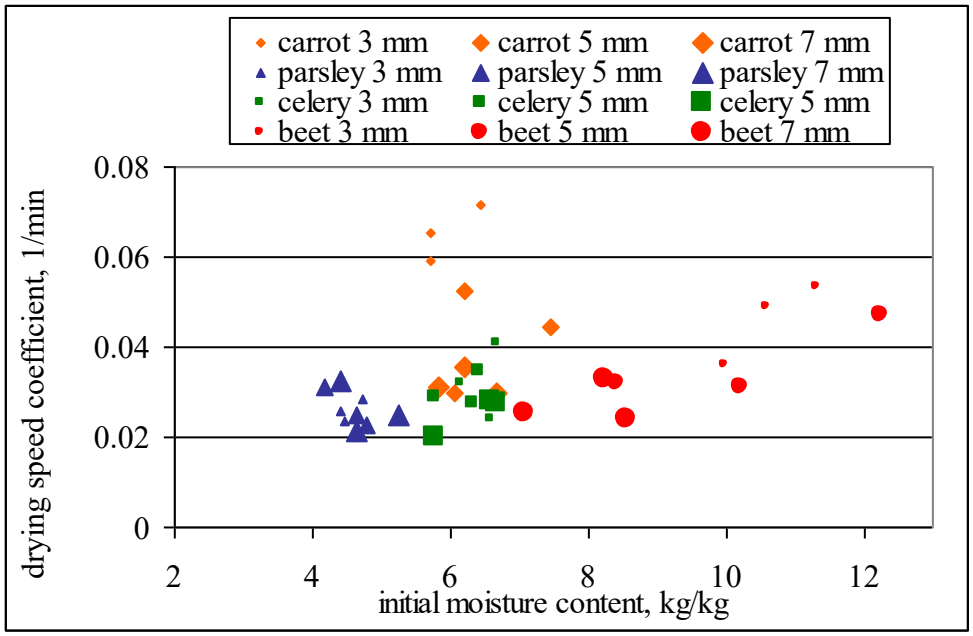

Figure 2. Dependence of the coefficient of the initial drying speed on the initial moisture content at the temperature of 50°C, considering slices thickness

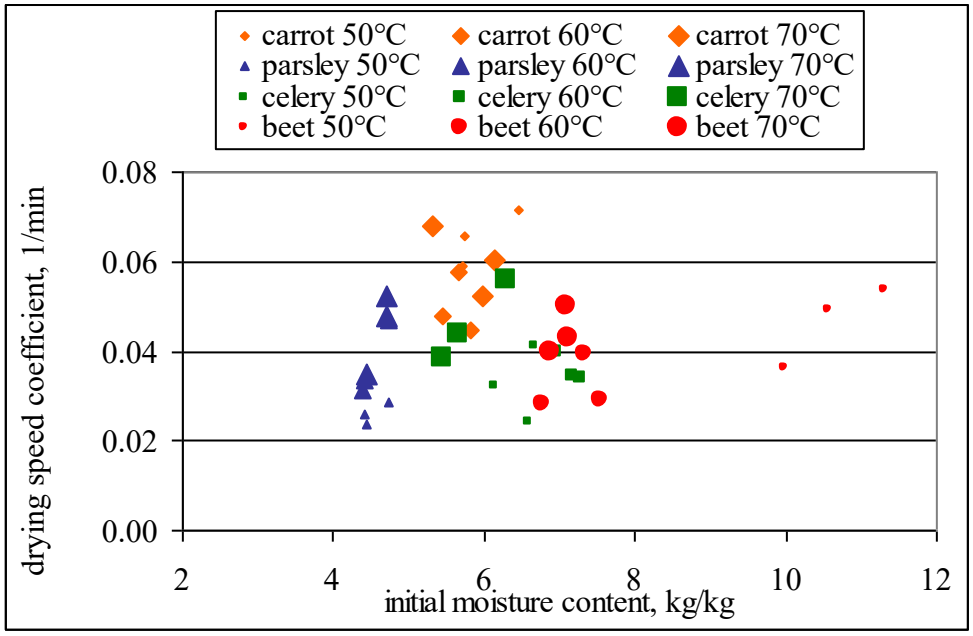

Figure 3. Dependence of the coefficient of the initial drying speed on the initial moisture content for 3 mm thick slices, considering drying temperature

CONCLUSIONS

The work presents the results of research on drying kinetics of root vegetables, in forced convection. Good knowledge of drying kinetics determines the possibility of optimizing and management the drying process on a production scale, which is an important element of sustainable agriculture. Four selected vegetables, i.e. carrot, parsley, celery and beet, sliced into 3, 5 and 7 mm thick slices, were dried in three different temperatures of drying air (50, 60, 70°C). The coefficient of the initial drying speed reached lower values for thicker slices, and increased together with the increase in the drying agent

temperature. The values of coefficient k_0 were higher for higher initial water content in the material. It means that the drying process is faster for moister materials.

The drying process took the shortest for samples of carrot, followed by red beet, celery and parsley, which took the longest. Initial water contents for the vegetables were different, and they ranged from 4.2 to 12.2 kg/kg, which caused difficulties in results analysis. Also, within the same vegetable, the initial water content varied, which may be attributed to a large degree of inhomogeneity of the material.

Initial drying speed coefficient k_0 for the examined vegetables ranged from 0.030 to 0.072 1/min for carrot, 0.022 – 0.053 1/min for parsley, 0.020 – 0.056 1/min for celery, 0.024 – 0.064 1/min for beet. Initial drying speed coefficient k_0, depending on the drying temperature reached the following values: 0.020 – 0.072 1/min for the temperature of 50°C, 0.022 – 0.058 1/min for temperature of 60°C, and 0.028 – 0.068 1/min for temperature of 70°C.

Depending on slice thickness, initial drying speed coefficient k_0 ranged between 0.024 and 0.072 1/min for 3 mm thick slices, 0.023 – 0.066 1/min for 5 mm slices, and 0.020 – 0.064 1/min for 7 mm thick slices. It is impossible to conclusively state whether the temperature or slice thickness has greater impact on the drying speed.

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EVALUATION OF STREIF'S INDEX VALUES DURING MATURATION OF TWO APPLE CULTIVARS

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Keywords: apples, harvest, product optimization, Streif's index

ABSTRACT

The paper presents the results of Streif's Index (SI) expression by new method of harvest date optimization, based on calculation one of its components - starch index (S), by image analysis. Harvest date prediction is a crucial factor in apple storage and subsequent shelf life, making it the main factor of product optimization. Apple fruits (Gloster and Rubin) after harvest were subjected to measurements of firmness, extract, and calculation of starch degradation as the main indicators of fruit storage suitability. The work presents basic changes of maturity indicators to assess credibility of its value in various stages of ripening. The results present that the use of precise digital image analysis reduces inaccuracies of Streif's Index to more test limits set. Streif's index value in the range of 0,7 – 0,8 for Rubin apples and 3 – 4 for Gloster, at which harvest of fruits is recommended, was obtained at different harvest dates for image analysis results based on different image filtration thresholds. This type of image analysis inaccuracies emerged as the main factor of SI deviations.

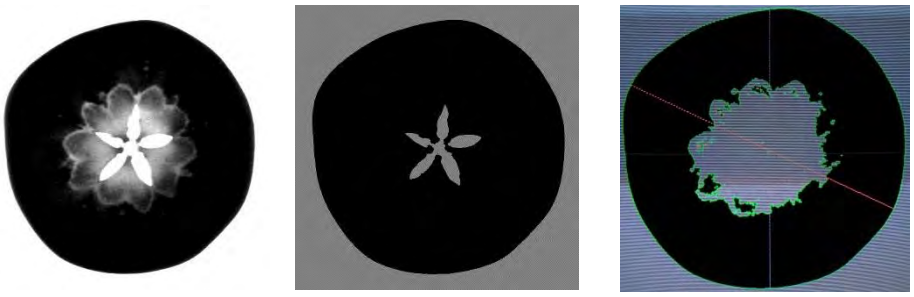
INTRODUCTION

New methods of storage and fruit processing require outside storage compartments with suitable equipment to ensure the maintenance of proper composition of the atmosphere, temperature and humidity and even pressure (Malinowska-Pańczyk, Kołodziejska 2010), the commodity collected at the optimum time, which determines its suitability for storage under the given conditions (Rutkowski 2001). Depending on their purpose, the harvest of fruit can be indicated that many methods (De Long 1999). If the fruits are intended for long term storage, the harvest period is determined on the basis of their physiological state (McGlasson et al. 2005). The state of physiological suitability is specified by fruit flesh firmness (Billy 2008), the ethylene content in the seed slot (Song, Bangerth 1996), soluble solids content and starch content (Łysiak 1998). The last indicator - starch index is performed in a simple, reliable test, possible to execute without sophisticated laboratory equipment (Jackman, Sun 2013). The starch content in apples, changes during maturation (Amissah et al. 2006). The initialization of its degradation is observed in August, and in September it undergoes a sudden acceleration (Doerflinger et al. 2015). As a result of starch degradation a set of monosaccharides appear in the fruit, which presence increases the concentration of soluble solids in the fruit juice (Fellman et al. 2003). Biochemical processes in the fruit during its maturation cause softening of the flesh, resulting in a gradual decrease in the firmness (Billy et al. 2008, Morales et al. 2007), The measurement of these three indicators is necessary to determine the aggregate index, the value of which is the basis for the decision to set. The most popular harvest indicator is the Streif's index. The results of fruit firmness and soluble solids content usually doesn't cause problems when it comes to readings taken from the instrument affected by constant, and small inaccuracy, usually given by its producer (Łysiak 1998,). Estimation of starch index with sufficient precision is, however, hard to perform, because it is based on visual, subjective assessment. The divergence in the assessment test in the group making the determination using standard tables reaches up to 60% (Peirs et al. 2002). The accuracy in estimation of this index

plays important role on decision that directly determines the quality of fruit. This paper proposes a calculation of starch index by digital images analysis, recorded during maturation of fruit.

MATERIALS AND METHODS

Apples (cv. Gloster and Rubin) were harvested in 4-days intervals. After the harvest, 10 apples picked from the trees were cut at equilibrium and subjected to standard starch test. Halves coloured by solution were cut to 5 mm thick slices. Those specimens were placed on illuminator screen and photographed by CCD 8-bit image converter camera. After photographs had been taken, picture analysis was conducted due to estimate the starch index values. The principle of measurement is illustrated by fig. 1.



A B C

Fig. 1. Stages of image transformation: A – slice image with starch pattern (primary image), B – binary image of the whole slice area, C – binary image of starch occupied area during measurement procedure

The starch index value was computed by the use of the formula:

$$S = 10(1 - \frac{p_w}{p_c}), \tag{1}$$

where:

S – starch index value,
p_c – the whole slice area,
p_w – the area occupied by starch pattern.

The second halve of apples were used to extract measurements. The apple flesh was mashed and juice was filtered by the piece of blotter due to extract measurements (Atago refractometer, ±0,1 Brix). The next 10 fruits in the sample batch were used to texture measurements. Firmness of the fruits was measured by the use of 11 mm penetrometer, which was immerged to 8 mm into apple flesh with the constant speed of 0,83mm/s. The resistance force (firmness) F was measured during the test, performed by TA.XT Plus texturometer. After all measurements were accomplished, the Streif's index was calculated:

$$IS = \frac{F}{R * S}, \tag{2}$$

where:

F- firmness of apple flesh [N],
R – soluble solids by refractometer [Brix],
S – starch index value.

RESULTS

The values of starch index estimated in the experiment were shown in table 1 and 2. The line of its changes indicates very different starch decomposition, described by computer image analysis. Optimum values of Streif's index (SI) at harvest are given in bold and underlined (Tab. 1 – 2). Relative deviations calculated in most harvest dates are above 10% (calculated as deviations from mean values). The errors calculated for terminal dates of harvest are smaller and their values are about 2 - 3%. Results obtained from image filtration threshold of 120 in 8-bit depth of colour, was the base of all calculations. The filtration threshold of s=120 was the base of all calculations. The deviated values of SI were calculated b the use of different threshold filters: s 100, s110, s115, s125, s130, s140 which were chosen by the analysis of area occupied by starch in the primary pictures.

The values of starch index as a main factor of Streif's harvest index were estimated by computer image analysis. All the data are collected in the table 1.

Gloster fruits are an example of apples where starch deterioration represents circular-type pattern on the cross section of fruit halves. These fruits should be harvested when Streif's index is in the range of 3 – 4. This maturity phase was observed in at most two harvest dates for each filtration procedure. Table 1 presents SI changes at different starch index (S) values, caused by variable filtration thresholds.

Tab. 1. Changes of Streif's index values in Gloster apples caused by variable image filtration threshold

Harvest date (Day of the year)	SI 100	SI 110	SI 115	SI 120	SI 125	SI 130	SI 140
253	**3,06**	4,45	5,89	9,37	11,14	14,39	21,60
257	2,57	**3,40**	4,44	5,70	8,54	10,87	15,70
261	2,06	2,55	**3,32**	4,32	5,38	7,08	9,87
265	1,70	2,11	2,74	**3,33**	**4,00**	5,19	7,18
269	1,46	1,78	2,35	2,68	**3,19**	**4,14**	5,20
273	1,34	1,69	2,04	2,32	2,68	**3,31**	**3,99**
277	1,22	1,48	1,89	2,19	2,42	2,82	**3,49**
281	1,06	1,27	1,63	1,85	2,10	2,35	2,87
285	0,98	1,13	1,41	1,60	1,74	1,96	2,32
289	0,84	0,95	1,10	1,27	1,43	1,55	1,86
293	0,75	0,80	0,88	1,00	1,12	1,26	1,48
297	0,66	0,69	0,73	0,80	0,91	1,03	1,25

Filtration thresholds at the range of 100 – 140 resulted in huge dispersion of possible harvest dates (253 to 281 day of the year). The initial harvest dates are taking into account harvest dates in many years before the experiment was performed. According to SI values obtained in the experiment, the optimum filtration value for primary images should be set above threshold of 120 (t120). The most appropriate value, observed on the basis of results obtained in the experiment, was t130. SI results obtained on the basis of image filtration t130 were probably the most suitable for optimum harvest date, placing it between 273 and 277 day of the year, which is the most possible "harvest window" period for apples intended for long-term storage.

Rubin apples are an example of fruits where cross-section starch decline during its maturation represents radial-type S deterioration, which is expressed by irregular starch

pattern of areas where starch vanished. Harvest date is suggested when Streif's index is in the range of 0,7 – 0,8. Following this recommendation, SI optimum values were obtained relatively late. The basis filtration threshold (t120) and upper values resulted in very late harvest dates (Tab. 2). This means that filtration procedure based on this threshold values leads to false results in starch index evaluations. Assuming this, the lower values of filtration thresholds (under t120) are recommended. The explanation of these results leads to conclusion, that increasing of threshold values resulted in expanding area occupied by starch-iodine complex, thus the S values were calculated as false, based on abnormal large areas, created as the result of improperly applied threshold values.

Tab. 2. Changes of Streif's index values in Rubin apples caused by variable image filtration threshold

Harvest date (Day of the year)	SI 100	SI 110	SI 115	SI 120	SI 125	SI 130	SI 140
253	1,55	1,75	1,99	2,12	2,34	2,54	2,94
257	1,41	1,57	1,74	1,90	2,04	2,20	2,55
261	1,29	1,43	1,55	1,73	1,84	1,98	2,29
265	1,06	1,18	1,30	1,37	1,55	1,67	1,89
269	0,95	1,05	1,13	1,23	1,36	1,46	1,67
273	**0,82**	0,90	0,97	1,08	1,18	1,26	1,45
277	**0,74**	**0,77**	**0,84**	0,94	1,04	1,14	1,29
281	0,66	**0,69**	**0,73**	**0,78**	0,88	1,01	1,18
285	0,58	0,58	0,61	0,63	**0,71**	**0,86**	1,02
289	0,51	0,52	0,52	0,53	0,56	**0,70**	**0,84**
293	0,47	0,48	0,48	0,49	0,50	0,61	**0,70**
297	0,45	0,46	0,46	0,47	0,48	0,53	0,57

The share of errors caused by deviations of F (force) and extract values R was very small. According to the user's manual, standard error in F assessment was smaller than 1% of measured values, and for simplicity in calculations this error was treated as constant value of 1N (this was higher value than real). Standard error in extract assessment was 0,1 Brix.

CONCLUSIONS

Computer image analysis of starch-iodine patterns is a promising tool in S and SI values evaluations. Several conditions however should be fulfilled. Streif's Index expressed by several levels of starch index decomposition has different values changes among the whole maturation period.

The use of computer image analysis isn't a good solution when the starch content is high (for example Gloster cultivar), because of high level errors at initial stages of starch decomposition. The main reason of diminished precision of complex index such as Streif's Index is wide range of threshold, resulted in inaccuracies of starch index (S) an then Streif's index (SI) estimation.

It should be born in mind that most apple cultivars represent two different models of starch deterioration. The choice of these two different apple cultivars, as an example of two important indicators evaluation, was not an accident. Because of its different starch decline during maturation, detailed analysis was needed. The image of apple fruits represents circular type of starch deterioration (Gloster) should be analyzed at slightly

higher levels of filtration thresholds, than the basic one (t120). Earlier studies (Peirs 2002) confirmed the results obtained in this study. In contradistinction to apples represent circular-type model of starch decline, the radial type apples (Rubin) of starch decomposition should be analyzed at lower filtration levels.

Prediction of fruits harvest date is possible when several conditions are fulfilled. The most important is reliability and accuracy of data put into calculation procedure. This leads to properly estimated harvest indicators before its inception. The issue of utmost importance is to continue research and laboratory work due to developing new measurements methods, which can become useful aids for optimization of fruits production, maintaining the product quality and making it more attractive for the consumer.

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FARMERS' KNOWLEDGE OF FERTILIZERS' PRACTICES ON THEIR FARMS

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Key words: Agriculture Extension, Farmers Knowledge, Fertilizers, Management of fertilization

ABSTRACT

This study was carried out in Lublin region to identify farmers' knowledge in the use of fertilizers. Data for the study were collected by an interview using a questionnaire of selected sample of 122 farmers to measure farmers' knowledge in the use of fertilizers. The majority (61.47%) of farmers were between 32-43 years, the results showed that there were significant differences between the average knowledge of the use of fertilizers according to the variables in the following categories: age, education level, years of work in agriculture. The results of the work will allow farmers and agricultural advisors to make the right decisions that will be beneficial for sustainable agriculture and the environment.

INTRODUCTION

Fertilizers are used to increase crop yields and to replace soil nutrients removed from harvested crops. They have been valuable in reversing the trend of declining soil productivity and soil nutrients. The importance of fertilizer is quite evident for maintaining the fertility of soil and getting an increased production. Natural fertilizers, including manure, slurry and manure, are valuable sources of organic matter and nutrients for plants. The skillful handling of natural fertilizers is important for economic and productivity reasons as it contributes to the improvement of soil fertility and fertility, and it also helps to reduce mineral fertilization. Excess natural fertilizers can, however, be a serious threat to the environment. In order to get the objectives of increasing agricultural production, firstly, it is very important that required quantity of fertilizer is easily available to farming community, and secondly, the recommended dose of fertilizer, is applied at the proper time and dose. Hence, the importance of fertilizers' use rises. Fertilizers are substances containing chemical elements such as nitrogen, phosphorus, potassium, magnesium and other elements that improve the growth of plants. They give nutrition to the crops. When added to soil or water, plants can develop tolerance against harmful organisms, like weeds, insects and diseases. This means that the need for herbicides and insecticides is reduced due to the production of healthier crops. Diseases can also be eliminated, which gives aesthetic value to the harvest. The agricultural extension has important role in this field through the transfer of new information and knowledge about the use of organic fertilizers to farmers and also to the development of information and the capacity of farmers in all the fields of agriculture. (Chauhan 2007, Kuepper 2003). However, most of these nutrient management technologies, programs, and recommendations have not been adopted by

farmers (Dan Pan 2014). The primary reason for this problem is rooted in the lack of knowledge and information by end users, because the majority of farmers have received limited education about the value and efficient use of plant nutrients (Huang 2008).
Fertilizers help plants to overcome stress situations by increasing their capacity to hold more water and improve the rooting depth. The potassium found in fertilizers is meant to make the stalks and straws of plants stronger. Fertilizers do not only assist in increasing yields and promoting healthy growth of plants, but also in their development.
According to the concept of sustainable development, agricultural production, the aim of which is the production of good quality food, must be carried out in accordance with the requirements of environmental protection. One of them is to minimize the loss of minerals, especially nitrogen and phosphorus, into the aquatic environment. This condition can be fulfilled when the fertilization is well managed, adapted for food needs of plants and soil conditions. You can expect good use of nutrients by plants, which reduces the risk of their losses from agriculture. It also has an economic and social dimension.

MATERIAL AND METHODS

The study was conducted in Lublin Regions and included 122 farmers. Data were collected through a questionnaire, which consisted of two parts. The first part included the independent variables. Level of education included: (1) a graduate of elementary education, (2) a graduate of secondary education, (3) a graduate of the agricultural Institute, (4) a graduate of college, (5) the highest certificate. Sources of agricultural information has been measured by (10) the sources of agricultural information (Extension agents - Friends and Relatives − Farmers association − Radio – Television − Agricultural Newspapers − Agricultural magazines − Mobile Phones – Internet and others) and alternatives included the following indicators (often, sometimes, and do not use) they were given numeric codes (1, 2, 3 respectively). The second part included the scale farmers' knowledge in the use of fertilizers. One point was given if no knowledge was used. Two points were given if the knowledge was at a low level. Three points were given if the knowledge was at a medium level. Four points were given if the knowledge in the use the fertilizers was at a high scale. Data were collected in the period between June to September 2015. The original data set included 17 paragraphs and the data were measured for validity and quality by a specialist at the Rural Development Department, based on the evaluation processes. Also, 30 questionnaires were excluded after determining the data consistency (total reliability coefficient was 0.89) (Pallant 2005). The frequencies, weighted percentage and Spearman-rank correlations, were used to analyze the data. Data were analyzed using the SPSS program.

RESULTS AND DISCUSSIONS

1. Identify level of farmers' knowledge in the use of fertilizers in Lublin District

The results showed that the highest value of farmers' knowledge in the use of fertilizers were 51 numeric values and the lowest was 22 with an average of (48.41) with a standard deviation of (3.33). The growers were divided into three categories according to the level of knowledge in the use of fertilizers. The first category was at the lowest level of their knowledge (22-31), with a mean (20.49 %) and the second category at the application level average ranged between (32-41), with a mean of (61.47%). The Third category representing the high application-level (42-51) with a mean of (18.04%) and this shows that the level of application of the farmers is medium tends to high, as in the table 1.

Table 1. Level of knowledge in use of fertilizers by cultivators in Lublin District

Categories Level of knowledge	Frequency	%
Low (22- 31)	25	20.49
Medium (32-41)	75	61.47
High (42-51)	22	18.04
Total	122	100.00

S.D = 3.33 X = 48.41

Table 2. Rank order of the items of scale to measure Knowledge of Farmers in use of fertilizers

No	Items	C.V	Mean
1	Use the fertilizers depended on crop type	0.233	3.45
2	Available nitrogen stored in the soil at planting	0.239	3.39
3	Nitrogen released by the soil during the growing season	0.257	3.05
4	Need for Sulphur fertilizer determined by a soil test	0.294	2.87
5	Soil moisture	0.305	2.78
6	Use the fertilizers depended on soil type (clay and organic matter content)	0.388	2.69
7	Type of fertilizer	0.391	2.57
8	Time of application	0.399	2.52
9	Banding fertilizer	0.411	2.49
10	Contributes to increased salinity on some soil	0.424	2.33
11	Assessment of economic returns from fertilizer	0.486	2.28
12	Fertilization as top dressing	0.511	2.21
13	Band Fertilization	0.518	2.14
14	Over and side application	0.566	2.09
15	Spraying onto leaves	0.574	2.01
16	Application by irrigation water	0.581	1.94
17	Fertilization as Top Dressing	0.589	1.88

2. Identify the relationship between Farmers' Knowledge about the use of the fertilizers and each of the independent variables

Age. The results in table (3) indicate that the highest age among the respondents was (55) years and the lowest age among the respondents was (19), The distribution of respondents into categories, found that the percentage of the category (19-31) years was (28.69%) and the percentage of the category (32-43) years was (48.36%), while the percentage of the category (44-55) years was (22,95%). The previous results mean that younger farmers were involved in organic farming practices more than older farmers.

Spearman correlation coefficient was 0.181 (at 0.05 probability), this agrees with Hameed and Sawicka (2017) for the relationship between the Farmers; Knowledge about the use of the fertilizers and age.

Education Level. The distribution of respondents into categories based on their education level is shown in table 3. The percentage of graduates of primary and secondary school was (9.83%) and (17.21%), respectively. The percentage of respondents who have a certificate of an Institute and College was (25.41%) and (38.52%) respectively the percentage of participants who have the highest certificate was (9.01%). The Spearman correlation coefficient was 0.303 (at 0.01 probability) between the Farmers' Knowledge about the use of the fertilizers and education level. This agrees with Chouichom and Yamao (2010).

Type of tenure. The results in table (3) indicate that the percentage of respondents who own land was (21.32%) and those who rent the land reached (27.04%), while the land contracts was (27.87%). The percentage of respondents with a type of possession of the land participation were (23.77%). The Spearman correlation coefficient was 0.046 between Farmers' Knowledge about the use of the fertilizers and type of tenure the correlation was not significant, this disagree with Chouichom and Yamao (2010), which indicates that this type of acquisition has no effect on Farmers' knowledge.

Years of work in agriculture. Table 3. shows that the percentage of respondents, who have a number of years of work in agriculture between (9-21 years), was (24.60%) and the percentage of respondents who work for (22-34 years) was (37.70%), while the percentage of respondents who work in agriculture for (35-47 years) was (37.70%). The results show that three-quarters of the respondents were working in agriculture for a long period of time. Spearman correlation coefficient for the Farmers' Knowledge about the use of the fertilizers and years of work in agriculture was 0.170 at (0.05 probability). The correlation value here indicates that the increase in the number of years of work in agriculture has a significant impact on the accumulation of experience related to the agricultural practices and may raise their knowledge in using the fertilizers.

Agricultural cultivated area. Table 3. shows, that the highest percentage of respondents who have an area of land between (12-36) ha was (31.15%) and the percentage of respondents who have an area of land between (37-61) ha was (40.16%), while the percentage of respondents who have an area of land between (62-86) ha was (28.69%). The Spearman correlation coefficient between Farmers' Knowledge about the use of the fertilizers and Agriculture cultivated land was not significant (0.057).

Agricultural information sources. The results presented in table 3. expressed that the highest numeric value to agricultural information sources was 30 and the lowest value was 10. The distribution of the respondents according to the categories of sources of agricultural information showing that the respondents who fall within the low category were making the highest percentage (42.63%), while the percentage of farmers in the category of medium level were (33.60 %) and the percentage of high-level reached

(23.77%). To find the relationship between the Farmers' Knowledge about the use of the fertilizers and agricultural information sources correlation coefficient of Spearman was used and it was not significant (0.087). This disagrees with Oyesola and Obabire (2011) and Oluwasusi (2014). Such an insignificant value might be due to the insufficient information that were provided for the farmers regarding another aspect.

Table 3. The correlation between some variables and level of application cultivators

The significance	Rs Value	%	Frequency	The variables
Age				
*	0.181	28.69	35	Year (31-19)
		48.36	59	Year (43-32)
		22.95	28	Year (55-44)
Education Level				
**		9.83	12	Primary school
		17.21	21	Secondary school
		25.41	31	Institute
		38.52	47	College
		9.01	11	High certificate
Type of tenure				
Not significant	0,046	21.32	26	Owned
		27.04	33	Rented
		27.87	34	Contract
		23.77	29	Participation
Years of work in agriculture				
*	0.170	24.60	30	year (21-9)
		37.70	46	year (34-22)
		37.70	46	year (47-35)
Agricultural cultivated area				
Not significant	0.057	31.15	38	ha (36-12)
		40.16	49	ha (61-37)
		28.69	35	ha (86-62)
Agricultural information sources				
Not significant	0.087	42.63	52	Low (16-10)
		33.60	41	Medium (23-17)
		23.77	29	High (30-24)

* Indicates that the value of morale at the level (0.05)
** Indicates that the value of morale at the level (0.01)

CONCLUSION

The level of farmers' knowledge about the use of the fertilizers in Lublin province is medium. The variables such as: Agricultural information sources, Agricultural cultivated area, Type of tenure, do not have a clear role in the development of the cognitive level of farmers about the use of the fertilizers. While, the variables such as: (age, education level, size of farm, average yields) play a significant role in the development of the cognitive level of farmers about the use of the fertilizers. The results presented in this paper will help farmers and agricultural advisers to make rational decisions, which will benefit the sustainable agriculture and the environment.

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THE STUDY OF MULTISTAGE GRINDING OF RYE

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Keywords: rye, grinding machinery, energy requirements, sustainable agriculture

ABSTRACT
The aim of the study was to propose the method of multistage grinding of rye grain. Investigations were carried out on rye cultivar (*Secale Cereale*) Bosmo, collected in the year 2016. The samples of rye were tempered to adjust moisture contents to: 10, 12, 14, 16, 18, and 20% (w.b.). The grinding process was carried out in three combinations: grains were ground by using the laboratory hammer mill, rye was ground using the laboratory roller mill and the grains were preliminary ground using hammer mill and in the second stage the roller mill was used. The particle size distribution was determined and the grinding energy indices were evaluated. The results showed that hammer mill grinding is more energy consuming than particle size reduction using a roller mill. Most importantly, the multistage grinding of rye (roller mill in the first stage) significantly reduced energy requirements for hammer mill grinding and caused the highest degree of fineness. This method is especially preferred for sustainable agriculture practices.

INTRODUCTION

Rye (*Secale cereal* L.) is an important crop in Eastern, Central and Northern Europe and a rich source of dietary fibre. It is an excellent raw material for healthy and tasty foods. (Johansson *et al*. 2017; Zieliński *et al*. 2008). Rye products have repeatedly been shown to induce lower postprandial insulin response, with or without a corresponding decrease in glucose response, compared with refined wheat bread (Johanssonet *et al.* 2017). Rye contains biologically active substances with antioxidant properties by acting as reducing agents, free radical-scavengers and through formation of complexes with metals (Afzal *et al*. 2013). The nutritional benefits of rye consumption include positive effects on digestion and decreased risk of heart disease, hypercholesterolemia, obesity, and non-insulin dependent diabetes, and rye also has a protective effect against cancer (Hansen *et al.* 2004).

The basic goals of sustainable agriculture are environmental health, economic profitability, and social and economic equity. The grinding process is the most important and the most energy consuming in processing of agricultural products. Thus the knowledge about the methods of grinding energy saving is in agreement with the goals of sustainable agriculture. The grinding energy depends both on the properties of the grinding material and on the used machines and their work parameters (Saiedirad *et al.* 2008). Particle size of ground grains has influence on properties of the flour (Dziki *et al*. 2014). Cereals grinding is mainly performed with the use of hammer mills and roller mills. The most commonly applied in practice are the roller mills. However they have little effect on bran size reduction. The hammer mills are more appropriate for grinding fiber-rich bran and germ and thus for whole grain flour production (Dziki and Laskowski 2010). Moreover, the knowledge of fracture characteristics of grains is imperative for a rational design of efficient grinding systems, as well as the optimization of the process and product parameters (Prabhasankar and Rao 2004). The objective of this study was to propose the method of multistage grinding of rye grain. Besides, the effect of grain moisture content on grinding energy requirements was studied.

MATERIAL AND METHODS

Investigations were carried out on rye cultivar (*Secale Cereale*) Bosmo, collected in the year 2016. The samples of rye were tempered by adding water or by drying at 35 °C to adjust moisture contents to: 10, 12, 14, 16, 18, and 20% (w.b.) and storing for 48 h. The tempered grains were divided in three portions. The grinding process was carried out in three combinations:

- grains were ground by using the laboratory hammer mill POLYMIX-Micro-Hammermill MFC equipped with a 2.0 mm screen size (Dziki 2008),
- rye was ground using the laboratory roller mill SK (Dziki and Laskowski 2004),
- grains were preliminary ground using hammer mill and in the second stage the roller mill was used.

The amount of energy consumed during grinding was obtained by means of a power transducer, a data acquisition and a computer system that recorded the data measured by the transducer. The unloaded grinder current was monitored prior to grinding and remained constant over all testing and the grinding energy was calculated by using special computer software. The energy required to run the mill with no load was determined and subtracted from the total energy to obtain the grinding energy. The specific grinding energy was determined as the ratio of the grinding energy to the mass of the material taken for grinding. The sieving test was used to determine the particle size distribution of the pulverized material. Sieving was carried out for 5 min, by using a laboratory screen (Thyr 2, SASKIA, Germany), and separated into fractions using sieves of sizes: 1.600, 1.200, 0.800, 0.630, 0.400, 0.315 and 0.200 mm. On the basis of the particle size distribution, the average particle size (d*p*) was calculated as follows (Velu et al. 2006). The grinding ability index (E_s) was calculated as a ratio of the grinding energy to the surface area of the pulverized material. The surface area of the pulverized material was evaluated according to the procedure described by Jha and Sharma (2010). The Sokołowski's grinding index was calculated on the basis of the size reduction theory described by Sokołowski (1996). Details of the procedure used in determining these indices can be found in Dziki and Laskowski (2010) and Dziki (2011).

The measurements of crushing energy and grinding energy were replicated in triplicate. The obtained data was further subjected to a statistical analysis and the consequent evaluations were analyzed with the variance analysis using the Statistica 6.0 software (StatSoft, Inc., Tulsa, USA). Moreover, standard deviations were evaluated and the relations were described using the regression equations. The statistical differences between the treatment groups were estimated with Tukey test. All the statistical tests were carried out at the significance level of $\alpha = 0.05$.

RESULTS

The sieve analysis of ground material showed that when roller mill was used for grinding the highest amount of coarse particles (above 1.6 mm) was obtained. When hammer mill was used for grinding alone or as a preliminary step before roller mill grinding the fraction of particles above 1.6 mm was not found in the ground rye. From the other hand, the highest mass fraction of fine particles (below 0.2 mm) was observed when two kinds of mills were used both (Table 1). When roller mill was used for grinding an increase the grain moisture content caused an increase of the mass fraction

of coarse particles and the highest mass fraction of fine particles was obtained when rye moisture was 14%. Interestingly this tendency was also found when roller mill and hammer mill were used together. In the case of hammer mill the highest mass fraction of these particles was found when grain moisture was 14%. The average particle size (*d*) of ground rye obtained from different methods of mill was presented on Fig. 1.

Table 1. Particle size distribution of ground material

Range of class (mm)	Used mill	Grain moisture (%)				
		10	12	14	16	18
>1.6	hammer mill	0±0.00	0±0.00	0±0.00	0±0.00	0±0.00
1.2 - 1.6		6.7±0.22	5.1±0.16	6.2±0.24	5.5±0.15	5.4±0.11
0.8 - 1.2		15.6±0.18	15.5±0.08	16.0±0.31	15.5±0.19	15.2±0.17
0.63 - 0.8		23.1±0.31	23.2±0.38	24.4±0.45	22.8±0.39	24.02±0.42
0.4 - 0.63		20.69±0.00	21.01±0.00	21.54±0.00	21.8±0.00	23.26±0.00
0.315 - 0.4		6.07±0.00	5.92±0.00	5.8±0.00	6.55±0.00	7.63±0.00
0.2 - 0.315		13.08±0.00	13.45±0.00	10.75±0.00	13.54±0.00	12.29±0.00
<0.2		14.87±0.00	15.89±0.00	15.2±0.00	14.3±0.00	12.22±0.00
>1.6	roller mill	0.2±0.01	0.9±0.03	0.9±0.04	7.0±0.38	16±0.62
1.2 - 1.6		9.0±0.23	18.6±0.41	19.4±0.52	28.4±0.74	28.3±0.35
0.8 - 1.2		9.8±0.26	10.5±0.35	11.0±0.27	9.4±0.55	8.3±0.18
0.63 - 0.8		17.3±0.28	13.7±0.31	11.3±0.14	11.1±0.12	9.7±0.21
0.4 - 0.63		37.0±0.56	28.1±0.42	29.7±0.51	19.3±0.33	15.1±0.17
0.315 - 0.4		7.6±0.14	7.3±0.18	6.1±0.07	5.0±0.11	4.7±0.15
0.2 - 0.315		7.8±0.08	7.7±0.19	6.6±0.14	6.7±0.23	6.0±0.14
<0.2		11.4±0.63	13.5±0.54	14.9±0.62	13.1±0.23	12.0±0.32
>1.6	roller mill and hammer mill	0±0.00	0±0.00	0±0.00	0±0.00	0±0.00
1.2 - 1.6		0.3±0.05	0.8±0.06	1.0±0.07	1.9±0.08	3.9±0.17
0.8 - 1.2		1.4±0.12	3.4±0.11	4.8±0.21	4.9±0.31	6.4±0.29
0.63 - 0.8		7.0±0.21	10.7±0.36	11.7±0.32	13.0±0.35	14.0±0.42
0.4 - 0.63		45.5±0.57	38.8±0.62	37.4±0.66	28.5±0.54	26.0±0.72
0.315 - 0.4		16.8±0.39	15.2±0.35	12.2±0.26	12.0±0.37	11.4±0.28
0.2 - 0.315		15.0±0.73	13.6±0.52	10.3±0.18	19.6±0.48	20.5±0.39
<0.2		14.0±0.58	17.6±0.56	22.7±0.73	20.2±0.61	17.8±0.65

The results showed linear relation between the average particle size and grain moisture. As the moisture of rye increased the particle size also increased. This tendency was found for each grinding method. Interestingly when the moisture of grain was 10% the similar values of average particle size was obtained after grinding rye by using hammer mill and roller mill. At the higher moisture content the highest values of average particle size were obtained when roller mill was used. When the two mills were combined into one grinding system the lowest values of particle size were obtained.

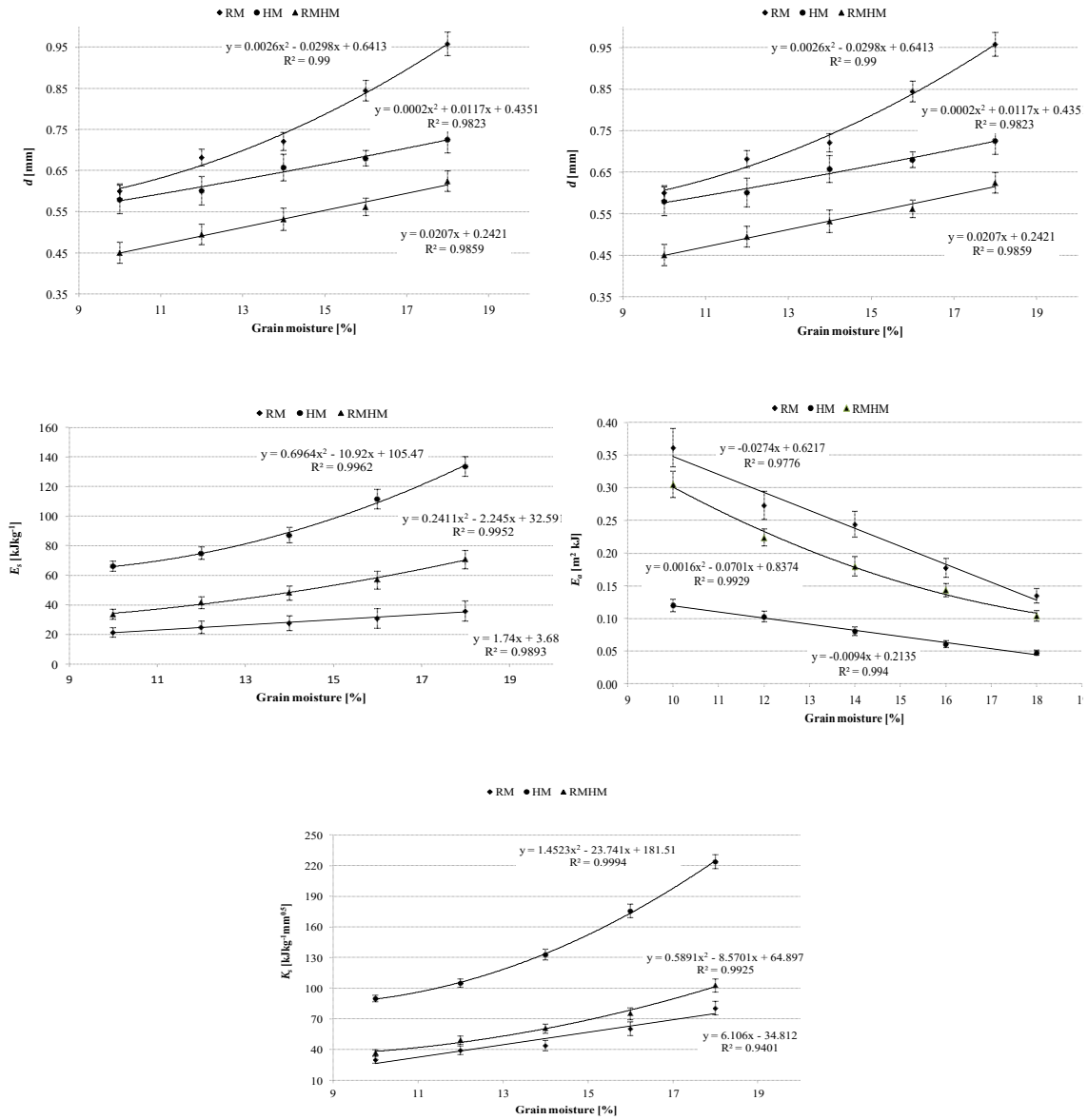

Fig. 1. Influence of moisture content and the method of grinding on average particle size (*d*), specific grinding energy (E_s), grinding ability index (E_a) and Sokołowski`s grinding index (K_s); RM- roller mill, HM – hammer mill, RMHM – roller mill and hammer mill

The obtained data showed that there is a significant influence of grain moisture and method of grinding on specific grinding energy. The highest values of specific grinding energy were found when hammer mill was used for particle size reduction, whereas the lowest values of this parameter were obtained when hammer mill was used. An increase of grain moisture content from 10% to 18% caused an increase of specific grinding energy from 21.3 to 35.7 kJ·kg^{-1}, from 66.2 to 133.6 kJ·kg^{-1} for roller mill and hammer mill and from, respectively. When roller mil was used as the preliminary step before hammer mill grinding the specific grinding energy ranged from 33.6 to 70.9 kJ·kg^{-1} (Fig. 1). The grinding ability index and Sołołowski`s grinding index are the important indices describing the grinding process because this indices take into account the particle size distribution of ground material.

CONCLUSIONS

The results clearly showed that hammer mill grinding is more energy consuming than particle size reduction using a roller mill. The specific grinding and grinding ability index were several times higher when hammer mill was used. Besides, the increase of grain moisture content caused an increase of specific grinding energy. However this effect was stronger and non-linear when hammer mill was used for grinding. Most importantly, the multistage grinding of rye (roller mill in the first stage) significantly reduced energy requirements for hammer mill grinding. Besides, the particle size distribution strongly depended on the methods of grinding and grain moisture. The highest mass fraction of fine particles (below 0.2 mm) was observed when two kinds of mills were connected in multistage grinding process. When roller mill was used for grinding alone an increase the grain moisture content caused an increase of the mass fraction of coarse particles and the highest mass fraction of fine particles was obtained when rye moisture was 14%. Interestingly, this tendency was also found when roller mill and hammer mill were used together. In the case of hammer mill the highest mass fraction of fine particles was found when grain moisture was 14%. Moreover, the multistage grinding caused the highest degree of fineness. The proposed integrated method of grinding is especially preferred for sustainable agriculture practices.

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ENERGETIC USAGE OF SLAUGHTER WASTE AS THE SUBSTRATE FOR BIOGAS PRODUCTION

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Keywords: biogas, slaughter waste, energetic usage

ABSTRACT

Sector of animal production is growing strongly in Poland within last years. This concerns especially poultry sector (first position in Europe with more than 900 million animals per year) bit also swine and cattle. This sector generates dynamic growth of meat export. However, this sector is responsible also for large scale production of slaughter waste which very often creates problem with its proper management and recycling. This paper describes the possibility of the energetic usage of slaughter waste as the substrate for biogas production. The biogas efficiency analysis of different waste like: waste category II, blood, feathers, soft waste category III and solid waste category III have shown its good usefulness for methane production. The calculations showed the energetic potential for analyzed slaughter house as 700 kWe.

INTRODUCTION

The most important factor determining the profitability of the agricultural biogas plant is type of the substrate used (except for technology used) (Ward et al., 2008). Maize silage, supplemented with animal excrements, predominates among the substrates in the whole Europe (Naik et al., 2010; Herrmann et al., 2015). These substrates can be used in the most common German technology NaWaRo spread on the continent (Dach et al., 2014). As a result of very low subsidies for energy produced from biogas in 2012-2016 (Wędzik at al., 2017), new and innovative technologies have emerged in Poland as a global vanguard in the field of highly efficient biogas waste treatment. Production results of installation in Międzyrzec Podlaski, Jaromierz or Upałty reach 8500 MWh from 1 MW of installed electrical power, which gives the efficiency at the level of 97%. As these biogas plants primarily use organic waste, it is evident that biogas plants primarily should use for fermentation processes the waste biomass and dispose animal waste.

In the meantime, in Poland, the use of slaughterhouse waste and carcase in biogas plants is almost completely ignored. Although research conducted at the Laboratory of Ecotechnologies in the Institute of Biosystems Engineering (Poznan University of Life Sciences, PULS) proves that these are very promising substrates, however, investors are afraid of this kind of waste (Cieślik et al., 2016b), Czekała et al., 2015). This is due to the fact that not every technology is able to efficiently digest all parts of the animal's body or carcass. It should be highlighted, that among the substrates used for the production of agricultural biogas, among the slaughterhouse waste there is a distinction i.e. fat issue, stomach contents, flea fats, feathers, blood or skin - and sometimes sediment from the sewage treatment plant and often slurry. The usefulness of the discussed substrates for fermentation is mainly related to the high content of fats and proteins, which is usually very high.

The slaughterhouse waste materials are strongly differentiated both physically, chemically and microbiologically and therefore should be used in installations dedicated

to the processing of a wide range of waste, such as ProBioGas technology from Bio Power company from Międzyrzec Podlaski or Dynamic Biogas from Poznań. However, it is important to remember that in any technology it is necessary to subject the waste to thermal treatment before being dumped into the fermentation chamber.

An additional advantage in the waste disposal in the biogas plant is, on the one hand, an answer to the waste and environmental problems for the plant, and a significant reduction of odors generated by the stored and disposed waste (Czekała et al., 2016a). Composting is another type of organic waste management (Wolna-Maruwka and Czekała, 2007). The process allows recycling of waste and the final product of the process is valuable fertilizer – compost (Białobrzewski et al., 2015; Waszkielis et al., 2013). Moreover, it is important to implement problematic waste for electricity and heat production and to ensure the energy self-sufficiency for the slaughterhouse. It should be remembered, that the acceptance of post-mortem residues in the biogas plant, still continues to preserve the status of an agricultural installation (of course, once the relevant requirements have been met). European Union legislation divides slaughter waste into three categories. In the biogas plants, after prior pre-treatment, only waste materials that are classified as category II (e.g. digestive tract) and category III (e.g. inedible parts of animals) can be used.

Meat production is characterized by considerable variation in the processes and the technologies used. Very often, different types of slaughterhouse waste can occur in different plants from the same animals. The best example are fatty and flotation deposits, where the content of dry matter and hence the productivity of methane can vary significantly between slaughterhouses.

The use of slaughterhouse waste, as a biogas substrate, makes it easy to improve the economic efficiency of the installation. The purchase cost is small (0-50 PLN/Mg), compared to the popularly used in the methane fermentation maize silage (100-130 PLN/Mg). Moreover, in some cases, it is possible to get extra revenue for the management of this kind of waste. Another benefit may be the sale of post-fermentation, which is a valuable fertilizer (Czekała et al., 2017; Czekała et al., 2016b).

The aim of this paper is to analyze an energetic usage of slaughter waste as the substrate for biogas production based on study-case of middle size meat factory in South-West Poland. The investor is going to build biogas plant connected with the poultry slaughter house in order to reduce the problems related to waste management, as well as increase the economic balance of the company.

MATERIALS AND METHODS

For the analysis, the waste substrates from the poultry slaughterhouse were taken directly from the slaughter plant and after cooling, were transported immediately to the Laboratory of Ecotechnology for basic analysis and determination of the biogas efficiency. The following types of waste were collected:

- waste category II;
- blood;
- feathers;
- soft waste category III;
- solid waste category III.

The fermentation inoculum used to verify the biogas efficiency of the substrates was obtained by separating the fraction of liquid fermentation pulp from a functioning agricultural biogas plant.

The dry mass (PN-75 C-04616/01) and dry organic mass (PN-Z-15011-3) were tested to determine the appropriate ratio between the tested substrate and the inoculum (Wolna-Maruwka, 2012). These parameters were also necessary to calculate the biogas efficiency of the substrates per m^3/Mg F.M. (fresh mass), m^3/Mg D.M. (dry mass) and m^3/Mg O.D.M. (organic dry mass). The analysis of the biogas efficiency of the substrates was carried out at the Laboratory of Ecotechnology in the Poznan University of Life Sciences, on the basis of internal procedures based on the internationally recognized German standard DIN 38 414/S8 and the standardized biogas guide of the German Engineers Association in Dresden - VDI 4630.

The research experiments were carried out in the reactors with capacity of 2 dm^3 in 39°C ± 1 water bath (mesophilic fermentation), which are part of the 21-reactor research stations constructed in the Laboratory of Ecotechnology (Fig.1). The qualitative and quantitative analysis of the produced gases (CH_4, CO_2, NH_3, O_2, H_2S) was performed every day using the Geotech GA5000 gas analyzer (Cieślik et al., 2016).

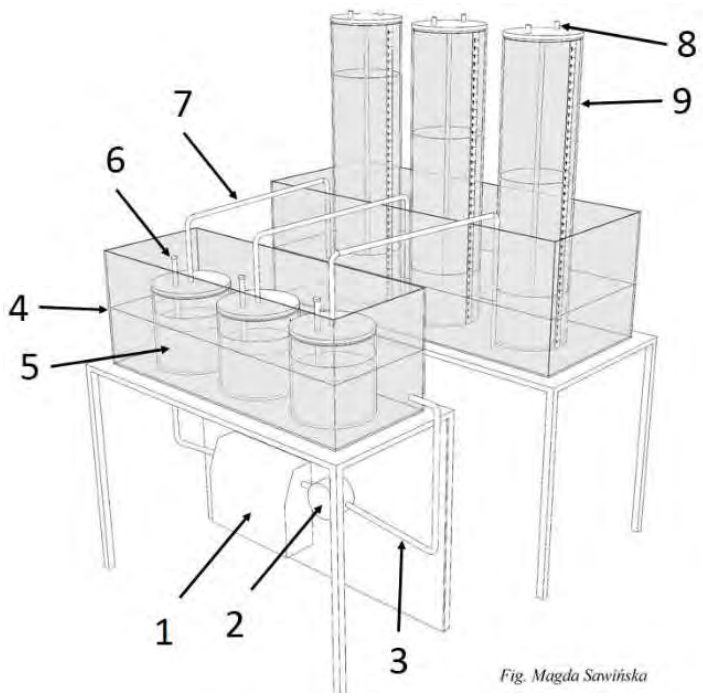

Fig. 1. Scheme of biofermenter for biogas production research (3-chamber section): 1 – water heater with a temperature in the range of 20-70ºC, 2 – water pump, 3 – isolated hot liquid tube, 4 – layer of water at temperature of 38°C, 5 – biofermentor with the input of 1.4 dm3 of capacity, 6 – sampling tube, 7 – tube for biogas flow, 8 – security valves (also used for taking biogas samples), 9 – biogas container made of poly (methyl methacrylate).

The energetic calculations were made according to the methodology created by the Institute of Biosystems Engineering, in close co-operation with the enterprises from Polish biogas sector (Cieślik et al., 2016).

RESULTS

Physical and biogas analysis

The results of the analysis of basic physical parameters of waste used as substrates are presented in Table 1.

Tab. 1. The basic parameters of analyzed substrates

Substrate	Dry Mass [%]	Organic Dry Mass [% D.M.]
waste category II	20.88	71.14
blood	17.58	94.62
feathers	12.90	98.75
soft waste category III	46.78	97.52
solid waste category III	47.11	70.36

As it can be noticed in Table 2, excluding Category II waste and Category III hard waste, other waste materials are characterized by very high organic matter content. Category III wastes, on the other hand, have high dry matter content, which is advantageous for their use in methane fermentation.

However, the results of methane efficiency tests (Table 2) showed, that the highest efficiency of CH_4 production was noticed in case of Category II waste (406.57 m^3/Mg), where dry matter content was more than half that of Category III waste.

Tab. 2. The results of methane efficiency tests

Substrate	Methane content [%]	Cumulated methane [m^3/Mg D.M.]	Cumulated biogas [m^3/Mg F.M.]
waste category II	69	406.57	589.23
blood	67	56.44	84.24
feathers	68	14.57	21.42
soft waste category III	70	282.63	403.75
solid waste category III	69	155.17	224.89

As a result of mesophilic fermentation of slaughterhouse waste, calculated as 1 Mg of fresh matter, most of biogas was obtained from waste category I, nearly 590 m^3, whereas least methane was obtained from fermentation of feathers as only about 21.5 m^3. All waste materials were characterized by an average methane content of about 70%. This is a very high result, by almost 20 percentage points higher than the methane content of the typical biogas produced from silage (methane content of 48-53%). On this basis, it should be emphasized that slaughter waste is much more energetic substrate than typical plant products used to supply biogas plants. It is also important to emphasize that the use of slaughterhouse waste to supply agricultural biogas plant enables it to continue to retain agricultural status, which means higher level of subsidy for energy produced compared to municipal waste treatment facilities and also facilitates (from a legal point of view) the use of post-fermentation as fertilizer agricultural.

Energetic analysis

Table 1 represents the results of energy calculations for the yields obtained for substrates as well as the total mass produced by the slaughterhouse.

Tab. 1. Results of energy calculations for the analyzed poultry slaughterhouse

Substrate mass	9120	Mg
Total volume of methane produced	1,570,539	m³
Total volume of biogas produced	2,255,600	m³
The amount of electricity produced	6048.77	MWh
The amount of thermal energy produced	6480.83	MWh
The amount of thermal energy produced	23652.66	GJ
Electrical efficiency of the aggregate	0.43	[-]
Thermal performance of the aggregate	0.45	[-]
Electric power of the biogas plant	0.70	MW
Thermal power of the biogas plant	0.75	MW

In total, during the year, the average poultry slaughter plant produces over 9100 Mg of waste. From this mass, it can be produced more than 1.5 million m^3 of methane. By burning this volume of methane with the efficiency of the cogeneration unit 43% we can produce over 6000 MWh electricity.

Assuming the operating time of the cogeneration unit at the level of 8600h per year, the planned biogas plant will have an electrical power of 0.7 MW.

CONCLUSIONS

1. The slaughterhouse waste (especially category II) is an energy waste that is suitable for use in agricultural biogas.

2. Very high methane content in biogas produced from slaughterhouse waste and high (up to 4 times) methane yields than in case of maize silage, makes these waste materials much more profitable for use in biogas plant than typical agricultural substrates.

3. In the analyzed case study, the electricity generated from the waste can cover completely the own needs of the plant.

4. The use of slaughterhouse waste for methane fermentation has a positive effect on the reduction of odors generated by stored and disposed waste.

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THE MOBILE SERVICE OF AGRICULTURAL MACHINES AS THE ELEMENT OF THE SUPPORT FOR THE SUSTAINABLE AGRICULTURE

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Key words: maintenance of agricultural vehicles and machines, servicing, sustainable agriculture

ABSTRACT
The current article presents the problems of agricultural production, including the sustainable system of farming, related to servicing agricultural vehicles and machines. It discusses solutions which ensure support for sustainable development. Moreover, it presents research into maintenance of agricultural vehicles and machines conducted by an authorised service in the aspect of the distance between the site where the works are performed and the premises of the company. It also presents the structure of service orders for four radii measuring $r = 0$ km, 0 km $< r \leq 50$ km, 50 km $< r \leq 100$ km and $r > 100$ km. The study was conducted in the years 2003-2013 in an enterprise which offers authorised servicing. The structure of 17,402 service orders executed in the company's garage (r=0) and those executed on farms or under field conditions (r>0) were represented graphically and analysed statistically with the use of the R programme.

INTRODUCTION

A sustainable system of farming which prevents the loss of organic matter in soil requires increased expenditures on agricultural activities. The promotion of such a method has been supported for years by subsidies from subsequent European Union programmes. Sustainable agriculture, introduced as part of the Rural Development Programme for the years 2007-2013, is continued as part of agricultural-environmental-climatic Package 1, which is in force in RDP for the years 2014-2020. An element which supports the rational use of natural resources and the limiting of the negative effect agriculture has on the environment is, to a significant extent, the up-to-date maintenance of agricultural vehicles and machines. Ensuring timely completion of agrotechnical works both influences the effectiveness of farming activities and optimises their effectiveness in the aspect of affecting the environment. However, a necessary condition is to possess technically fit agricultural vehicles and machines as well as the guarantee of restoring them to usefulness quickly by a service station.
Contemporary agricultural production, especially on larger farm areas, makes use of modern and efficient vehicles and machines produced by international concerns. The producers have built an up-to-date structure in Poland which distributes products and replacement parts as well as offers comprehensive maintenance services (Juściński 2012a, 2012b; Lorencowicz and Cupiał 2012, 2013; Tomczyk 2015). The distribution of users of vehicles and machines is uneven both across the country and particular voivodeships. Service orders are made by users living at various distances from dealerships. In order to reduce the costs of transporting broken-down agricultural vehicles and machines, as well as the time of repairing them, various forms of executing orders are employed (Buchwald and Staszak 2013, Rzeźnik et al. 2015, Skrobacki and Ekielski 2012). Maintenance services conducted in service stations constitute only a part of the demand for servicing, as an increasing number of orders is realised by mobile servicing teams in the field (Juściński 2012c, Niari et al., 2012). Maintenance services on modern vehicles and machines are performed in an area with a radius measuring at least several dozen kilometres. It creates difficulties in managing various works aimed

at fixing operational failures or conducting repairs or inspections. A random configuration of types of works and their geographical location is a logistic challenge for the servicing department. Farmers' universal access to information and communication technologies provides support for maintenance services, as it facilitates making arrangements and reduces the time of waiting for repairs to be made (Cupiał and Kobuszewski 2011, Cupiał et al., 2015). It should be stressed that ensuring an optimal level of service, in face of varying demand, generates high fixed costs of the functioning of maintenance services (Gazzarin 2014, Gazzarin and Lips 2013). It is only possible for mechanics to travel to execute individual orders in the months when demand is low. One method to increase the rate of utilising time for effective work of servicing teams is to execute several orders on subsequent customers' premises during a single trip.

MATERIAL AND METHODS

The aim of the conducted market research was the identification and analysis of the demand for the maintenance of agricultural vehicles and machines realised by authorised services in the aspect of the distance between the place of performing works and the premises of the company. The study concerned four radii (distance): $r = 0$ km, 0 km $< r \leq$ 50 km, 50 km $< r \leq$ 100 km and $r >$ 100 km. Statistical analysis of inspections and repairs was conducted for $r = 0$ km and $r > 0$ km, or for services in the company's garage and all works in the field. The research conducted in the years 2003-2013 concerned servicing departments which offered maintenance services for agricultural vehicles and machines. Inspection and repair orders executed on the premises of service stations, on farms and under field conditions involved agricultural tractors produced by John Deere, Zetor, Pronar, Same, Deutz Fahr and Lamborghini. Maintenance services were also performed on agricultural machines produced by such concerns as John Deere, Kuhn, Väderstad, Manitou, Lemken, Kongskilde, Joskin and Hardi, as well as machines produced by Polish enterprises which together form Unia Group. The maintenance services of agricultural vehicles and machines performed by the servicing department in company garages (r=0) and the works conducted by mechanic teams on farms and under field conditions (r>0) were ordered in the form of monthly observations. The statistical analysis of maintenance services of agricultural vehicles and machines was conducted with the use of the R programme (Aczel and Sounderpandian 2009, Crawley 2013).

RESEARCH RESULTS

During 11 years of research, servicing centres realised in total 17,402 orders in company garages, on farms and under field conditions. The distribution of maintenance services on a monthly basis is presented in a histogram (Fig. 1).

The research into the structure of the territorial configuration of service orders confirmed:

- 10,616 service orders with r=0 km,
- 1,297 service orders with 0 km < r≤50 km,
- 1,687 service orders with 50 km < r≤100 km,
- 3,802 service orders with r>100 km.

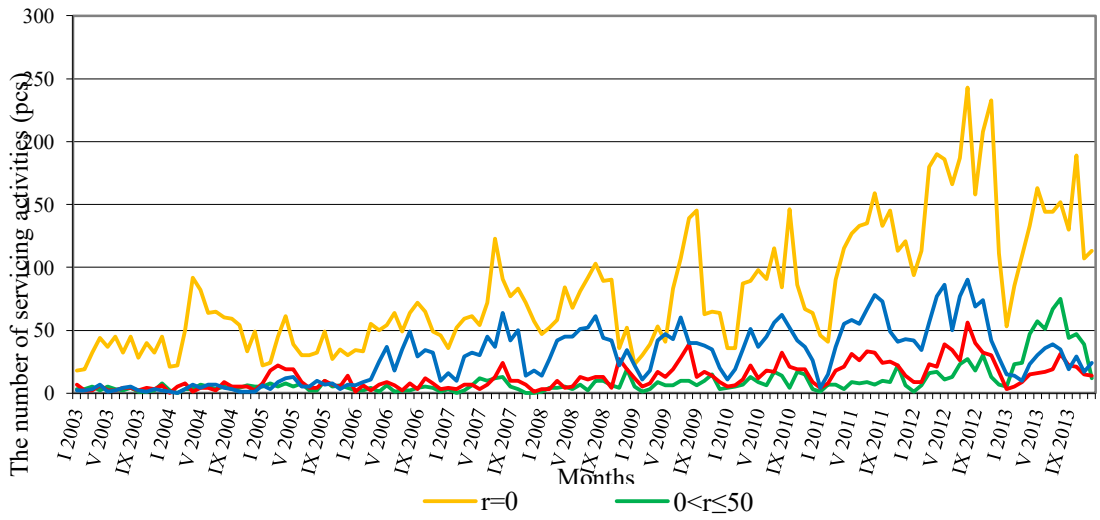

Fig. 1. The distribution of the number of inspections and repairs of farm vehicles and machines carried out by the service point for particular radiuses of distance in the years 2003-2013 (The author's own study)

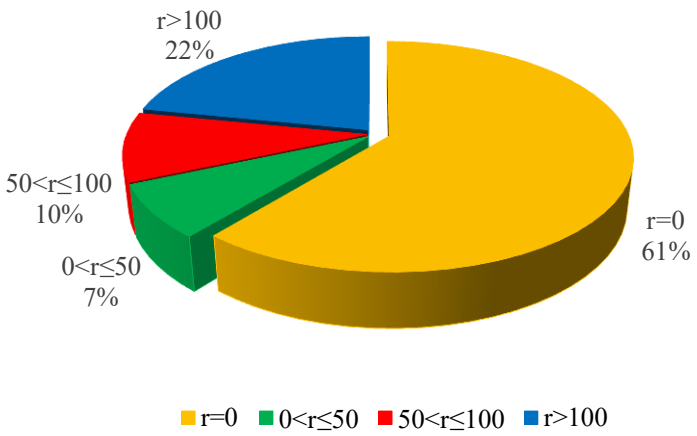

Fig. 2. The structure of the number of inspections and repairs of farm vehicles and machines carried out by the service point in the years 2003-2013 (The author's own study)

The structure of the number of inspections and repairs of agricultural vehicles and machines conducted by service stations attests to a large representation (39%) of orders executed in the field. It constitutes a significant condition for reducing the time necessary for executing the order, and thus reduces the costs of business activities (Fig. 2). Optimisation of time and costs is particularly important in the aspect of sustainable system of farming.

DISCUSSION

The value of seasonal indices for maintenance services of agricultural vehicles and machines conducted at the premises of the company's service station is presented in Fig. 3.

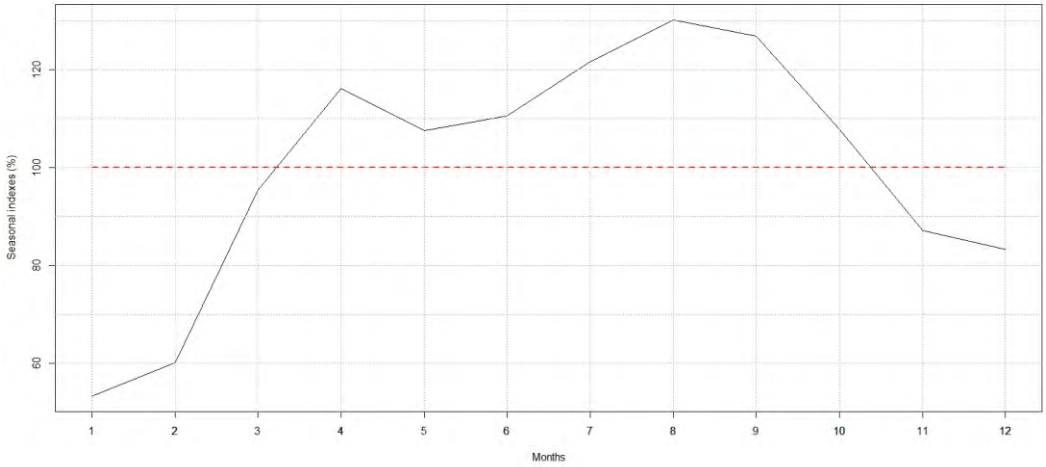

Fig. 3. Seasonal indices for the number of inspections and repairs of farm vehicles and machines for radius of distance r=0 in the years 2003-2010 (The author's own study)

In the first quarter of the year, the number of works performed by the service station was less than the reference level by, respectively, 45.14%, 39.14% and 4.0%. The period when no agrotechnical practices are carried out and therefore there is a reduction in the use of vehicles and machines was characterised by decreased demand for their servicing. As a result of seasonal variations, after the beginning of spring agricultural works, an increase in the number of service orders was noted, with their value higher than the average level by 19.42% in April. In subsequent months, seasonal demand for maintenance services was gradually increasing. The harvest of cereals and root crops from July to September resulted in a maximum increase in demand, with indices reaching the values of, respectively, 21.8%, 32.3% and 27.8% above the reference level. As a result of seasonal variations, after agricultural works were finished, there was a decrease in the number of orders, and seasonal indices were lower by respectively 19.5% and 13.4% than the average level.

The value of seasonal indices for maintenance services of agricultural vehicles and machines conducted on farms and under field conditions (r>0) is presented in Fig. 4.

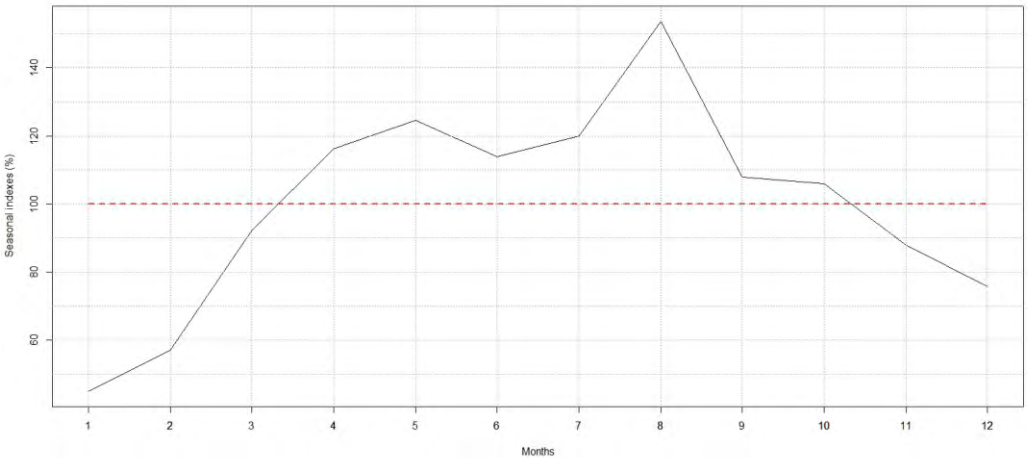

Fig. 4. Seasonal indices for the number of inspections and repairs of farm vehicles and machines for radius of distance r>0 in the years 2003-2010 (The author's own study)

In January, February and March, the number of services performed by servicing teams was lower than the reference level by, respectively, 55.1%, 42.9% and 7.8%. Seasonal variations resulted in a radical decrease in demand for maintenance services conducted in the field during the winter period, as in general, weather conditions in Poland make it impossible to perform such tasks. The period of spring agricultural works brought about an increase in the number of orders for inspections and repairs executed by servicing teams. From April to July, seasonal indices were higher than the reference level by, respectively, 16.3%, 24.5%, 14% and 20%. The period of cereal harvest in August marks the seasonal maximum demand for maintenance services conducted in the field. It was then that index reached the value of 53.7% above the reference level. In September and October, during root crops harvest and autumn agricultural works, seasonal indices were slightly above the reference level. After the end of agricultural works, a seasonal decrease in the number of orders was noted, and seasonal indices in November and December amounted to, respectively, 12.1% and 24.3% below the average level.

CONCLUSIONS

1. Demand for servicing of agricultural vehicles and machines carried out in service stations ($r = 0$ km) as well as on farms and under field conditions (0 km $< r \leq$ 50 km, 50 km $< r \leq$ 100 km and $r >$ 100 km) varied over the period of the research. The number of inspections and repairs carried out increased during the majority of the studied periods. The creation of a large population of vehicles and machines in the area served by a dealer dynamised the increase in the number of conducted maintenance services.
2. The structure of the obtained values of seasonal indices constitutes a basis for concluding that agrotechnical works and practices considerably affect cyclical changes in demand for servicing agricultural vehicles and machines. As a result of seasonal variations, there was a radical reduction in demand for servicing during the winter months, when no agricultural works are carried out. Seasonal variations, in turn, caused an increase in demand for servicing in the spring and during cereal harvest and autumn agricultural works.
3. Services carried out in the field ($r > 0$ km) provide important support for agricultural production, and in terms of sustainable agriculture, they optimise its efficiency. Activities of servicing teams in the field constitute a serious organisational and logistic challenge, which needs to undergo ongoing verification in order to optimise mechanics' time of work and to reduce distances they travel to customers.

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INFLUENCE OF METAL NANOCOLLOIDS ON SELECTED ABIOTIC STRESS FACTORS IN PUMPKIN

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Keywords: sustainable agriculture, pumpkin seeds, nanoparticles (NPs), LPO, SOD, stress oxidative

ABSTRACT

Nanotechnology could be a solution for providing sustainable agriculture, clean water and a better environment. Various nanomaterials can sustain the agricultural sectors. Plants are essential fundamental components of all ecosystems, and the interaction between NPs and plants is an indispensable aspect of the risk assessment. Originally, this research focuses on NP phytotoxicity, which is an important precondition to promote the application of nanotechnology and to avoid the potential ecological risks. SOD removes O_2^{+-}, prevents generation of highly toxic OH^*, and catalyzes the dismutation of superoxide radical into molecular oxygen and hydrogen peroxide. SOD is ubiquitous and can be found in virtually all oxygen-consuming organisms, aero-tolerant anaerobes, and some obligate anaerobes.

The objective of the study was to determine the effect of nanoparticles (NPs) on the oxidative stress parameters, of pumpkin seedlings. The study comprised analyses of the effect of two NPs (NKAg, NKCu) on the total soluble leaf protein content, lipid peroxidation (LPO), superoxide dismutases (SODs) activity. The effect of the concentration of NPs (50, 100 and 150 ml L^{-1}), was studied.

INTRODUCTION

Designed "nano" materials are characterized by specific physical and chemical properties. In addition, their size causes that they have greater penetration area, reactivity and solubility than their mass counterparts (Nowack and Bucheli, 2007). These materials, especially silver and copper, are increasingly being used in numerous industrial production processes as an additive to opacifiers, catalysts, semiconductors, cosmetics, microelectronics and in agriculture as nanofertilizers capable of delivering one to several nutrients to plants thus influencing their growth and yields (Curtis et al. 2006; Buzea et al., 2007; Anjum et al., 2013; Ma et al., 2015). In the context of sustainable agriculture, the use of innovative agricultural nanotechnology (including fertilizer development) is considered as an intentional, as one of the most promising ways to significantly increase plant production to meet the needs of ever-increasing populations in the world. It should be noted, however, that safe and sustainable use of nanotechnology in agriculture requires standards for the use of NPs in crop production and in soil and water environments (OECD 2014). Due to the appropriate size, nanoparticles can easily penetrate the organisms affecting their changes at the DNA level (Auffan et al. 2012), protein oxidation, electrolyte loss, and damage of cell membrane contributing to stress (ROS) (Dimkpa et al., 2012; Rui et al,. 2015; Zhang et al., 2015), and finally to a cell death (Meriga et al., 2004; Sharma et al., 2012). Environmental conditions can cause stress in plants that alters the system of phytochemical synthesis. Reactive oxygen species (ROS), such as hydrogen peroxide (H_2O_2) and superoxide radical anion (O_2^-), are primarily produced as mitochondrial aerobic respiratory byproducts and can damage many cellular macromolecules, including lipids, proteins, and nucleic acids (Finkel and Holbrook, 2000). Plants have evolved and successfully developed a defense system that would prevent the accumulation of ROS and repair damages caused by the formation of ROS. This system includes fat soluble antioxidants (e.g. tocopherols and carotenoids),

water-soluble antioxidants (e.g. ascorbate and glutathione) and enzymes, such as catalase (CAT) or superoxide dismutase (SOD) (Imahori, 2014).

The purpose of this study was to determine the effect of two nanocolloids: silver and copper, on selected factors of abiotic stress in pumpkin leaves.

MATERIALS AND METHODS

Plant material

In the experiment, non-encapsulated seeds of Polish pumpkin cultivar 'Miranda' were used. Nano-materials for the study were two commercially available products in 1L bottles represented by silver and copper nanocolloids at a concentration of ≥ 0.2% for silver (2KAg) and ≥ 0.1% for copper (1KCu) produced by ITP-SYSTEM Ltd. in Dąbrowa Górnicza, Poland. In order to carry out the experiment to determine the impact of abiotic stress on the plant, pumpkin seeds were placed in a 70% ethanol solution for surface sterilization (30 s). They were then transferred to a 1.5% solution of sodium hypochlorite (NaClO) for 15 min. After this time, the seeds were washed five times in distilled water and then laid on round plastic trays 30 cm in diameter lined with a paper towel. Each tray contained about 500 seeds. They were moistened by pouring about 100 ml of distilled water into each tray, then covered with aluminum foil and inserted into the phytotron FD 711 DD INOX to germinate under the following conditions: relative humidity 60% at 20/18 °C day/night, in the dark. Seeds were ventilated daily. The germination process lasted 7 days.

Plant growth

After germination of seedlings to a similar size with well-developed roots and having about 1.5 cm of length, seedlings were transferred to a modified, aerated Hoagland medium with optimum pH 6. Plants were grown in phytotron for the next 21 days under the following conditions: relative humidity 60%, temperature 20/18 °C day/night, photoperiod 18/6h day/night. After 21 days, the seedlings were sprayed with a prepared variant of nanocolloids in amount of about 4 ml (NKAg and NKCu at 3 different concentrations: 50 ml L^{-1}, 100 ml L^{-1} and 150 ml L^{-1}). After spraying, the samples were grouped in variants to avoid possible contact with plants treated with other concentrations. Analytical material was collected on day 22 (after first spraying with nanocolloid) and on day 29 of the plant life. For the biochemical analysis, the first leaves were separated from each of 30 plants, then their central parts were separated by weighing 0.5 g samples and then frozen at -60 °C.

Preparation of plant homogenates

Prepared 0.5g samples were removed from the freezer and placed in ice. Then the samples were ground in a water-bath with 4.5 ml of cooled (4 °C) 50 mM sodium phosphate buffer (pH 7.5) containing 0.1 mM EDTA and 2% PVP. The homogenate was filtered through a nylon fabric thereby producing a "crude homogenate" used directly to determine lipid peroxidation degree (LPO). The remaining part was centrifuged at 11,000 RPM for 20 min at 4 °C. The resulting homogenate (supernatant) was used for other biochemical analyses (Balakhnina et al., 2015).

Soluble protein content according to Bradford

The reagent was prepared by dissolving 100 mg of G-250 Coomassie Brilliant Blue G-150 in 50 ml of 95% EtOH. Then 100 ml 85% (w/v) H_3PO_4 was added and when the dye was completely dissolved, diluted to 1 liter with distilled water and filtered through a laboratory filter (65 g cm^{-2}). Immediately before use, the reagent was diluted 5 times with distilled

water. The volume of 5 ml of reagent was added to 0.25 ml sample and incubated for 10 min in the dark. Absorbance was measured at 595 nm. The calibration curve was made using bovine albumin from serum (Bradford, 1976).

Lipid peroxidation (LPO)

The level of oxidative stress (LPO) was determined by the TBARS method. The reaction mixture consisted of 3 ml 1% H_3PO_4, 1 ml 0.6% thiobarbituric acid, 0.1 ml 0.28% $FeSO_4$ and 0.3 ml "crude" homogenate. Prepared samples were placed in a water bath at 100°C for 45 min. After this time, they were immediately cooled on ice and extracted using 4 ml of n-butanol. The upper fraction was collected and after centrifugation (3,000rpm/5min), spectrophotometric measurements were performed at 532 nm and 600 nm wavelengths. The amount of malonic dialdehyde was expressed in nMg of g fresh weight^{-1}. For calculations, a molar extinction coefficient equaled to 1.56×10^{-5} mol cm^{-1} was used (Uchiyama and Mihara, 1978).

Superoxide dismutase (SOD) activity

Prepared reaction mixture consisted of 2.1 ml phosphate buffer, 0.1 ml 13 mM methionine, 0.1ml 75 µM tetrazole blue chloride (NBT), 0.1 ml homogenate, 0.2 ml gelatin (5mg ml^{-1}) and 0.2 ml 2 µM riboflavin. The first measurement was done in the dark, after which the reaction mixture was exposed for 10 min using a fluorescent lamp (30 W and 30 cm distance) as the only light source. One unit of superoxide dismutase activity was defined as the amount of enzyme responsible for 50% inhibition of NBT photoreduction (Giannopolitis and Ries, 1977).

Statistical analysis

Achieved results were analyzed statistically by considering all variables, for which the mean values ± SD were calculated. Because the results did not show normal distribution (Shapiro-Wilk test, $p<0.05$), non-parametric Kruskal-Wallis test ($p<0.05$) was used for statistical analysis. The results are reported as mean values (n=9).

RESULTS AND DISCUSSION

Reactive oxygen species are able to oxidize almost any compound in a plant cell leading to numerous internal injuries. The lipid peroxidation LPO, by biological membrane disorders, attacks particularly unsaturated fatty acids, destabilizing their stability and contributing to disintegration in subsequent reactions to produce aldehydes and alcohols. The suppression of this phenomenon occurs in the presence of enzymatic and non-enzymatic antioxidants, i.e. low molecular weight antioxidants, including carotenoids and enzymes, among which SOD can be distinguished (Herrero et al., 2008; Gill and Tuteja, 2010).

The protein content (Fig. 1) for day 22 of the controls' growth and after NKAg and NKCu application was 7.37 mg g^{-1} FW and 7.61 mg g^{-1} FW. Nanocolloid spraying of individual metals did not cause statistically significant differences in protein levels, except for NKCu application at 100 ml L^{-1} (+7.3%) concentration.

The level of LPO (Fig. 2) in the control plants was 242.1 nmol g^{-1} FW on the 22nd day of plant growth for NKAg and 198.8 nmol g^{-1} FW for NKCu.

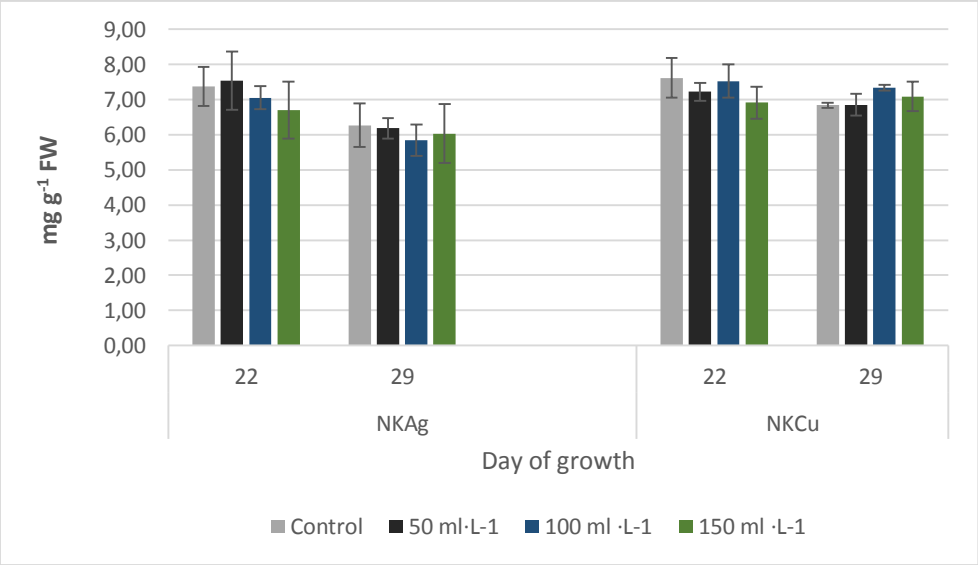

Fig. 1. Content of soluble protein in pumpkin leaves. Mean values ± SD (n=9). a – significant difference in relation to corresponded control (Kruskal-Wallis test, $p<0.05$).

After silver application, statistically significant decrease in peroxidation was observed for each of the concentrations as compared to the control, and it amounted to -8.1%, -19.3% and -23.1%. When NKCu was used on plants at day 22 of growth, for the first two concentrations of 50 ml of L^{-1} and 100 ml of L^{-1} a slight increase by +1.5% and +1.4% was observed, respectively. At the highest concentration of the applied formulation, LPO was reduced as compared to the control sample and was 192.8 ml of L^{-1} (-3%). On the 29th day of plant growth, the amount of LPO for individual nanocolloids in the control was 225.9 nmol g^{-1} FW and 218.4 nmol g^{-1} FW. After silver application, statistically significant decrease in peroxidation was observed for the concentration 50 ml of L^{-1} (-8%). Following NKCu administration, statistically significant increase in activity was observed using all concentrations, which were higher by +14.3%; +23.4% and +6,7%.

Superoxide dismutase (SOD) is an antioxidant enzyme that catalyzes the conversion of superoxide anion radical to H_2O_2 and molecular oxygen (Fridovich, 1972; Krötz et al., 2002). The SOD expression is a response to various stressors, including metallic impurities (Doyotte et al., 1997) permeating the plants during their spraying. The activity of SOD (Fig.3) in control samples was 24.84 U mg^{-1} protein (NKAg) and 19.18 U mg^{-1} protein (NKCu) for 22 days of plant growth. A slight decrease in activity at a concentration of 50 ml of L^{-1} was observed after spraying with silver nanocolloid, which was lower by -1.3% as compared to the control. For higher (100 and 150 ml L^{-1}) applications, a statistically significant increase in SOD activity was observed, which was higher than the control by +8.3% in both cases. Following NKCu administration, statistically significant increase in activity was observed using 50 and 150 mL L^{-1} concentrations, which were higher by +9.7% and +6.7%. For the 29th day of plant growth, the SOD values obtained in control samples for nanocolloids amounted to 27.85 U mg^{-1} protein and 21.10 U mg^{-1} protein.

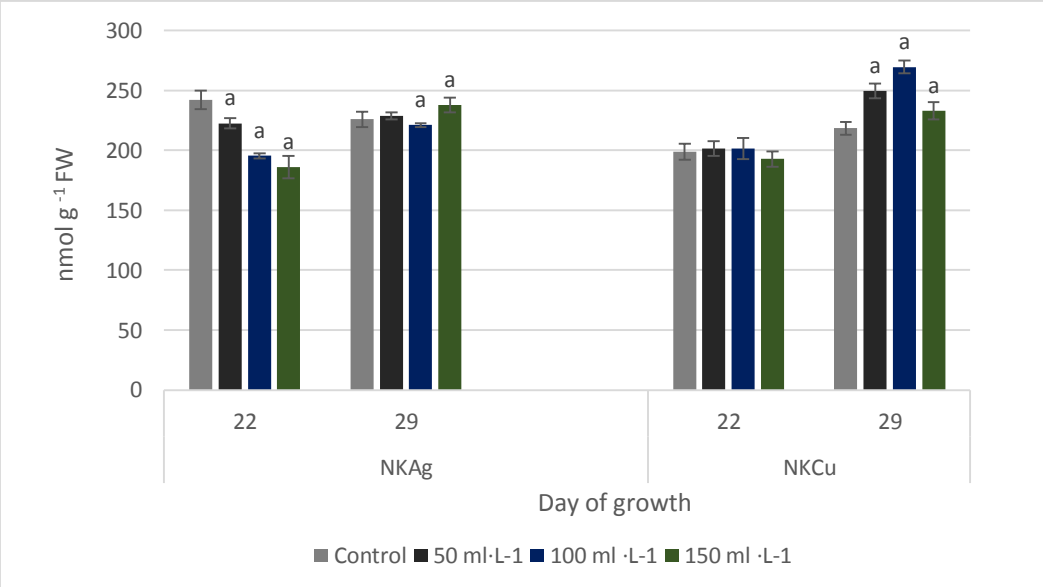

Fig. 2. Lipid peroxidation in pumpkin leaves. Mean values ± SD (n=9). a – significant difference in relation to corresponded control (Kruskal-Wallis test, $p<0.05$).

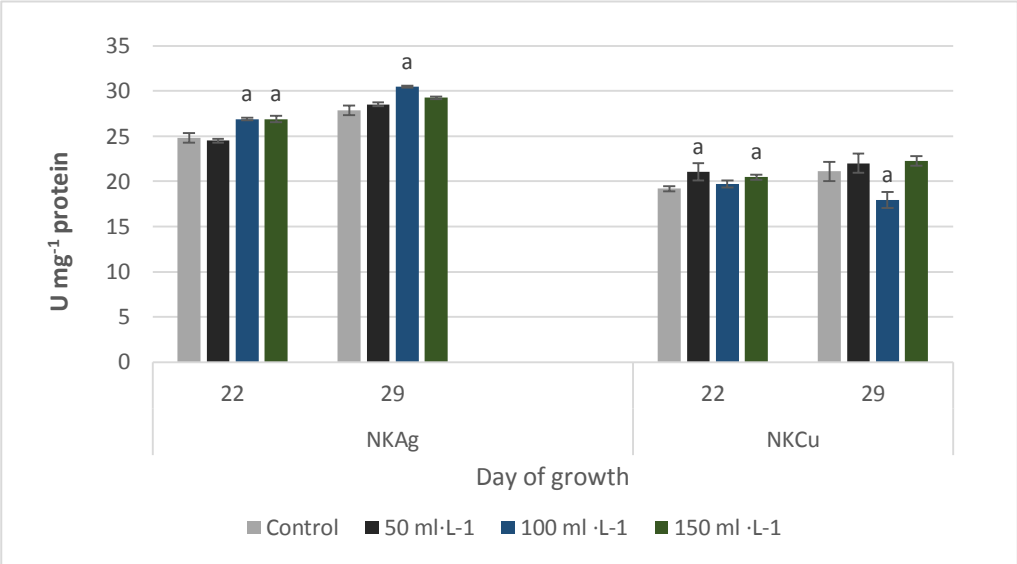

Fig. 3. SOD activity in pumpkin leaves. Mean values ± SD (n=9). a – significant difference in relation to corresponded control (Kruskal-Wallis test, $p<0.05$).

CONCLUSIONS

The use of nanotechnology in sustainable agriculture, especially in, and the interaction between NPs and plants is an indispensable aspect of the risk assessment. Current study reveal that:

1. The silver nanocolloid application on the pumpkin leaves at day 22 and day 29 resulted in a slight decrease in protein synthesis in the plant, except for the concentration of 50 ml of L^{-1} on day 22 of their growth. Despite the lower protein content, the plant growth has not been disturbed.
2. After NKCu application on day 22 of growth, a decrease in protein synthesis was observed. On 29 day of growth, the amount of protein increased and was slightly higher than in the control.

3. The effect of NKAg on lipid peroxidation (LPO) on day 22 of growth was negative and its reduction was greater along with increasing the applied concentration. The use of NKCu at day 22 of growth did not cause oxidative stress, but for day 29, there was a significant increase and its highest value was observed at a concentration of 100 ml L^{-1} (+23.4%).
4. After application of NKAg and NKCu in most concentrations, it contributed to an increase in SOD activity in photosynthetic tissues. This indicates a higher ability of plants to neutralize the superoxide anion radical that cause oxidative stress.

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THE EFFECT OF DIESEL FUEL TEMPERATURE, SPEED AND LOAD ON SOME PERFORMANCE PARAMETERS OF TRACTOR ENGINE

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Keywords: diesel fuel, fuel consumption FC, exhaust gas temperature EGT, noise intensity dB

ABSTRACT

An experiment was conducted to study the effect of inlet fuel temperature on the performance of diesel engine for tractor (Anter-71). The experiment was carried out during June, 2014 in College of Agriculture, University of Baghdad. Three levels of diesel fuel temperature 40, 45, and 50˚C, and two levels of load (without load and with load), with variant engine speeds (1000, 1500, 2000 rpm) were used as factors. Engine performance that was studied included fuel consumption FC, exhaust gas temperature EGT and noise intensity were measured at different fuel temperatures and loads. Treatment data were analyzed by using (SAS 2000) statistical program, factorial design under Complete Randomized Design (CRD), with three replications and Least Significant Differences LSD; 5% were used. Results obtained showed that changing fuel temperature from 50˚C to 45˚C and 40˚C led to a significant reduction in fuel consumption, exhaust gas temperature and noise intensity. A comparison between working tractor engine with load and without load showed that loading tractor engine led to significant increase on FC, EGT, and noise intensity.

INTRODUCTION

Diesel engines generally draw more fuel than is needed for the combustion process, the excess fuel drawn is designed to cool and lubricate the engine fuel system. Mamat et al. (2009) mentioned that after circulation through the engine, fuel is returned to the fuel tank, this "returns" fuel, if untreated, will carry heat rejected by the fuel system and can over an extended run period and elevate the temperature of the fuel stored in the tank. Therefore as inlet temperature exceed (37.8^{0}C), fuel density and lubricity decrease, so diesel fuel expands slightly in volume and its temperature increases like all liquids. Pedley et al. (1989) showed that thermal expansion for diesel fuel coefficient equal to 0.00083 liter per Celsius degree and engine power can de-rate as much as 1% for every 5.6^{0}C in fuel temperature increasing. At approximately 73^{0}C some engines are automatically shut down by their protection systems, since diesel fuel provides cooling for the Injection system, the temperature of the fuel may vary considerably due to engine operating temperature. As fuel temperature increased, fuel density and viscosity were decreased, along with the lubrication capabilities of the fuel. There are many apparatuses and devices or methods were used to control the inlet and outlet fuel temperature for diesel engine. Chyo et al. (2011) were gained a patent by designing an apparatus to cool the fuel by fan and controlling the coolant pump. Rafidah (2012) reported that, most engine manufactures specify a maximum inlet fuel temperature to allow a full output rating. Aworanti et al. (2012) showed that as fuel temperature increased, the fuel density would be decreased that led to increase fuel consumption. Due to, higher injection pressure is required to gain an equal fuel mass in order to produce the same required brake power, that cause to increase engine fuel consumption. Oluwa Funmilayo (2012) defined load as external resistance which specify engine is subjected in practical engine operation, to produce useful work, Pawan (2009) also observed an increase in fuel consumption with present of load, engine running with load consumed more fuel than running without load, due to increasing in the external load

caused an increase in the amount of power required to do same work, in order to overcome resistance due to external load. This needs more fuel consumption per time. Mohanty (2007) mentioned that external load would increase engine friction power. That increased the external resistance on the engine, led to increase the amount of power required to do the same work therefore more operating of the engine and thus more combustion of the fuel per unit time. hence load cause to influence of engine parameters, such as engine friction power which represent the difference between the indicated power (power at piston top as produced by the combustion gases) and the brake power (useful power) which available at the output engine shaft. Velmoragan and Gowthamn (2012) showed that clear increase in exhaust gas temperature with the load. Engine running with load recorded higher exhaust gas temperature than running without load, because with increasing the external load, the temperature of combustion chamber increases due to more fuel quantity is burned and thus resulting in higher cylinder wall temperature, consequently increasing of exhaust gas temperature. The aim of this research is to study the effect of fuel temperature, speed and loads on some of engine performance by controlling the temperature of fuel entering the engine.

MATERIALS AND METHODS

The conventional pure diesel fuel supplied by Al- Dura Refinery Company was used in this research. The fuel analyzed to test its physical properties under selected temperatures in laboratories of Oil Training Institute- Baghdad. The results of fuel analysis were shown in table 1.

Table 1. Fuel analysis with variant temperature

Test type	Results	ASTM test
Viscosity @ 40 °C . cSt	3.8	D445
Viscosity @ 80 °C. cSt	2.1	D445
Cloud point °C	-2	D2500
Pour point °C	-6.7	D97
Diesel index (min)	50	D287
Cetane Number (min)	53	D445
Specific gravity @ 35 °C	0.821	D287
Specific gravity @ 40 °C	0.816	D287
Specific gravity @ 45 °C	0.813	D287
Specific gravity @ 50 °C	0.810	D287

An apparatus for controlling diesel fuel temperature was fixed in the front of the radiator of tractor (Figure 1).

Fig. 1. Location of the apparatus:
1- Temperature sensor;
2&3 – Thermometer;
4-Flow valve;
5- Mounted channel;
6- Radiator grid;
7-Mounted frame;
8- Scale fuel tank

The parts of apparatus and experimental set up diagram showed in figure 2 and 3 respectively. Fertilizer sprayer implement disc type was used with the tractor to generate load on PTO shaft.

Fig.2. Parts of apparatus
1 -Temperature sensor 2-Inlet fuel thermometer 3-Outlet fuel thermometer 4-Radiator shield 5-Fixed Frame 6-Scaled fuel tank 7-Radiators frame 8-Radiator core

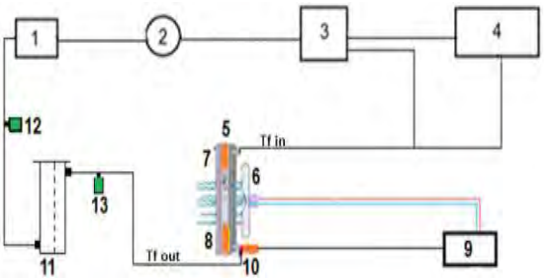

Fig 3. Schematic diagram of experimental setup
1-Preparing fuel pump 2-Fuel filter 3-Fuel injection pump 4-Engine 5-Radiator 6-DC fan (7, 8, 12, 13) Thermometers 9-Control unite 10-Temperature sensor 11-Scaled fuel tank.

Test procedure

Practically the factors of the experiment included, three levels of fuel temperature (40, 45, and 50°C).Three levels of engine speed (1000, 1500 and 2000 rpm) and two levels of load (without load, and with load). Initially, scaled fuel tank (2 liters) must be filled with diesel fuel, run the engine for minimum 30 minutes on idle speed to warming up, then the engine speed was increased and fixed (by control lever) to 1000 rpm, setting fuel temperature control on 40°C. In that moment the fuel consumption was recorded manually which was determined by measuring the time (t) was taking for the engine to consume a given volume of fuel, also the other parameters were registered which included, noise intensity and exhaust gas temperature by specific devices. Repeated the same test but with setting fuel temperature control on 45°C and followed the same steps that were done in the previous test and so that with setting fuel temperature at 50°C. Every test was repeated three times to be more accurate. All these tests were done without load and so that followed the same steps and engine speed 1500 rpm and 2000 rpm The same previous tests were done again by loading the tractor engine by engaging the fertilizer implement with PTO shaft. The fertilizer was filled with 100 kg of Urea NH_3 and run the engine on 1000 rpm with different fuel temperatures (40, 45, and 50°C), and followed the same steps at engine speed 1500 rpm and 2000 rpm by the same above procedure. Every test was repeated three times at different times to be more accurate. Treatment data were analyzed by using (SAS 2000) statistical program, factorial design under Complete Randomized Design (CRD), with three replications and Least Significant Differences LSD; 5% were used. Engine performance was analyzed by using the mathematical formulas.

RESULTS AND DISCUSSION

Figure 4 showed that the interaction between fuel temperature and speed has significant effect on FC. Fuel with low temperature 40°C and low speed1000 rpm recorded the lower rate 1.494 kg/h of FC, and fuel with high temperature 50°C and high speed 2000 rpm recorded the higher rate 4.506 kg/h of FC. Figure 5 showed that the interaction between fuel temperature and load has a significant influence on FC. Fuel temperature 50°C recorded the higher rate of FC 3.096 kg/h with load, while low fuel temperature 40°C recorded the lower rate of FC 2.533 kg/h without load. Figure 6 represent the interaction between engine speed and load on fuel consumption FC. The higher rate of FC was 4.154 kg/h recorded at higher speed 2000 rpm with load, and the lower rate of FC 1.566 kg/h recorded at low speed 1000 rpm, without load. Figure 7 showed that the triple interaction between the fuel temperature, speed and load has a clear impact on the FC.

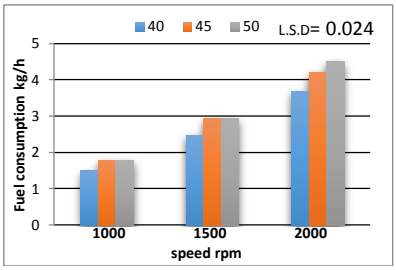

Fig.4. Effect of fuel temperature and Speed on FC

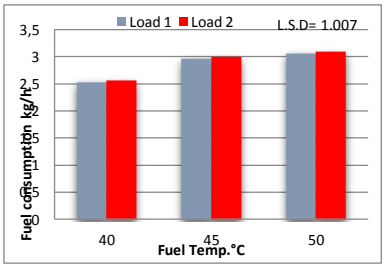

Fig 5. Effect of fuel temperature and load on FC

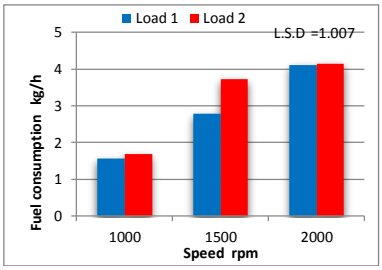

Fig 6. Effect of fuel engine speed and load on FC

The interaction between fuel temperature at 50°C; with load and engine speed of 2000rpm fuel consumption recorded was 4.526 kg/h. With fuel temperature level 40°C, the lower rate 1.479 kg/h of FC without load and lowest speed was recorded. It can be noticed that effect of fuel temperature has more influence than other factors.

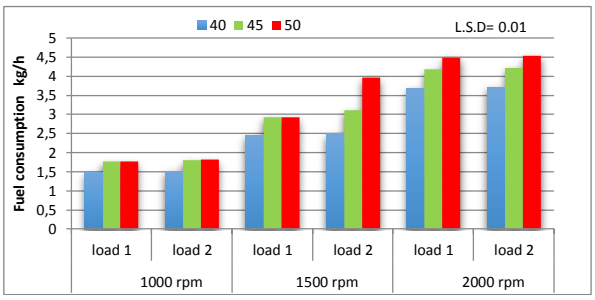

Fig. 7. The effect of triple interaction between fuel temperature, Speed and load on fuel consumption.

Figure 8 illustrated the interaction between fuel temperatures and speeds on EGT. Fuel at 40°C and 1000rpm speed was recorded the lowest rate 124°C of EGT, while fuel at 50°C with 2000rpm speed recorded the higher rate 151.5°C of EGT. Figure 9 showed that the interaction between fuel temperature and load has a significant effect on EGT. The highest rate 151.3°C of EGT was recorded when using fuel temperature at 50°C and with load while the lowest rate 124.3°C of temperature was registered when fuel temperature at 40°C and without load. Figure 10 showed a significant interaction between speed and load on EGT. The higher rate 162°C of EGT was recorded at 2000 rpm with load and the lower rate 125°C of EGT was recorded the interaction between 1000 rpm and without load.

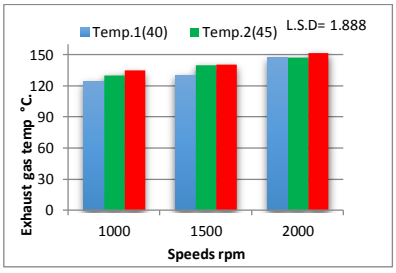

Fig. 8. Effect of fuel temperature and Speed on EGT

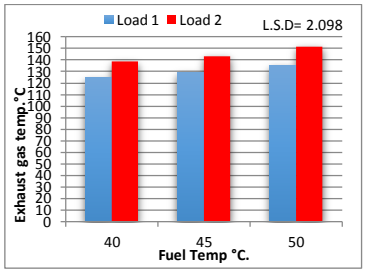

Fig. 9. Effect of fuel temperature and Speed on EGT

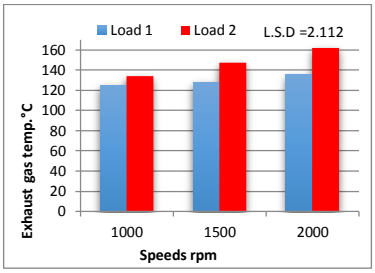

Fig. 10. Effect of speed and load on EGT

Figure 11 showed the triple interaction between fuel temperatures, speeds and load on EGT. The higher rate of EGT was 165°C which recorded, with fuel temperature at 50°C, and speed of 2000 rpm and with load and the lower rate118°C of temperature which was recorded at 40°C and, 1000 rpm and without load. It can be noticed that effect of engine speed has more influence than other factors.

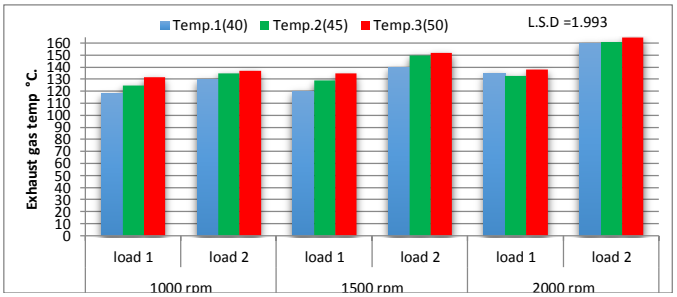

Fig.11. The effect of triple interaction between fuel temperature, Speed and load on EGT

Figure 12 showed the interaction between engine speed and fuel temperature on noise intensity, lower noise intensity rate 81.217 dB was recorded at speed of 1000 rpm with fuel temperature at 40°C, while the higher noise intensity rate 90.667 dB was recorded at engine speed of 2000 rpm with fuel temperature 50°C. It can be seen from fig 13 showed the effect of interaction between load and fuel temperature on noise intensity. It has a significant effect to achieve the lower noise intensity 83.333 dB, at temperature 40°C, without load .While the higher noise intensity reached 88.589 dB that was recorded at high fuel temperature 50°C with load. Figure 14 showed interaction between engine speeds with load. It has a significant effect on noise intensity to achieve the lowest rate 83.641dB, as engine running speed of 1000rpm, without load .while with engine speed at 2000rpm registered higher noise intensity 90.160 dB, with load.

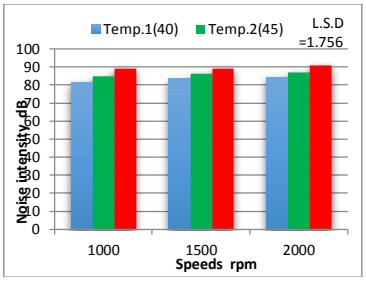

Fig.12. Effect of speed and load on noise intensity

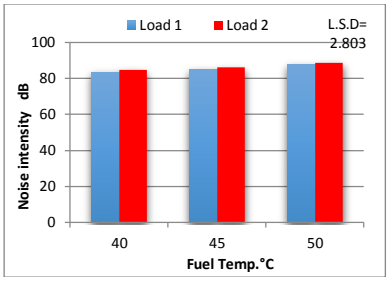

Fig. 13. Effect of FT and load on noise intensity

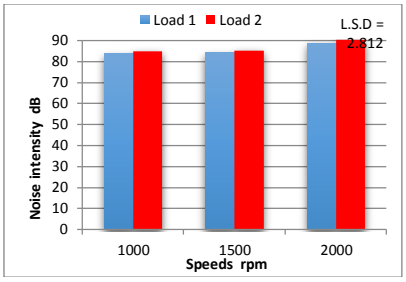

Fig.14. Effect of speed and load on noise intensity

Fig. 15 showed the triple interaction between fuel temperatures, speeds and loads. Fuel at 50°C recorded highest rate 91.000 dB of noise intensity with load, at speed of 2000rpm, while the lowest rate 80.000 dB of noise intensity was recorded at lowest engine speed of 1000 rpm and fuel temperature at 40°C without load. It can be noticed that effect of fuel temperature has more influence than other factors.

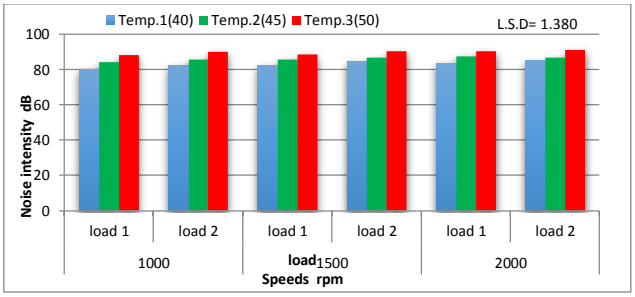

Fig.15. The effect of triple interaction between fuel temperature, Speed and load on noise intensity

CONCLUSIONS

1. The present work demonstrate the possibility of controlling fuel inlet temperature by using an apparatus connect with fuel supply line of diesel engine and test it at different fuel temperature ranging from (40-50°C);
2. Inlet fuel temperature have a vital role on fuel consumption, therefore fuel at temperature 40°C recorded lower rate;
3. There is a positive significant effect of fuel temperature on most of engine performance indicators included FC, EGT, noise intensity;
4. Significant reduction rate in noise intensity was observed when fuel temperature at 40°C.

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MODIFICATION OF RHEOLOGICAL PROPERTIES OF BIOFUELS FROM SOYBEAN OIL

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Keywords: biofuels, viscosity, soybean oil, sustainable agriculture

ABSTRACT

In this paper, the influence of fuel additives on rheological properties of crude soybean oil was presented. The tests were performed for low shear rates (1.2 - 12.4 s^{-1}) at a temperature range of 5 to 30°C. The fuel mixtures were prepared in a proportion of 80% soybean oil to 20% diesel or 20% depressor. Flow curves, viscosity curves, flow index and consistency coefficients were determined. Diluting soybean oil with fuel additives caused a significant decrease in viscosity and changed the rheological character of the obtained oil biofuels. Diesel oil has reduced the viscosity of soybean oil more visibly than the depressor. Modification of soybean oil by fuel additives significantly reduces the viscosity of the obtained fuel blends and can contribute to the development of sustainable agriculture.

INTRODUCTION

Vegetable oils are renewable and clean energy source and can be a substitute to diesel fuel (Shay 1993; Altin et al., 2001) The vegetable oils can be produced from numerous oil seed crops and have high energy contents (Franco and Nguyen 2011). Biofuels from vegetable oils are biodegradable and nontoxic, have low emission profiles and so are environmentally beneficial (Ma and Hanna 1999).
The added advantage of biofuels is that they can be used for their own use by small farms (Kobus at el., 2015), what is important for the development of sustainable agriculture.

A major obstacle deterring their use in the direct-injection diesel engine is their high viscosities (Schwab et al., 1987; Mustafa and Gerpen 1999).

The viscosity of the fuel is of great importance for the correct exploitation of the engine and fuel system. It determines the quality of spraying in the combustion chamber, the flow resistance of the fueled wires and filters, and affects the lubrication of the injection pumps (Baczewski and Kołduński 2005, Jakóbiec et al., 2011). One of the ways to improve selected properties of crude vegetable oils is to use common fuel additives (Shah and Ganesh 2016). These include conventional fuels (diesel) or cold starters (depressors).
The aim of the study was to investigate the effect of different compounds on the rheological properties of soybean oil.

MATERIAL AND METHODS

The raw soybean oil obtained after screw pressing was used in the study. Diesel and depressor were used to modify the oil properties. In both cases, the fuel blend was prepared in the proportion of 80% soybean oil and 20% fuel additive.

Rheological properties were measured using Brookfield viscometer (Brookfield Engineering Laboratories: model LVDV-II + PRO). A sample of 16 ml of oil was used in ULA-baker for all experiments. The temperature of sample was changed from 5 to 30°C and kept at constant value using water bath (Brookfield TC-502P). The computer

software (Rheolac 3.1) was applied to control viscometer and data acquisition. All experiments were carried out in three replications.

RESULTS

In Figure 1 the viscosity curves of soybean oil, diesel and depressor at temperature of 30°C were shown.

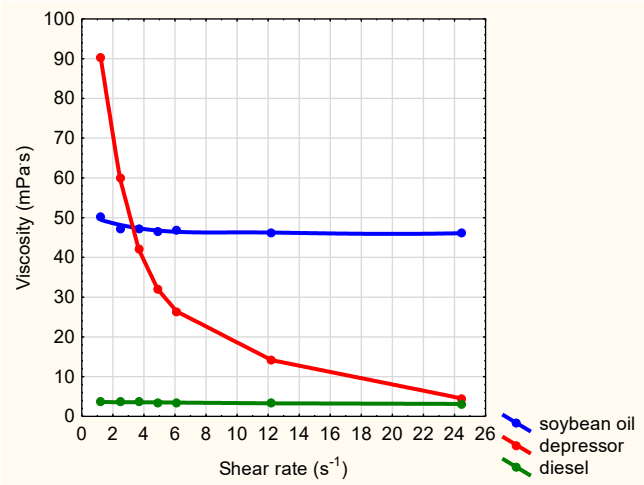

Fig. 1. The viscosity curves of soybean oil, diesel and depressor at temperature of 30°C

The tested liquids significantly differed in both viscosity values and rheological characteristics. Diesel has been characterized by Newtonian fluid behavior and low dynamic viscosity. Raw soybean oil exhibited the characteristics of a Newtonian liquid and had about 18 times larger the apparent viscosity. The depressor exhibited strong pseudoplastic properties and had the highest apparent viscosity at the lowest shear rate.

In Figure 2 the flow curves of soybean oil with addition of diesel and depressor at different temperatures were shown.

a b

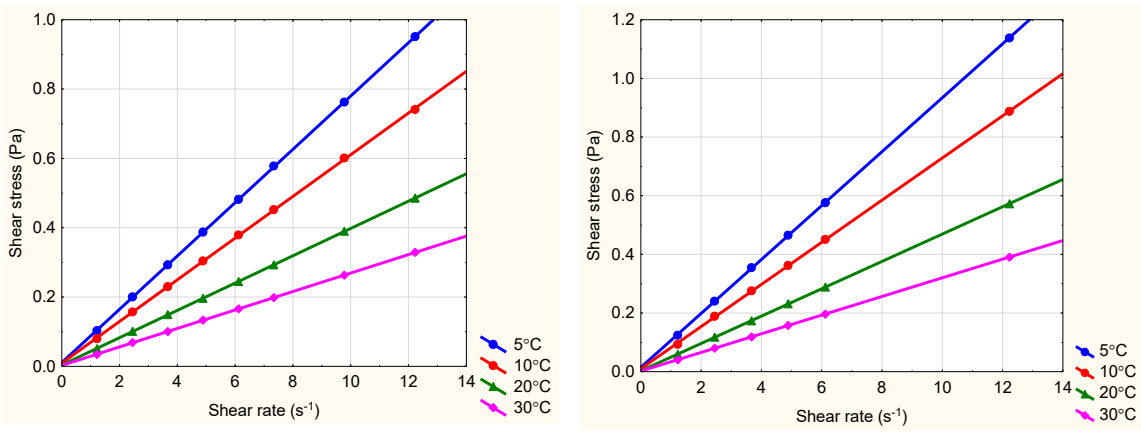

Fig. 2. Flow curves of soybean oil at different temperatures with addition of: a) diesel, b) depressor

In Figure 3 the viscosity curves of soybean oil with addition of diesel and depressor at different temperatures were shown.

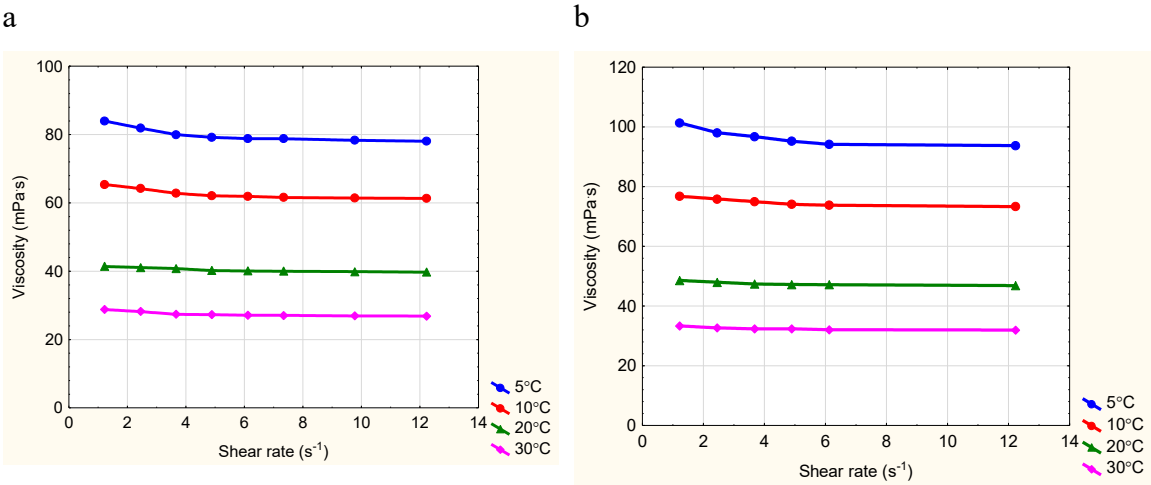

Fig. 3. Viscosity curves of soybean oil at different temperatures with addition of: a) diesel, b) depressor

To verify the rheological character of the obtained fuel blends, the flow index and the consistency coefficient were calculated. These values are summarized in Table 1.

Table 1. Rheological properties of power law model for modified soybean oil

Temperature (°C)	**Soybean oil + diesel**		**Soybean oil + depressor**	
	Consistency coefficient (Pa·s^n)	Flow behaviour index (-)	Consistency coefficient (Pa·s^n)	Flow behaviour index (-)
5	0.085	0.95	0.102	0.95
10	0.066	0.98	0.078	0.97
20	0.042	0.99	0.049	0.99
30	0.029	0.99	0.033	0.99

Flow indexes for temperatures ranging from 10 to 30°C were close to unity, what confirms a Newtonian behaviour of soybean oil mixture with fuel additives. Only in the case of the 5°C temperature, the flow index of the fuel blends was slightly different from the unity, what indicates on the pseudoplastic nature of the tested liquid.

CONCLUSIONS

Rheological analysis of soybean oil and its mixtures with diesel and depressor was performed. The tests were conducted at a temperature range from 5 to 30°C. The soybean oil showed non-Newtonian, pseudoplastic behaviour at the range of low shear rates (1.2 - 12.4 s^{-1}). The addition of diesel fuel resulted in a significant decrease in the viscosity and for the temperature range of 10 to 30°C and the change of rheological character of oil from non-Newtonian to Newtonian. In the case of 5°C temperature, the fuel mixture retained its pseudoplastic character. A similar effect was obtained when the depressor was added to soybean oil. However, diesel fuel was a more effective agent than the depressor in viscosity reduction of mixtures derived from soybean oil. The applied fuel additives significantly lowered the viscosity of soybean oil fuel blends. The proposed biofuels could significantly reduce the environmental pollution and contribute to the development of sustainable agriculture.

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EFFECT OF SOLVENT POLARITY ON THE EFFICIENCY OF ULTRASOUND-ASSISTED EXTRACTION OF POLYPHENOLS FROM APPLE POMACE

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Keywords: apple pomace, ultrasound, polyphenols, energy consumption, extraction efficiency

ABSTRACT
In this paper influence of solvent polarity on the efficiency of ultrasound-assisted extraction of polyphenols from apple pomace was studied. In the experiment, three solvents were used: water, 60% ethanol and 96% ethanol. The extraction process was aided by ultrasonic waves at intensity of 60 W. Efficiency of extraction was determined by measuring total phenolic content, antioxidant activity, energy consumption and unit energy consumption. It has been shown that a 60% solution of ethanol is the most effective solvent for ultrasound-assisted extraction of polyphenols from apple pomace. The application of an appropriate solvent allows a significant reduction in the energy consumption of the extraction process, what is important for the sustainable use of energy sources in the food and agriculture sector.

INTRODUCTION

Waste utilization is a very important issue in the development of sustainable agriculture. Apple pomace is the main by-product of the industrial production of apple juice and cider (Reis et al., 2012). The basic way of pomace utilization is use of it in cattle feed. Apple pomace can be also applied as fuel. Because of its high carbon and nitrogen content, up to 80% of organic matter the pomace can be converted into high-energy gas. The better way of pomace using is production of food preparations. The high content of fiber causes the waste bond metals well, what improves the removing it's from organism. On the other hand high content of polyphenols makes it possible to use the pomace for the production of preparations with increased antioxidant activity (Cao et al., 2009; Ćetković et al., 2008).

Extraction is one of method for production of phenol preparations. The convectional extraction techniques such as maceration, percolation, extraction with mixing or Soxhlet extraction are usually time-consuming. Because of the above, new methods are being searched to increase the yield of extraction and to provide high quality of antioxidant components at the same time (Chemat et al., 2012). There are different methods of extraction aided: pulsed electric field (Lohani and Muthukumarappan 2016; Schillinga et al., 2007), microwave (Grigoras et al., 2013) or ultrasound (Kobus 2008).

The ultrasonic assisted extraction method significantly shortens the time of the process and increases the extraction of phenolic compounds from fruit waste including apple pomace (Pradal et al., 2016). The ultrasonic extraction mechanism itself is widely known, but still different research is conducted into factors affecting the process efficiency such as: frequency and intensity of ultrasound, time and temperature of the process and nature of the solvent (Kobus and Kusińska 2008).

The selection of a suitable solvent during ultrasonic extraction has a significant effect on the content of polyphenol compounds obtained from apple pomace and reduces the energy consumption (Pradal et al., 2016). The polar nature of the solvent affects the content of substances extracted from the solid and passing to the solvent. From the

eluotropic solvent series only ethanol and water are used in the food industry because of the non-toxic nature. Between these solvents, a large difference in the Snyder polarity index can be observed, respectively: 5.2 for ethanol and 9.0 for water (Snyder 1974). In both solvents, there is a hydroxyl group, which makes it possible to form hydrogen bonds with soluble substances. Available results confirm that the effectivity of polyphenols extraction depends on the chemical structure of the extractant and the propagation of ultrasonic waves in liquid media.

The purpose of the study was to investigate the effect of solvent polarity on the process of ultrasonic extraction of polyphenols from apple pomace.

MATERIAL AND METHODS

The material used for the study was the apple pomace of the Jonagold variety bought at the local supermarket Tesco (Lublin, Poland). The apples after the wash were crushed and the juice was centrifuged in the juicer. Three types of solvents were used: water, ethanol 96% and ethanol 60%. A sample of 20 g of the pomace was mixed with 200 ml of solvent. Ultrasound-assisted extraction was performed using an ultrasonic processor (Sonic VCX 750) with a frequency of 20 kHz. The ultrasonic intensity was 60 W and the processing time 30 min. The extraction process was carried out in a water bath (Brookfield TC-502) maintaining a constant temperature of 25°C.
The content of polyphenols was measured using a spectrophotometer (Shimadzu UV-1800, Japan) using a modified Singleton method based on Folin-Ciocalteu reagent at 760 nm (Singleton et al., 1965). The total polyphenol content was expressed as mg gallic acid equivalent per 100 grams of apple pomace.

Antioxidant activity was determined according to the modified Brand-Wiliam method and co-workers using the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical (Brand-Williams et al., 1995). For the analysis, 0.2 ml of apple juice was mixed with freshly prepared solution of DPPH radical dissolved in methanol. After 30 minutes of incubation in a dark room, the absorbance of the solution was measured at 516 nm. The antioxidant activity was expressed as the percentage inhibition of the DPPH radical calculated from the formula:

$$AA(\%) = \frac{A_0 - A_t}{A_0} \cdot 100\% \quad (1)$$

where:

A_0 – initial DPPH absorbance value,
A_t – absorbance of the DPPH radical after a fixed reaction time.

The analysis energy consumption of ultrasonic-assisted extraction was performed with respect to the polyphenol contents obtained in the apple pomace. The unit energy input was determined by the following formula:

$$N = \frac{E}{m} \quad (2)$$

where:

E – energy consumption (kJ),
m – mass of polyphenols (g).

Each measurement was done in triplicate. The results of the study were statistically analyzed in the Statistica program using the one-way analysis of variance ANOVA. The significance of differences between means using the t-Tukey test was also investigated.

RESULTS

The physical and chemical properties of solvent play an important role in extraction process. The solvent has a significant effect on the amount of substance eluted from the solid matrix. The properties of the solvent affect its applicability and the cost of the extraction process. Figure 1 shows the total polyphenol content for 3 extractant types expressed in mg gallic acid per 100 g apple pomace.

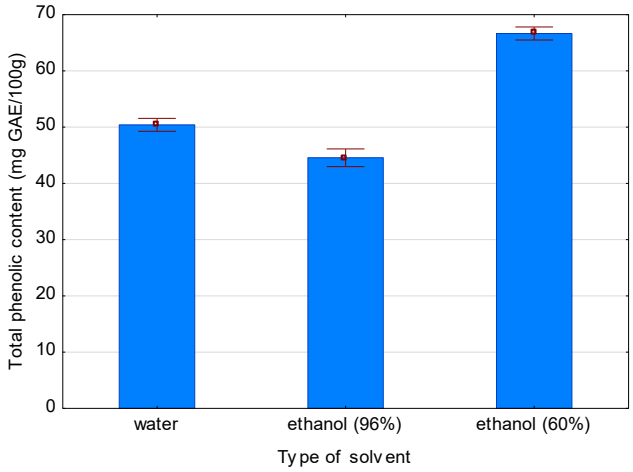

Fig. 1. Influence of solvent polarity on yield of ultrasound-assisted extraction

There were statistically significant differences between the total content of polyphenols and the type of solvent. The highest extraction yield was obtained with a mixture of water and ethanol (60% ethanol) and the lowest with ethanol (96%). The use of pure water as a solvent produced about 11% higher yield than 96% ethanol.

Water is more effective solvent due to higher polarity coefficient (Pin et al., 2009). The efficiency of the extraction process depends on the nature of the phenolic compounds present in the raw material. Gallic acid contains four hydroxyl groups and a carboxy group and is better soluble in highly polar solvents such as water.

Research conducted by Arize et al., (2014) also showed that water due to a higher polarity factor elutes more phenolic compounds from the solid than ethanol. Ethanol, due to its different molecular structure, is more effective in eluting such compounds as chlorogenic acid and flavonoids (Wijngaarda and Brunton 2010). Hence, a mixture of water and ethanol provides higher polyphenol extraction efficiency than the use of these solvents separately.

The important parameter determining the value of extracts is their ability to sweep free radicals (Panzella et al., 2013). The effect of solvent polarity on antioxidant activity is shown in Fig. 2.

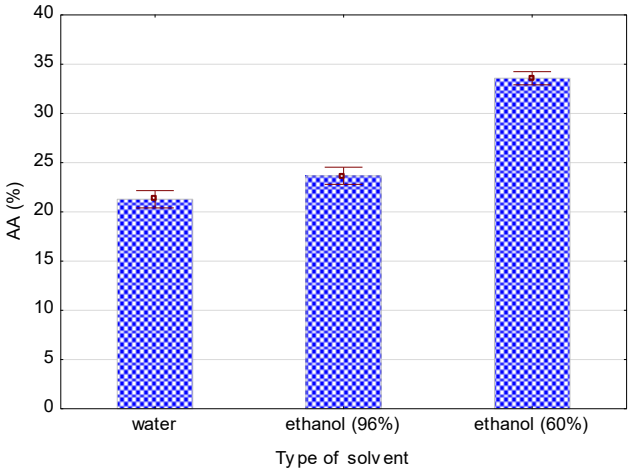

Fig. 2. Influence of solvent polarity on antioxidant activity (AA) in % of obtaining extracts

There was a significant effect of solvent polarity on the antioxidant activity of the obtained extracts. The smallest value of this parameter was observed for the extract obtained with water, and the largest with a 60% solution of ethanol. Extracts obtained with a 96% ethanol solution had slightly higher antioxidant activity than aqueous extracts, despite the fact, that they contained less phenolic in total. These findings are consistent with the results obtained by other authors. Galván d'Alessandro et al., (2012) and Virot et al., (2010) studying the solubility of polyphenols in various mixtures of water and ethanol achieved the highest solubility of these compounds in a 50% ethanol solution. Pradal et al., (2016) examining ultrasonic extraction of polyphenols from the root of chicory found the highest antioxidant activity in the case of 60% ethanol extracts. Wijngaard and Brunton (2010) extracting apple polyphenols (without the use of ultrasound) achieved the highest ability to sweep free radicals for extracts with an alcohol concentration from 50 to 60%.

The changes of energy consumption in the ultrasonic extraction of polyphenol from apple pomace, depending on the type of solvent used, are shown in Figure 3.

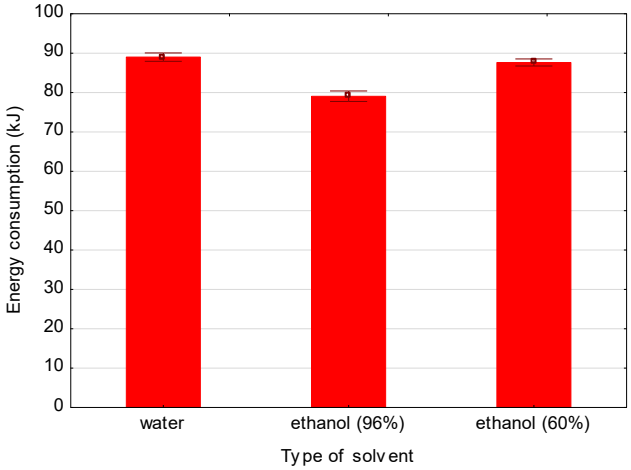

Fig. 3. Influence of solvent polarity on energy consumption (kJ) during ultrasound-assisted extraction

There was a statistically significant effect of the solvent type on the energy consumption during the ultrasonic extraction of polyphenols from apple pomace. The lowest energy

consumption was observed during extraction with 96% ethanol and the lowest during water extraction.

Kobus and Kusińska (2008) showed that the type of solvent used and its physical properties have a significant effect on the amount of energy emitted by the ultrasonic head. This is because the constant amplitude of the ultrasound wave generated by the device depends on the resistance of the liquid. The ultrasonic processor consumes more energy in liquids with higher acoustic impedance. Hence, the energy generated by the sonicator during water extraction is higher than during the extraction with ethanol as a solvent.

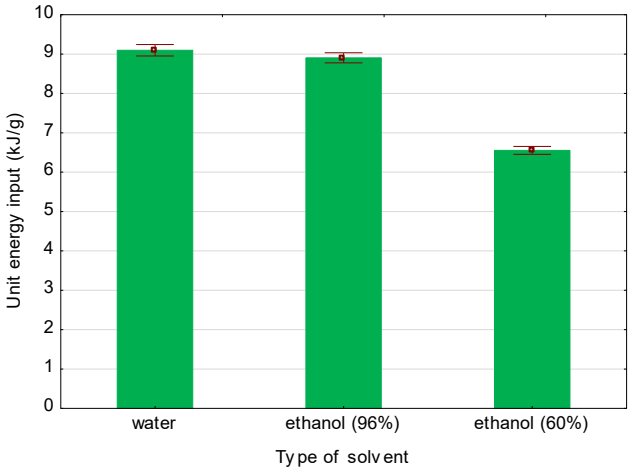

Fig. 4. Influence of solvent polarity on unit energy consumption (kJ/g) during ultrasound-assisted extraction

An important parameter during ultrasound-assisted extraction is the energy input needed to obtain the unit of extracted substance. Changes in this factor depending on the type of solvent are shown in Figure 4. There was a statistically significant effect of the type of solvent used on the value of unit energy input. The smallest unit energy input was observed during extraction with 60% water and ethyl alcohol, while the highest in extraction with pure water as a solvent. The results clearly show that during the ultrasound assisted extraction of polyphenols from apple pomace, the best solvent is a 60% mixture of ethyl alcohol and water.

CONCLUSIONS

In the paper, an evaluation of the type of solvent used on the efficiency of the ultrasound assisted extraction of polyphenols from apple pomace was carried out. The results showed that total polyphenol content ranged from 45 to 68 mg GAE/100 g apple pomace, depending on the solvent used. The highest extraction yield was found in the case of 60% ethyl alcohol. Polyphenols obtained using this solvent also had the highest antioxidant activity. Energy efficiency analysis has shown that using 60% ethanol allows to obtain the lowest unit energy input. This input was about 28% lower than for the use of pure water as an extractant. Taking into account process efficiency and energy consumption, it is recommended to conduct the extraction of polyphenol from apple pomace using a 60% ethyl alcohol solution. The application of ultrasound-assisted extraction coupled with the selection of suitable solvent reduces energy consumption, what is important in the rational management of energy resources.

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FOLIAR APPLICATION OF BIOSTIMULANTS AND THE ANTIOXIDANT PROPERTIES OF SOYBEAN SEEDS

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Keywords: antiradical activity, biostimulant, *Glycine max*, sustainable agriculture

ABSTRACT

The study was carried out in 2014 - 2016 in Perespa, Poland. Soybean seeds Mavka cultivar were sown in the third decade of April. During the growing season four biostimulants: Kelpak SL (*Eclonia maxima* extract), Terra Sorb Complex (free amino acids), Atonik (phenolic compounds) and Tytanit (titanium) were used in four combinations each other, using lower or higher concentrations and single or double foliar spraying. All the results were compared to control (no biostimulant applied). After harvesting the plants, the antiradical activity of the seeds against ABTS •+cation radical was evaluated. Biostimulators enhance the yield quality without affecting the environment, thus they are recommended for use in sustainable agriculture. It was determined that the foliar application of Terra Sorb Complex had the most favorable influence on the studied property.

INTRODUCTION

Biostimulators aim at minimizing the influence of unfavorable stressors on crops, stimulating their growth, development, and enhancing the size and quality of the yield (Calvo, Nelson, & Kloepper, 2014; Matyjaszczyk, 2015). This particularly concerns abiotic factor–sensitive plants such as soybean or bean. Furthermore, the use of such agents appears to be valid in cases where traditional agronomic treatments are not sufficient to obtain yields that are higher and better in qualitative terms, such as proper cultivation, crop rotation, fertilization, or justified economic protective treatments (Słowiński, 2004).

Biostimulants may have natural or synthetic origin and contain free amino acids, humic compounds, extracts from algae and fruits, chitin, chitosan, efficient microorganisms (natural biostimulants) or growth regulators, phenolic compounds, inorganic salts, and nutrients (Al, Co, Na, Se, Ti, and Si) (synthetic biostimulants) (Calvo, Nelson, & Kloepper, 2014). The available publications demonstrate that legumes are rich in antioxidants (Amarowicz & Pegg, 2008; Marathe, Rajalakshmi, Jamdar, & Sharma, 2011; Gebrelibanos, Tesfaye, Raghavendra, & Sintayeyu, 2013). Moreover, different methods are available for improving antioxidant properties of fruits and vegetables, such as ozonization (Onopiuk et al., 2017), and use of biopreparations. However, the reports on the influence of biostimulators on the antioxidant activity of legume seeds are very few (A. Kocira, S. Kocira, Złotek, Kornas, & Świeca, 2015; A. Kocira et al., 2017). Therefore, the research on the influence of biostimulants on the antioxidant properties of soybean cultivar Mavka seeds appears to be desirable.

MATERIALS AND METHODS

The study was carried out in 2014-2016 in Perespa (50°66′N; 23°63′E), Poland. The soil type was characterized as Brown Rendzina belonging to the Rendzinas soil group. It is alkaline (pH in 1M KCl around 7.4–7.5) and rich in phosphorus, potassium, and magnesium. The experiment was established in a randomized block design in four replications with an elementary experimental plot area of 5 m^2. Seeds of soybean (*Glycine max* (L.) Merr.) cultivar Mavka were sown in the third 10-day period of April with the spacing of 30 x 3.5 cm. Over the growing season, four biostimulants: Kelpak SL (*Ecklonia maxima* extract), Terra Sorb Complex (free amino acids), Atonik (phenolic compounds), and Tytanit (titanium), were used in four combinations each other, using lower or higher concentrations and single or double foliar spraying (Table 1). The biostimulants were applied with a GARLAND FUM 12B battery field sprayer (Lecher LU 120–03) at a pressure of 0.30 MPa, using 300 L liquid per hectare. All the results were compared to control, where plants were treated with the same volume of water (no biostimulant applied). Tillage of plants was done using good agricultural practices. No pesticides were used (pest number did not exceed the thresholds of harmfulness).

Table 1. Scheme of biostimulants application.

Biostimulants	Number of applications Plant's stage	Concentration
Atonik	single spraying BBCH 13-15	0.1%
		0.2%
	double spraying BBCH 13-15 BBCH 61	0.1%
		0.2%
Tytanit	single spraying BBCH 13-15	0.07%
		0.13%
	double spraying BBCH 13-15 BBCH 61	0.07%
		0.13%
Kelpak SL	single spraying BBCH 13-15	0.7%
		1%
	double spraying BBCH 13-15 BBCH 61	0.7%
		1%
Terra Sorb Complex	single spraying BBCH 13-15	0.3%
		0.5%
	double spraying BBCH 13-15 BBCH 61	0.3%
		0.5%

After harvesting the plants, the antiradical activity of the seeds against ABTS •+cation radical was evaluated. The seeds were dried, ground in a laboratory grinder, and sieved (mesh size 0.310 mm). Flour was stored at a temperature of -20°C until analyzed. The antiradical activity of soybean seeds against ABTS•+ was determined using an acetone extract prepared acc. to a modified method by Kumar, Rani, Dixit, Pratap, & Bhatnagar (2010). Ground soybean seeds (100 g) were weighed into a conical flask with a ground glass stopper, poured with 2 mL of 70% acetone, and shaken at a room temperature of 2 h. Next, the samples were centrifuged at the speed of 10,000 x g and temperature of 20°C for 15 min. The supernatant was collected and stored in the dark at a temperature of -50°C until analyzed. The antiradical activity was determined according to the method

developed by Re et al. (1999) ABTS (diammonium 2,2'-azino-bis (3-ethylbenzo-thiazoline-6-sulphonic acid) was dissolved in distilled water until it has reached the concentration of 7mM. The ABTS•+ cation radical was obtained as a result of ABTS reaction with 2.45 mM potassium persulfate (K2S2O8). The reaction mixture was incubated at a room temperature for 12 h. The ABTS•+ solution was diluted with distilled water until its absorbance of 0.700 (±0.02) has reached at the wavelength of $\lambda = 734$. Determination of the antiradical activity consisted in the measurement of absorbance decrease during ABTS•+ cation radical reduction under the influence of antioxidants contained in the analyzed extracts, resulting in the formation of a colorless ABTS. To this end, 250 µL of the ABTS•+ solution was added to 5 µL of the extract, and the mixture was thoroughly mixed. Absorbance of the resultant solution was measured after 2h at the wavelength of $\lambda = 734$, using an EPOCH 2 microplate reader (BioTek, USA). The antiradical activity was expressed as Trolox equivalent (TE) w mg/g d.m.

Data on the antiradical activity of soybean seeds from four replicates of each combination were subjected to the statistical analysis. The Shapiro-Wilk test was performed for the normal distribution of data. The results were analyzed using one-way analysis of variance, ANOVA. The significance of differences between evaluated mean values was estimated by means of Turkey's test intervals of confidence at a significance level of $p < 0.05$. The statistical analysis was performed with Statistica 12 (StatSoft, Inc.).

RESULTS

Biostimulators and the methods of their usage influence the antiradical activity of soybeans (Table 2). In all the years of study of biostimulators this property was most favorably influenced by the foliar application of Terra Sorb Complex. In addition, in 2015 and 2016, similar effects were obtained using Atonik. Furthermore, increase of this property was obtained using Tytanit in 2014 and Kelpak SL in 2016. Only in the first year of study a significant influence of the application method on the studied property was determined. In that year, increased antioxidant properties in soybeans were obtained after a single and double application of lower concentration of the preparations. However, a tendency for increase of this property was observed in 2015 in the same biostimulator applications, and in 2016 after a single application of the preparation independent of the used concentration. In 2014, no significant differences in the studied property were observed between the control and combinations: single use of lower Tytanit concentration, double use of higher concentration of Atonik and Tytanit, single higher concentration of all preparations, and double higher concentration of Terra Sorb Complex. In the following year, a lack of significant differences in this property was observed between the control and the single application of lower Atonik concentration and higher Terra Sorb Complex concentration, as well as double use of Kelpak SL at higher concentration. In 2016, the antiradical activity of the seeds obtained from the control did not differ significantly from the combinations using Atonik, Kelpak SL, and Terra Sorb Complex. The interaction of biostimulators and their usage methods showed an increase of the property after the double use of lower Terra Sorb Complex concentration in 2014, as well as single higher concentration of the preparation in 2015 and 2016. In addition, significant increase in antioxidant properties was found in the last year of study after single application of lower Atonik concentration.

Table 2. Change in the antiradical activity of soybean cultivar Mavka effected by the application of biostimulants.

Year	Application (B)	Biostimulant (A)				Mean	Control
		Atonik	Tytanit	Kelpak SL	Terra Sorb Complex		
2014	B1	5.52 bc	5.66 efg	5.47 ab	5.58 cde	5.56 A	5.69 fg
	B2	5.69 fg	5.69 fg	5.57 cde	5.81 h	5.69 B	
	B3	5.70 fg	5.74 gh	5.62 def	5.64 ef	5.67 B	
	B4	5.45 ab	5.53 bcd	5.42 a	5.70 fg	5,52 A	
	Mean	5.59 B	5.66 C	5.52 A	5.68 C	5.61	
2015	B1	4.81 ghi	4.77 fgh	4.55 ab	4.65 b-e	4.69 A	4.91 ij
	B2	4.80 gh	4.75 e-h	4.63 bcd	4.73 d-h	4.73 A	
	B3	4.69 cf	4.60 abc	4.71 d-g	4.92 j	4.73 A	
	B4	4.80 gh	4.52 a	4.82 hij	4.65 b-e	4.70 A	
	Mean	4.78 B	4.66 A	4.68 A	4.74 B	4.71	
2016	B1	5.57 d	5.20 a	5.43 cd	5.46 cd	5.41 A	5.50 cd
	B2	5.38 bc	5.23 ab	5.39 c	5.49 cd	5.37 A	
	B3	5.51 cd	5.19 a	5.42 cd	5.56 d	5.42 A	
	B4	5.39 c	5.19 a	5.50 cd	5.40 c	5.37 A	
	Mean	5.46 B	5.20 A	5.44 B	5.48 B	5.39	

Abbreviations: B1- single spraying with low concentration of biostimulant; B2- double spraying with low concentration of biostimulant; B3 - single spraying with high concentration of biostimulant; B2- double spraying with high concentration of biostimulant. Different letters within the same year denote significant differences between the treatments at $p<0.05$.

The plants treated once with Atonik, in both concentrations as well as double treatment with lower concentration of the preparation, obtained similar values of antiradical activity of the seeds (Figure 1) which did not differ significantly. On the other hand, double application of higher concentration of this biostimulator reduced the studied property. The highest radical-scavenging activity was obtained after a single application of the higher concentration of Terra Sorb Complex, which slightly differs from the double application of a lower concentration of the biostimulator. In addition, these values do not significantly differ from the values obtained for the control. Both single use of lower and double use of higher concentration of Terra Sorb Complex resulted in a decrease of property, and the obtained values did not differ significantly. However, in the case of a double spray of the plants with higher Terra Sorb Complex concentration the obtained value of the property did not differ from the control. Low radical-scavenging activity was observed upon single application of lower Kelpak SL concentration. Furthermore, along with the increase of the number of applications and concentration of the preparation, the property was found to increase, and the highest value not differing from the control object was obtained after a single application of the higher concentration. On the other hand, an analysis of the influence of Tytanit on the property provided the highest radical-scavenging activity after the double application of the lower concentration, which differed slightly from the single use of the preparation at the same concentration. A decrease in the studied property was observed along with the increase of Tytanit concentration, and the lowest value was obtained after the single application of the higher concentration.

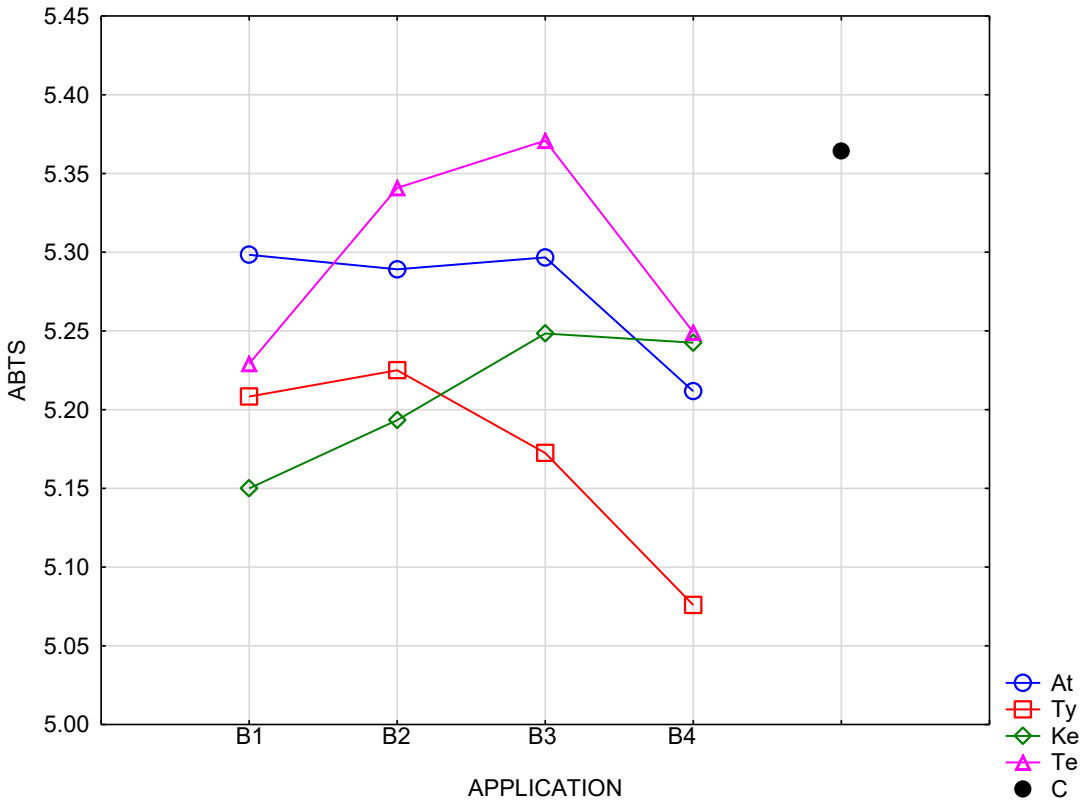

Figure 1. The influence of biostimulants on the antiradical activity of soybeans cultivar Mavka (mean from 2014–2016).

CONCLUSIONS

Biostimulators are safe for both humans and environment, and are recommended for use in sustainable agriculture. When used in crop cultivations, they contribute to enhance the quality of the yield. In the present study, biostimulators determined the quality of soybeans expressed as antioxidant properties. However, the use of these preparations did not result in the increase of the property in comparison to control in all cases. The most favorable influence on the antioxidant properties was the foliar application of the biostimulant based on free amino acids (Terra Sorb Complex) in the form of a single plant sprayed with a higher concentration or double with lower concentration of the biostimulant. Good effects were also obtained after single application of the biostimulator based on phenolic compounds (Atonik), irrespective of the concentration used, as well as after the double application of the lower concentration. In addition, the double use of higher Terra Sorb Complex or single use of higher Kelpak SL concentration had positive influence on the antioxidant properties of the seeds. The value of each tested character obtained in the above combinations did not differ significantly from the control object. In the remaining combinations, the antioxidant properties of the seeds differed clearly from the control by being significantly lower.

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EFFICIENCY OF EXPENDITURES AND THE ECONOMIC SIZE OF FARMS IN POLAND

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Keywords: FADN, work expenditures, total expenditures, economic efficiency

ABSTRACT

This study analyzed the efficiency of various types of expenditures such as human labor, energy, total, and expenditures in farms which are classified into six groups based on their economic size. Analysis was performed during the period 2004–2015 for farm holdings from the entire area of Poland, and those participating in the Farm Accountancy Data Network. It was determined, that the total efficiency has a decreasing tendency in all holding groups. Both the holdings with the lowest as well as largest economic size in case of turbulence in financial markets (e.g., the financial crisis of 2007¬2009) obtain the total expenditure efficiency below 1. The efficiency of human labor expenditures has a tendency to increase through the entire period of analysis for the largest holdings. The direct expenditures are most efficiently used in the smallest holdings, and they are slightly over 50% higher than in the largest holdings.

INTRODUCTION

The basic task for a farm holding is to generate (obtain) income to ensure the maintenance of the farmer's family. The level of income largely depends on the scale and structure of production in a holding (Sobierajewska, 2015; Skarżyńska 2011). However, holdings with similar area of arable land (AR) often vary in terms of the income generated. As observed by Niezgoda (2009), the profitability of farms in Poland is highly diverse (Niezgoda 2009). These differences stem from the management method of a holding, which often depends on its size. One of the indicators of the farm holding size is the agricultural lands (AL), animal stock and the economic size of the farm. The economic size influences the modernization possibilities of farm holdings (Kołtun et al. 2015). One of the economic measures of farm holding management efficiency includes the management efficiency indexes. Values of these indexes are relatively low in Poland. This state is influenced by the excessive employment and low average surface of the holdings. Also, the overload of the holdings with fixed assets has a negative effect on the management efficiency (Malaga-Toboła et al. 2015; Wasilewski and Wasilewska 2008). The economic size of a holding is used to determine its economic viability (Szeląg-Sikora 2009). Considering the above information, it appears viable to perform an efficiency analysis for the expenditures in holdings with different economic sizes.

MATERIALS AND METHODS

The study material originates from the Farm Accountancy Data Network (FADN). The study included approximately 1200 individual farm holdings, for which data was collected within Polish FADN. The analysis covered results of holding operations in the period of 2004–2015.

The Polish FADN is a system of collecting and using accountancy data from farm holdings. It was created based on the Act on Collecting and Using Accountancy Data from Farm Holdings of 29 November 2000 (Journal of Laws 2001, No. 3, item 20 with later amendments). It functions within the European system of collecting and using accountancy data.

In general, the efficiency measure is the ratio between the effect and its cause, which is the labor and financial expenditure in economic terms. For labor, the measure of efficiency was assumed as the relationship between the value of total agricultural production and the human labor, energy, total, and direct expenditures.

The human labor expenditure efficiency was calculated based on the following formula:

$$E_{PL} = \frac{P_O}{N_P}$$

E_{PL} – Efficiency of human labor expenditures (€·man h^{-1})

P_O – Total production (€·hold.$^{-1}$)

N_P – Human labor expenditure (man h·hold.$^{-1}$)

The energy expenditure efficiency was calculated based on the following formula:

$$E_E = \frac{P_O}{N_E}$$

E_E – Efficiency of energy expenditures incurred (€·€$^{-1}$)

N_E – Energy expenditures (€·hold.$^{-1}$)

The total expenditure efficiency was calculated based on the following formula:

$$E_O = \frac{P_O}{N_O}$$

E_O – Efficiency of total expenditures (€·€$^{-1}$)

N_O – Total expenditures (€·hold.$^{-1}$)

The direct expenditures efficiency was calculated based on the following formula:

$$E_B = \frac{P_O}{N_B}$$

E_B– Efficiency of direct expenditures (€·€$^{-1}$)

N_B – Direct expenditures, (€·hold.$^{-1}$)

The economic size of the holding shall be determined on the basis of the total standard output of the holding. It shall be expressed in euro. The method of calculating the economic size of the holding and the economic size classes shall be as set Commission Regulation (EC) No 1242/2008.

The economic size of a holding is measured as the total standard output of the holding expressed in Euro. Holdings are classified by size classes, the limits of which are set out below.

1 - from 2 000 to less than 8 000 €,
2 - from 8 000 to less than 25 000 €,
3 - from 25 000 to less than 50 000 €,
4 - from 50 000 to less than 100 000 €,
5 - from 100 000 to less than 500 000 €,
6 - above 500 00 €.

RESULTS

The total production in the tested period per one ha of AL in the tested holding groups was variable, which increased in the largest holdings and decreased in the smallest holdings (Figure 1). A decrease in production occurred in all groups in 2009.

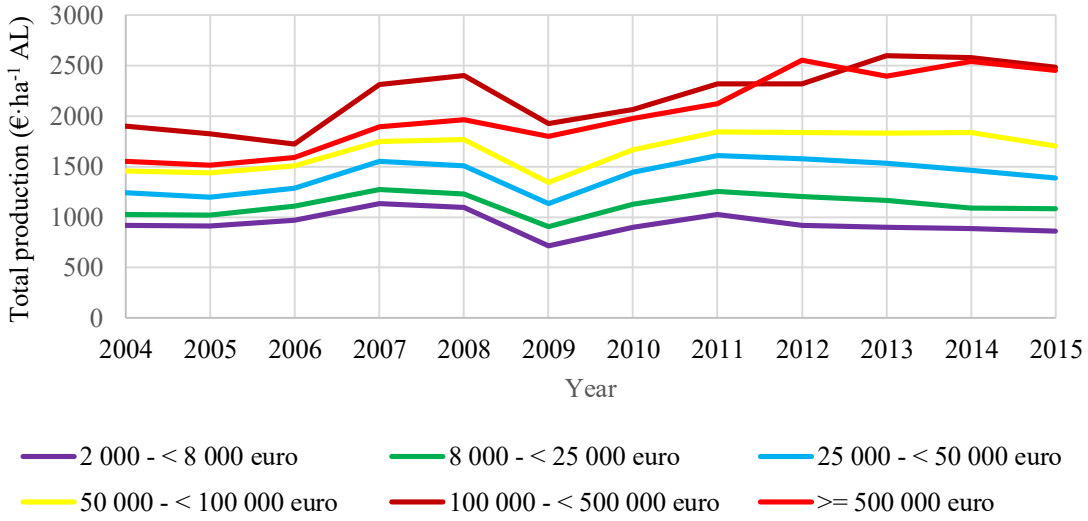

Figure 1. Total production in individual holding groups during 2004–2015.

Similar to the total production, in the groups with the lowest economic size a decrease in the labor expenditures (in man h/ha AL) was observed. In the remaining groups, the expenditures were subjected to minor fluctuations (Figure 2).

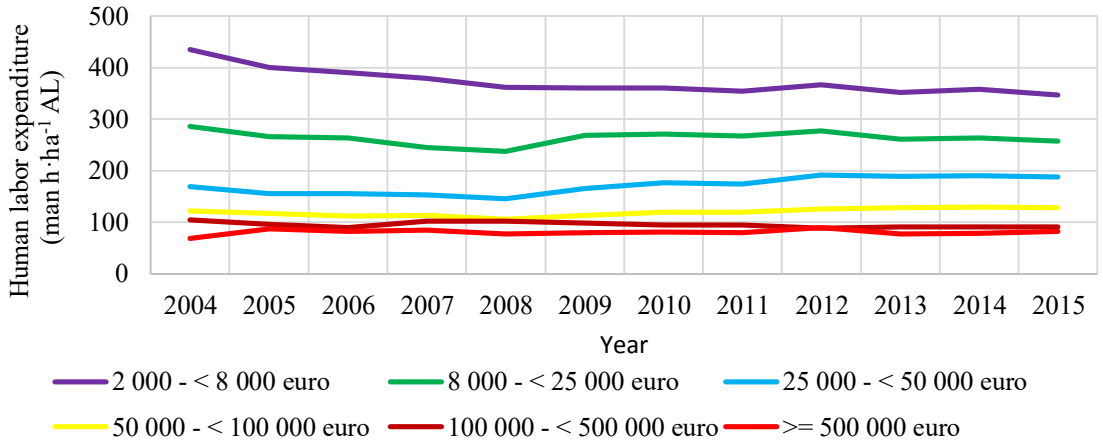

Figure 2. Labor expenditures in individual holding groups during 2004–2015.

The efficiency of human labor expenditures in holdings with economic size ranging from 100,000 to 500,000 € in the tested period increased from 18.2 €·man h^{-1} to 27.5 €·man $^{h-1}$. Also in the holdings with the economic size exceeding 500,000 € a 32% increase of efficiency of human labor expenditures was observed. In the remaining groups of holdings, the value of the index in the tested period remained at a similar level. In 2009, a clear decrease of efficiency of labor expenditures can be seen caused by the decrease of the total production value. The global financial crisis influenced the total production value.

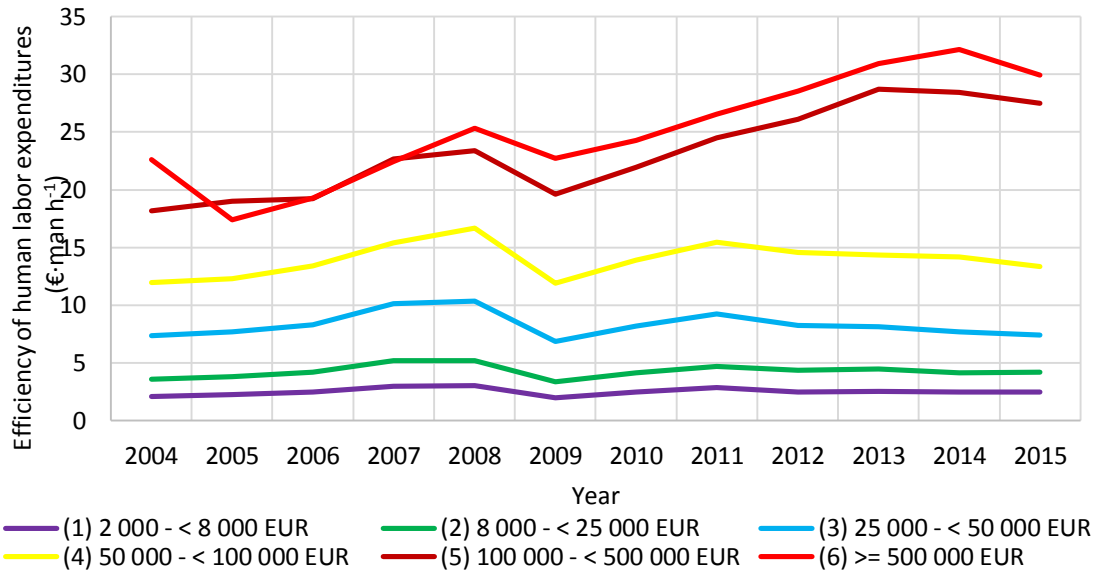

Figure 3. Efficiency of labor expenditures in individual holding groups during 2004–2015.

The efficiency of energy expenditures in years 2004–2015 decreased in all holding groups (Figure 4). This was probably caused by the substitution of human labor with objectified labor, as the proceeding mechanization of agricultural activities is linked to the simplification of production technologies, resulting in increased energy expenditures in the production processes. In the last analyzed year (2015) an increase in the efficiency of energy expenditures was observed in all holding groups, however, this increase had begun in the largest holdings in 2013.

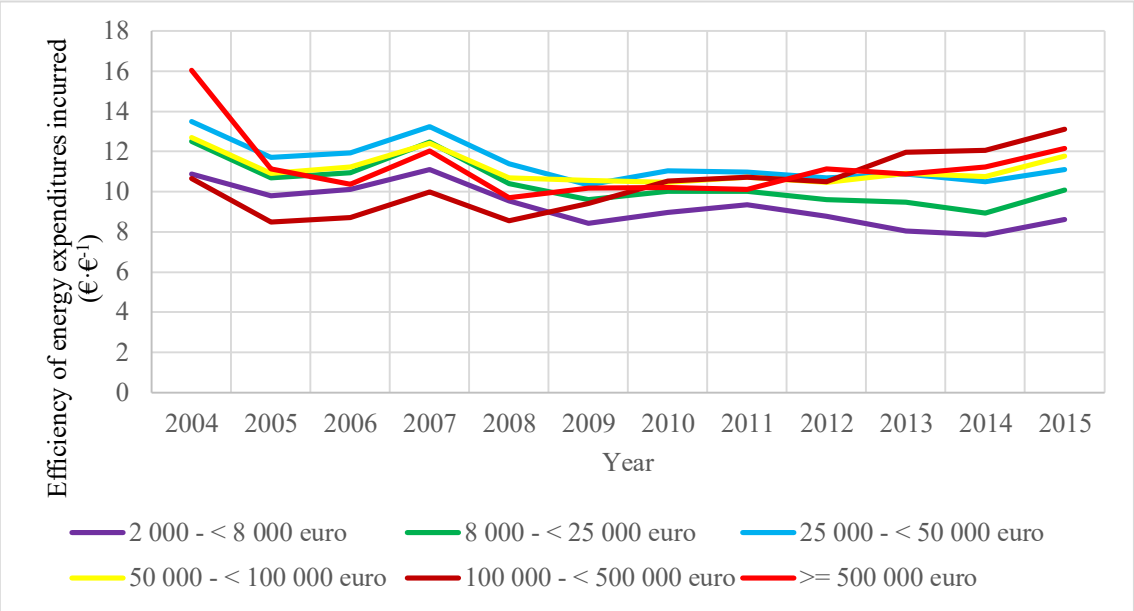

Figure 4. Efficiency of energy expenditures in individual holding groups during 2004–2015.

Unfortunately, one of the most important measures of efficiency (efficiency of total expenditures) had a decreasing tendency in all studied holding groups (Figure 5). In extreme cases, it attained a value below 1, indicating higher expenditures than the obtained sales income. The highest efficiency was exhibited by the holdings ranging from 25,000 to 100,000 €. The observed tendency of decreasing efficiency of total

expenditures indicates that the increase of expenditures for production is higher than the increase of production value. During the period of the financial crisis (2008–2010), a dramatic decrease of expenditure efficiency was observed in all tested holding groups.

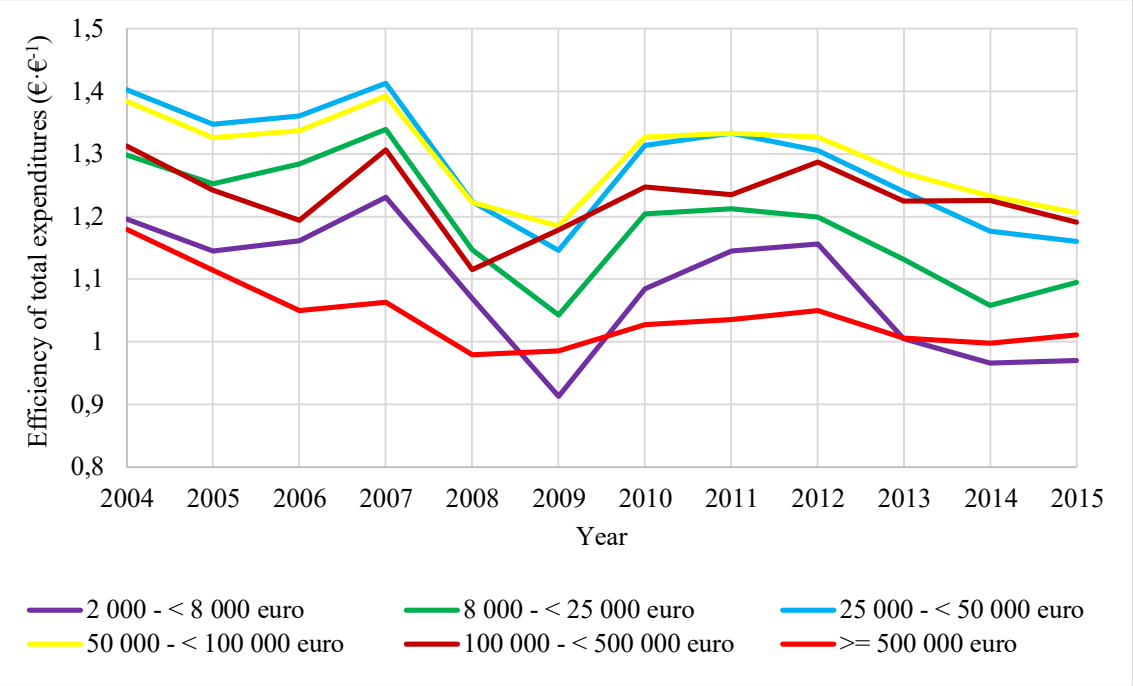

Figure 5. Efficiency of total expenditures in individual holding groups during 2004–2015.

The index for direct expenditures efficiency remained at a constant level for all groups in the studied period. Only the smallest holdings indicated high variability of the index (Figure 6).

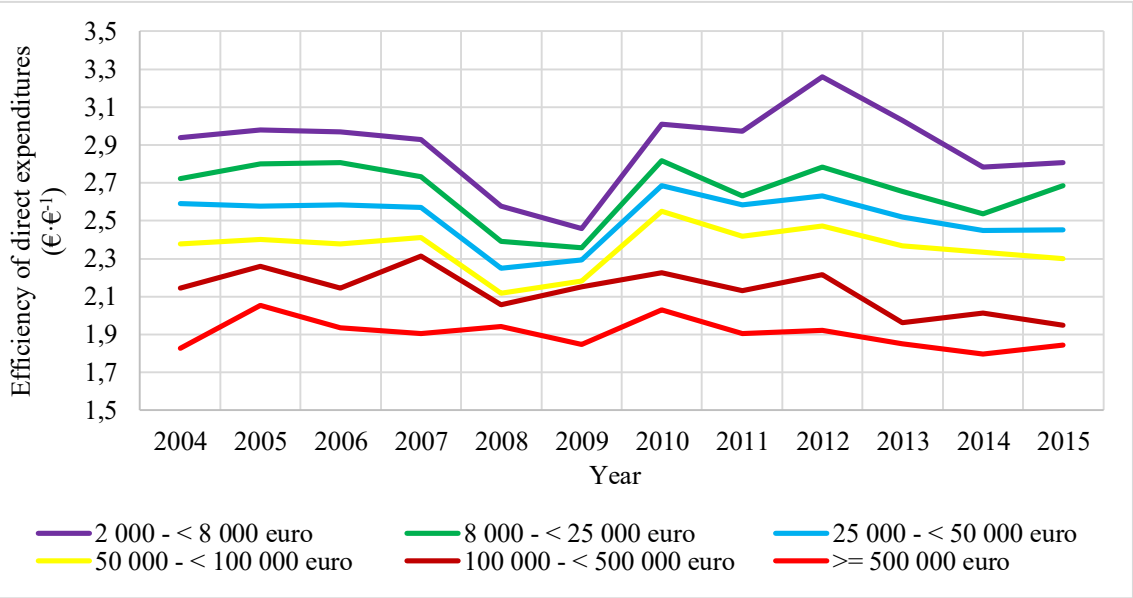

Figure 7. Efficiency of direct expenditures in individual holding groups during 2004–2015.

CONCLUSIONS

The conducted analysis of total production and efficiency of expenditures in holdings grouped according to their economic size has demonstrated that the total production in

the period 2004–2015 per ha AL increased at the highest rate in large and very large holdings, whereas the economically weakest holdings are characterized by the highest labor expenditures per ha AL.

Both the holdings with the lowest and the largest economic size, during turbulence in financial markets (e.g., the financial crisis of 2007–2009) obtain the total expenditure efficiency below 1.

It was determined that labor expenditure efficiency increased during the first 4 years after Polish access to the EU structure. In the subsequent analyzed years, the efficiency increased only in the large and very large holdings.

It was observed that the efficiency of total expenditures has a decreasing tendency. It is an alarming signal as it influences the profitability of farm holdings.

The efficiency of direct expenditures in individual groups remained at a constant level. Only during the latest financial crisis (2007–2009), a decrease of efficiency of these expenditures took place.

The direct expenditures are most efficiently used in the smallest holdings, and they are slightly over 50% higher than in the largest holdings.

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FUNGAL BIODIVERSITY ON RUNNER BEAN GROWING IN TWO SYSTEMS OF PLANT PROTECTION

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Keywords: runner bean, root and stem rot diseases, ejector nozzles

ABSTRACT
The aim of the investigation was to evaluate three fungicides (Dithane NeoTec 75 WG, Sumilex 500 SC, Amistar 250SC) for their antifungal activity against fungi occurring on bean seeds using two types of nozzles: standard RS-MM 110 03 and injector type ID 120 03 C. Studies of three years (2007-2009) were conducted at Czesławice in the south-east of Poland. The objects of research were the plants and seeds of cultivar Blanka. The following agents were used for protection. Observations were carried out in October in each year. Diseased plants were collected for mycological analysis. Seeds with symptoms were noticed on the investigated plantations. The results of mycological analysis showed that bean plants were colonized by *Fusarium* spp., *Sclerotinia* spp. and *Alternaria alternata*. The best health status and the lowest number of colonies were noticed on plants protected by azoksystrobine with both types of nozzles.

INTRODUCTION

Runner bean (*Phaseolus coccineus* L.) is an important legume with high nutritional value commercially grown in different parts of the world. The health of bean is spoiled by many pathogens. Seedborne diseases have been found to affect the growth and productivity of the legume. The greatest yield losses owing to pathogens occur when seeds used for planting are infected. Seedborne pathogenic fungi can prevent germination, kill seedlings, or reduce plant growth by damaging the roots and the vascular system, which prevents the transport of water and nutrients (Mancini et al. 2016). Seedborne pathogenic fungi that cause losses of yield and quality of bean worldwide include *Sclerotinia sclerotiorum, Fusarium oxysporum., F.solani,* and *Rhizoctonia solani* (Schwartz et al. 2005; Naseri et al. 2008). Recommended fungicides are often effective but windy weather weakens their effectiveness. In Poland the pesticides should be applied with wind lighter than 4 m/sec and that is why attempts are being made to improve the effectiveness of spraying and looking for modern methods of application (Doruchowski 2013; Subr et al. 2015). The main goal in pest-management research is to improve pesticide application technology for its effective action and rapid dissipation from crop tissuses (Gamliel 2010).

Effectiveness of spraying depends largely on the technique which was used for doing it. In practice of plant protection different types of nozzles are used. In field spraying flat-stream standard nozzles are used most frequently. With higher work pressure they give small and very small droplets which perfectly cover the spraying surface but are prone to drifting. The second kind of tested nozzles were air-ejector nozzles. These nozzles generate a lot of aerated droplets which are less prone to drifting and to a lesser extent cover the spraying surface. Nowadays on the labels of pesticides there is information on parameters of doing spraying and recommended spectrum of droplets (Nuyttens 2009).

The aim of investigation was to determine the influence of the fungicides sprayed by means of standard and thick drop nozzles on the healthiness of plants of the cv. Blanka and to estimate the fungal communities colonising seeds of bean grown in the field.

MATERIAL AND METHODS

The experiment was conducted at the Agricultural Research Station in Czeslawice, Lublin region, Poland (51°18'23''N 22°16'02''E). The experiment was conducted in a randomized complete blocks design with four replicates where block was the random effect. The seeds were planted in the field in May. The experimental combination consisted of 40 plants of each plot (in 4 replicates). Bean cv. Blanka received three levels of fungicide treatments: (1) – non- treated control and (2)- three fungicide applications with the use of standard RS-MM 110 03 (Marian Mikołajczyk) sprayers and (3) - three fungicide applications with the use of thick drop nozzles ID 120 03 (Lechler). Fungicide was applied starting 6 weeks after planting and repeated every 14 days thereafter. Three products were used: Dithane NeoTec 75 WG (a.i. mancozebe), Sumilex 500 SC (a.i. procymidone) and Amistar 250 SC (a.i. azoxystrobine). Pressure of spray amounted to 3 bars and working speed was 4 km/h. To define the degree of covering plants with fungicide when doing plant spraying with two kinds of nozzles, water sensitive papers were placed on plants on the upper part. The healthiness of plants and seeds was estimated after harvest in October.

Seeds of common bean cv. Blanka (200 from each combination) produced in the crop seasons were subjected to asepsis with a sodium hypochlorite solution and immediately rinsed in sterile distilled water. After such procedure, the seeds were placed on the mineral medium on Petri dishes. The obtained fungal colonies were transferred to potato dextrose medium (PDA, Difco) and identified to the species with the available monographs (Kopacki and Wagner 2006).

CONCLUSIONS

Black or brown spots were observed on diseased seeds. Weather conditions in 2007–2009 were very favourable for the development of pathogenic fungi.

Percentage of seed infection determined by visual observation and fungal isolation ranged from 19,2-63,0% in all as shown in Table 1.

Table 1. Percentage number of seeds infected with fungi

Combination	Seeds with diseases symptoms (%) in year		
	2007	2008	2009
Control	60.5	53.2	63.0
Dithane NeoTec 75WG	47.2	57.2	28.2
Dithane NeoTec 75 WG ID	38.1	39.0	33.1
Sumilex 500 SC	53.2	36.4	45.1
Sumilex 500 SC ID	48.2	39.0	47.2
Amistar 250 SC	33.2	20.9	28.3
Amistar 250 SC ID	29.0	21.4	19.2

The results of three-year investigation showed that the type of atomizer had no effect on the populations of bean seeds pathogens. We saw the differences between monitored fields where we did not carry out the security plants and fields where this operation was. On the monitored fields all plants had diseases symptoms. The chemical preparation which was used has some influence on this illness. The best was Amistar 250 SC

chemical preparation especially in 2008. Amistar 250 SC and Sumilex 500 SC preparations, used in thick drops nozzles ID" with broad-spectrum of drops, were effective. Where we used Dithane NeoTec 75 WG preparation and standard RS-MM nozzles all plants were infected with lots of symptoms. Because we didn't have enough parameters we must carry out more investigation about effectiveness protection at use of different kinds of nozzles.

To define the degree of covering plants with fungicide when doing plant spraying with two kinds of nozzles, water sensitive papers were placed on plants on the upper part. To measure the degree of covering water sensitive papers were used. The papers were attached to leaves of sprayed plants. On each paper the area of 1000 mm2 surface was analysed. After spraying the papers were scanned and the obtained image was analysed. The image analysis was done with the use of Image-Pro Premier 3D. The degree of covering the water sensitive papers was defined in percentage. The diameter of droplets which fell on the plants was measured and the number of droplets which were on the analysed surface was defined. Percentage share in particular fractions of droplets in eight size intervals was defined. Average results from eight measurements for each kind of nozzles were presented in Table 2.

Table 2. The degree of covering the sprayed surface with the use of two kinds of spraying nozzles.

	Average sample from RS- MM 110 03	Average sample from Lechler ID 120 03
Sample surface area [mm^2]	1000.00	1000.00
Droplets surface area [um^2]	4968647.25	1168369.53
Degree of covering [%]	49.19	22.81
Number of droplets [pcs.]	360	199

In 2007–2009 from seeds, as the result of mycological analysis, 1456 fungal colonies belonging to 17 species were isolated. The predominating species were *Alternaria alternata*, *Fusarium* spp., and *Sclerotinia sclerotiorum* (Tab. 3). More colonies were obtained in autumn than in summer.

A. alternata, *Fusarium* spp. and *S. sclerotiorum* predominated among fungi which are regarded as pathogenic. The occurrence of individual species of *Fusarium* depended on the used fungicides. *F. oxysporum* was isolated frequently from seeds, especially from plants treated by azoksystrobine with both types of nozzles. Numerous colonies of *F. avenaceum* were obtained every year especially from seeds treated with mancozeb, procymidone and azoksystrobine.

A. alternata occurred on all combinations but more frequently on seeds from plants treated with mancozeb and procymidone. *S. sclerotiorum* colonised frequently seeds especially in 2007 and 2008. *Thanatephorus cucumeris*, *B. cinerea* and *C. gloeosporioides* colonised the seeds very rarely.

Table 3. Fungi colonizing seeds of runner bean

Year	Fungus species								Total (%)
		Control	Dithane		Sumilex		Amistar		
			S	ID	S	ID	S	ID	
	Acremonium scrictum W.Gams	27							27(5)
	Alternaria alternata (Fr.) Keiss.	58	56	41	21	12	12	16	216 (38)
	Epicoccum nigrum Link	14	8	11	1				34(6)
	Fusarium avenaceum (Corda ex Fries)Sacc.	13	14	2	6	4	2	2	43(7)
07	*Fusarium equiseti* (Corda) Sacc.	21				12			33(6)
	Fusarium oxysporum Schlecht.	6	4	8	4	2	2	12	38(7)
	Gliocladium catenulatum Gill. et Abb..	16		4		1			21(4)
	Penicillium spp.	22					1	2	25(4)
	Thanatheporus cucumeris Kühn	21	11	1		1			34(6)
	Sclerotinia slerotiorum (Lib.) de By	21	11						32(6)
	Trichoderma harzianum Rifai	2	14				1	1	18(3)
	Trichotecium roseum (Pers.) Link	14	1	2		1	14	18	50(8)
	total	235	119	69	32	33	32	51	571
	Alternaria alternata (Fr.) Keiss.	13	31	29	12	1	22	40	148 (24)
	Aspergillus niger van Tieghem		34	11			4		49(8)
	Botrytis cinerea Pers. ex Fries.		8		5	23			36(6)
	Epicoccum nigrum Link	3	21	23					47(8)
	Fusarium avenaceum (Corda ex Fries) Sacc.	3	22	2	4	12	8		51(8)
	Fusarium culmorum (Smith) Sacc.	3		14					17(3)
08	*Fusarium equiseti* (Corda) Sacc.				2	2			4 (1)
	Fusarium oxysporum Schlecht.	6	31	6	2	14	6		65 (11)
	Mucor mucedo Mich. Ex St.-Am.				7	12			19 (3)
	Penicillium spp.	6	12	3			4		25 (4)
	Sclerotinia slerotiorum (Lib.) de By		32			12	2		46 (8)
	Trichoderma harzianum Rifai		21	2	11	5	6		45 (7)
	Trichoderma koningii Oud.	3	14				4		21 (3)
	Trichotecium roseum (Pers.) Link		22				14		36 (6)
	total	37	248	90	43	111	70	40	609
	Alternaria alternata (Fr.) Keiss.	11	7	6			2	2	28(10)
	Botrytis cinerea Pers. ex Fries.	2							2(1)
	Colletotrichum gloesporioides (Penz.)	4	7		11		4	2	28(10)
	Epicoccum nigrum Link						6		6(2)
	Fusarium avenaceum (Corda ex Fries) Sacc.	4		6		4	4	4	22(8)
	Fusarium equiseti (Corda) Sacc.	2							2(1)
09	*Fusarium oxysporum* Schlecht.	13	13	26	7	18	2	18	97(35)
	Penicillium spp.	1		6		8		6	21(7)
	Stemhyllium botryosum Wallr.	4			2				6(2)
	Thanatheporus cucumeris Kühn	4	10		8	8	17	8	55(20)
	Trichoderma harzianum Rifai	2							2(1)
	Trichoderma koningii Oud.			2			5		7(3)
	total	47	37	46	28	38	49	40	276

The results of investigations showed the effect of tested fungicides on the health status of seeds of bean. Probably with stronger infection pressure it would be possible to observe the greater differences in the effectiveness of tested fungicides with the application of various drop nozzles (Foqu´e and Nuyttens 2011). The results proved that *A. alternata*, *Fusarium* spp., *S. sclerotiorum* were most probably the cause of diseases of bean seeds from plants protected with fungicides. These known fungi cause bean seed diseases worldwide (Marcenaro and Valkonen 2016). The best results are connected with the use of azoxystrobine in all combinations both types of nozzles.

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EVALUATION OF THE USE OF BIOGAS PLANT DIGESTATE AS A FERTILIZER IN FIELD CULTIVATION PLANTS

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Keywords: digestate, fertilizer, winter rape, winter wheat, sustainable agriculture

ABSTRACT

Biogas production in an agricultural biogas plant is connected with generation of large amounts of post-digestion liquid as a result of anaerobic decomposition of plant debris. Due to its physicochemical properties, post-digestion liquid can be used as a fertilizer. A possibility of agricultural utilization of digestate as a fertilizer was investigated. Digestate obtained from an agricultural biogas plant was tested for the content of macroelements and heavy metals. The content of macroelements was also examined in the soil before and after digestate application. Digestate was used for in the cultivation of fodder winter rape and winter wheat. The content of macroelements as well as the content of protein in the grains of winter wheat fertilized with digestate were on the same levels as in the grains of wheat fertilized with mineral fertilizers. Similar tendency was also observed in winter rape grains. Digestate utilization as a fertilizer brings tangible benefits in agricultural production and can reduce the negative effects of mineral fertilization and contribute to development the sustainable agriculture. The study has shown that digestate can be used as a fertilizer.

INTRODUCTION

Biogas production from anaerobic decomposition has been highly developed in recent years. In this process, large amounts of liquid are also produced. Post-digestion liquid is rich in nitrogen and phosphorus. It is possible to utilize digestate as a fertilizer on farmland (Dębowski et al., 2016).

A biogas plant located in agricultural areas should collect organic products from local farms. Farmers, on the other hand, in their efforts to ensure soil quality on their farms, should use digestate from local biogas plants as a fertilizer (Comparetti et al. 2013, Garfi at al. 2011, Kowalczyk-Juśko et al. 2015, Tao et al. 2014).

Fermented biomass has the same or higher agricultural value than liquid manure since it contains more mineral components (including nitrogen) and less organic matter. Digestate also has undesirable properties, such as: smell, viscosity, considerable humidity and high content of fatty acids which are phytotoxic, this is why digestate can be pathogenic (Bustamante et al., 2014).

The use of post-digestion liquid as a fertilizer brings substantial benefits for agriculture; the possibility of using fermented biomass as a fertilizer contributes to improved soil fertility and higher crop yields. The utilization of post-digestion liquid as a fertilizer leads to the reduction of the use of mineral fertilizers (Cecchi, Cavinato, 2015, Cai et al., 2016, Di Maria et al., 2013).

The aim of this investigation is to examine the justifiability of digestate utilization as a fertilizer in field cultivation of biennial plants, and also compare the content of macroelements after fertilization with digestate and mineral fertilizers in winter rape and winter wheat cultivation.

METHOD

Digestate obtained from the biogas plant in Piaski (Lubelskie Province) was applied on experimental fields for winter rape and winter wheat cultivation. There were sown fodder winter rape of Starter variety and wheat of Zyta variety. For the sake of comparison, all the plants mentioned above were sown and fertilized with mineral fertilizers as well. The experimental fields are located in Uchanie Commune, Lubelskie Province. The area of each experimental field was 50 m^2. The soil on the fields is 2nd valuation class. Winter rape was sown at the end of August 2016, winter wheat in the first decade of September 2016. Digestate was used in the amount of 180 l per 50 m^2 (36000 l/ha). On the field fertilized with mineral fertilizers, for winter wheat sowing, there were used: nitrogen – 140 kg/ha (first dose: pre-sowing and for spring pre-sowing cultivation, second dose in the period of shooting, third dose during earing), phosphorus – 60 kg/ha, potassium – 80 kg/ha. Rape was fertilized using the following doses: 50 kg/ha of Polifoska 6 in autumn, and 65 kg/ha of Polifoska 12 in spring.

Digestate was tested for the content of macroelements and heavy metals. Soil samples were examined for the content of macroelements as well. The tests were conducted before and after digestate application.

Laboratory tests were performed at the District Chemical-Agricultural Station in Lublin and in the Central Agro-ecological Laboratory at the University of Life Sciences in Lublin.

RESULTS

The biogas plant (a biogas combined heat and power plant) is located in Piaski Commune, Lubelskie Province. The electric power is 0,99 MW, and the thermal power – 1,1 MW. The annual electricity production – approximately 8 400 MWh. The generated biogas is desulfurized, dewatered, cooled and pumped by means of an underground gas pipeline into a cogeneration engine which generates electricity and heat in a combined process. The following are used as an input into the digestion process: green waste matter, maize silage, beet pulp, stillage, whey.

Prior to its application, digestate was examined for the content of macroelements and heavy metals (Table 1). The pH reaction of the digestate used for winter rape and winter wheat cultivation was 8,57, and it is similar to the pH reaction of bovine liquid manure (7,90).

The analysis of the results showed that the digestate sample contained no heavy metals. Moreover, the digestate contains substantial amounts of macroelements, therefore it can be used as a fertilizer. This is confirmed by the investigation conducted last year (Koszel et al. 2016).

In view of many authors' indications that digestate does fertilize soil and can be used instead of mineral fertilizers, soil samples were examined as well. Those examinations were also aimed at detecting changes in the content of macroelements. They were performed before and after digestate application. In addition, tests were performed on soil samples after the harvests of winter rape and winter wheat. The results of the analyses are presented in Tables 2 and 3.

Table 1. Comparison of selected macroelements and heavy metals in the digestate used for the field crops

Examined feature	Content in digestate
Phosphorus [g/l]	0,16
Potassium [g/l]	5,22
Calcium [g/l]	0,35
Magnesium [g/l]	0,10
Cadmium [mg/l]	<0,43
Lead [mg/l]	<0,43
Nickel [mg/l]	<0,43
Chromium [mg/l]	<0,43
Copper [mg/l]	0,49
Zink [mg/l]	2,05
Manganese [mg/l]	2,00
Iron [mg/l]	75,66

Table 2. Tests for pH reaction and macroelements content in the soil for winter rape cultivation

Examined feature	Before digestate application	After digestate application	After winter rape harvest
Reaction [pH]	7,41	7,45	7,24
Phosphorus [mg per 100 g of soil]	41,11	50,19	47,68
Potassium [mg per 100 g of soil]	14,30	17,73	16,79
Magnesium [mg per 100g of soil]	15,79	19,44	17,92

Table 3. Tests for pH reaction and macroelements content in the soil for winter wheat cultivation

Examined feature	Before digestate application	After digestate application	After winter wheat harvest
Reaction [pH]	7,61	7,63	7,52
Phosphorus [mg per 100 g of soil]	50,68	59,52	56,39
Potassium [mg per 100 g of soil]	17,12	18,63	17,70
Magnesium [mg per 100g of soil]	14,21	17,88	16,54

The tests of the soil for winter rape cultivation showed a very slight increase in pH reaction, from 7,41 to 7,45, then it dropped to 7,24 after the wheat harvest. A similar tendency was observed while testing the soil for winter wheat cultivation. The pH reaction increased from 7,61 to 7,63, and after the harvest its value dropped to 7,52. The increase in the soil pH reaction reported above is of no special importance since it is still a basic reaction, which is favourable to good development of plants. After winter wheat harvest the value of pH reaction was observed to fall to 7,52, which is basic reactions. After the harvest of winter rape pH reaction value fell to 7,24, which is a neutral reaction. There was also observed increase in the content of the selected macroelements.

In winter rape cultivation, after digestate application, the content of phosphorus rose by 9,08 mg per 100 g of soil, potassium by 3,43 mg per 100 g of soil, and magnesium by 3,65 mg per 100 g of soil. As it was in the case of wheat cultivation, also after rape harvest there was observed decrease in the content of macroelements: phosphorus by 2,51 mg per 100 g of soil, potassium by 0,94 mg per 100 g of soil and magnesium by 1,52 mg per 100 g of soil. In winter, wheat cultivation the content of phosphorus rose by 8,84 mg per 100 g of soil, potassium by 1,51 mg per 100 g of soil and magnesium by 3,67 mg per 100 g of soil. Decrease in the content of macroelements was observed after winter wheat harvest: phosphorus by 3,13 mg per 100 g of soil, potassium by 0,93 mg per 100 g of soil and magnesium by 1,34 mg per 100 g of soil. The decrease in macroelement content after the harvests is connected with good absorption of macroelements by plants.

The increase in the content of macroelements in the soil has positive implications. Potassium is a macroelement which has a fundamental significance for plant nutrition. It plays a key role in plant water balance, activates enzymes, takes part in the process of photosynthesis and transportation of assimilates, and also activates sensitivity to water stress associated with drought. The basic role of magnesium in plants is connected with its presence in chlorophyll particles, thus influencing photosynthesis processes. This element plays a significant role in determining the quality of plant products in terms of their nutritional value for animals and people. Phosphorus deficiency inhibits plant growth, reduces yield and its quality. If soil is rich in macroelements, plants absorb them more easily, and produce a higher yield.

Winter rape grains collected from the fields fertilized with mineral fertilizers and digestate were also examined. The mean value of protein content in the winter rape grains collected from the field fertilized with mineral fertilizers was 21,7%, and the mean fat content– 43,4%. In the rape grains collected from the field fertilized with digestate the protein content reached 21,8%, and the fat content – 44,1%. Table 4 shows changes in the content of macroelements in winter rape grains.

Table 4. The content of selected macroelements in winter rape grains

Examined feature	Winter rape sown on the soil fertilized with mineral fertilizers	Winter rape sown on the soil fertilized with digestate	Difference
Nitrogen [%]	3,02	3,09	0,07
Phosphorus [%]	0,62	0,65	0,03
Potassium [%]	0,65	0,66	0,01
Calcium [%]	0,49	0,50	0,01
Magnesium [%]	0,37	0,37	0,00

The analysis of the test results revealed a slight percentage increase in the content of particular macroelements in winter rape grains. The highest rise was observed in the content of nitrogen, 0,08 p. p. The relative percent differences for the examined macroelements were as follows: nitrogen – 2,32%, phosphorus – 4,84%, potassium – 1,54%, calcium – 2,04%, magnesium – 0%.

Winter wheat grains were collected from the fields fertilized with mineral fertilizers and digestate. The moisture of the grains collected from the field fertilized with mineral fertilizers was 11,8%, and from the field fertilized with digestate – 12,7%. The

elementary feature of wheat grains which determines their value in use is protein content. The protein content in the winter wheat grains collected from the field fertilized with mineral fertilizers was 9,7%, and from the field fertilized with digestate 10,0%. The relative percent difference for the protein content in the wheat grains is 3,09%. The changes in the content of macroelements in winter wheat grains are presented in Table 5.

Table 5. The content of selected macroelements in winter wheat grains

Examined feature	Winter wheat sown on the soil fertilized with mineral fertilizers	Winter wheat sown on the soil fertilized with digestate	Difference
Nitrogen [%]	1,56	1,77	0,21
Phosphorus [%]	0,39	0,43	0,04
Potassium [%]	0,47	0,51	0,04
Calcium [%]	0,11	0,12	0,01
Magnesium [%]	0,19	0,19	0,00

The analysis of the results revealed a slight percentage increase in the content of particular macroelements in winter wheat grains. The highest rise was observed in the content of nitrogen, 0,21 p. p., as well as phosphorus and potassium, 0,04 p. p. The relative percent differences for the examined macroelements were as follows: nitrogen – 13,46%, phosphorus – 10,26%, potassium – 8,51%, calcium – 9,09%, magnesium – 0%.

CONCLUSIONS

Anaerobic decomposition is a technology which enables the conversion of food industry or municipal waste into renewable energy sources. The process of anaerobic decomposition consists of a number of metabolic reactions performed by a wide range of microorganisms in anaerobic conditions. As a result, biogas and post-digestion matter are formed (Comparetti et al. 2015).

The major factors determining the way of digestate utilization include its quality, local conditions and legal regulations. In Poland the factor which determines the utilization of biogas plant's by-products is legal norms, which do not facilitate digestate management (Czekała et al. 2012).

This investigation revealed that post-digestion liquid contains large amounts of macroelements. However, no heavy metals were found in digestate. The examination of soil samples before and after digestate application showed increase in the content of macroelements in the soil, which implies a good fertilizing value of digestate.

The examination of winter wheat grains from the soil fertilized with digestate also revealed a rise in protein content as compared to the winter wheat grains from the field fertilized with mineral fertilizers. The investigation results related to winter rape confirmed the efficiency of post-digestion liquid application as a fertilizer. Consequently, post-fermentation residues from biogas plants can be used as a fertilizer.

Fertilizing fields with digestate brings numerous benefits, e.g. reduction of demand for plant protection products (destruction of weed seeds during fermentation), or destruction of possible pathogens. Digestate utilization as a fertilizer brings tangible benefits in agricultural production, but it is also a product the application of which can reduce the negative effects of mineral fertilization and contribute to development the sustainable agriculture.

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STABILIZATION OF LIQUID OUTFLOW SPEED FROM A SLOTTED SPRAY NOZZLE

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Keywords: slotted spray nozzle, technical parameters, outflow speed

ABSTRACT
Unequal distribution of the liquid outflow from the slotted spray nozzle forms a wide spectrum of drops. This affects the level and uniformity of spraying and the degree of drip drift compensation. The purpose of the work was to determine a method of stabilizing the speed of liquid outflow from the nozzle. The result of the study was construction of a speed stabilizer - an insert mounted in the nozzle. Advantage of the patented design is, besides stabilizing the liquid outflow speed, also a uniform flux of liquid flow over the entire length of the nozzle.

INTRODUCTION

One way to protect plants is by spraying them with aqueous solutions of the appropriate substances. Achieving the biological effect of chemical plant protection depends largely on the quality of the spray nozzle work. They affect the level and uniformity of application of the solution and the degree of wind drift compensation, Dorr et al. (2013), Vallet et al. (2013), Szewczyk (2010). Commonly used sprayers in agriculture are slotted spray nozzles. The principal drawback of these nozzles is uneven distribution of liquid flow rate from the nozzle, Vallet et al.(2013), Kowalik (2014). This parameter has a decisive influence on the quality of spraying, since on it depends the resulting droplet spectrum, Dorr et al.(2013), Szewczyk et al.(2013), Truck et al. (1997). In case of slotted spray nozzles this spectrum is unfavorable since diameter of droplets ranges from a few to several hundred micrometers, Hawitt (2008), Orzechowski et al. (2008), Truck et al. (1997). In addition, outflow density in the central nozzle section in these sprayers is much higher than in the outside, which affects the selection and setting of the sprayer boom and the uniformity of spraying, Parafiniuk, Sawa, Wołos (2011), Parafiniuk, Sawa, Huyghebaert (2011). Satisfactory effect is achieved on a flat surface and a sprayer boom parallel to this surface, Szewczyk (2010). Droplet size is now controlled by the use of sprayers with nozzles of different geometrical dimensions, changing pressure of the liquid used, the use of anti-drip inserts, Orzechowski et al. (2008). The range of droplet size control by these methods does not reduce the drop spectrum, but limits the operating parameters of the sprayer. Another way to adjust the droplet size is to aerate them (injectors). With these sprayers, larger diameter droplets are more easily disseminated on the surface of leaves. However, large numbers of large droplets result in less stream density resulting in less droplets per unit area, which influences the biological efficiency of the process, Butler et al.(2002), Szewczyk et al. (2013).

The aim of the study was to determine the conditions that should be met in order to obtain a constant liquid outflow speed from slotted spray nozzle and consequently reduce the drop spectrum.

MATERIAL AND METHODS OF RESEARCH

The subject of the study was a slot spray nozzle used in agricultural sprayers. In this nozzle is a channel with r radius ended with spherical surface and an opening that looks like a slot. In the spherical part of the nozzle the surface perpendicular to the liquid flow direction is in the shape of a circle and varies from Πr^2 to 0. Thus, according to the mass conservation law, the flow velocity of liquid changes inversely proportionally to that surface, (Orzechowski et al. (1997). In the spherical part, a one-dimensional flow model is used for calculating in which only the velocity component parallel to the sprayer axis is considered (perpendicular to the liquid flow surface). The liquid flow surface (nozzle) perpendicular to the stream direction takes the shape of an ellipse with axes 2a and 2b. The sprayer was places in a coordinate system in such a way that axis 2a is located on the x axis, axis 2b on the y axis and the sprayer axis on the z axis.
Direct measurement results, slotted spray nozzle output and part of the calculation method were used from a paper to determine the variation of the fluid outflow parameters from the slotted spray nozzle, Kowalik (2014).

In order to calculate the volume of fluid outflowing at a constant velocity v at the individual points of the nozzle, the ellipse was divided along the long axis 2a into n parts ($n \rightarrow \infty$) with an area of F_n.
The liquid stream flowing through the area F_n at velocity v is:

$$\Delta Q_{Rn} = F_n \, v \tag{1}$$

The value of the liquid stream flowing through the surface perpendicular to the direction of flow at point n is:

$$Q_{Rn} = Q_{Rn-1} - 2\Delta Q_{Rn} \tag{2}$$

where: Q_{Rn-1} – value of the stream flowing through the surface at n-1;
The initial value of the stream at n = 1 is:

$$Q_{R1} = 2\sum_{i=1}^{n} \Delta Q_{Rn} \tag{3}$$

The surface needed for the flow of liquid at the n point in the volume Q_{Rn} at the velocity v is:

$$A^*_{Rn} = Q_{Rn} \, v^{-1} \tag{4}$$

The surface perpendicular to the direction of flow at the point n of the spherical part of traditional nozzle, Kowalik (2014) pattern 10 and fig. 2 is:

$$A^*_n = A_n - 2\Delta A_n \tag{5}$$

The surface A^*_n is larger than surface A^*_{Rn} and therefore should be reduced by:

$$\Delta A^*_n = A^*_n - A^*_{Rn} \tag{6}$$

The surface ΔA_n^* has the shape of a circle of diameter:

$$D_{Rn} = \sqrt{4\Delta A_n^* / \Pi} = 2R_n \quad (7)$$

D_{Rn} is the diameter of the speed stabilizer insert at point z_n.
The influence of different outflow rates on the R_n value for the same nozzle was also analyzed.

RESEARCH RESULTS AND THEIR ANALYSIS

As a result of the calculations, the design parameters of the slotted spray nozzle were determined to ensure a constant outflow rate of the liquid.

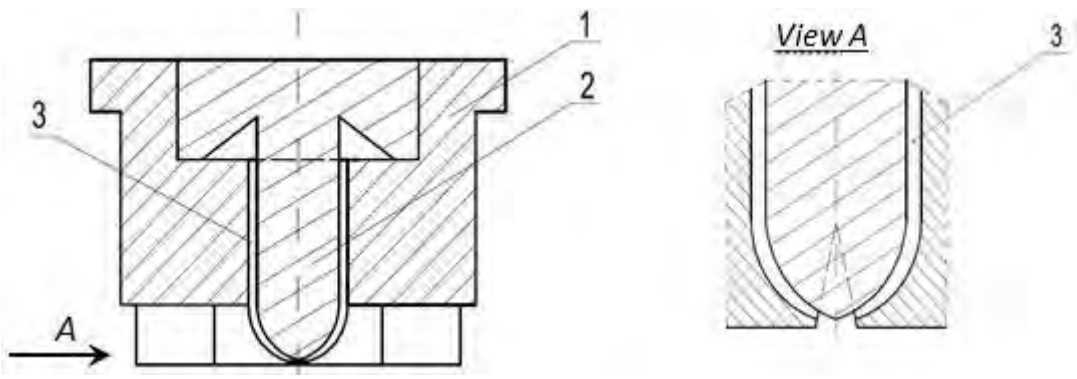

Fig. 1. Speed stabilizer; 1- slotted spray nozzle, 2- speed stabilizer insert, 3- coaxial liquid flow channel

The main component of the speed stabilizer is the insert 2 (fig. 1), which forms a coaxial liquid channel 3 in the spherical part of the nozzle. Dimensions of the stabilizer insert depend on the design parameters of the slot spray nozzle (channel and spherical part diameters and nozzle dimensions) and the flow rate of the work fluid is controlled by pressure change.
Figure 2 shows the mutual dependence of the speed stabilizer height z_n and the corresponding radius R_n. The rotation of the resulting curve around the axis z_n shows the shape of the insert in the spherical part of the nozzle. The trend line equation is the pattern of generation function of the speed stabilizer.

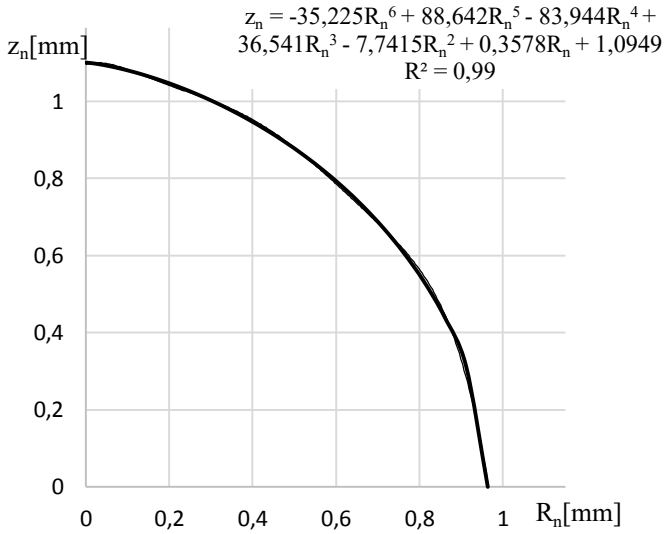

Fig. 2. Generation function of the speed stabilizer

Liquid flow from the slotted spray nozzle at constant speed over the entire length of the nozzle makes the volume flux density ΔQ_{Rn} also constant. As shown in fig. 3, the liquid volume stream for the nozzle without speed stabilizer (curve b) varies from $9 \cdot 10^{-7}$ $m^3 \cdot s^{-1}$ in the center of the nozzle to zero at extreme outer points. On the other hand, for the same sprayer with a speed stabilizer the calculation showed a stable course of these values almost over the entire length of the nozzle (curve a).

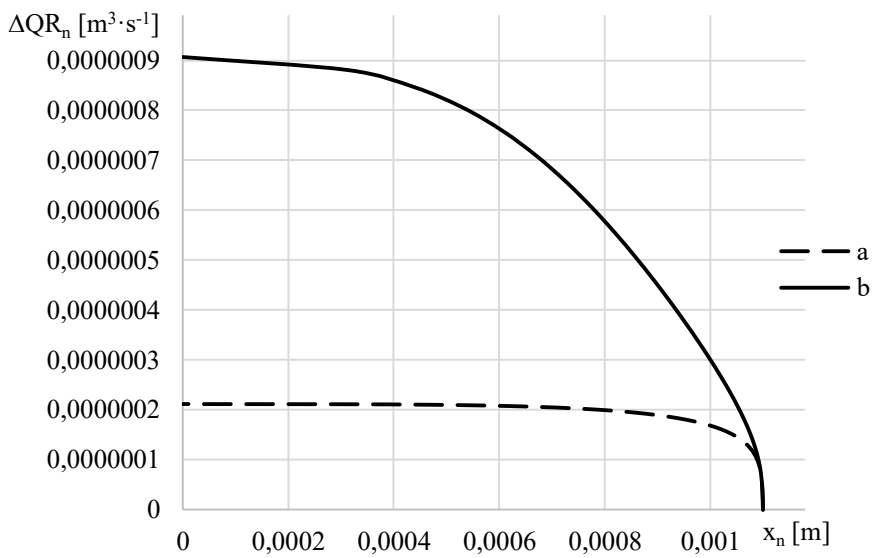

Fig. 3. Liquid volume stream distribution: a – with a speed stabilizer, b – in a traditional sprayer

CONCLUSIONS

1. The outflow of liquid from the slotted spray nozzle with constant speed can be obtained by forming in the spherical part of the sprayer a coaxial channel with a speed stabilizer insert.

2. The design dimensions of the stabilizer insert depend on the design parameters of the slot spray nozzle.
3. A set of points expressed in the form of functions representing the dependence of the height of the insert in the spherical part and corresponding to that height radius constitutes a generation function of the speed stabilizer.
4. The speed stabilizer insert makes the density of the liquid volume flux at each point of the nozzle equal.

Result of the research was the construction of the speed stabilizer in the slotted spray nozzle (patent P.412369)

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CONCEPT OF USING FRUIT POMACE ON SUSTAINABLE FARMS

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Keywords: sustainable farms**,** agglomeration, antioxidant activity, polyphenols, pomace

ABSTRACT
The paper presents the possibility of using fruit pomace as the management of poor products on sustainable farms. Processing of raw materials in the fruit and vegetable industry involves generation of manufacturing waste, of which pomace that may be processed in different ways, constitutes the highest share. Pomace is most commonly used as fuel in biogas plants, or as feed additives. Despite its high microbial instability, pomace is a great source of numerous bioactive substances.Therefore, it may be used alternatively in the production of granulated fruit and herbal teas.The aim of this paper was to assess the possibility of using fruit pomace in the production of granulated teas with addition of *Melissa officinalis*. Material used in the study was the agglomeration of dried and fragmented black chokeberry and apple pomace blended with *Melissa officinalis*. Prepared granules were used to make infusions for which the total polyphenol content, antioxidant activity and sediment amount were determined.

INTRODUCTION

Pomace constitutes the largest group of manufacturing waste generated during fruit and vegetable processing. Significant amounts of pomace produced in a relatively short time span pose a considerable problem for entrepreneurs, as it is highly perishable. What is more, due to high water content reaching as much as 73%, microbial development processes can start very quickly. Immediate pre-treatment of generated pomace allows solving this problem, however only to some extent. Despite its high microbial instability, pomace is a great source of numerous bioactive substances, such as flavonoids, tannins, anthocyanins or fibre. It is a relatively inexpensive and easily accessed raw material, used most commonly as feed additives. Its chemical composition enables to significantly reduce costs related to animal feeding. Pomace may also be processed into biogas or biofuels. It may also be used in the manufacture of colourants and acquisition of fibre (Kruczek et al. 2016, Tańska et al. 2016).

Waste materials coming from fruit and vegetable processing contain a considerable amount of strong antioxidants – phenols in particular, which play a highly important role in determining the nutritional value and sensory characteristics. They are able to protect the body against the activity of free radicals, thus preventing heart diseases, cancer, cataract, and slowing the ageing processes (Dobson et al. 2015, Kozak et al. 2016, Tańska et al. 2016). Due to their health promoting properties, an alternative pomace management solution may be production of fruit teas. Such teas are growing in popularity, and they have started to outsell black teas available on the market. They are characterized by specific flavour and aroma, and they have high nutritional value. They are often enriched with herbal additives to increase their content of bioactive substances (Almajano et al. 2008, Szlachta&Małecka 2008, Zych&Krzepiło 2010).

The aim of this paper was to assess the possibility of using chokeberry and apple pomace in the production of granulated teas. Material used in the study was the agglomeration of dried and fragmented pomace with *Melissa officinalis*. Prepared granules were used to prepare infusions for which the content of total polyphenols and antioxidant activity were determined. Amount of sediment was also measured.

MATERIALS AND METHODS

The material used in the study was fruit and herbal infusions prepared from agglomerated pomace, with addition of lemon balm (*Melissa officinalis L.*). Chokeberries (*Galicjanka* variety) and apples (*Daret* variety) were obtained from private plantations in the Lubelskie province. The fruit were of high quality, they were properly ripe and juicy. Chokeberryfruit was frozen and stored at -18°C for 24 hours. Chokeberry pomace was obtained by pressing the thawed fruit, using a laboratory fruit press manufactured by RECHT company. Fresh apples were pre-crushed and pressed using the same device. Fruit pomace was dried in an air flow drying machine (POL-EKO), in order to obtain the moisture level of 8%. Next, dried fruit were ground using a lab grinder (WŻ-1 manufactured by ZBPP Bydgoszcz). Raw materials prepared in this manner were blended into chokeberry and apple mixes with 5, 10 and 15% additions of lemon balm with particle size ranging from 0.5-1 mm. Ready-made fruit and herbal blends were subject to non-pressure agglomeration using a disk granulator, with 40% aqueous solution of starch as the moisturizing liquid. The control samples were granules obtained bynon-pressure agglomeration of the fruit pomace. After drying and hardening the granules, they were weighed as 2g portions and locked up in tea filter papers using a HENDI vacuum sealer.

Infusions were made by pouring 100 cm3 of demineralised water of 90°Coverbags containing herbal granules, and brewing them for five minutes, covered. Produced infusions were drained through medium-pore qualitative filter paper, and weighed after drying. Difference between pure filter paper weight and its weight after draining was the basis for determining the amount of sediment present in fruit and herbal infusions.

In order to determine the total polyphenol content in fruit and herbal infusions, spectrophotometry using Folin-Ciocalteu reagent and gallic acid as a standard (Borkataky 2015, ISO 14502-1 2005) was performed. Absorbance was measured at 765 nm against distilled water, after 30 minutes of sample preparation. Total content of polyphenolic compounds in the infusions was expressed as gallic acid equivalents - mg (GAE)•100 cm^{-3}.

Antioxidant activity of fruit and herbal infusions was determined using a stable free 1,1-diphenyl-1-picrylhydrazyl radical(DPPH), using a method developed by Zych and Krzepiło (2010). Alcoholic solution of DPPH of 0.5 mM was prepared and diluted to obtain absorbance (A_0) approximating 0.9 at λ =517 nm. Spectrophotometer was calibrated with methanol. An examined sample contained 3 cm^3 of DPPH solution and 0.4 cm^3 of a given infusion. Absorbance of the prepared samples (A) was measured 30 minutes after onset of the reaction. For each measurement, three independent repetitions were conducted and the average absorbance value (A_{avg}) was measured for a given infusion.

The ability to quench a radical was expressed as a percent value of inhibition of the examined infusion, using the following formula:

$$\% \text{ of inhibition} = 100\ (A_0 - A_{avg})/A_0$$

where:

A_{avg}– average absorbance of the examined infusion containing an antioxidant,
A_0 – absorbance of the solution of DPPH free radical.

Ten measurements were performed for every infusion. Obtained results were subject to statistical analysis using STATISTICA 10.0 software. Statistical significance (P) and F test value (ANOVA) were determined.

RESULTS

The examined fruit and herbal teas presented different sediment content (Fig. 1). Addition of lemon balm significantly reduced the amount of sediment found in the examined infusions. Infusions made from granulated apple pomace had nearly double sediment content when compared with chokeberry teas, which was probably the result of pulp particles penetrating into the infusions during brewing.

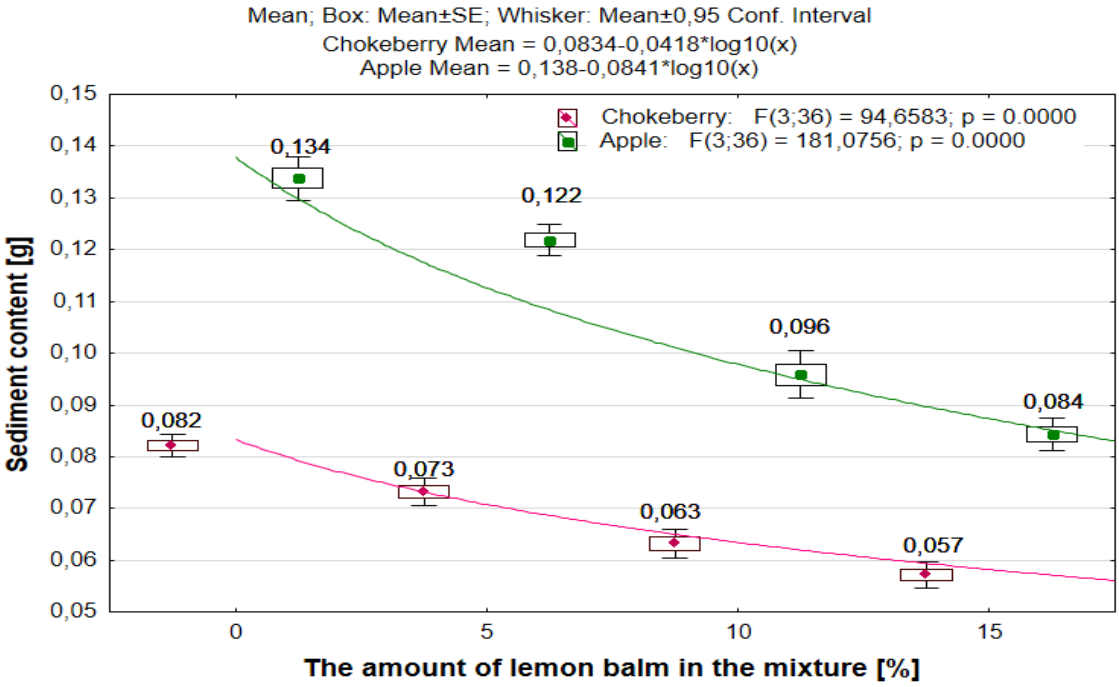

Fig. 1. Effect of lemon balm addition on fruit tea sediment content.

Fig. 2 presents the effect of lemon balm addition on total polyphenol content in fruit teas. Addition of lemon balm considerably increased polyphenol content in the examined infusions, in case of the highest share by as much as 30% in chokeberry teas and by more than 40% in apple teas. Chokeberry-based teas used as the control presented three times higher polyphenol content (33.81 mg·100 cm^{-3}) when compared to infusions prepared from apple pomace (10.41 mg·100 cm^{-3}). While examining antioxidant activity of teas and fruit dried for commercial use, Szlachta and Małecka

(2008) found a similar relationship. Infusion made from dried chokeberries contained about 18.4 mg·100 cm^{-3} of phenolic compounds, whereas tea made from dried apples only 4.40 mg·100 cm^{-3}. A significantly higher polyphenol content in teas prepared from granulated fruit pomace may effect from shorter pomace drying time when compared to drying of fresh fruit since, as confirmed by data available in the literature, phenolic compounds are more sensitive to higher temperatures. What is more, polyphenol content is also determined by a given variety, method and place of production, as well as raw material storage conditions (Almajano et al. 2008, Andrzejewska et al. 2015).

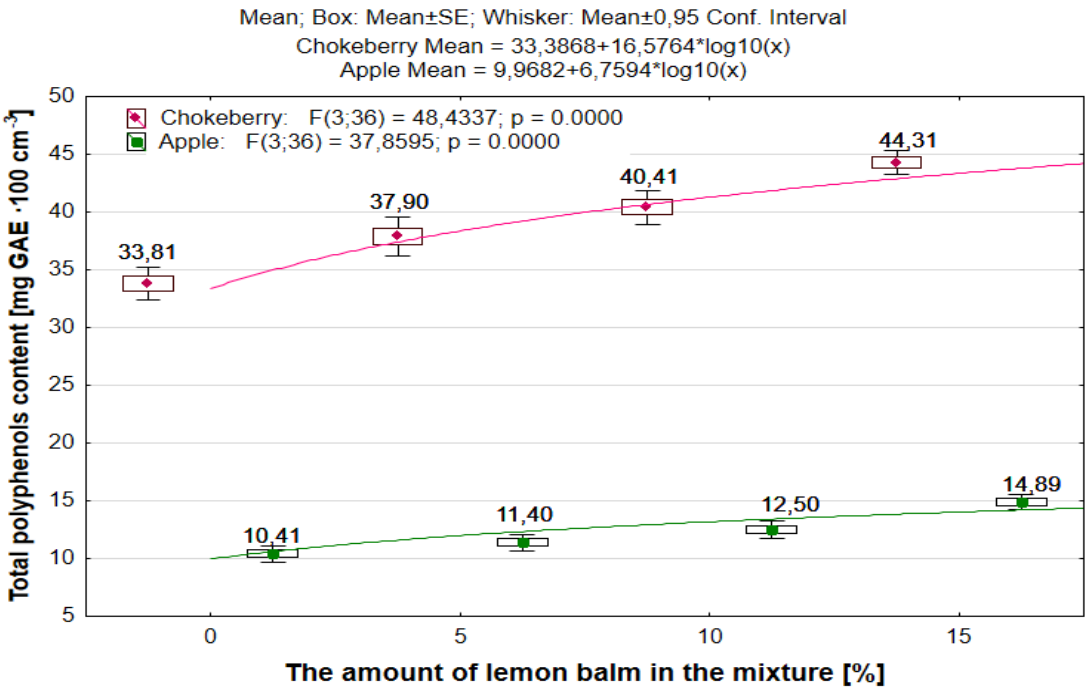

Fig. 2. Total polyphenol content in fruit teas depending on added amount of lemon balm.

As shown in numerous findings, the ability to quench free radicals is strictly related to the content of phenolic compounds (Bonarska-Kujawa et al. 2012, Borkataky 2015, Kozak et al. 2017), which was confirmed by results of the study presented in Fig. 3; it demonstrates the effect of lemon balm addition on antioxidant properties of fruit infusions. Chokeberry teas displayed a significantly higher polyphenol content, as well as higher ability to quench DPPH radical, when compared to apple-based infusions.

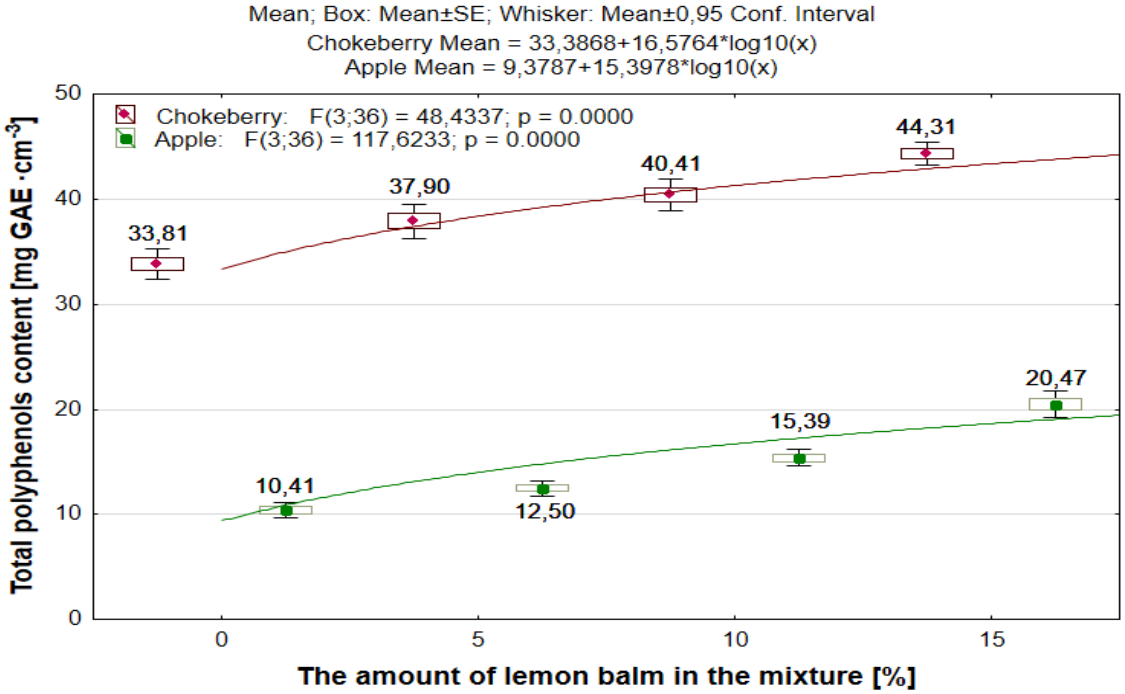

Fig. 3. Antioxidant activity of fruit teas depending on percent content of lemon balm in the mixture.

CONCLUSIONS

The study has shown that non-pressure agglomeration is an alternative method for managing fruit pomace for food uses, and that it allows obtaining new products in the form of granulated fruit teas.

Teas made from granulated apple pomace had the highest sediment content, with the average of 0.13 g, which could result from penetration of pulp particles during the brewing process. Addition of lemon balm considerably reduced the amount of sediment found in all prepared infusions.

Infusions from granulated chokeberry pomace had three times higher content of bioactive substances when compared to apple-based teas.

Addition of lemon balm during granulation of fruit pomace increased polyphenol content and antioxidant activity in case of all fruit teas, which allowed obtaining products with high health-promoting properties that can be used as dietary supplements.

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EMISSION OF HYDROGEN DURING COMBUSTION OF PLANT BIOMASS PELLETS ON THE GRATE OF A LOW POWER BOILER

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ABSTRACT

Analysis of the wheat, rye, triticale, buckwheat straw and meadow hay pellets combustion process was carried out for hydrogen emissions. Tests were performed in grate upper combustion boiler. The air was supplied through a ventilator beneath the grate at the rate of 1.5 $m \cdot s^{-1}$. Differences in obtained hydrogen amounts in exhausted gas were observed: from 216 to 266 ppm, on average. This substance presence was usually characterized by negative correlation with exhaust gas temperature, while positive with the air excess. This aspect emissions hydrogen is very important for achieving the goals of sustainable agriculture that meet current and future human needs. It would be advisable to enhance tests using other forms of combusted bio-fuels, as well as to carry out the analyses of other components of exhausted gas generated during combustion.

INTRODUCTION

Malaga-Tobola et al. (2008) report that Polish agriculture, due to the land and labor resources, has considerable opportunities to compete on European market, while structural reality, especially excessive resources of labor in agriculture, contributes to its low efficiency.

Increasing the productivity can be achieved by directing the production towards organic assortment using post-production remains. Therefore, it becomes important to use the agricultural-origin biomass for energy purposes. These actions should refer not only to agricultural production, but also subsequent utilization of products. Baum (2003) and Krasowicz (2006) indicated the need to realize the agricultural policy while maintaining the rules of sustainable development strategy, which when realizing the pro-ecological tasks, takes into account the compromise between energy and ecological effectiveness.

When combusting the solid bio-fuels, management of the air supplied, that depends on the type of combusted fuel, but also on the furnace construction, is very important. Much information on that can be found in works by Fournel et al. (2015), Obernberger (2003), Obernberger et al. (2006) as well as Van Loo and Koppejan (2007). Those papers, along with publications by Olsson and Kjällstrand (2002) and Kraszkiewicz (2016) include information that the use of solid bio-fuels in low-power heating devices makes problems with uncontrolled emission of many gaseous harmful products of incomplete combustion such as carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), volatile organic compounds (LZO) and tars. Works by Schultz et al. (2003), Saxen et al. (2008), Vollmer et al. (2012) and Pieterse et al. (2013) indicate the poorly recognized hydrogen (H_2) emission, the presence of which in the atmosphere enhances the lifetime of greenhouse gases.

During combustion, hydrogen arises in a series of chemical reactions that are also used to its industrial production under controlled manner. These reactions are described in details by Kordylewski (2006) and Saxen et al. (2008).

Kothari et al. (2008) point out that the characteristic feature of hydrogen that can be determined its oxidation, thus emission into the atmosphere, is self-ignition temperature of 585°C, which is even higher than that for methane 540°C. Vollmer et al. (2012) found that hydrogen presence launches other reactions, e.g. decomposition of NO to N_2O. However, the literature lacks information about this compound emission size or mechanisms of its arising in an aspect of solid bio-fuels combustion in low-power heating devices.

Therefore, the aim of the preset study was to perform the combustion of pellets made of selected types of biomass in low-temperature upper combustion water boiler, and to carry out the analysis of exhaust gas for the hydrogen presence, supplied air excess, and exhaust gas temperature.

MATERIAL AND METHODS

Tests involved pellets made of rye, wheat, triticale, buckwheat straw and meadow hay. Following methods were applied for determining their physicochemical properties:

- moisture – gravimetric method according to PN-EN 14774-1:2010;
- calorific value – according to PN-EN 14918:2010 after determination of calorific value;
- ash – according to PN-EN14775:2010;
- carbon, hydrogen – IR absorption according to CEN/TS 15104:2006;
- nitrogen – using automatic analyzer equipped with thermal conductivity detector according to CEN/TS 15104:2006;
- sulfur – automatic IR analyzer according to PN-G-04584:2001;
- length and diameter – direct measurement of 10 representative pellets.

Average values of physical and chemical properties of tested solid bio-fuels are presented in Table 1.

Table 1. Physical and chemical properties of the treated pellets in working condition.

Fuel parameters - average values	Unit	Pellets				
		made of rye straw	made of wheat straw	made of triticale straw	made of buckwheat straw	made of meadow hay
Length	mm	28.7	32.3	31.3	36.6	31.7
Diameter	mm	8.5	8.3	8.4	8.1	8.5
Moisture	wt. %	10.82	11.42	10.6	11.3	9.6
Net calorific value	$MJ \cdot kg^{-1}$	16.23	16.32	16.1	15.45	16.14
Ash content	wt. %	3.4	2.31	3.78	6.28	6.21
C	wt. %	46.72	47.7	46.5	44.4	46.04
H	wt. %	5.6	5.5	5.74	5.56	5.64
N	wt. %	1.15	0.77	0.7	0.88	1.37
S	wt. %	0.12	0.06	0.09	0.13	0.61

Source: own study

The combustion tests of the study material were carried out in the testing position, the integral part of which consisted of boiler of upper combustion with fixed grate with nominal thermal power of 10 kW, fed periodically. The fuel feeding and ash removal was manual. Boiler was equipped in air supply ventilator and circulating pump of working liquid. The device was controlled by means of microprocessor regulator.

Tests consisted of combusting the 1 kg sample of pellets supplying air beneath the grates at the rate of 1.5 $m \cdot s^{-1}$. Exhaust gas was samples from the chimney at the distance of 1 m from boiler's flue. The measuring probe was connected to exhaust gas dryer PGD-100, from which gas was directed to analyzer. Portable exhaust gas analyzer Photon was used. This device works based on the IR sensors (NDIR). During combustion, measurement of H_2, O_2 contents in exhaust gas was performed using type K thermocouple. Measurement results were written to database every 4 seconds from the moment of combustion of the fuel portion after its supplying on stabilized embers layer, till the end of combustion process.

Achieved results of H_2 concentration in exhaust gas were also referred to the stream of dry exhaust gas volume of 10% oxygen content and normal conditions ($mg \cdot m^{-3}$) at 0°C and 1013 mbar according to guidelines in PN-EN 303-5:2012. Accumulated data was subject to statistical analysis in STATISTICA 13.1 software. The Shapiro-Wilk test verified the conformity of results with normal distribution, while Brown-Forsyth was used to evaluate the variance uniformity. When the lack of variance uniformity was found, Kruskal-Wallis test was applied. In order to describe the dependence between particular variables, Spearman rank correlation test was used. In all analyses, the significance level was assumed at $p < 0.05$.

RESULTS

Concentration of hydrogen H_2 in exhaust gas, air excess, and temperature of exhaust gas characterizing the combustion process of tested pellets is presented in Tables 2-4.

Table 2. Concentration of hydrogen H_2 measured in the exhaust gas during combustion of the pellets in question.

Fuel type	Concentration H_2, ppm				
	sample size	min	max	mean	standard deviation
pellets made of rye straw	389	0	1871	216	364
pellets made of wheat straw	231	0	1572	103	329
pellets made of triticale straw	195	0	3035	237	559
pellets made of buckwheat straw	535	0	930	253	217
pellets made of meadow hay	208	0	1610	266	538

Source: own study

Table 3. Excess air during the combustion process of the pellets in question.

Fuel type	Excess air				
	sample size	min	max	mean	standard deviation
pellets made of rye straw	389	1.66	32	6	6
pellets made of wheat straw	231	1.40	81	12	15
pellets made of triticale straw	194	1.13	87	5	9
pellets made of buckwheat straw	535	4.07	299	28	45
pellets made of meadow hay	208	2.25	70	8	12

Source: own study

Concentrations of H_2 measured in exhaust gas originated during combustion of test pellets were similar and average values ranged within 216-266 ppm. Only for pellets made of wheat straw, the value was 103 ppm. Higher differentiation was revealed by

maximum values that most often ranged within 1571-1871 ppm. However, for pellets made of buckwheat and triticale straw, the levels were completely different: maximum hydrogen concentrations in exhaust gas were 930 and 3035 ppm, respectively.

Table 4. The temperature of the exhaust gas during combustion of the pellets in question.

Fuel type	The temperature of the exhaust gas, ºC				
	sample size	min	max	mean	standard deviation
pellets made of rye straw	389	0	536	331	138
pellets made of wheat straw	231	0	598	294	154
pellets made of triticale straw	195	0	753	302	208
pellets made of buckwheat straw	535	0	232	96	52
pellets made of meadow hay	208	0	397	247	105

Source: own study

Parameter characterizing the combustion process was the air demand expressed as its excess. Combustion with the largest air excess (28 on average) was recorded for buckwheat straw pellets. Other types of pellets were combusted more intensively at larger air consumption (5-12 on average). Meanwhile, in this group with the largest air excess, wheat straw pellets were combusted. At the moment of the highest air demand, when combustion was the most intensive and advanced, the minimum values of air excess are very interesting: they amounted to 1.13-1.66 for pellets made of wheat, rye and triticale straw, while for buckwheat straw and meadow hay, these values were much higher – 4.07 and 2.25, respectively (Table 3).

Temperature of exhaust gas during combusting the analyzed pellets revealed similar differentiation as previously discussed parameters. Buckwheat straw pellets combustion was characteristic, because maximum temperature of exhaust gas was only 231 ºC (at the mean value of 96 ºC), which was from 30% to 60% of this parameter reached for other bio-fuels (Table 4).

Values of emission calculated for the normal conditions at 10% oxygen content are presented in Table 5. Hydrogen emission indicators referenced to the normal conditions revealed lower differentiation between applied pellets tested. Average values, in general, ranged within 0.10-0.13 $mg \cdot m^{-3}$. Only for pellets made of wheat straw, the value was lower at the level of 0.05 $mg \cdot m^{-3}$ (Table 5).

Table 5. Emission factors H_2 converted to reference state at 10% O_2 in exhaust gas.

Fuel type	Emission factors H_2 at 10% O_2 in exhaust gas, $mg \cdot m^{-3}$				
	sample size	min	max	mean	standard deviation
pellets made of rye straw	389	0	0.89	0.10	0.17
pellets made of wheat straw	231	0	0.75	0.05	0.16
pellets made of triticale straw	195	0	1.44	0.11	0.27
pellets made of buckwheat straw made of meadow hay	535	0	0.44	0.12	0.10
pellets made of meadow hay	208	0	0.76	0.13	0.26

Source: own study

Table 6 illustrates Spearman rank correlations between analyzed values.

Table 6. Spearman's correlation coefficients.

Variables	Pellets				
	made of rye straw	made of wheat straw	made of triticale straw	made of buckwheat straw	made of meadow hay
H_2 (ppm) vs Tgas (°C)	-0.835	-0.284	-0.519	0.798	-0.631
H_2 (ppm) vs Excess air (-)	0.848	0.166	0.528	-0.706	0.599
Tgas (°C) vs Excess air (-)	-0.981	-0.910	-0.950	-0.912	-0.940

Source: own study

In general, Spearman rank correlation coefficients indicated that negative dependencies were present between hydrogen content in exhaust gas and exhaust gas temperature. Only during combusting the buckwheat straw, the dependence was strongly positive, whereas between hydrogen concentration vs. air excess, these relations were positive, while for buckwheat straw pellets - negative (Table 6). Inter-relations occurring in test conditions indicate incomplete combustion of buckwheat straw pellets and intensive process of their gasification.

The combustion tests of selected bio-fuels differed due to use of pellets with different physical and chemical properties. Comparative analysis of achieved results of hydrogen content in exhaust gas recorded in particular combustion tests is difficult. The literature references, among others in Fournel et al. (2015), Obernberger (2003), Obernberger et al. (2006) as well as Van Loo and Koppejan (2007) did not take into account the hydrogen emission during the biomass fuels combustion. The own tests revealed that referring to tested pellets, there were remarkable divergences in the combustion process, hence hydrogen concentrations in exhaust gases. Pellets made of buckwheat straw differed from other ones, because they were not combusted in a satisfactory way due to their chemical properties.

CONCLUSIONS

Performed tests allowed for making following remarks and drawing conclusions:

1. Combustion of cereal straw and meadow hay pellets generated hydrogen presence in exhaust gas at the level from 216 to 266 ppm, while maximum concentration of this compound during combustion pellets made of buckwheat straw amounted to 930 ppm, and triticale straw – 3035 ppm.
2. Hydrogen emission indicators recalculated onto reference of 10% O_2 in exhaust gas were uniform and average values of the parameter, in general, range from 0.10 to 0.13 $mg \cdot m^{-3}$. Only combustion of wheat straw pellets resulted in the parameter value at the level of 0.05 $mg \cdot m^{-3}$.
3. Hydrogen emission to the atmosphere during combustion of tested fuels, in general, was characterized by negative correlation with exhaust gas temperature, while positive with the air excess. Only for pellets made of buckwheat straw, these dependencies were different.
4. Work on knowing and reducing hydrogen emissions, when burning biofuels of agricultural origin, into the atmosphere is part of the problem of improving air quality, which promotes quality of life in the community. This aspect is very important for achieving the goals of sustainable agriculture that meet current and future human needs.

5. Due to significant differentiation of concentrations and influence of hydrogen content in atmosphere on the natural environment and other chemicals, it would be reasonable to enhance studies with other forms of combusted bio-fuels, as well as to carry out the analyses of other components of exhaust gas generated during their combustion.

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ENERGY CONSUMPTION AND SELECTED PHYSICAL PROPERTIES OF CORN-OAT INSTANT GRUELS UNDER SPECIFIC EXTRUDER CONFIGURATIONS

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ABSTRACT
The extrusion-cooking technique was used for the processing of corn-oat blends with three various screw configurations. The procedure involved the assessment of the effects of the processing conditions on energy consumption. The initial moisture level ranged from 16 to 22% and the screw speed applied during the processing varied from 80 to 120 rpm. Corn-oat gruels were tested for water absorption and bulk density. A significant effect was reported of the initial moisture and screw speed on energy demand as well as on the physical properties of extrudates. The use of the shortest version of the extruder requires more energy than with the longer ones. Corn-oat instant gruels processed with an elongated barrel showed lower water absorption compared with the shorter one. The most important parameter having an influence on the product quality was the initial moisture content of extruded blends. The obtained results can be helpful in management of sustainable settings, low-energy processing conditions and the proper characteristics of extruded instant corn-oat gruels.

INTRODUCTION

Among the many natural raw materials enriching the production of functional foods, more and more interest is attached to pseudo-cereals, such as oat (*Avena sativa*), which is characterized by the unique health and dietary values and is considered a cereal crop of the 21st century. Oat is a cereal used most often for feed purposes: only a small amount of it is intended for consumption. Oat, compared to other cereals, stands out because of its specific chemical composition and its nutrients influence the production of fortified and fitness foods suitable for human nutrition (Butt et al. 2008). Oat has high levels of non-starch polysaccharides, including pentosans and β-glucans, which are important constituents of dietary fiber, and less saccharides, in particular starch, than other cereals (Kawka 2010). This grain is a source of B vitamins, minerals, dietary fiber (soluble and insoluble) and antioxidants with the ability to remove free radicals, able to stimulate the immune system to reduce the risk of hyperinsulinemia, hyperglycemia, obesity, hypertension, coronary heart disease, and contribute to the lowering of total cholesterol (Berski and Gambuś 2014, Singh et al. 2013). Fat contained in oat has a positive ratio of unsaturated to saturated fatty acids (Zhou et al. 1999), though it could hamper processing. The extrusion-cooking technology is sustainable method used for the production of a wide range of cereal products: crisps, cereals, batteries, flat bread, pellets, texturized proteins, baby food, confectionery (chewing gum, sweets), animal feed and specialty products, e.g. modified starch or functional components. By applying pressure, specific temperature and shearing, the material is mixed, cooked, plasticized, and expanded. Following such treatment, intense changes occur in the chemical and physical properties of the materials, their results depending mainly on the extruder configuration and extrusion conditions (Mościcki et al. 2007). These technical and technological aspects of extrusion could also influence energy consumption during the processing and the degree of sustainability of this method compared with other food processing techniques.

MATERIALS AND METHODS

Corn grits (purchased from Lubella Sp. z o.o. Sp. K., Lublin, Poland) and oat flour (Metvit S.A., Warszawa, Poland) were used as the basic raw material in the amount of 25% of the blend. The materials were mixed with a ribbon mixer and moistened with a specific volume of water (Wójtowicz, 2008) to obtain the moisture content before the extrusion-cooking at the level of 16, 18, 20 and 22%. The extrusion-cooking was carried out by means of the modified single screw extruder TS-45 (Metalchem, Gliwice, Poland) with the L/D configurations of 12:1, 16:1 and 18:1, at the temperature ranged 120-135°C, with a forming die of 3 mm and at the screw speed ranged 80-120 rpm. The extrudates were dried below 10% of the moisture content and ground with the laboratory grinder LMN10 (TestChem, Radlin, Poland) to a granulation below 1 mm. Power consumption, expressed as SME (Specific Mechanical Energy), was determined at each change of the rotational speed of the screw during the extrusion-cooking of mixtures with the different initial moisture content in raw materials. The engine load and process efficiency of each test were converted into SME ($kWh \cdot kg^{-1}$) as proposed by Kręcisz (2016), taking into account the extruder working parameters. The water absorption index (WAI) was determined through centrifugation (Bouasla et al. 2017, Wójtowicz and Mościcki 2014) for each sample in three replications as the amount of absorbed water (g) per g of a dry sample. Bulk density was assessed in five replications as a mass (kg) of specific sample volume (m^3) using a measuring cylinder filled gently with corn-oat gruels (Wójtowicz et al. 2013). The obtained results were tested with the bidirectional ANOVA analysis of variance using the Statistica software (version 10.0, USA). The first factor was moisture (M) and the second was the screw speed (S). The RSM (response surface methodology) was used for fitting the polynomial models ($Y=b_0+b_1X_1+b_2X_2+b_{11}X_{12}+b_{12}X_1X_2+b_{22}X_{22}$, where X_1 was the moisture content and X_2 was the screw speed applied), and quadratic equations of the tested characteristics were designated depending on the variables used in the experiment (Table 1).

Table 1. Adequacy of two-variable model used for the tested characteristics of instant corn-oat gruels.

Parameter	Fitted model	R^2
L/D = 12:1		
SME ($kWh \cdot kg^{-1}$)	$SME=-0.39+0.07M-0.003S-0.002M^2+0.0001MS+6.03E-6S^2$	0.64
WAI ($g \cdot g^{-1}$)	$WAI=-15.52+3.32M-0.18S-0.11M^2+0.009MS+1.6E-5S^2$	0.87
ρ_b ($kg \cdot m^{-3}$)	$\rho_b=2476.05-262.91M-1.76S+8.02M^2+0.073MS+0.004S^2$	0.93
L/D = 16:1		
SME ($kWh \cdot kg^{-1}$)	$SME=-1.05+0.10M+0.004S-0.003M^2-3.47E-5MS-1.69E-5S^2$	0.64
WAI ($g \cdot g^{-1}$)	$WAI=3.53+0.18M+0.01S+0.002M^2-0.004MS+0.0002S^2$	0.55
ρ_b ($kg \cdot m^{-3}$)	$\rho_b=-898.56+169.32M-9.65S-4.61M^2+0.36MS+0.017S^2$	0.86
L/D = 18:1		
SME ($kWh \cdot kg^{-1}$)	$SME=-0.26+0.06M-0.004S-0.002M^2+0.0001MS+9.09E-6S^2$	0.68
WAI ($g \cdot g^{-1}$)	$WAI=5.36+0.39M-0.09S-0.01M^2+0.002MS+0.0003S^2$	0.10
ρ_b ($kg \cdot m^{-3}$)	$\rho_b=2125.81-204.27M-2.92S+5.22M^2+0.41MS-0.03S^2$	0.72

M – moisture; S – screw speed; SME - Specific Mechanical Energy; WAI – Water Absorption Index; ρ_b – Bulk Density

RESULTS AND DISCUSSION

The extrusion-cooking of corn gruels with the addition of oat flour in the amount of 25% with the L/D configuration of 12:1 demonstrated the specific mechanical energy consumption (SME) within 0.064-0.122 kWh·kg^{-1} (Fig. 1a). The SME values depended mainly on the moisture content ($p_{\text{-value}}$=0.000). Along with the increase of the moisture content in the mixture, greater SME values were reported, which may be also seen in the results presented by Kręcisz (2016), where an increase in the moisture content increased the SME value in corn instant gruels. Some increase of SME with higher rpm was observed for the extrudates with 18 and 20% of initial moisture ($p_{\text{-value}}$=0.064).

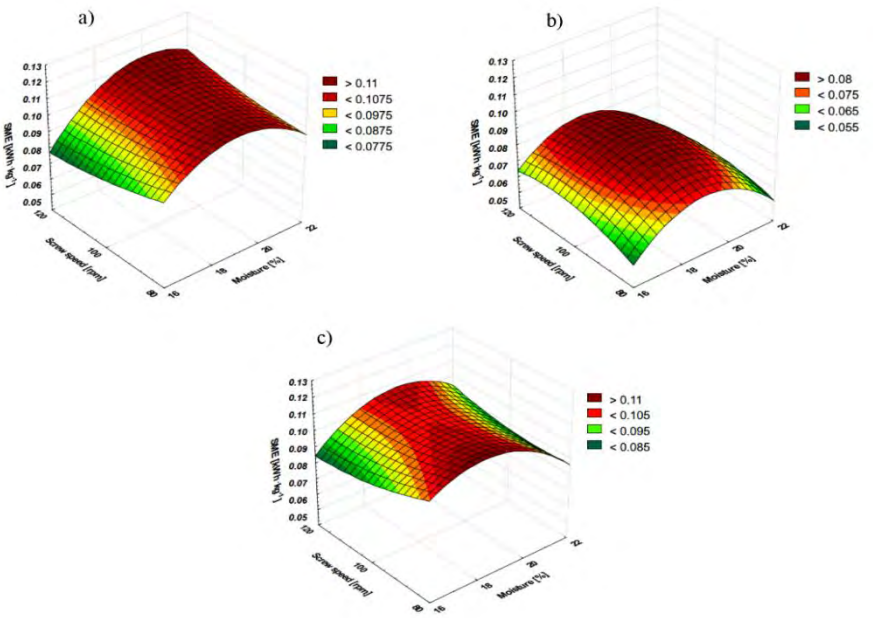

Fig. 1. SME of corn-oat instant gruels processed with various L/D configurations depending on moisture and the screw speed applied: a) 12:1, b) 16:1, c) 18:1.

When the extrusion-cooking was done using the L/D configuration of 16:1, the SME values increased along with the rise in moisture up to 18%; yet, a further increase of moisture of up to 22% resulted in a significant decrease of the SME values ($p_{\text{-value}}$=0.000). The influence of the screw speed on the SME values was also significant ($p_{\text{-value}}$=0.026). Based on the test results, it can be concluded that a higher screw speed (up to 100 rpm) resulted in a significant increase of SME consumption. Higher rpm applied during the processing resulted in the lower SME values, especially if the initial moisture content of blends was 16 and 18% (Fig. 1b). During the extrusion-cooking of corn-oat blends with the L/D configuration of 16:1, a decrease in energy consumption (0.048-0.099 kWh·kg^{-1}) was observed compared with L/D=12:1. The results with L/D=18:1 demonstrated that the increase of blend moisture of up to 20% caused the increased SME (Fig. 1c). It was found that the values of SME varied between 0.081 and 0.118 kWh·kg^{-1} depending on the applied processing parameters. Changes in SME significantly depended on the moisture of raw materials ($p_{\text{-value}}$=0.000) and the screw speed ($p_{\text{-value}}$=0.006). The higher moisture content resulted in the lower SME values of instant gruels. The results show a significant impact of the screw rational speed on the SME value as the increased rpm caused higher energy consumption up to 100 rpm. The higher screw speed caused the decrease of specific mechanical energy consumption during the extrusion-cooking process of corn-oat gruels. Similar results were reported for SME of corn extrudates (Kręcisz 2016)

and wheat and spelt flour extrudates (Wójtowicz and Juśko 2012). Water absorption is also relevant in the treatment intensity during the extrusion-cooking (Bouasla et al. 2017). The WAI of instant gruels based on corn and oat reached the values from 4.21 to 6.02 $g \cdot g^{-1}$ if the shortest L/D=12:1 configuration was applied for the processing (Fig. 2a). The WAI values were much higher than those presented for elongated extruder configurations and indicating more intensive treatment of corn-oat blends. The moisture content of the raw materials had a significant effect ($p_{\text{-value}}$=0.000) on the water absorption results. A higher moisture content level lowered the WAI of extrudates. The screw speed applied had no significant effect on the water absorption results ($p_{\text{-value}}$=0.064).

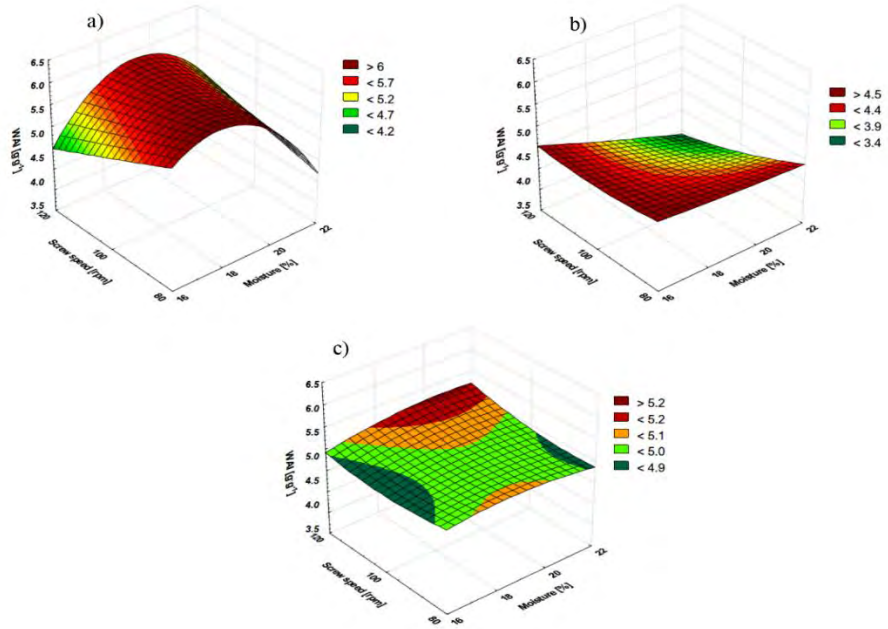

Fig. 2. The WAI of corn-oat instant gruels processed with various L/D configurations depending on moisture and the screw speed applied: a) 12:1, b) 16:1, c) 18:1.

The WAI of instant gruels processed at L/D=16:1 ranged from 3.39 to 4.82 $g \cdot g^{-1}$ (Fig. 2a). The range of the WAI reported by other authors depends on the raw materials and processing conditions used and, for example, varied from 5.58 to 6.38 $g \cdot g^{-1}$ for gluten-free extrudates based on 75:25 corn-rice blends (Kręcisz and Wójtowicz 2017). This time the moisture content ($p_{\text{-value}}$=0.769) and the screw speed applied ($p_{\text{-value}}$=0.861) had no significant effect on the WAI. The results presented in Fig. 2c for L/D=18:1 showed that the highest water absorption was seen in instant gruels processed at 18% of the initial moisture content at 100 rpm. The WAI values of instant gruels extruded with the longest barrel configuration ranged from 4.50 to 5.7 $g \cdot g^{-1}$. The higher initial moisture content in corn-oat extrudates had no significant effect on the water absorption values ($p_{\text{-value}}$=0.577). The influence of screw speed on the WAI values was insignificant ($p_{\text{-value}}$=0.290). Bulk density evaluated for instant gruels processed with L/D=12:1 ranged from 264.82 to 651.86 $kg \cdot m^{-3}$ (Fig. 3a). The higher moisture content in the recipe has a significant impact ($p_{\text{-value}}$=0.000) on the increased bulk density of extrudates. The results showed that the highest bulk density was measured for instant gruels with the highest moisture content. The effect of screw speed was not significant ($p_{\text{-value}}$=0.780).

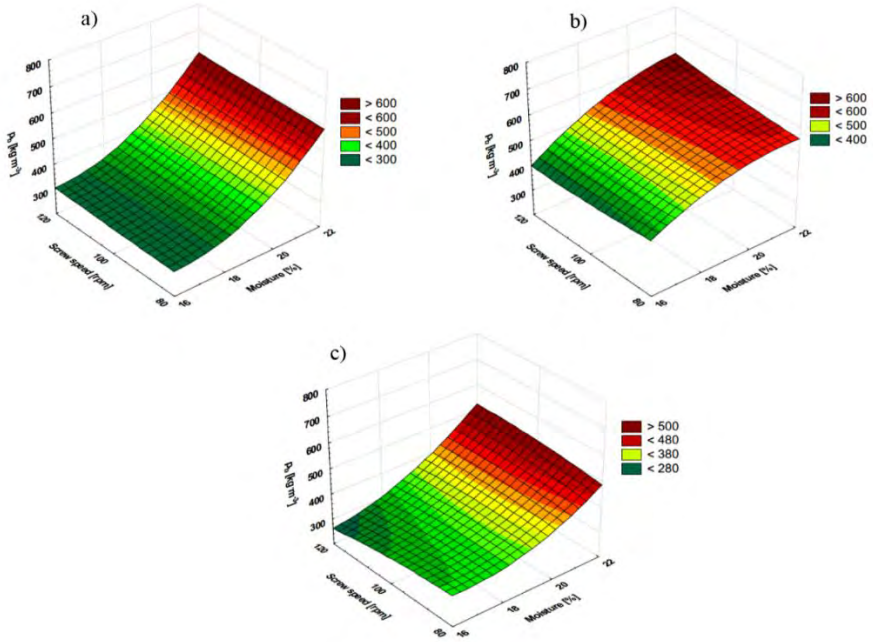

Fig. 3. Bulk density of corn-oat instant gruels processed with various L/D configurations depending on moisture and the screw speed applied: a) 12:1, b) 16:1, c) 18:1.

For corn-oat products processed at L/D=16:1, the bulk density ranged from 392.91 to 612.76 $kg \cdot m^{-3}$ (Fig. 3b). The products processed with the high initial moisture content exhibited a denser and less porous structure, which has an impact on the higher values of bulk density. The increase in the initial moisture content in corn-oat blends showed a significant effect on the bulk density values ($p_{\text{-value}}$=0.002). Increased bulk density with an increase of rpm was observed for extrudates processed at 22% moisture content, but generally the screw speed had no significant effect on bulk density ($p_{\text{-value}}$=0.122). When extrusion-cooking was done at L/D=18:1, the bulk density values of instant corn-oat gruels ranged from 237.71 to 517.36 $kg \cdot m^{-3}$ (Fig. 3c). Kręcisz and Wójtowicz (2017) reported that the density values of corn-rice extrudates varied from 137.83 to 362.18 $kg \cdot m^{-3}$ depending on the extrusion temperature and moisture content. They also concluded that density rose along with higher moisture of the raw materials used. The moisture content of raw materials had a significant effect ($p_{\text{-value}}$=0.039) on bulk density, but the effect of the screw speed on the bulk density values was insignificant ($p_{\text{-value}}$=0.798).

CONCLUSIONS

The extrusion-cooking as sustainable process for the processing of corn-oat blends produced instant gruels resulted with various products characteristics. The level of initial moisture content and the rotational speed of the extruder screw used during the treatment had a significant effect on energy consumption and the tested properties of extruded corn-oat instant gruels. The processing of extrudates using various configurations of the single screw extruder yielded different properties of the extrudates. The research demonstrated a significant impact of the screw rotational speed on the SME value. The use of the elongated extruder configuration at L/D=16:1 resulted in low SME, lowered WAI and increased density of instant gruels. The results showed the highest WAI in instant gruels processed at L/D=12:1, which was the most intensive treatment of corn-oat blends. The most important parameter having an influence on the product quality was the

initial moisture content of extruded blends. The discussed results should be helpful in selecting the adequate management and low-energy processing conditions in order to achieve the desired characteristics of extruded instant corn-oat gruels.

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EMISSION OF PARTICULATES AND CHOSEN GASEOUS EXHAUSTS COMPONENTS DURING A DIESEL ENGINE STARTING PROCESS

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Keywords: exhaust emission, diesel engine, start-up, sustainable agriculture

ABSTRACT
It is very important to reduce harmful emissions in rural areas. One of the ways is to replace old tractors and farm machinery with the modern, equipped with engines of the highest standards. However, the cost of such replacement is very high and not always acceptable, especially for smaller farmers, nevertheless, due to the needs of sustainable agriculture it should be kept up. This work focuses on exhaust harmful emission during a start-up of a diesel engine installed in a small agricultural tractor. Based on measurements and recorded data, calculations of exhaust gas emission were carried out. The results indicate that the engine starting process, and its initial temperature, have a considerable impact on the emissions during the analyzed operation period. The most important is cold start process which is responsible for most harmful pollutants emission during the initial period of engine work. The temperature of cold start is also noticeable for cold starts and for worm starts as well.

INTRODUCTION

The growing problem of increasing air pollution is more and more the outstanding issue in the agrarian areas. Tractors and agricultural machinery used for the field work and transport purposes constitute one of the emission sources. This paper regards ecological aspect of operating a tractor concerned with its engine start-up and its work right after the start. Engine start-up is especially significant in terms of reliability (Droździel & Krzywonos, 2009). On the other hand it is an extremely hazardous process in terms of emission of toxic substances (Fan, Bian, Lu, Li, & Deng, 2012; Kuranc, 2008; Kuranc & Tarasińska, 2009). Emission of exhaust gases is influenced by a number of construction design-related factors that are also very important operation-related factors (Mysłowski, 1996). Fuel and engine oils as well as engine wear-and-tear (Ambrozik, Ambrozik, & Lagowski, 2015; Wolak & Zając, 2017; Zając & Węgrzyn, 2008) are extremely significant for efficiency of the engine start-up, and in particular for preparation of proper air/fuel mixture as well as airtightness of combustion chamber of a cold engine and minimize resistances during the start-up. A tractor or machinery wear-and-tear as well as its technical advancement related to exhaust gas after treatment methods used for neutralization purposes matter, too (Merkisz, Lijewski, & Walasik, 2010; Sarkan, Stopka, Gnap, & Caban, 2017). Although a successive replacement of agricultural machinery with new and more ecological one has been being observed for several years now, numerous farmsteads still use machinery and equipment that is obsolete in terms of construction (Lorencowicz, 2016; Skudlarski, 2017). URSUS 2812 agricultural tractor, very popular in the 80s and 90s of the 20th century, still manufactured until 2009, is an example of quite simple construction that was examined.

STUDY OBJECTIVE, OBJECT AND SUBJECT MATTER

The aim of the study was to measure the emission of particulate matter and some of the gas components emitted during the engine start-up and right after the start when the engine was idling. For the purpose of the study the instruments such as the MPM4 particulate matter measuring instrument and the MGT5 exhaust gas analyser had been adjusted for continual analysis, and equipped with a computer hardware and software for recording data purposes.

The study covered measurements and analysis as well as track recording of the following parameters:

- engine rotational speed – RPM, (min^{-1}),
- engine oil temperature – T, (°C),
- emission of particulate matter – PM (Particle Matter), ($mg \cdot m^{-3}$),
- volumetric shares of chosen gas components – CO carbon oxide, CO_2 carbon dioxide , O_2 oxygen, (%), and HC unburned hydrocarbons, NO_X nitrogen oxides, (ppm),
- λ air excess coefficient computed by the analyser.

The measurement results were recorded at the frequency of 1Hz.

Next, the emissions of the distinguished exhaust gas components were computed.

METHODS

URSUS 2812 (MF235) agricultural tractor equipped with Perkins AD3.152 self-ignition engine was the object of the study (ZPC URSUS, 1987). Before the study was commenced, the tractor and its engine alongside power supply system, intake system, cooling system, lubrication system, start-up system, and the battery had undergone check-up procedures. Filters and exploitation fluids had been replaced and the injection pump and the fuel injectors had been checked and regulated. After having completed the check-up procedures, the engine load tests were conducted by means of the dynamometer stand to assess whether the condition of the engine was good.

For the purpose of the exhaust gas study, the 5-component gas analyser of „0" class - type MGT5 (MAHA, 1999) was used, additionally measuring the rotational speed and engine oil temperature. The MPM4 particulate matter measuring instrument was aligned with the exhaust gas analyser (MAHA, 2008). The aforementioned instruments, including the PC and dedicated software, made up the measuring-and-recording system. The research stand was located outside the laboratory in order to take advantage of natural temperature conditions.

Within the start-up time limits, engine stabilisation time before start ranges from 6 hours to 12 hours (Mysłowski, 1996). During the aforementioned measurements and analyses, before every measurement for the cold start-up, the tractor had been pre-conditioned in ambient conditions for approximately 20 hours. The temperature of respective parts and exploitation fluids at the moment of the cold start-up was assumed to be equal to the ambient temperature. Measurements during the so called warm start-up were conducted after the measurements for the cold start-up, given the same surrounding, had been completed.

The recorded results in relation to the data on air composition and fuel combustion process formula have allowed to define the composition of exhaust gases for the engine under consideration under the specific conditions. Details on the method of computing the mass volume of emission of respective components had already been elaborated upon (Kuranc, 2015).

RESULTS

Phenomena occurring in the course of starting a combustion engine are complicated and depend on a sequence of factors. The thorough analysis of the impact of the first fuel injection upon emission during the start-up has been presented (Fan et al., 2012). Our analyses refer to a longer period of time. In the Figure 1 the print screen of recorded parameters for the cold start-up in the ambient temperature of 5°C has been presented. Upon the first fuel injections, unburned hydrocarbons (HC), being the proof of misfiring fuel during first cycles of turning the engine shaft, are first to appear. The maximum value of their concentration stands approximately at 55ppm for 5°C. Next we have observed the decrease in the concentration of oxygen (O_2) in exhaust gases and appearance of carbon dioxide (CO_2) and carbon oxide (CO), which is the proof for the combustion process. Carbon oxide alike hydrocarbons prove imperfection of the combustion process and local lack of oxygen. It is evident within seconds after the start-up when its emission volume reaches the peak value of 0.64%. Later on, during the idling, the concentration of CO is stabilised at 0.05%.

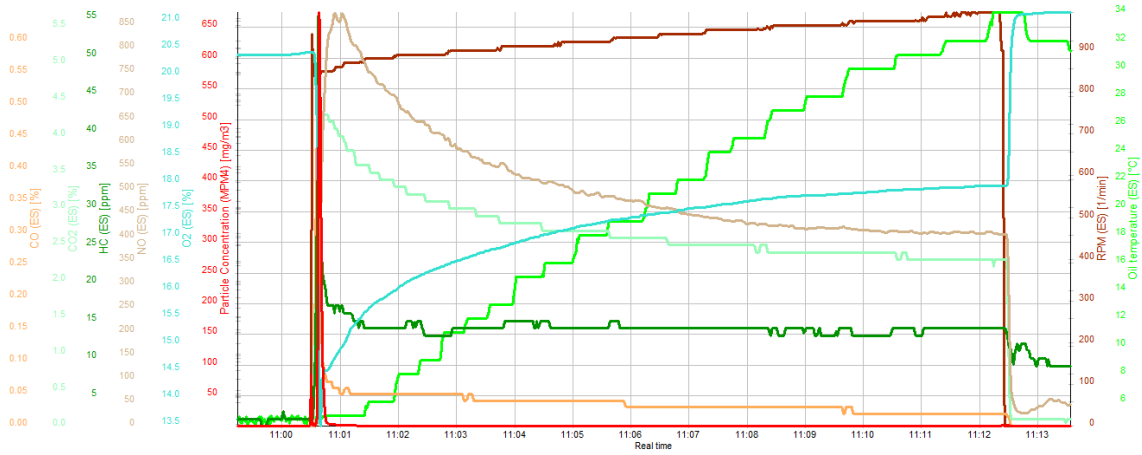

Figure 1. AD3.152 engine fumes composition changes after a cold start at ambient temperature 5°C – software print screen MAHA EmissionViewer Version 1.0.4.380

At the start-up the emission of particulate matter (PM) is also pretty evident and its peak value reaches 670 $mg \cdot m^{-3}$. Emission of PM and observed smokiness mainly result from high temperature deterioration of fuel particles and local unburning and then coagulation and conglomeration of PM. In the absence of external engine load, such a situation is limited to first cycles of operations. In subsequent seconds, PM emission decreases and after a dozen of seconds after having started the engine, its value does not, exceed 10 $mg \cdot m^{-3}$.

In the same period when carbon oxide and particles appear, nitrogen oxides (NOx) appear, too, and prove the combustion since they appear exclusively when there is high pressure and high temperature that accompany the burning process. However, the peak value of NOx emission (approximately 650ppm) is reached approximately 15 seconds later than that for hydrocarbons, carbon oxide or particles. This is caused by a very large influence of low temperature of the cylinder walls that absorb substantial quantity of heat and, in this way, hamper the process of creation of nitrogen oxides. However, their later decrease in concentration may be explained by means of diminishing resistance of motion of the engine being warmed up and thus diminishing fuel dose indispensable for

keeping it in motion, which contributes to the decrease in maximum temperature and pressure, responsible for creation of NOx, in the cylinder.

Due to the emission of exhaust gases, it is worth comparing the cold and warm start-up of the engine (Figure 2). In the case of the warm start-up, the period, during which the emission of HC, CO, NOx and PM is higher, is shortened to last for a dozen of seconds. Therefore, the peak values of their concentration multiply. In the case of PM, they are ten times lower.

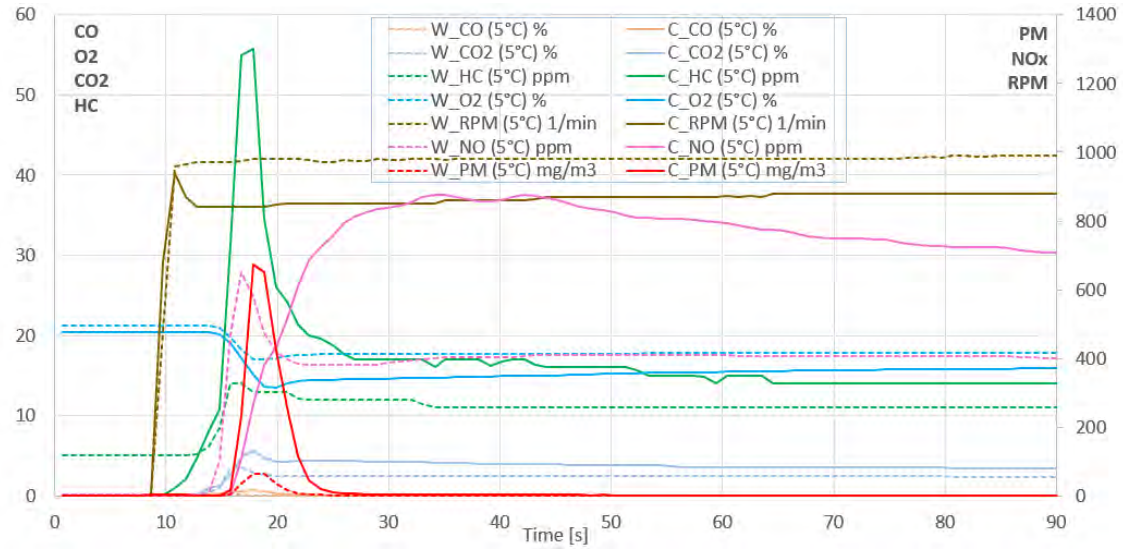

Figure 2. Volumetric shares of chosen fumes compounds at cold (C) and warm (W) startups within the first 90 seconds of work at ambient temperature 5°C for engine AD 3.152

Summing up the emission in the beginning of operations of the engine, the table (Table 1) of mass emission of gas exhaust components for cold and warm start-ups in ambient temperature of 0°C and 5°C has been presented. The table has been drawn up in respect of first 90 seconds following the start-up on the basis of computations referring to the flow of exhaust gases and their composition.

Table 1. Emissions and fuel consumption at cold and warm startups within the first 90 seconds of work at ambient temperatures 0°C i 5°C for engine AD 3.152

	Total	CO_2	O_2	CO	HC	NOx	PM	Fuel
	[kg]	[kg]	[kg]	[g]	[g]	[g]	[g]*10^{-1}	[kg]*10^{-1}
Cold 0	1.6454	0.0917	0.2967	1.5921	0.1054	1.3992	1.0507	0.2839
Cold 5	1.6453	0.0897	0.2886	1.3141	0.0797	1.4731	0.3751	0.2833
Warm 0	1.4339	0.0544	0.2877	0.4659	0.0454	0.9014	0.0317	0.1664
Warm 5	1.4330	0.0512	0.2888	0.4175	0.0477	0.7247	0.0408	0.1576

The analysis of the figures (Figure 3) indicates that cold start-ups in temperature 0°C and 5°C are similar in terms of emission, which is also the case with warm start-ups. For cold start-ups largest differences may be spotted in the case of emission of particles of 105.07 mg and 37.51 mg (64%), respectively, carbon oxide of 1592.1 mg and 1314.1 mg (17%), respectively, and hydrocarbons of 105.4 mg and 79.7 mg (24%).
In the case of warm start-ups, emission of hazardous substances is much lower than that for cold start-ups. The comparison of warm and cold start-up in temperature of 5°C for the period of 90 seconds indicates the reduction in the emission of PM by 89%, CO by 68% and HC by 40%, NO_X by 51%.

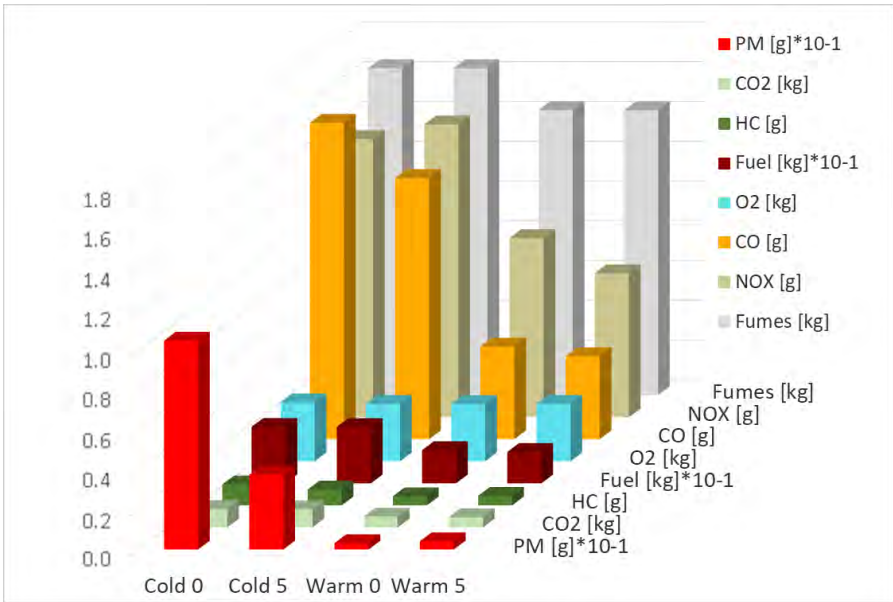

Figure 3. Emissions and fuel consumption at cold and warm startups within the first 90 seconds of work at ambient temperatures 0°C and 5°C for engine AD 3.152

In the case of fuel consumption and emission of carbon dioxide, differences have also been considerable and have amounted to 44% and 43%, respectively.

CONCLUSIONS

On the basis of the results, regarding the composition of exhaust gases during the start-up and the following warming up period, the temperature of the engine at the start-up proves to substantially influence the emission of hazardous components of exhaust gases. As far as the period of 90 seconds is concerned, the differences in the emission for the cold and warm start-up have been extremely evident and have reached the value of 89% for particulate matter, 68% for carbon oxide, 40% for hydrocarbons and 51% for nitrogen oxides.

Due to the higher internal resistance of the cold engine that inter alia results from higher viscosity of lubricant, the start-up process may happen to be a very energy-consuming process (Mysłowski, 1996). In our study the aforementioned cold start has manifested itself by approximately 44% higher fuel consumption and related approximately 43% higher emission of carbon dioxide than the warm one.

The comparison sets of cold start-ups as well as the sets of warm start-ups have not indicated such considerable differences as it has been the case with the comparison of the cold and warm start-up, however such differences also occur and the impact of ambient temperature upon the emission and composition of exhaust gases is evident. Lower temperature of the cold start-up increases the emission of particles, carbon oxide and hydrocarbons whereas it doesn't increase the creation of nitrogen oxides, which can also be observed in this case. In the case of warm start-ups, differences are noticeable, however, they are not that considerable as in the case of cold start-ups.

Taking into consideration the above, it is plausible to aim at reducing the emission and shortening idleness of the engine being warmed up as much as possible and at the same time one should pay attention to the manufacturer's recommendations in respect of the engine load when it is being warmed up.

Another way to reduce harmful emissions in rural areas is to replace old tractors and farm machinery with the new ones equipped with engines of the highest standards. However, the cost of such replacement is very high and is not always acceptable, especially for smaller farms. It is a long-lasting process requiring generations to be done, however, due to the needs of sustainable agriculture it should be kept.

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SUSTAINABLE INTENSIFICATION OF MODERN AGRICULTURE THROUGH PRODUCTION TECHNOLOGIES ON DIFFERENT READINESS LEVELS

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Key words: agriculture, technologies, sustainable intensification, technology readiness, market readiness

ABSTRACT
The modern agricultural production is facing the problem of a growing society as well as different environmental threats. To solve this issue, agricultural production should be more sustainable and efficient which can be reached by using new technologies. In the paper the most important technologies, which were evaluated to find how and when they could be used for a sustainable intensification of agriculture were highlighted by applying technology and market readiness models. It was found that technologies that collect or utilize advanced data (sensors, drones) are more applicable for use, contrary to nanotechnologies where the costs of development and applications limits the readiness.

INTRODUCTION

Agriculture is a major area of human activity affecting both its safety and well-being and the environment in which it lives. It thus becomes the primary factor conditioning global changes. Agriculture should be treated as a complex system with inherent adaptive abilities (Maciejczak, 2017). The complexity of agriculture is the result of the interplay of its individual elements as well as the interconnections of elements throughout the system and between the system and its surroundings. Over the centuries the economic pressures have led to systemic domination of agriculture based on the mechanisms of commercialization, concentration, specialization, agrarian structural change and capital-intensive intensification. Such actions have led to the imbalance in both the natural and the social systems interacting with agriculture. Currently, agriculture is facing many problems, i.e. the need for the increase of food production by 60-110% by 2050 due to the population growth while ensuring at the same time the protection of the environment under the sustainability demand (Foley at al., 2005). In order to face these issues, the dominating concept of quantitative (solely economic) growth is being replaced by the approach of the development based on the qualitative - more sustainable nature. Tittonell (2014) postulates adaptation actions within the complex agricultural system, based on strategies for further intensification, however based on the sustainable assumptions. This could be induced in a number of different ways with only the two most effective ones being pointed out here. The first is called industrial intensification and aims to maintain the industrial path based on innovation in the technological and organizational sphere. The second named as agro-ecological intensification is focusing on the intensification of more targeted agro-ecosystems, the use of more production-friendly technologies that provide better harmonization of production and environmental objectives. The future prospect of modern industrialized agricultural systems is being challenged on several fronts because of its dependence on capital, external energy and agrochemical inputs, and for its adverse impact on biodiversity and on human health (Struik et al., 2014).
Regardless of the strategic options of sustainable intensification, this concept requires application of innovative technologies. However, these technologies of modern agriculture are in different stages of development and use. This significantly influences

the dynamics of changes in agriculture. Therefore, the main objectives of the paper are threefold. Firstly, the paper aims to present, based on literature review, the needs and solutions for innovative technologies which are most promising for further development of modern model of sustainably intensive agriculture. Secondly, using the foresight approach, it aims to assess the technology and market readiness levels of selected technologies. Finally, based on experts' opinion, it will provide the recommendations for development and diffusion of the most perspective technologies.

MATERIALS AND METHODS

This paper uses different methodologies selected to correspond best to the goals set. The investigations are based on primary and secondary data sources. Firstly, the literature review of scientific papers was performed. Using different key words, based on abstract review, there were selected 79 papers, which later, after full text analysis, were reduced to 17. Based on the review 10 most promising technologies were selected, 6 from crop production and 4 from animal production. The primary data comes from the Real-Time Delphi survey. The rationale for the choice of the foresight heuristic Delphi method was more the hypothetical then empirical impact of selected technologies for modern agriculture. There was used Real-Time Delphi approach (Grisham, 2009). Using a web-based tool a qualitative and quantitative survey was held. The questionnaire was open from 1st May 2017 to 31st August 2017. There were identified 10 experts from two countries: Poland and Germany. From each country participated 5 experts being: farmers, technology developers and traders, consumers, policy makers and academics. All experts were chosen deliberately because of their knowledge about agriculture and its technological advancement. There was a basic assumption about possible application and impact of assessed technology in mit-term perspective of 2025 having in mind the needs of sustainable development. Two scales of Technology Readiness Level (TRL) and Market Readiness Level (MRL) were applied. TRL enables the assessment of the maturity of a particular technology and the consistent comparison of maturity between different types of technologies. It is based on a scale from 1 to 9, with 9 being the most mature technology (EARTO, 2011). MRL enables the assessment of the readiness of technology for commercialisation and diffusion. It is based on a scale from 1 to 5, with 5 being the most marketable (Aasrud et al., 2010). To analyse linkages between TRL and MRL the rho-Spearman correlation test was used (Parlińska and Parliński, 2011).

RESULTS AND DISCUSSION

Modernisation in agriculture is a very relative concept (ILO, 1991). It differs very much depending on the country, the region as well as on individual farm perspective. Many factors are associated with the progress made due to implementation of new techniques, technology or other innovative solutions. Therefore, for the purpose of this research, the framework for the concept of the modernization of agriculture will be established. The analysis is limited to the European perspective with the focus on developed farms which are considered as enterprises. For such farms, implementation of innovations, esp. in forms of new technologies is attached to the umbrella approach of precision agriculture. It is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops, or to aspects of animal rearing (Takacs-Gyorgy et al., 2014). The benefits to be obtained are chiefly due to increased yields and/or increased profitability of production to the farmer. Other benefits are better working conditions, increased animal welfare and the potential to improve various aspects of

environmental stewardship. As stressed by (Weiss, 1996) the implementation of precision farming has become possible as a result of the development of innovative technologies i.e. sensors, or drones combined with procedures to link mapped variables to appropriate farming practices such as tillage, seeding, fertilization, herbicide and pesticide application, harvesting and animal husbandry. Subsequently, it is relying on automatic monitoring of individual animals and is used to monitor animal behaviour, welfare and productivity as well as their physical environment. Advances in nanotechnologies could also be implemented in a wide spectrum i.e. for health maintenance of both animals and plants. Nevertheless, one needs to remember that the adoption of this concept encounters specific challenges not only due to the size and diversity of farm structures but also due to the readiness of available technologies to meet high demands of technological, economic, social and environmental efficiency. The detailed literature review enabled us to distinguish 10 technologies that could contribute the most to the development of precision agriculture (table 1).

Table 1. Top 10 technologies of future sustainable agriculture – a literature review

Technology	Description	Authors
CROP PRODUCTION		
NANOTECH -NOLOGY	Use nanotechnology for disease control in crop production.	Fraceto et al., 2016, Kuzma & VerHage, 2006
YIELD	Use all the data that is collected from guidance system to get an overview over your work and in- and output.	Takacs-Gyorgy et al., 2013, Francik, 2010
SOIL	Use tractor mounted sensors to get information about the nitrogen in the soil to control the fertilizer use.	Frewer et al. 2011, Sanders and Masri, 2016
DRONES	Use drones to analyse e.g. the chlorophyll content of the crops to use fertilizer or pesticides more precisely.	Gozdowski et al., 2010, Dukaczewski and Bielecka, 2009
SENSORS	Get more sensors connected through new and cheaper systems than SIM Cards.	Jensen et al., 2012, Ojha et al. 2015
AUTONOMY	Use fully autonomous tractors to reduce labour costs and work more efficiently.	Dukaczewski and Bielecka, 2009; Xiweia and Xiangdong, 2007
ANIMAL PRODUCTION		
DEVICES	Use smart devices like electronic earmarks to get information about the position and health of animals.	English et al., 2013, Cupiał et al., 2015
DATA	Use on-time software to get recent information about e.g. the feeding behaviour of your animals.	Tyler and Griffin, 2016, Cupiał et al., 2015
NANOTECH -NOLOGY	Use nanotechnology to make more precise diagnoses as well as creating smart medicine.	Parisi et al., 2014, Głód et al., 2014
SENSORS	Use more sensors to monitor and control different variables of the digestion and wellbeing of the animals.	Kopiński ,2014, Ojha et al., 2015

Source: own research based on the literature review

The Delphi results of the technological and market readiness levels of selected technologies (fig. 1 and 2) showed for both perspectives similar results. Also, the calculated rho-Spearman correlation between TRL and MRL confirmed a strong correlation on the level of 0.933 ($r < 0.001$). It means that the market readiness is closely associated with the technological readiness. The more technology is prepared to be implemented on the market the more market is creating conditions for its release. With this respect, the majority of experts agreed also on the importance of knowledge, which could be considered as a fourth dimension of market readiness. The farmers need to know how the technology works and what the benefits of its use are, not on experimental fields, but in other farms.

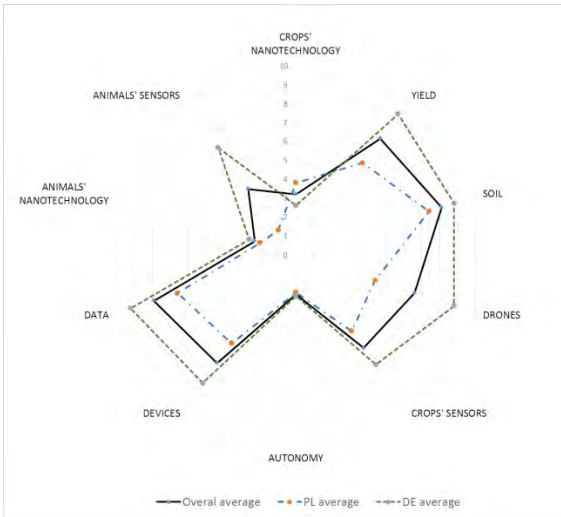

Fig. 1. Technology Readiness Level of analysed technologies. *Source: own investigation*

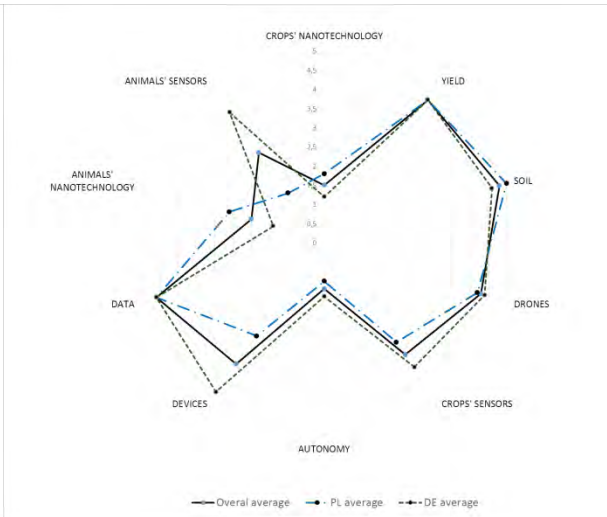

Fig. 2. Market Readiness Level of analysed technologies. *Source: own investigation*

The analysis and evaluation of the different opinions of the experts showed that there are many similarities as well as differences in the way Polish and German experts are seeing the market and technology readiness of the chosen technologies. The average value for nanotechnology in crop production in terms of technology readiness was 3.2. This is a quite low value. The German experts saw an average TRL at 2.6 and the Polish experts at 3.8. The market readiness was on average also very low (1.5). With 1.8 the Polish experts were more optimistic with this technology while the German experts saw it at a low value of 1.2. The most common opinion was that Nanotechnology is an interesting technology but application will need more time and a high investment. Some experts were not optimistic at all but this is often the case when talking about technologies of the far future. Collecting data from your guidance system is far readier in terms of technology and market readiness. With an overall average TRL of 7.6 and 9.2 in Germany and 6 in Poland and an average MRL of 4.6 in general, in Poland and Germany the technology is already adopted in those countries. From German experts, there were concerns about the user-friendliness of the product. In Poland, this technology is just used by big farms which means that there is some space for development. Beside data collection, soil analysis was also a technology that was ranked highly in terms of readiness levels. The average values for TRL were 8.1 overall, 7,4 for Poland and 8.8 for Germany. The values for MRL were 4.8 in general, 5 in Poland and 4.6 in Germany. This technology is also already adopted to the market and needs some improvements in terms of costs so that also small farmers can use it. Drones had average values more in the middle field (6.6). What was interesting is that the TRL for Germany (8.8) and Poland (4.4) were quite different. The same occurred for the MRL where the average for all was 4.1, for Poland 3.8 and for Germany 4.4. The German experts were still not happy about the costs. Furthermore, experts argued that the technology is not useful due to the fact, that modern satellite pictures could bring the same information. The Polish experts were really sure that this technology will help to become more sustainable. Sensors left also some room between both experts. In general, the TRL was 6,1 while the value in Germany was 7.2 and in Poland 5. The market readiness was in average 3.5 and in Poland 3 and Germany 4. The opinion of the Polish experts was really positive on that technology. The opinions of the German experts were also positive. One expert said that the technology will only be important if a farmer uses a completely automatic system.

With autonomy in crop production, that last technology was a big topic of the future. The TRL in general was 2.1 in Germany 2.2 and in Poland 2. The MRL was low as well. In average, it was 1.4 in Germany 1 and in Poland 1. The biggest problem from German experts were the legal issues while the Polish experts argued more that autonomy will just be a topic of some niches. In animal production, the devices got an average TRL of 7.1. The value for Poland was 5.8 and the value for Germany 8.4. The MRL was 3.9 in average, 3 in Poland and 4.8 in Germany. Here you can see again big differences. The Polish and German concerns are that this technology is too expensive to be adopted. For data analyses in animal production the values of TRL are also different. In average, it is 7.9 while for Poland it is 6,6 and for Germany 9.2. The MRL is in both cases 4.6. In Germany, the technology should be better developed in terms of usability. The Polish doubts are connected with the farmers' knowledge for using this technology. Nanotechnology in animal production seems to be again a technology that will be more interesting in far future. Thus, it gets low values of TRL (overall average 2.3, Germany 2.6 and Poland 2) and MRL (overall 2, Poland 2.6 and Germany 1.4). It is interesting that those values are lower than the values for Nanotechnology in crop production. The argumentation was in part the same, but it seems that the experts are more comfortable to use this technology with crops than with animals. The last technology was sensors in animal production. The average value for TRL was 4,3 while Germany was really high with 7 and Poland really low with 1.6. The MRL was in average 2.8 while in Poland 1.4 and in Germany 4.2. The Polish experts are seeing many problems in the difficulty of measuring the values. German experts were more optimistic, due to the fact that sensors are getting cheaper. One key of this technology is that the data should be made usable.

CONCLUSION

The conducted research confirmed that development of modern model of agriculture requires strategic options based on sustainability approach applied similarly and comprehensively on the intensification concept. This could be obtained and driven by the application of modern technologies. These technologies have a great potential to provide benefits of sustainable values. It was proved, however that the technologies that could bring these values are on different technological readiness and thus its market readiness is also different. The highest TRL and MRL results showed technologies that collect (i.e. sensors or drones) or use (soil or yield management systems) of data. The lowest results were obtained with very advanced technologies connected to nanomaterials. This suggest that for sustainable management of modern agriculture the more detailed data are needed and the more technology is fulfilling this requirement for knowledge building the bigger its readiness and diffusion. On other hand nanotechnologies, which development is very expensive are very promising, but in mid-term perspective they application due to the costs and efficiency is limited.

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ANALYSIS OF ENERGY PROPERTIES AND EMISSIONS FACTORS OF SELECTED PLANT BIOMASS AND PEAT

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ABSTRACT
The use of agricultural biomass for renewable energy purposes is part of the assumption of sustainable agriculture standards and leads to change current management of biomass from agricultural and forestry production and to development of agroenergy production. Considering the above the paper describes energy properties and emission factors for peat and selected biomass species (wood chips-pine, oat grains, wheat straw) and the mixtures of peat with biomass to demonstrate differences in emissivity in the combustion process by using a mixture of biofuel and fossil fuels. Studies have shown that the net calorific value of the tested materials is similar (about 15 $MJ \cdot kg^{-1}$), but the highest value was recorded for mixtures peat-oat grains and obtained 15.75 $MJ \cdot kg^{-1}$. Ash content was highest for peat 16.58% but volatile matters content was lowest 50.14%. Wood chips characterized by the highest carbon content of 45.73%, hydrogen at 6.5% by oat grains, and 2.96% nitrogen and sulphur 0.25% by peat. Determined emission rates indicate a reduction of 4-10% CO, 1-5% CO_2, 25-58% NOx, 19-61% SO2, 26-41% dust depending on the type of used biomass.

INTRODUCTION

The energy sector plays an important role in European and global industry and finance. The economy of almost every country is determined by the costs and availability of coal, crude oil and natural gas. However, the use of fossil fuels significantly contributes to excessive carbon dioxide emissions into the atmosphere (Nelson *et. al.,* 2014). Studies have shown that in 2010 more than two thirds of total anthropogenic greenhouse gas emissions came from fossil fuel combustion (IPPC, 2014). The main assumption of a low-carbon economy is the achievement of specific economic effects with the least possible use of natural resources and the minimization of environmental pollution (Xie, 2014; Nakomcic-Smaragdakis *et al.*, 2016). The diversification of energy sources is an important issue in implementing a low carbon economy in Europe. Hence, new energy sources are being sought, both for the very efficient ones and those which contribute to the reduction of harmful emissions to the environment.

Peat is produced by the same processes as hard coal and lignite and is the initial stage in the formation of these minerals. Just like hard coal, peat can be used for energy purposes, as fuel in private homes or as fuel in power plants (Ozaist, 2012). The most commonly used for the combustion of peat products are (Ilnicki, 2002): peat fuel, peat briquettes and peat bricks produced by pressing low or transition peat and finally peat charcoal. Power plants also use peat powder (combustion in pulverized and fluidized furnaces), and the latest solution is the combustion of volatile substances released in the gasification process of the raw material (Ozaist, 2012). In power plants using peat deposit, the raw material is usually blended with the other type of fuel especially with biomass (Ozaist, 2012). The production of biofuels from plant biomass compared to the use of conventional energy sources is very beneficial for environmental, economic and energy security reasons (Pimentel and Patzek, 2005). Among the most important environmental benefits of biomass fuels is the significant reduction in greenhouse gas emissions, primarily methane and carbon dioxide (the CO_2 released during biomass processing is then absorbed by the growth of the biomass, the emission balance is close

to zero) and also biodegradability of biomass (Jahirul *et al.*, 2012; Tumuluru *et al.*, 2015; Fournel *et al.*, 2015). Moreover, there is the possibility of efficient management of organic waste from various industrial sectors and no problem with the storage of toxic waste (Jegannathan *et. al.*, 2009; Chisti, 2008).

The aim of the study was to present the energetic properties of selected plant biomass, peat and peat mixtures with the studied biomass and the presentation of differences in emission levels for raw materials and mixtures of biomass with peat.

MATERIAL AND METHODS

The research focused on the results of a technical and elementary analysis of peat, plant biomass (wheat straw, wood chips and oat grains) and peat mixtures (1:1/m:m) with studied biomass. Studies were performed for the raw material and mixtures samples in order to determine the difference in physicochemical properties of these materials. An assessment of volatile matter (V), ash (A) and moisture (W) content in the tested samples of solid biofuels was done by using thermogravimetric analyser Leco TGA701 with the PN-EN ISO 18123:2016-01, PN-EN ISO 18122:2016-01 and PN-EN ISO 18134-2:2015 standards, respectively. The net calorific value (Q_i) was determined according to PN-EN 14918:2010 standard, using a calorimeter LECO AC 600. The content of other combustible solid fractions FC (%) was determined from Eq. (1):

$$FC = 100 - W - A - V \tag{1}$$

where: W – moisture content (%), A – ash content (%), V – content of volatile matter (%).

The fuel ratio (FR, %) was calculated according to Eq. (2):

$$FR = FC/V \tag{2}$$

In turn, the elemental analysis (coal, hydrogen, nitrogen, sulphur content) was carried out using an automated analyser Leco CHNS 628 in accordance with the PN-EN ISO 16948:2015-07E and PN-EN ISO 16994:2016-10 standards. Oxygen in the samples was determined using the indirect method specified in Eq. (3):

$$O = 100 - C - H - N - S - W - A \tag{3}$$

where: C, H, N, S, O – content of elemental carbon, hydrogen, nitrogen, sulphur, and oxygen in the fuel (%)

The determination of emission levels of individual gases and dust was based on the factor's emission method. The CO_2 emission factor was calculated using the calculation method based on the carbon content and calorific value of fuels. For the calculations were used the formulas 3-5 (Borycka, 2008):

SO_2: $$E = B \cdot w \cdot S \tag{3}$$

$NO_x/CO/CO_2$: $$E = B \cdot w \tag{4}$$

Dust: $$E = B \cdot w \cdot A \cdot 100/(100 - K) \tag{5}$$

where: E – amount of emission (kg), B – fuel consumption (Mg), S – sulphur content in fuel (%), A – ash content in fuel (%), K - combustible components content in dust (5% for biomass) (%), w - emission ratio.

The results underwent the statistical analysis conducted by means of the STATISTICA 13 software. The normality of distribution of the properties under consideration was checked by means of the Shapiro –Wilk compliance test. The impact of a certain matter upon the value of incineration gross and net calorific value, ash content, volatile matter, C, H, N, S content and basic element and heavy metals content in ash was assessed by means of the ANOVA test. Homogeneity of variance was checked by Levene's test. In case of heterogeneity of variance, the F Welch test was performed. The significance level of the diversity was also confirmed by means of the Tukey (HSD) test. All the statistical analyses were conducted at the significance level of $\alpha = 0.05$.

RESULTS

Studies have shown that the highest net calorific value characterized in oat grains 15.72 $MJ \cdot kg^{-1}$, and the lowest in wheat straw 15.32 $MJ \cdot kg^{-1}$ (Table 1) and the difference was approx. 2.5%. Among mixtures, the highest net calorific value was obtained for peat-oat grains (15.75 $MJ \cdot kg^{-1}$) and the lowest for peat-wheat straw (14.51 $MJ \cdot kg^{-1}$) with a difference of 7.8%. Intermediate results were recorded for peat and wood chips, while the lowest was peat and wheat straw. Net calorific value of mixtures of peat-wood chips and peat-wheat straw are lower than the net calorific value of raw biomass (and also peat), and the net calorific value of material consisting of peat and oat grains has a slightly higher net calorific value than raw oat grains and peat. In each case, the addition of peat reduced the net calorific value of the mixture relative to raw biomass as opposed to oat grains. The studies have shown the smallest ash content in wood chips, only 0.54%. Also in oat grains, the content of non-combustible substances is small, only 2.71%. The ash content in wheat straw is 8.37% of its weight, while the ash content of peat is about 16.5%. The best peat additives in this aspect are wood chips and oat grains. Analysis of the test results shows that their admixtures will not significantly affect the amount of ash content and the level of net calorific value. The ash content after combustion process of peat and biomass mixtures is higher each time than in the case of raw wood chips, oat grains or wheat straw. In the first two cases, the percentage of ash increases several times. Nevertheless, given the amount of ash produced during the combustion of biomass and peat mixtures it is much more beneficial than combustion peat itself. In each case, after combustion process such material, less ash is produced than in the case of combustion only peat. The results of the analysis indicate a low coalification of wood biomass, wheat straw and oat grains. In each case, the results of volatile matter content were about 70%. Peat in turn, is a much more metamorphic raw material which the coagulation processes are more advanced in. This is evidenced by the lower volatiles matters content, which fluctuate within 50%. The addition of peat influenced the reduction of the volatiles in mixtures relative to raw wood biomass, oat grains and wheat straw. Materials consisting of peat and wood chips and peat and wheat straw have similar volatile components (57.46% and 58.22% respectively), corresponding to a greater degree of coagulation of raw peat. In the case of oat grains-peat mixtures, the addition of peat had a lesser effect on the amount of gaseous substances emitted during pyrolysis process. There was a decrease in the volatiles relative to oat grains, but the content of the coal (C) in this mixture was the lowest. The percentage share of coal content in the tested materials remained at a similar level, ranging from 41.04% to 45.73%. It was at the same time the main elementary element of each biomass studied. There was also a divergence in the results of hydrogen testing. The analysed materials differ considerably in terms of the proportion of nitrogen and

sulphur in the flammable substance. Most of the nitrogen contained peat (2.96%) - almost six times more than wheat straw (0.52%), which was also characterized by a very low sulphur content of only 0.07%. The analysed biomass types exhibited similar technical parameters, as evidenced by the 0.19-0.23 range of the fuel ratio (FR). The low ratio suggests that the fuels were characterised by low content of combustible solids (13-15%) and high content of volatiles (68-71%), which is characteristic for the biomass. In the case of peat, the fuel ratio was higher (0.43) than for biomass and mixtures. The mixtures also obtained similar technical characteristics in which the fuel ratio was in the range of 0.29 to 0.33 and content of combustible solids was higher than in the raw biomass (17-19%), while the volatiles content was lower (57-61%) but higher than peat (50.14%).

Table 1. Physicochemical properties of analysed biomass and peat

Material	Wood chips (pine)	Oat grains	Wheat straw	Peat	Peat-wood chips (1:1)	Peat-oat grains (1:1)	peat-wheat straw (1:1)	F
Q_i (MJ·kg^{-1})±S_x	15.42a ±38.55	15.72b± 9.23	15.32a± 5.77	15.58e ±8.08	15.12d ±19.62	15.75b ±12.70	14.51c ±55.24	741.75*
W (%)±S_x	14.41f ±0.12	11.81d± 0.02	8.05b± 0.02	11.52a ±0.01	13.31e ±0.04	11.51a ±0.07	10.31c ±0.16	1658.21*
A (%)±S_x	0.54a ±0.02	2.71b ±0.01	8.37c ±0.03	16.58d ±0.01	10.14e ±0.05	9.67f ±0.06	12.19g ±0.10	29160.43*
V (%)±S_x	71.72a ±0.19	69.71b ±0.26	68.65c ±0.02	50.14d ±0.01	57.46e ±0.06	61.04f ±0.05	58.22g ±0.03	11154.22*
FC (%) ±S_x	13.34b ±0.33	15.77d ±0.03	14.94c ±0.01	21.76e ±0.02	19.10a ±0.07	17.79f ±0.05	19.28a ±0.07	1410.66*
C (%)±S_x	45.73d ±0.85	41.86ab ±0.05	41.04a ±0.05	42.68bc ±0.02	43.28c ±0.08	42.12bc ±0.20	41.43a ±0.11	52.05*
H (%)±S_x	5.8d ±0.06	6.5e ±0.02	5.59b ±0.01	4.81c ±0.02	5.13a ±0.07	5.56b ±0.08	5.19a ±0.02	324.30*
N (%)±S_x	0.91a ±0.01	1.53b ±0.02	0.52c ±0.01	2.96d ±0.02	2.21e ±0.05	1.97f ±0.08	1.23g ±0.04	1024.93*
S (%)±S_x	0.09b ±0.01	0.11a ±0.00	0.07b ±0.00	0.25d ±0.01	0.16c ±0.00	0.11a ±0.00	0.14ac ±0.00	138.09*
O (%)±S_x	32.61e ±0.66	35.56b ±0.09	36.42b ±0.05	21.45c ±0.02	25.94d ±0.18	29.18a ±0.25	29.65a ±0.10	1067.53*
FR	0.19	0.23	0.22	0.43	0.33	0.29	0.33	-

*S_x - standard deviation; * - Significant value of the F test at significance level α = 0.05; a-g - Significant difference at the level of significance of α=0.05; F - F test*

The ANOVA test proved that the kind of matter under consideration did have an impact indeed upon of all tested characteristics (Table 1). The Tukey HSD test proved that the properties under consideration are substantially diversified in those groups for majority of the values of $p<0.05$.

Table 2 shows the results of estimated emission factors for tested materials. It can be seen that levels of carbon monoxide emissions are similar for all raw materials (50-56 kg Mg^{-1}). In the case of carbon dioxide, the highest emission factor was found for wood chips, while the lowest for wheat straw and the difference was 10.24%. Among mixtures, the highest emissivity of CO_2 is the mixture of peat and wood chips, whiles the smallest of peat-wheat straw mixture and is 4.28% lower. The use of peat mixture with wood chips causes in a 5.34% reduction in CO_2 emissions, 1.30% peat with oat

grains, and 2.92% peat with wheat straw. By analysing NO_x emissions among raw materials, the highest emissions are peat (10.45%) and in biomass group oat grains (5.39%).

Table 2. Emission factors of analysed fuels ($kg \cdot Mg^{-1}$)

Material	CO	CO_2	NO_x	SO_2	Dust
Wood chips (pine)	56.34	1379.53	3.20	0.08	0.68
Oat grains	51.58	1262.98	5.39	0.10	3.43
Wheat straw	50.57	1238.24	1.83	0.07	10.57
Peat	52.58	1287.51	10.45	0.26	20.94
peat-wood chips (1:1)	53.32	1305.72	7.80	0.21	12.81
peat-oat grains (1:1)	51.89	1270.72	6.95	0.10	12.21
peat-wheat straw (1:1)	51.04	1249.90	4.34	0.12	15.40

The use of peat and biomass mixtures also leads to a reduction in NO_x emissions compared to raw peat in combustion process, and when it mixed with wood chips, the reduction is 25.36%, while with the oat grains is 33.49% and with wheat straw is 58.47%. The same situation is in the case of SO_2 emissions. The mixture of peat with wood chips is characterized by a lower SO_2 emission factor of 19.23% compared to peat, oats grains by 61.54%, and wheat straw by 53.85%. Mixing peat with biomass also leads to a reduction in dust emission, and for wood chips it is 38.83% lower, oat grains 41.69%, and wheat with 26.46% as compared to raw peat.

CONCLUSIONS

Studies have shown that the most favourable is combustion a mixture of peat and oat grains. The material obtains the highest net calorific value, generating the smallest amounts of ash among all the examined mixtures and almost a twofold lower amount than those formed by the combustion process of peat. The remaining mixtures are less caloric than raw peat, but as a result of their combustion, there is definitely less ash than use only peat. The least favourable was the combustion of a mixture of peat and wheat straw. Net calorific value for this mixture is not only lower than in case of raw peat, but also lower than that recorded during the combustion of wheat straw. The addition of peat to each biomass resulted in an increase in ash content compared to the incineration of only biomass (the most significant increase was for peat and wood chips as well as peat and oat grains); however, after biomass combustion there is less ash than after peat combustion. The low-emitting fuel with the smallest ash content is a mixture of peat and oat grains. The content of volatile matters in individual biomass components is similar, while peat carburization processes are much more advanced.

Research also has shown that the addition of biomass to fossil fuel which is peat, results in lower emission factors. It should be emphasized that the most favourable indicators were noted for NO_x and SO_2, where the emission reductions were 61.54% and 41.69%, respectively, for the addition of oat grains. The addition of biomass to peat in the combustion process also contributes to dust emission reduction of up to 41.69% in the case of oat grains. Therefore, it should be pointed out, that the addition of biomass to fossil fuel in the form of peat contributes to the reduction of pollutant emissions in the combustion process.

In conclusion, new biomass management systems from agricultural and forestry production should be sought, which will contribute to the development of agroenergy production. The use of agricultural biomass for renewable energy purposes is part of the assumption of sustainable agriculture standards by the possibility of using waste biomass from agricultural production. Exploiting agro-biomass for energy purposes as a supplement to the fossil fuels will primarily contribute to reducing the consumption of conventional fuels and consequently reducing greenhouse gas emissions and harmful emissions to the environment during their combustion.

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USE OF ACTIVE SUBSTANCE DEPENDING OF THE FORMULATION OF PLANT PROTECTION PRODUCTS APPLIED WITH AGRICULTURAL SPRAYERS. A CASE STUDY OF WINTER WHEAT IN POLAND

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Keywords: crop protection, plant protection products, active substance, dose

ABSTRACT
The study into the use of an active substance per hectare was performed to examine the matches of plant protection products applied by agricultural sprayers, containing the same active substance but with a different formulation. The doses of fungicides and herbicides registered in Poland to protect winter wheat against two economically important pests were analyzed. On the basis of the results it is difficult to draw any definite conclusions regarding the influence of formulation on the dose of active substance used per hectare. In some cases, use of a different formulation may be connected with the different amount of an active substance used per hectare. However, the results strongly differed depending on the analyzed active substances. It seems that more cases should be examined to determine whether there are any discernible patterns.

INTRODUCTION

In agriculture and food production numerous studies regarding overall safety (Kazimierczak et al. 2016, Melski et al. 2011) and residues in crops (Szpyrka et al. 2017, Jankowska et al. 2016) are performed. The fertilization and other aspects of plant cultivation influence the crop (Bereś 2016, Pikuła and Rutkowska 2014, Hurej et al. 2017, Zarzyńska et al. 2017, Matyjaszczyk 2011), but the public is especially concerned by the pest management, particularly chemical pest control.

From chemical point of view pesticides (plant protection products) are usually mixtures of active substance(s) and other components (solvents, emulsifiers, safeners, synergetics, adjuvants etc), introduced on the market in different formulations. The component of plant protection product that acts against the pest is the active substance. The aim of the other components is, generally speaking, enabling the safe and effective use of the active substance. From the point of view of environmental safety however it is not only the content of the active substance, but also the formulation and the form of application that counts (Doruchowski et al. 2017, Hoesel et al. 2017, Parafiniuk et al. 2015). Integrated pest management (IPM) – obligatory in all European Union member states from the beginning of 2014 emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems. The professional user should keep the use of pesticides and other forms of intervention to levels that are necessary; among others by reduced doses, reduced application frequency or partial applications (Directive 128/2009).

The aim of this paper is to answer the following question: If and how does the formulation of plant protection products affect the dose of active substance used per hectare?

MATERIAL AND METHODS

Research into the Polish register of plant protection products in May 2017 was carried out. The study was performed using fungicides and herbicides registered for the protection of winter wheat (the most important Polish crop as regards the cultivation area) against the same pests. The selected pests were powdery mildew (*Blumeria*

graminis) in case of fungicides and lamb's quarters (*Chenopodium album*) in case of herbicides. The both pests are economically important in winter wheat production in Poland. All products on the market were analyzed. Only formulations registered to be applied with agricultural sprayers were considered.

The objective of the research was to find matches of plant protection products applied with agricultural sprayers, containing the same active substances and registered for protection of winter wheat against the selected pests in different formulations. To calculate the amount of an active substance per hectare it was estimated (following the methodology of Matyjaszczyk (2017)) that the products were applied according to the maximum recommended dosage.

RESULTS

During the research it was noted that the occurrence of products which contain identical active substances for winter wheat protection in different formulations was not uncommon. In the course of the research it became evident that several matches of products with different formulations are registered to control the selected pests in winter wheat. The details are presented in Table 1 (herbicides) and Table 2 (fungicides). It was found that among fungicidal active substances fulfilling the search criteria only one: tebuconazole was registered in different formulations. For the herbicides six cases fulfilling the search criteria were found: four active substances solo plus two combinations of two different active substances.

The results as regards the dose used per hectare are the following:

- All herbicides matching the search criteria were registered in two different formulations, the only fungicide was registered in three different formulations.
- For one active substance, namely herbicide metsulphuron methyl identical maximal dose was recommended, regardless of the trade names of the products and the formulation.
- For both herbicidal combinations of active substances different maximal doses were recommended in different formulations, however recommended dose of one active substance was higher, while of the second – lower. Since it is very difficult to compare quantitative use of different active substances, therefore in both cases it is difficult to draw any conclusions regarding the quantitative use of active substance per hectare.
- For two active substances, herbicide MCPA and fungicide tebuconazole the maximal recommended dose depended rather on the product, that on the formulation. In both cases majority of products on the market, regardless of the formulation were registered in identical dose: for MCPA 750g/ha, while for tebuconazole 250 g/ha. However for MCPA one product was registered in significantly higher dose 900g/ha and for tebuconazole three products were registered in slightly higher dose 258 g/ha and one in significantly higher dose 312,5 g/ha.
- For two active substances: herbicides tribenuron and fenoxaprop-P the formulation seems to influence the maximal dose of active substance recommended per hectare. In case of fenoxaprop-P the registered dose is higher in formulation EW than in formulation EC and the difference is below 10%. For tribenuron results are not so clear because several different doses is registered under different trade names, however generally speaking the recommended dose was higher in formulation SG, than in formulation WG.

Table 1. Comparison of matches of herbicides containing the same active substance in different formulations registered for protection of winter wheat against *Chenopodium album*, registered in Poland in May 2017.

Active substance	Formulation*	Product trade name	Dose	Content of active substance	Total use of active substance
MCPA	SL	Premier 300 SL	3 l/ha	300 g/l	900 g/ha
		Agritox 500 SL, Premier 500 SL	1,5 l/ha	500 g/l	750 g/ha
		Agroxone Max 750 SL, Ceridor MCPA 750 SL, Chwastoc Professional 750 SL, Dicoherb 750 SL, Premier 750 SL	1 l/ha	750 g/l	750 g/ha
	EC	Chwastoc AS 600 EC	1,25 l/ha	600 g/l	750 g/ha
2,4-D+dicamba	EC	Aminopielik D Maxx 430 EC	1,5 l/ha	376 g/l+54 g/l	564 g/ha+81 g/ha
	SL	Aminopielik Super 464 SL, Dicopur Top 464 SL, Tayson 464 SL	1 l/ha	344 g/l+120 g/l	344 g/ha+120 g/ha
thifensulfuron-methyl+metsulfuron-methyl	WG	Chenkar 750 WG, Ergon 750 WG, Looma 750 WG, Vima-Tifenmet	75 g/ha	682 g/kg+68 g/kg	51,15 g/ha+5,1 g/ha
	SG	Concert SX 44 SG	150 g/ha	400 g/kg+40 g/kg	60 g/ha+6 g/ha
		Finish SX 40 SG	75 g/ha	333 g/kg+67 g/kg	24,97 g/ha+5,02 g/ha
metsulfuron-methyl	WG	Coma 20 WG, Finy 200 WG, Pike 20 WG, Winnetou 20 WG	30 g/ha	200 g/kg	6 g/ha
	SG	Galmet 20 SG, Primstar 20 SG, Superherb 20 SG	30 g/ha	200 g/kg	6 g/ha
tribenuron	WG	Lumer 50 WG	30 g/ha	500 g/kg	15 g/ha
		Cuckoo 750 WG	25 g/ha	750 g/kg	18,75 g/ha
		Helgran 75 WG, Naxel 75 WG, Nuance 75 WG, Pleban 75 WG, Ranga 75 WG, Sabata 75 WG, Tribe 75 WG, Viking 75 WG	20 g/ha	750 g/kg	15 g/ha
	SG	Granstar SX 50 SG	35 g/ha	500 g/kg	17,5 g/ha
		Toraya 50 SG, Triben Super 50 SG, Trimax 50 SG, Tristar 50 SG	40 g/ha	500 g/kg	20 g/ha
fenoxaprop-P	EW	Fantom 069 EW, Foxtrot 069 EW, Norton 069 EW, Puma Uniwersal 069 EW, Pumex 069 EW, Rumba 069 EW	1,2 l/ha	69 g/l	82,8 g/ha
	EC	Fenoxinn 110 EC, Herbos 110 EC, Monarchi 110 EC	0,7 l/ha	110 g/l	77 g/ha

**A key to formulation codes: SL (soluble concentrate), EC (emulsifiable concentrate), WG (water dispersible granule), SG (water soluble granule), EW (emulsion, oil in water)*

Table 2. Comparison of matches of fungicides containing the same active substance in different formulations registered for protection of winter wheat against powdery mildew, registered in Poland in May 2017.

Active substance	Formulation*	Trade names of products	Dose	Content of active substance	Total use of active substance
tebuconazole	EC	Brasifun 250 EC, Mystic 250 EC	1 l/ha	250 g/l	250 g/ha
	EW	Clayton Tabloid EW, Darcos 250 EW, Domnic 250 EW, Erasmus 250 EW, Furtado 250 EW, Helicur 250 EW, Kosa 250 EW, Orius Extra 250 EW, Riza 250 EW, Sokolov 250 EW, Sparta 250 EW, Syrius 250 EW, Tarcza Łan 250 EW, Tebu 250 EW, Tebusha 250 EW, Toledo 250 EW, Trion 250 EW, Troja 250 EW, Tyberius 250 EW	1 l/ha	250 g/l	250 g/ha
		Tarcza Łan Extra 250 EW	1,25 l/ha	250 g/l	312,5 g/ha
	SC	Ambrossio 500 SC, Venturo 500 SC	0,5 l/ha	500 g/l	250 g/ha
		Bounty 430 SC, Spekfree 430 SC, Starpro 430 SC	0,6 l/ha	430 g/l	258 g/ha

** A key to formulation codes: EC (emulsifiable concentrate), EW (emulsion, oil in water), SC (suspension concentrate)*

CONCLUSION

On the basis of the results, it is difficult to draw any definite conclusions regarding the influence of formulation on the dose of active substance used per hectare. The collected data show that in many cases for the same active substance and formulation different maximal doses were recommended to control the same pest in the same crop, it may however depend on the recommended growth stage of application, which was not considered. In some cases, use of a different formulation may be connected with the different amount of an active substance used per hectare. However, the results strongly differed depending on the analyzed active substances. Probably more cases should be examined to determine whether there are any discernible patterns.

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INTENSITY OF PRODUCTION ORGANIZATION AND TECHNICAL EQUIPMENT OF POLISH AGRICULTURE

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Keywords: organization intensity, farm equipment, fixed assets, sustainable agriculture

ABSTRACT

The work presents the relationship between the intensity of production organization and technical equipment of Polish agriculture. The intensity of production organization was determined using B. Kopeć's indicator method. Updates have been introduced to this method in order to reflect the changes that have occurred in Polish agriculture in the last thirty years. The state of farm mechanization and its changes were determined on the basis of the data collected by the Central Statistical Office (GUS) of Poland. The relationship between agriculture organization intensity and the basic indicators characterizing farm mechanization was analyzed.

INTRODUCTION

Since intensity is a qualitative phenomenon, it is unmeasurable. The intensity of agriculture organization can be evaluated using a point scale. Such a scale takes into consideration the share of high-input crops in the crop structure, and the number of livestock units per unit of area. One of the methods used for determining agricultural organization intensity is the indicator method developed by B. Kopeć in the 1950s. The first publication presenting this method appeared in 1958 (Kopeć 1958) and the last in 1987 (Kopeć 1987). Kopeć's method is used by numerous Polish authors (Figurski, Lorencowicz 2010; Jankowski, Bieńkowski, Holka 2010; Kluba, Rudnicki, Wiśniewski 2016; Kocira 2009; Kołtun 2014; Kopiński 2009; Lorencowicz 2009; Malaga-Toboła, Kocira 2013; Parafiniuk 2013; Polna 2009; Sawa 2009; Szeląg-Sikora 2008; Szeląg-Sikora, Cupiał, Niemiec 2015; Szuk 2009; Żak 2013), which proves its usefulness.

The objective of the research is to determine the relationship between the intensity of production organization and the technical equipment of Polish agriculture.

METHODS

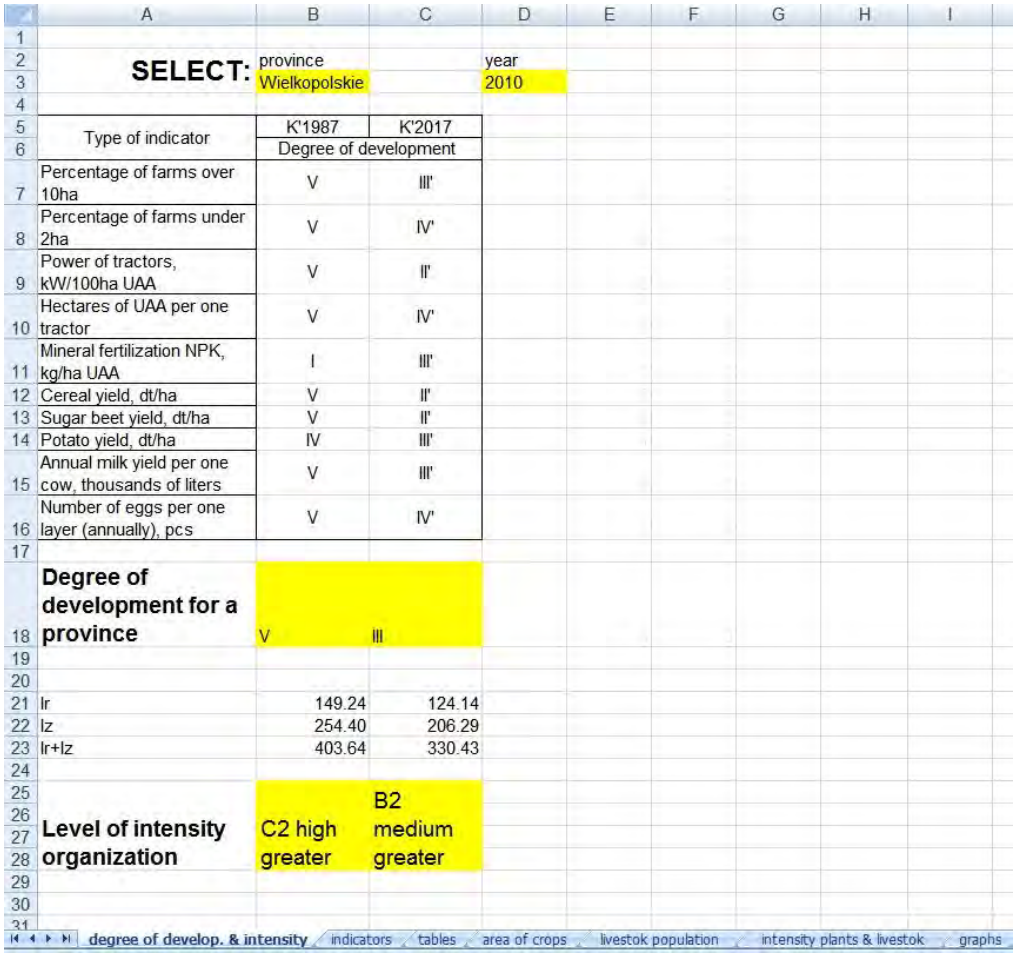
Over the past twenty years, significant changes, both economic and technological, have occurred in Polish agriculture. There has been a significant increase of cultivated plant yields, an increase of productivity in animal production, as well as changes concerning fertilization and farm mechanization (Tab. 1).

Tab. 1. Selected parameters characterizing the changes in Polish agriculture over 1995-2015

Specification	Unit	1995	2015	Change 1995-2015
Yield of five basic cereals	dt/ha	30.6	37.9	24%
Sugar beet yield	dt/ha	344	520	51%
Potato yield	dt/ha	164	210	28%
Annual milk yield per one cow	thousands of liters	3136	5164	65%
Average annual number of eggs per one hen	pcs	163	231	42%
NPK mineral fertilizers	kg/ha	76.6	123.2	61%
Utilized agricultural area (UAA) per one tractor	ha	13.6	10.2*	-25%
Installed power of tractors	kW/100ha	229.4	416.7*	82%

*2013 data.
Source: Central Statistical Office of Poland, GUS (1995-2016).

Therefore, it was necessary to update Kopeć's method (Lorencowicz, Mazurek, Kocira 2017). Taking into consideration selected factors which characterize agriculture, changes were proposed to point ranges determining the degree of intensity (degrees of development). An application has been developed in the spreadsheet for calculating the intensity and its level for particular provinces of Poland in 1995-2015 (Fig.1). The results obtained show the intensity level according to the original Kopeć's method (hereinafter referred to as "K'1987") and after its update ("K'2017").



	A	B	C	D
2	SELECT:	province		year
3		Wielkopolskie		2010
5	Type of indicator	K'1987	K'2017	
6		Degree of development		
7	Percentage of farms over 10ha	V	III'	
8	Percentage of farms under 2ha	V	IV'	
9	Power of tractors, kW/100ha UAA	V	II'	
10	Hectares of UAA per one tractor	V	IV'	
11	Mineral fertilization NPK, kg/ha UAA	I	III'	
12	Cereal yield, dt/ha	V	II'	
13	Sugar beet yield, dt/ha	V	II'	
14	Potato yield, dt/ha	IV	III'	
15	Annual milk yield per one cow, thousands of liters	V	III'	
16	Number of eggs per one layer (annually), pcs	V	IV'	
18	**Degree of development for a province**	V	III	
21	Ir	149.24	124.14	
22	Iz	254.40	206.29	
23	Ir+Iz	403.64	330.43	
25–28	**Level of intensity organization**	C2 high greater	B2 medium greater	

degree of develop. & intensity | indicators | tables | area of crops | livestok population | intensity plants & livestok | graphs

Fig. 1. Application determining intensity level of agriculture organization for provinces in 1987-2017

Farm mechanization changes were determined using the following indicators:

- installed power of tractors [kW/100 ha]
- utilized agricultural area (UAA) per one tractor [ha/tractor]
- number of combine harvesters per 100 ha [combines/100 ha]

The data used in the analyses were obtained from the database of the Central Statistical Office of Poland (GUS 1995-2016). For most of the parameters analyzed, the data availability covered the entire period under investigation, yet in some cases data from selected years were unavailable, which made interpretation of the results difficult.

RESULTS

In the period under review, there were significant changes in the intensity of the agriculture organization. In 2006-2015 (Fig. 2) the intensity of the agriculture organization in Poland increased by 13.8% as measured by the original method

(K'1987) or by 16% as measured by the updated method (K'2017). In both cases, there is a noticeable increase in intensity; however, the point ranges are different, which essentially illustrates the changes in the method.

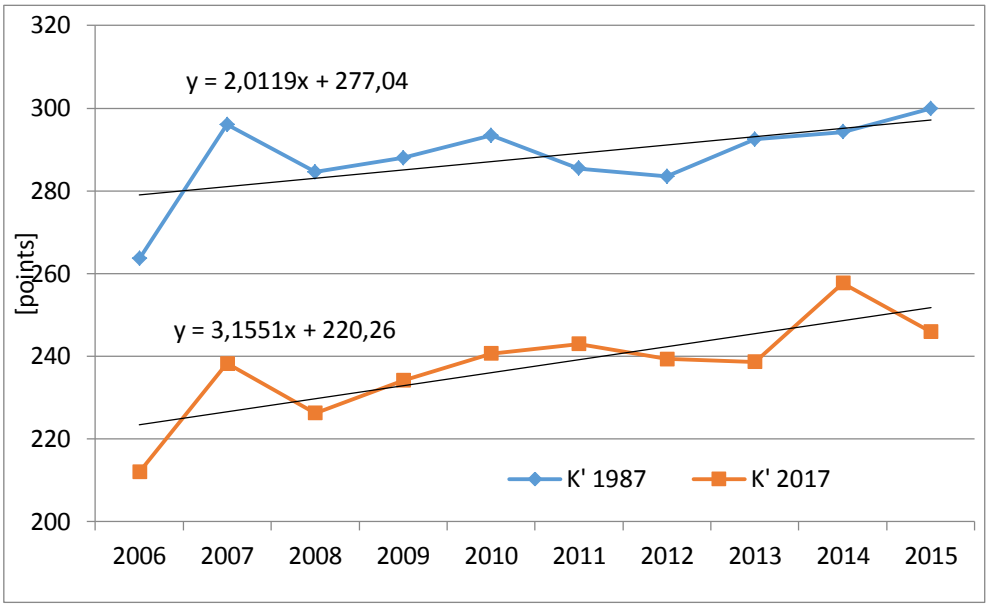


Fig. 2 Intensity of production organization in Poland in 2006-2015

Detailed results of studies in the intensity of agriculture organization for particular provinces are presented in Tab. 2. As it is in the graph, intensity fluctuations are noticeable, but the general trend is increasing.

Tab. 2. Summary of the results of the intensity agriculture organization assessment according to the original (K'1987) and updated (K'2017) method for particular provinces in 2006-2015

Province	2006		2015		Change 2006-2015	
	K'1987	K'2017	K'1987	K'2017	K'1987	K'2017
Dolnośląskie	204.3	168.9	206.7	171.2	1%	1%
Kujawsko-pomorskie	372.0	254.7	343.2	256.6	-8%	1%
Lubelskie	187.5	172.5	232.5	192.6	24%	12%
Lubuskie	124.0	149.9	207.4	155.1	67%	3%
Łódzkie	211.9	211.9	319.0	263.4	51%	24%
Małopolskie	169.1	169.1	221.6	180.8	31%	7%
Mazowieckie	292.6	200.5	310.7	231.0	6%	15%
Opolskie	279.9	208.7	271.2	271.2	-3%	30%
Podkarpackie	139.3	127.7	186.2	139.1	34%	9%
Podlaskie	316.8	234.9	356.6	265.3	13%	13%
Pomorskie	258.8	191.8	253.0	208.3	-2%	9%
Śląskie	224.8	166.6	255.8	210.7	14%	26%
Świętokrzyskie	180.3	180.3	260.7	178.9	45%	-1%
Warmińsko-mazurskie	249.6	206.3	240.0	198.6	-4%	-4%
Wielkopolskie	310.2	286.5	420.4	386.3	36%	35%
Zachodniopomorskie	165.2	123.6	186.4	153.5	13%	24%
Mean value	263.6	212.0	299.9	246.0	14%	16%

The increase of UAA per 1 tractor (Fig. 3) can be attributed both to the increase in the farm acreage and to the purchase of more powerful tractors than those used previously.

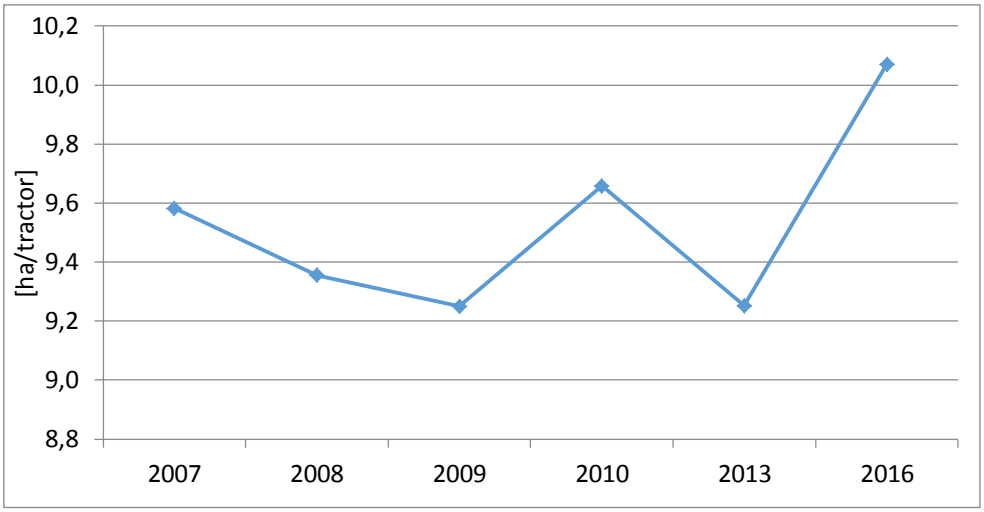


Fig. 3. Utilized agricultural area per one tractor in Poland in 2007-2016

In most of the cases observed, the number of combine harvesters per 100ha (Fig.4) increases. This may indicate a constant demand for these machines in the Polish farms as well as an increasing profitability of smaller farms for which owning a combine harvester had not been possible before for economic reasons. On average, there are 2 combine harvesters per 100 ha UAA in Poland.

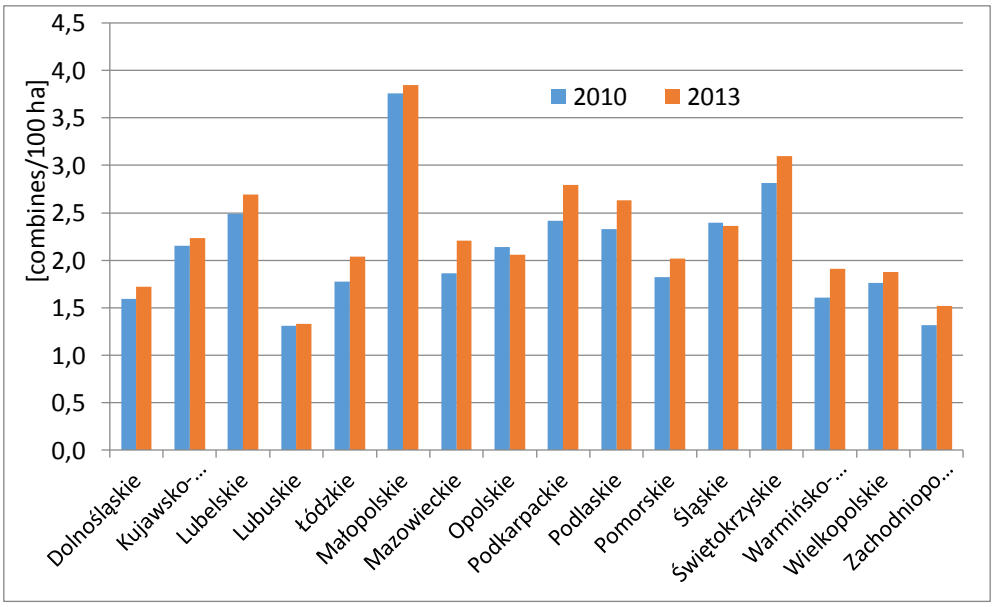


Fig. 4. Number of combine harvesters per 100 ha of cereals in particular provinces of Poland in 2010 and 2013

The installed power of tractors increased from 2.1% up to even 22.5% depending on the province. The change dynamics of this indicator is varied and it is in no direct relation to the production organization intensity in agriculture.

The graphs and tables presented show the general increase in the value of installed power indicators. By comparing the values of the indices directly with the values of production intensity, it is not possible to determine unequivocally the relationships between the traits under examination.

Tab. 3. Installed power of tractors in kW/100ha and intensity of production organization in particular provinces of Poland in 2007-2013

Province	2007	2007	2010	2010	2013	2013	Change 2007-2013 in %	
	kW/100ha	points	kW/100ha	points	kW/100ha	points	kW/100ha	points
Dolnośląskie	258.4	168.3	226.5	162.0	264.0	164.7	2.1%	-2.1%
Kujawsko-pomorskie	337.3	298.1	308.2	324.6	360.2	280.3	6.8%	-6.9%
Lubelskie	473.8	178.5	458.5	177.2	531.3	217.7	12.1%	22.0%
Lubuskie	165.1	138.0	168.6	130.3	202.4	155.2	22.5%	12.5%
Łódzkie	485.4	251.2	475.9	244.7	559.2	283.7	15.2%	12.9%
Małopolskie	710.7	248.2	659.6	151.2	833.3	159.7	17.3%	-35.7%
Mazowieckie	418.9	235.9	395.8	241.4	477.5	248.7	14.0%	5.4%
Opolskie	308.5	233.1	280.6	267.0	293.1	242.3	-5.0%	3.9%
Podkarpackie	641.9	141.4	596.8	113.2	696.7	125.0	8.5%	-11.6%
Podlaskie	358.6	262.1	358.1	289.7	412.6	238.3	15.1%	-9.9%
Pomorskie	248.8	195.5	218.6	198.7	269.0	235.1	8.1%	20.2%
Śląskie	485.4	180.1	427.3	168.7	518.3	172.9	6.8%	-4.0%
Świętokrzyskie	568.6	193.8	569.7	169.7	696.7	189.2	22.5%	-2.4%
Warmińsko-mazurskie	201.0	186.3	183.4	197.0	217.9	177.5	8.4%	-4.8%
Wielkopolskie	349.1	337.3	321.4	330.4	376.1	327.6	7.7%	-2.9%
Zachodniopomorskie	134.5	138.7	124.9	139.6	145.5	131.3	8.2%	-5.3%

The graphs show the increase in both the intensity and the indicators expressing farm mechanization. It can be stated that the increase in production intensity affects the quantity of fixed assets, or that changes in farm mechanization affect the increase of intensity.

CONCLUSIONS

On the basis of the data analyzed, the impact of the intensity of production organization on farm mechanization in Poland cannot be clearly determined. Some relationships may be noticed, such as a general increase in the number of tractors and, what it involves, an increase in the level of tractive force, and a decrease in surface area per one tractor with the simultaneous increase in intensity. These relationships are not immediately noticeable for particular provinces.

Only a more detailed analysis based on research studies on a group of selected farms will allow to determine precisely the relationships between the examined features.

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THE INFLUENCE OF AERATION RATIO ON ENERGETIC ASPECTS OF COMPOSTING PROCESS OF SEWAGE SLUDGE WITH AGRICULTURAL WASTE

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Keywords: wastewater sludge, sewage sludge, composting, aeration, agricultural waste

ABSTRACT
Composting process of sewage sludge is one of the most common methods in the world for sludge management. Due to, inter alia, unfavorable ratio of carbon to nitrogen and the high hydration, sludge waste requires usually additional preparation before composting process. Especially in agricultural areas, the use of agricultural waste seems to be beneficial to improve the properties of the compost mixture. Such co-substrates will create favorable water and air conditions inside the pile or in-vessel. In addition to the composition of the mixture, another important aspect is the appropriate aerating of the compost. It depends on what time and how effective will be the composting process. The aim of the work was to present the influence of aeration ratio on energetic aspects of composting process of sewage sludge with agricultural biomass. In this case maize straw was the structural addition.

COMPOSTING OF SEWAGE SLUDGE WITH AGRICULTURAL WASTE

Reducing the number of livestock farming has contributed to the decline in the production of natural fertilizers, which resulted in the search for alternative, environmentally safe sources of organic matter, which can be composted sludge, processed into fertilizer in agriculture (Szwedziak 2006).

Wastewater sludge is a significant biomass resource in the scale of the economy, which can be used in various ways. Analysis of Eurostat data shows that Poland is at the top of the sewage sludge production (above 568 000 tons/year, data from 2015 data) only from the urban wastewater treatment process (Eurostat 2017). Large volumes of such waste are only produced by Germany, United Kingdom, France Spain and Italy - it is estimated that these five countries generate altogether almost 75% of the European wastewater sludge (Kacprzak 2017).

Analyzing the directions of wastewater sludge management in Europe and Poland in the recent years, there is a strong trend towards reducing the amount of sediment deposited on landfills in favor of their agricultural use and composting (Duan 2017, Eurostat 2017).

Properly managed composting process is one of the most common waste management methods, as far as sustainability issues are concerned to stabilize organic waste including wastewater sludge results in stable and harmless end-product, which may be used as a fertilizer or soil conditioner that does not pose an environmental hazard (Białobrzewski et al. 2015, Kosicka 2015 et al., Malamis et al. 2016). Composting is a viable, beneficial option in biosolids management and it is a proven method for pathogen reduction and results in a product that is easy to handle, store, and use (Bauza-Kaszewska 2010 et al., Starzyk and Czekała 2014, Mroczek-Krzyzelewska et al. 2017).

Wastewater sludge composting technology is typically done at higher temperatures (Berggren 2004) which imitates an accelerated natural process that takes place on open floor where the organic materials (leaf litter, animal wastes) are broken down. Resulting in an overall reduction of volume, or converted to more stable organic materials.

CHARACTERISTICS OF WASTEWATER SLUDGE

The composition of sewage sludge depends on the organic and mineral content of the wastewater and the degree of mineralization of the organic substance in the stabilization processes. Dewatered wastewater sludge (dry), depending on stabilization processes, contains on average 50–70% of organic matter, and 30–50% mineral components (including 1–4% of inorganic carbon), 3.4–4.0% N, 0.5–2.5% P and significant amounts of other nutrients, including micronutrients (Kacprzak 2017, Kosicka 2016 et al.).

Due to inter alia unfavorable ratio of carbon to nitrogen and the high hydration, sludge waste requires usually additional preparation before composting process (Czekała et al. 2015, 2016). For these reasons, the use of wastewater sludge as an unconventional fertilizer contributes, according to Jezierska-Tyś et al. (2004) to improve the physicochemical properties of the soil, have a soil-forming effect, and also promote the accumulation of humus compounds.

Especially in agricultural areas, the use of agricultural waste seems to be beneficial to improve the properties of the compost mixture (Ucaroglu and Alkan 2016, Grau et al. 2017). Such co-substrates will create favorable water and air conditions inside the pile or in-vessel. In addition to the composition of the mixture, another important aspect is the appropriate aerating of the compost.

METHODOLOGY, SCOPE AND OBJECT OF RESEARCH

The research was carried out at the Institute of Biosystems Engineering at the Poznań University of Life Sciences, in the Laboratory of Environmental Technology. The composting process was carried out in specially designed bioreactors (Fig. 1). The influence of external factors was eliminated by the use of thermal insulation.

In order to ensure adequate structural properties of the composted feed, the ingredients were selected in appropriate proportions. The sewage sludge from the municipal wastewater treatment plant and the agricultural waste in the form of straw rape were used for the study. The dry weight was 18.61% for sludge and, for rapeseed straw, 87.71%. In the experiment 25 kg of sludge and 5.4 kg of rape straw were used in each compartment.

Seven models of bioreactors were used for testing. Each of them was built in the shape of a cuboid with a side length of 0.5 m, height of 0.7 m and has a capacity of 165 dm3. The walls of the chambers are made of plastic and additionally reinforced by metal elements. The walls of the chambers were insulated thermally.

Aeration of the bioreactors was carried out using an air-pumping pump (Fig. 1, item 1). The amount of air injected into the chambers was controlled and evenly distribution of the pressurized air allowed the metal grate, at the bottom of the tank.

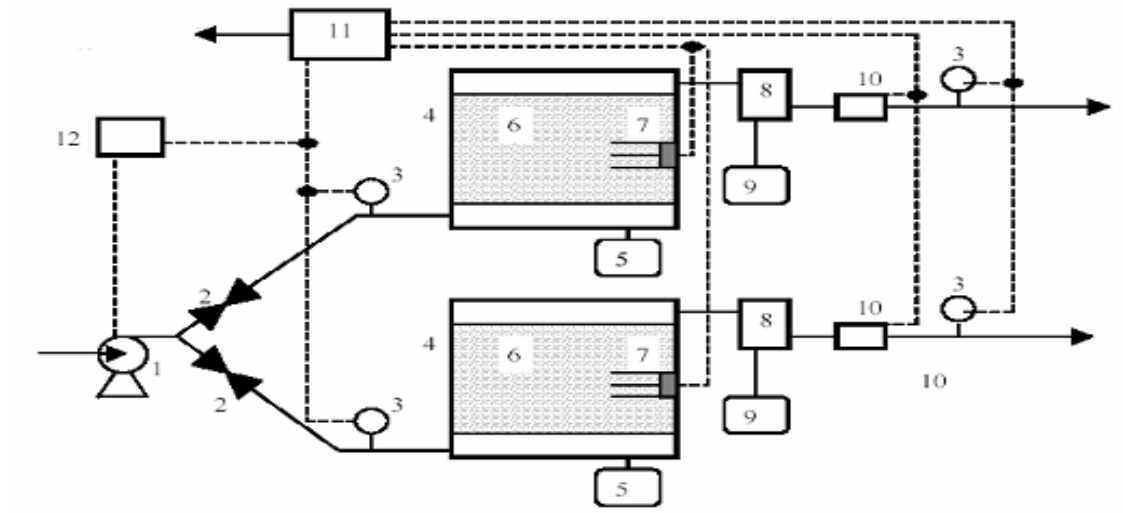

Figure 1. Diagram of 2-chamber bioreactor section (1. pump, 2. air flow regulator, 3. flow meter, 4. chamber, 5. leach tank, 6. composted mixture, 7. measuring sensor assembly, 8. air cooling system, 9. condensate tank, 10. gas sensors (NH3, O2, CO2, CH4, H2S), 11. signal recorder, 12. air flow controller)

Composition of each compost mixture in 7 chambers and initial parameters of materials used for composting are presented in tab. 1. The temperature inside the chamber was measured twice daily for the first 14 days and then from 15 day once a day using PT 100 sensors.

In the experiments carried out in 6 chambers, differentiated air flow was maintained and one chamber devoid of flow. Airflows were checked daily without allowing anaerobic conditions to occur.

Table 1. Initial parameters of materials used for composting

Parameter/ chembers		K0	K1	K2	K3	K4	K5	K6
Weight [kg]		30.4	29.1	29.2	29.2	29. 3	28.3	27.3
Dry matter [%]	Wastewater sludge	18	18	18	18	18	18	18
	Rape straw	88	88	88	88	88	88	88
Volume [dm^3]		97	106	114	111	111	125	129
Density [kg/m^3]		315	274	255	262	264	227	212
Flow rate [dm^3/min]		0	4	5	6	7	8	12

RESULTS

The temperature at the start of the experiment was 20°C in each chamber. The rapid rise in temperature was noted only a few hours after closure of the chambers with the composted material. The transition from the mesophilic phase to the thermophilic phase (above 40°C) occurred relatively quickly (within 3 days). The most intense thermophilic phase was in chamber K1 where it reached a maximum temperature of 68°C, K2 and K3 - 64.6°C and K4 - 64.4°C. The thermophilic phase did not occur in chamber K0 and reached a maximum value of 34.5°C (Fig. 2).

In the chambers with the lowest aeration K1 (4 dm^3/min), the temperature increase, in the thermophilic phase, was highest and reached a maximum value of 68.4°C. In the K5 and K6 chambers, the thermophilic phase was not as intense and the maximum temperature was 57°C. K0 while in the chamber, which was devoid of aeration the temperature course during the whole composting process was relatively similar.

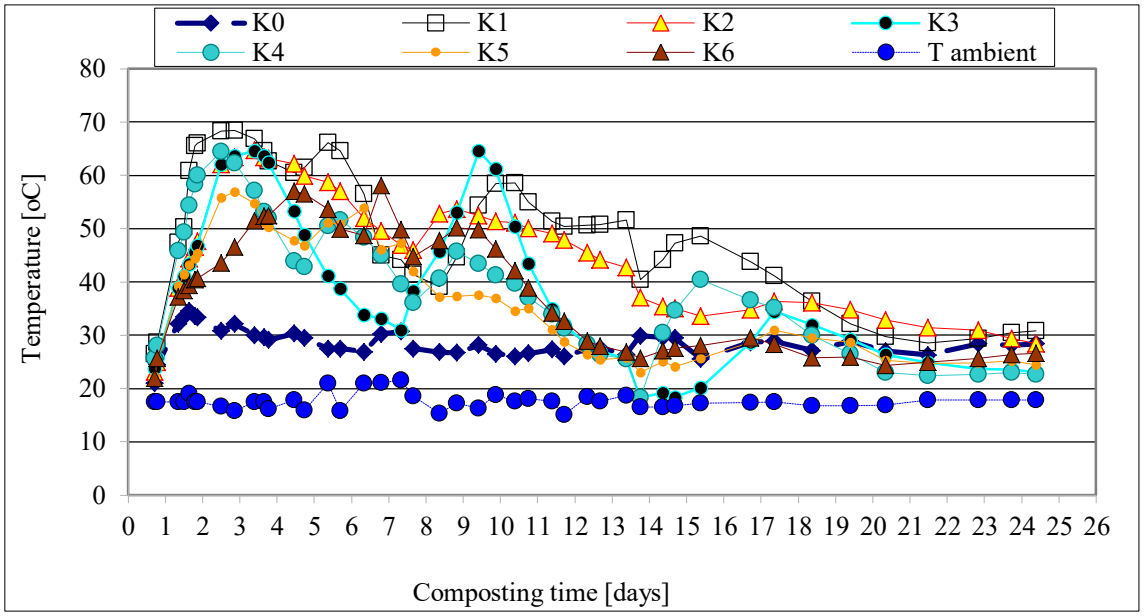

Figure 2. The course of temperature during the composting

Thus, the course of temperature changes was related to the aeration intensity of individual chambers. With less aeration, the thermophilic phase was much more intense. In the case of more air introduced, the processes were slower and longer. At the time of the temperature drop, aeration was performed on the sixth and thirteenth day of the experiment. After mixing, the temperature inside the chambers was rapidly reduced and the temperature increased again during the following days.

The process of the composting was dependent on temperature changes in the bioreactor. After 16 days, the temperature began to gradually decrease and about 21 days started the stabilization phase of the compost with a constant temperature of 30°C. Stabilization of temperature was the decisive factor in the end of the experiment on day 25.

In the chambers with the lowest air flow (K1, K2), the cumulative temperature reached the highest values (Fig. 3). However, in the K3, K4, K5 and K6 chambers, where the aeration was higher, the cumulative temperature in the composted material was lower. This was due to the fact that excess air caused faster cooling of the material. During the experiment, changes in the weight and dry matter of the composted mixture were also investigated, and the results of weight reduction and dry matter content (in %) are shown in Figure 3. In each of the chambers the final mass was reduced to the initial mass. The largest decrease in weight was recorded in K6 chamber from which it lost 15.67 kg (57.3%), then in K4 - 16.41 kg (55.9%), K5 - 15.29 kg (53.9%), K2 - 14.33kg (49%), K3-14.21 (48.6%), K1- 13.86 (47.6%). The smallest weight loss of 4.46 kg (14.8%) was noticed in the K0 chamber. K0 was deprived of aeration, which led to the occurrence of anaerobic conditions, so the mass decrease was the smallest.

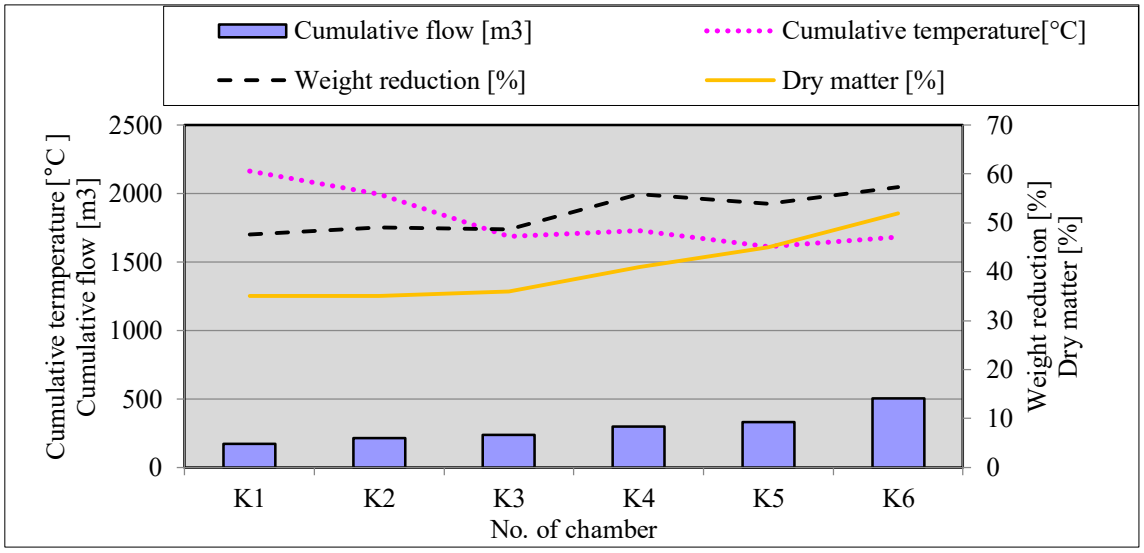

Figure 3. Relationship between cumulative temperature and air flow

CONCLUSION

In this study, a significant decrease in the weight of composted sewage sludge mixtures was observed in the range of 14.8 - 57.3%. This proves the correct course of the process, as a number of authors state that intense thermophilic composting leads to a significant decrease in the mass of the material to be processed as a result of evaporation of water and CO_2 emissions (Iranzo et al. 2004, Dach et al. 2007). These processes are associated with a very violent thermophilic phase, i.e. temperature increase to about 60°C for at least a few days.

The appropriate aerating of the compost mixture is one of the most important aspect during operation, which enables proper biomass conversion. From the energy point of view, the best aeration had a capacity of 4 dm^3/min. But in these studies, it has been shown that even up to three times higher aeration intensity, relative to the most favorable energetically, allowed to obtain thermophilic conditions in the compost mixture. Moreover, it should be taken into account that weight reduction and dry matter increase positively correlated with increasing aeration intensity but negative with cumulative temperature, which is of particular importance when transporting the finished mixture.

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INFLUENCE OF PHYSICAL PROPERTIES OF WATER-ADJUVANT MIXTURE ON THE DROPLET STAINS DEPOSITING ON AN ARTIFICIAL TARGET

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Keywords: adjuvant, stains, water sensitive papers, liquid temperature

ABSTRACT
The study was designed to determine the effect of adding different concentration of the adjuvant (0, 50 and 100% as compared to the recommended concentration from the adjuvant producer) on the surface tension of water from different sources and at different liquid temperature. As well as determining the stains spreading properties (area, diameter and coverage) on water-sensitive papers (WSP's) after the drops from different mixtures released from two heights. The volume of the released drops during the test of stains spreading was kept unchanged and irrespective of the surface tension obtained. The results show that adding the adjuvant produced a change in surface tension of the working liquid. As the adjuvant concentration increased, the surface tension decreased which in turn increased the spreading (area, diameter and coverage) of the stain on the WSP's especially at temperature of 10 ^{o}C.

INTRODUCTION
The spray application could be affected significantly by adding the adjuvant to the tank mixture; this influence depends on the properties of this adjuvant and its concentrations on the spray. This effect comes from the change in spray drops physicochemical properties (size, velocity, impact and spread behavior) as a result of adding the adjuvant (Holloway et al., 2000). Costa et al. (2017) reported decrease in the drops median diameter as a result of adding the adjuvant, this was accompanied by higher number of drops which tend to drift. This decrease was because of the surface tensions of those drops which decreased and it depended on the chemical group of the adjuvant. This decrease in the drop size as a result of reduction in the surface tension value was observed also by Basi et al. (2012), the measurement of the liquid was done by a spectrofluorophotometer and it was at lower impulse widths and larger orifice diameters of a pneumatic drop-on-demand generator system. Decaro Junior et al. (2015) found that the surface tension of a mixture of spraying liquid decreased when adding and when increasing the concentration of mineral oil (Argenfrut®). Lin et al. (2016) found that adding the surfactant to deionised water and pesticide spray resulted in clear spreading of the drops on the leaf surfaces. In contrast, the drops of spray without the surfactant stayed in a spherical shape and did not spread. They found also that the best concentration of the surfactant was 0.25% to get better spreading of the drops and more wetted area. The same results were reported by Xu et al. (2010) in their study on waxy leaves, adding that this change depends on the plant species and the adjuvant class. They suggested that the proper choice of the adjuvant class enhanced the deposit formation on waxy leaves significantly which, in turn, will result in more effectiveness of pesticides. Xu et al. (2011) found that increasing the adjuvant concentration resulted in an increase in the wetted area on waxy and hairy leaf surfaces. They recommended using correct adjuvant concentration in the spray mixture which could lead to a great

improvement on the spray coverage homogeneity on the target surfaces which, in turn, could reduce pesticide use.
The objectives of this work are:

1. Determine the effect of adjuvant concentrations and mixture temperature on the surface tension of water from different sources;
2. Determine the difference in the stains size and the stains coverage percentage on WSP depending on the drops releasing height for the individual adjuvant concentrations and temperature.

METHODS

The experiment tests were done in the pesticide application laboratory of the Department of Machinery Exploitation and Management of Production Processes - University of Life Sciences in Lublin, Poland. Water sensitive papers (dimension: 26 × 76 mm) were used as an artificial surface for the deposited drops which were released from a needle (size 0.513 mm) at two heights, with fixed drop volume equal to 14 µl. The treatments included the following parameters:
1. Adjuvant concentration: 0%, 50%, 100% of the manufacturer's recommended dose (50 ml for 100 l water)
2. Diluting water type (Table 1) : Distilled water (D); Water from the building of University of Life Sciences in Lublin (UP); Tap water from a farm located in the municipality of Sosnówka (S)
3. Liquid temperature: 10°C; 15°C; 20°C
4. Releasing (of drops) height: 12.5 cm; 25.0 cm (distance from needle tip to the WSP surface).

Table1. Density and hardness for the water types used in the tests

Water type	Density, g/cm³			Water hardness
	Temperature, °C			
	10	15	20	
D	0.9997	0.9991	0.9982	very soft
S	0.9998	0.9992	0.9983	slightly hard
UP	1.0001	0.9995	0.9986	very hard

Five drops were released on each WSP, they were distributed randomly on the surface of WSP without touching one another (Figure 1). The WSP's were scanned after they were dried with a proper photos-resolution for the further investigation. The image pro software was used to analysis the WSP's photos and the following traits were calculated:
1. Stain area (in mm^2); 2. Stains diameter (in mm); 3. Stains percentage coverage (in %)

Surface tension for the treatments liquid was measured using DSA30 KRÜSS GmbH Drop Shape Analyzer device and according to the pendant drop method. The type of adjuvant used in the test was SUPERAM 10AL (PZH-2825/2013 approval), it is moistens and enhances adhesion of the liquid mixture beside it has combined use with plant protection chemicals in field crops.

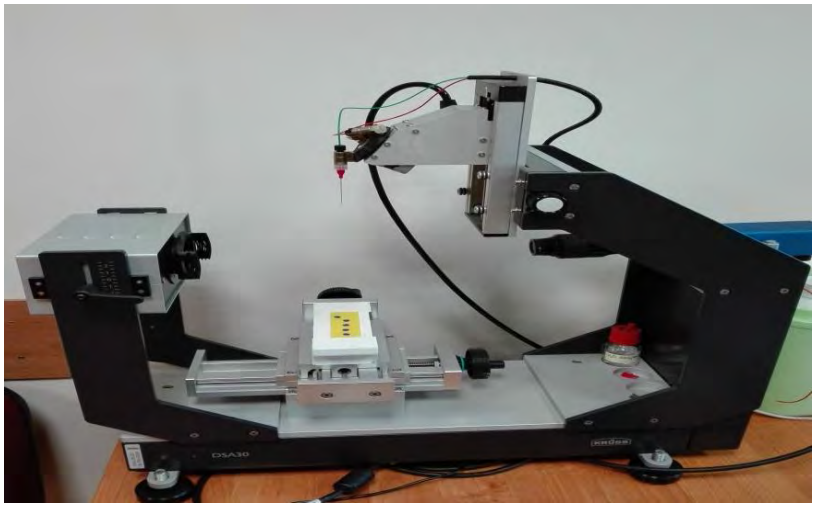

Figure1. Releasing the drops on the WSP's from the needle of DSA30 KRÜSS GmbH Drop Shape Analyzer device

RESULTS

The area for the released drops after they deposited on the surface of WSP had the highest value (Table 2) when using water type UP at temperature of 10 ºC, also when using 100% concentration of the adjuvant and 25 cm releasing height.

Table2. Mean values for the area (in square millimeter) of deposited drops from different types of water, temperature, releasing heights, when adding different concentration percentage of adjuvant

Adjuvant percentage, %	Water type*	Height 12.5 cm			Height 25.0 cm		
		Temperature, ºC			Temperature, ºC		
		10	15	20	10	15	20
0	D	31.1	29.8	28.1	34.5	33.3	33.2
	S	33.1	31.9	32.7	36.1	38.8	37.9
	UP	33.4	31.3	32.8	36.1	34.7	36.4
50	D	31.3	24.3	24.8	35.2	27.8	27.0
	S	30.2	32.7	33.5	35.7	35.7	36.3
	UP	34.4	32.1	33.4	40.0	37.3	36.9
100	D	32.9	28.8	27.7	37.6	33.2	26.5
	S	35.6	30.7	28.6	40.4	35.6	35.1
	UP	34.5	29.7	28.6	41.9	35.0	34.4

* D-Distilled water; UP- tap water from the building of University of Life Sciences in Lublin; S- tap water from a farm located in the municipality of Sosnówka

Averaged diameter results for the deposited stain (Table 3) showed that releasing the drops from 25 cm height produced larger diameter stains comparing with 12.5 cm height. The smallest stain diameter was obtained when releasing the drops of distilled water + 50% concentration adjuvant mixture from 12.5 cm height and at temperature of 15 ºC.

Table3. Mean values for the stains diameter (in millimeter) using different types of water, temperature, dispersing heights, when adding different percentage of adjuvant

Adjuvant percentage, %	Water type	Height 12.5 cm			Height 25.0 cm		
		Temperature, °C			Temperature, °C		
		10	15	20	10	15	20
0	D	6.23	6.11	5.93	6.58	6.45	6.44
	S	6.44	6.33	6.40	6.73	6.98	6.89
	UP	6.48	6.26	6.41	6.81	6.60	6.76
50	D	6.26	5.52	5.57	6.63	5.90	5.82
	S	6.15	6.41	6.49	6.69	6.70	6.75
	UP	6.57	6.34	6.48	7.09	6.85	6.81
100	D	6.43	6.00	5.87	6.87	6.45	5.75
	S	6.68	6.21	5.98	7.12	6.68	6.64
	UP	6.58	6.10	5.98	7.25	6.62	6.57

Increasing the concentration of the adjuvant resulted in higher values for the percentage coverage, especially from 25 cm releasing height (Table 4). The highest value occurred when the temperature of the mixture (water from UP) was 10 °C. Releasing the drops from 12.5 cm height for the distilled water (has temperature of 15 °C and 50 percent adjuvant concentration) resulted in the lowest value for the stains coverage percentage (25.0%).

Table 4. Mean values for the stains percentage area or coverage (%) ± standard deviation using different types of water, temperature, dispersing heights, when adding different percentage of adjuvant

Adjuvant percentage, %	Water type	Height 12.5 cm			Height 25 cm		
		Temperature, °C			Temperature, °C		
		10	15	20	10	15	20
0	D	31.8±1.6	30.5±0.9	28.8±1.5	35.3±1.3	34.1±0.9	34.0±2.5
	S	33.8±0.4	32.7±1.3	33.5±0.4	36.9±1.3	39.7±1.3	38.8±0.7
	UP	34.2±0.5	32.0±0.9	33.5±0.8	37.8±0.7	35.6±1	37.3±0.7
50	D	32.2±0.8	25.0±0.8	25.4±1.3	36.0±0.9	28.5±0.7	27.6±1.6
	S	30.9±1.8	33.5±1.1	34.3±1.0	36.5±1.4	36.5±1.6	37.2±1.1
	UP	35.2±0.5	32.8±1.1	34.2±1.1	40.9±1.2	38.2±0.9	37.8±0.7
100	D	33.7±0.8	29.5±0.9	28.3±0.6	38.5±1.9	34.0±0.6	27.1±1.1
	S	36.5±1.6	31.5±0.3	29.3±0.9	41.5±1.6	36.4±1.1	35.9±0.6
	UP	35.4±1.7	30.4±0.3	29.2±0.9	42.9±1.2	35.7±1.3	35.2±0.8

Generally, adding the adjuvant with 100% concentration reduced the surface tension for the mixture to the lowest values comparing with 50% and 0%. The lowest value for the surface tension happened when using Sosnówka farm water at temperature of 20 °C and with 50% adjuvant concentration.

Table5. Average surface tension values (mN/m) with standard deviation (SD) using different types of water, temperature, when adding different percentage of adjuvant

Water type	Adjuvant percentage, %	Temperature, °C					
		10		15		20	
		Surface tension	SD	Surface tension	SD	Surface tension	SD
D	0	73.51	2.15	74.67	1.63	72.56	0.97
	50	43.83	1.41	42.11	1.1	37.39	2.37
	100	40.02	1.48	38.47	1.32	35.84	1.12
S	0	75.56	1.2	72.73	1.34	72.25	1.27
	50	45.87	1.73	44.7	1.64	33.22	1.6
	100	39.16	2.2	36.46	1.37	35.92	3.23
UP	0	67.96	2.34	67.77	0.84	71.04	1.45
	50	42.55	1.29	38.78	2.46	36.43	1.32
	100	37.23	1.41	35.43	1.11	34.07	0.98

From those results we can notice that using the laboratory tap water (UP water) with 100% concentration adjuvant and at 10 °C produced higher values for stains area, diameter and percentage coverage when the drops of this water released from 25 cm height. When linking these results with the surface tension measurement, we can conclude that to gain higher percentage coverage, the surface tension must be reduced to the possible lowest value. However, the water from Sosnówka farm, which has the lowest surface tension value, did not produced the highest coverage percentage and this is probably because of the physical properties of the water which are beyond the current study scope.

CONCLUSIONS

Adding the adjuvant especially with higher concentrations reduced the values of surface tension of the adjuvant-water mixture. This decrease in the surface tension produced higher values of stains area, diameter and percentage coverage especially at temperature of 10 °C.

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INFLUENCE OF TILLAGE SYSTEMS IN A LONG-TERM EXPERIMENT ON TRACK DEPTHS AND CROP YIELDS UNDER PANNONIAN CLIMATE

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Keywords: tillage systems, track depth, soil water content, Pannonian climate, winter wheat

ABSTRACT
Based on a long-term experiment under Pannonian climate, the tillage effects on track depth, soil moisture content and grain yield of winter wheat in the vegetation period 2016/2017 are shown. The physical soil properties were measured in March 2017 indirectly: soil strength was measured through the track depth caused by a wheel load ballasted tractor with a rear wheel load of 13.7 kN. Soil moisture content was measured with a soil moisture meter at the depth of 5 cm after track depth measurement. No tillage resulted in the lowest track depth. Water content was highest in the conservation tillage systems, which had also a higher grain yield of winter wheat than the mouldboard-plough-system.

INTRODUCTION

Soil tillage systems can and should play an important role in solving future challenges in producing food. The effect of the tillage systems on yield depends mainly on climate and soil conditions. A global meta-analysis by Pittelkow et al. (2015) showed that conservation tillage in dry climates produce equivalent or greater yields than conventional tillage. The lower water losses and better water storage capacity are mainly responsible for the yield effects of conservation tillage systems (Thaler et al. 2012). Neugschwandtner et al. (2015) showed that in eastern Austria winter wheat yields were higher with ploughing than with no-tillage in years with a high amount of rainfall but did not differ between tillage treatments in dry years.
Brunotte et al. (2007) revealed in their experiments a better soil bearing capacity (expressed in lower track depths) under conservation tillage systems than in soil-turning systems.
This paper deals the influence of tillage systems under Pannonian climate conditions on the track depths (parameter for soil stability), soil water content and grain yield of winter wheat in the vegetation period 2016/2017.

MATERIALS AND METHODS

Site description

The experiment was established in 1996 at the Experimental Station of the University of Natural Resources and Life Sciences Vienna (BOKU) in Raasdorf (48°14'N, 16°33'E; 153 m a.s.l.). The field site is located in the east of Vienna (Austria) on the edge of the Marchfeld plain, which is an important crop production region in the north-western part of the Pannonian Basin. The silt loam soil is classified as a Chernozem of alluvial origin and is rich in calcareous sediments (pH$CaCl_2$: 7.6, soil organic carbon: 2.3%). The mean annual temperature is 10.0° C, the mean annual precipitation is 560 mm (1911-2015). Long-term precipitation pattern shows that the most rainfall occurs from May to September with

monthly values above 55 mm and with the highest amount in June (72 mm). Average temperature and precipitation during the vegetation period of winter wheat (from October 2016 until June 2017) were 7.6°C and 261.8 mm.

Experimental design and management

The experiment is conducted in a split-plot design with four replications and involves two factors: tillage system is assigned to the main plots (24 × 40 m) and crop rotation (A and B) to the subplots (12 × 40 m). It started in the year 1996. In the period 1997-2017, rotation A had a share of winter wheat of 50% winter wheat and rotation B of 45%. Winter wheat was grown on rotation A and B in the year 2016/2017. The pre-crop of winter wheat in rotation A was maize and rotation B was soybean.
The purpose of the trial was to perform a long-term comparison of four different tillage systems: Mouldboard plough (MP), deep conservation tillage (CTd), shallow conservation tillage (CTs) and no-tillage (NT). The sequence of tillage operations are shown in Table 2. The technical working width of the four furrow reversible mouldboard plough was 1.7 m and for the other implements (wing sweep cultivator, subsoiler, pneumatic universal seed drill) 3.0 m, respectively. The wing sweep cultivator had seven tines on two bars with a tine distance of 84 cm and a line distance of 42 cm. Behind the tine bars three rotary hoes for crumbling and a wedge ring roller for crumbling and depth adjustment were mounted. The subsoiler had four fixed tines (tine distance: 75 cm) with wings (34 cm width) at the bottom and a roller harrow for depth adjustment. The pneumatic universal seed drill consisted of the pre-implement short disc harrow, which can be lifted up for seeding in NT.

Table 1. Tillage systems with used implements and working depth (in brackets)

Tillage operation	Mouldboard plough (MP)	Deep Conservation tillage (CTd)	Shallow conservation tillage (CTs)	No-Tillage (NT)
Stubble cultivation	Wing sweep cultivator (5-8 cm)	Wing sweep cultivator (5-8 cm)	Wing sweep cultivator (5-8 cm)	–
Primary tillage	Mouldboard plough (25-30 cm)	Wing sweep cultivator (16-20 cm) Subsoiler (35 cm)	Wing sweep cultivator (8-10 cm)	–
Seeding	Pneumatic universal seed drill[1)] (3 cm)	Pneumatic universal seed drill[1)] (3 cm)	Pneumatic universal seed drill[1)] (3 cm)	Pneumatic universal seed drill[2)] (3 cm)

[1)] with short disc harrow, [2)] without short disc harrow

The combined chassis and packer unit after the short disc harrow is used for re-compacting the soil before seeding with 24 double disc coulter in offset. The total weight of the pneumatic universal seed drill with the empty seed-hopper (3,000 L) was 4,550 kg.Sowing, plant protection, fertilization and harvest were performed with regular farm machinery. Wheat was sown in mid-October with 320 germinable seeds/m^2. One herbicide application for broadleaf weed control was done in mid-April on all plots and on NT plot additionally with non-selective herbicides for weed control before sowing. The nitrogen fertilizer calcium ammonium nitrate (CAN, 27%) was applied at a total of 130 kg N/ha, splitted in two applications. Harvest was performed with a plot combine harvester (Wintersteiger® Delta) with yield and moisture monitoring system (Harvest Master Classic GrainGage) at 12th July 2017.

Measuring track depth

Track depth and soil moisture content were measured at 23th March 2017. During the two weeks before 16 mm rainfall was recorded. Especially the soil of MP showed a crusty soil surface. A rear ballasted tractor with a with rear wheel load of 13.7 kN (=1400 kg) was used (Figure 1). The narrow rear tires with the dimension 9.5-42 were adjusted with an inflation pressure of 300 kPa. The track depth measurement was carried out with a girder bridge and measuring stick according Schick 1991 (Figure 1).

Figure 1. Track depth measurement in the area between the axle

From the plot edge the tractor was reversed 10 m. On each track at the deepest tire print, two measurements were done in the area between axles. After 5 m reverse the measurement was repeated. 16 measurements per plot in four repetitions were made. Per treatment 64 measurements were taken. The soil moisture content was measured vertically with a soil moisture meter at the depth of 5 cm 28 times per tillage treatment.

Statistical analysis

All analyses were conducted using IPM® SPSS® Statistics 21.The requirements for analysis of variance were tested with the Levene test and normal distribution of residues. One-factorial ANOVA tests were carried out for track depth, soil moisture content and grain yield. The multiple comparison test to separate means was carried out with the Student-Newman-Keuls procedure ($p<0.05$).

3. RESU LTS

Track depth and moisture content

NT had a significant lower track depth than in MP (Figure 1). CTs had in the same track depth level than MP. CTd showed the highest track depth, which can be explained by the better loosening effect with increased soil porosity through the wing sweep cultivator in comparison soil loosening with mouldboard plough.

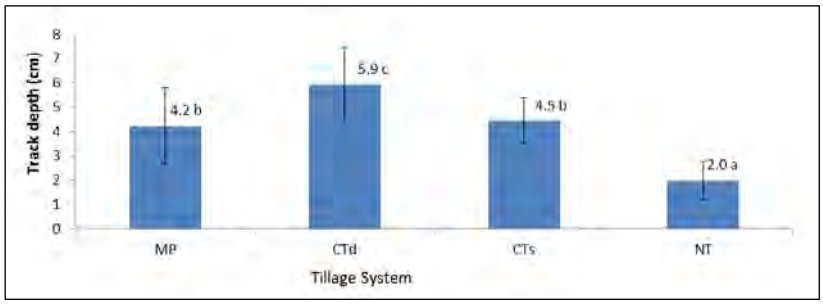

Figure 1. Mean track depth with SD in different tillage systems; N=64; measuring date: 23th March 2017.

Figure 2 shows the soil water conserving effect of the conservation tillage systems CTd, CTs and NT. The soil water content at the measuring time in 23th March 2017 was significant higher in CTd, CTs and NT than MP.

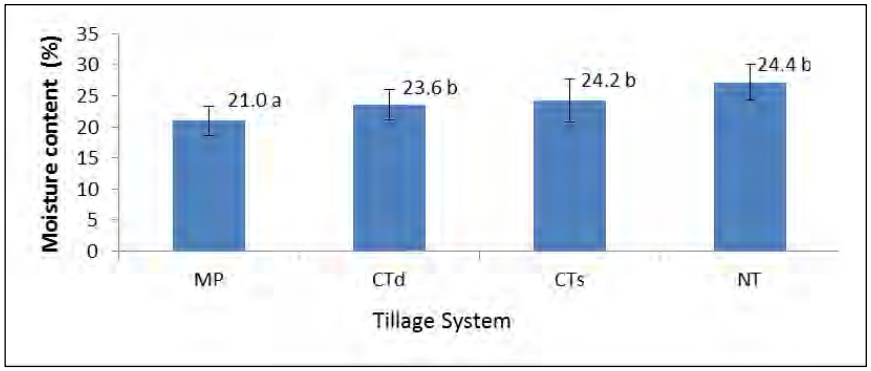

Figure 2. Mean moisture content with SD in different tillage systems; N=28; measuring date: 23th March 2017

Grain yield

The pre-crops in rotation A (maize) and rotation B (soybean) did not influence the grain yield of winter wheat. Grain yields were affected by the tillage systems (Figure 3). The yields were higher in the conservation tillage systems than with MP, which is mainly caused by their better water storage capacity. The highest yield was reached with NT. These results confirm the positive yield effect of conservation tillage systems in dry regions (Pittelkow et al. 2015).

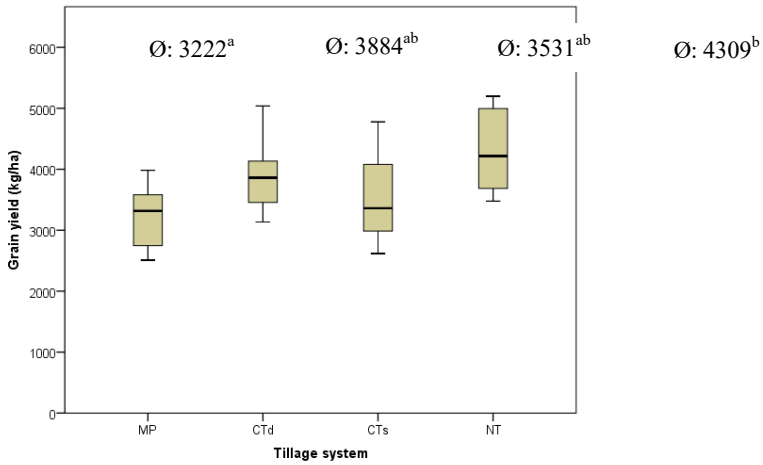

Figure 3. Mean grain yield with box-plots of winter wheat in different tillage systems in the year 2017

CONCLUSIONS

- The increased soil stability in NT decreased the track depth in the field.
- The stability of the soil is determined by the tillage implement. The deep cultivator application caused a smaller bearing capacity with larger track depths than a mouldboard plough.
- Conservation tillage systems CTd, CTs and NT had a better soil water conserving capacity which results in higher yields in the semi-arid climate region.

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CHARACTERISATION OF SELECTED APPLE CULTIVARS IN THE ASPECT OF JUICE PRODUCTION IN THE CONDITION OF A FARM

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Keywords: apple, juice, pressing, efficiency, fruit farm

ABSTRACT
Pressing is the most common method of fruit juice acquisition. Not all apple cultivars are suitable for juice pressing. The use of suitable fruit cultivars for juice pressing may reduce the cost of pressing and at the same time guarantee high quality of the juice produced. The scope of the study comprised the determination of pressing efficiency and of the quality parameters of apple juice obtained, such as acidity and the content of extract. The results of the study indicate that the efficiency of pressing and the quality of the juice obtained are significantly affected by the varietal traits of the apples. The choice of suitable cultivars allows to achieve a high pressing efficiency and to obtain juice characterised by a high content of extract and high acidity.

INTRODUCTION

Pressing is the most common method of apple juice acquisition (Markowski, Baron, Le Quéré, Płocharski, 2015). At present, juice pressing under industrial conditions is performed most frequently with the use of presses for periodic operation (mainly basket-type) and for continuous operation (screw-type presses, roller presses or belt presses) (Bump, 1989). Fruit processing methods employed on the industrial scale may significantly alter the nutritional properties of the fruits (De Paepe, Valkenborg, Coudijzer, Noten, Servaes, De Loose, Voorspoels, Diels, Van Droogenbroeck, 2014). Therefore, it is necessary to develop such methods of fruit processing that will minimise the negative effects of the processing on the health-promoting properties of the fruits (Rothwell, Medina-Remón, Pérez-Jiménez, Neveu, Knaze, Slimani, Scalbert, 2015). In certain countries orchard farms are equipped with complete lines for the pressing and delicate preservation of fruit juices. Recently one can observe a development of juice pressing services with the use of mobile presses, which means that juices are produced on site at the fruit producer's farm (http://mobilejuicefactory.com/mobile-juicing/).

As can be seen from the literature data, not all apple cultivars are suitable for juice pressing. The efficiency of the pressing process and the quality of the juice obtained depend on numerous factors, among which the technological properties of raw material play an important role (Renard, Le-Quéré, Baudin, Symoneaux, Le Bourvellec, Baron 2011). In Poland, more than 60 apple cultivars are entered in the National List of Varieties. However, there is a lack of complete knowledge on their applicability for juice pressing. The use of suitable fruit cultivars for juice pressing may reduce the cost of pressing and at the same time guarantee high quality of the juice produced (Eiselea, Drakeb, 2005; Sedov, Levgerova, Salina, Serova, 2010). This justifies research on various apple cultivars in the aspect of estimation of their applicability for juice pressing, especially in farm conditions (orchards), i.e. without the use of specialised preliminary processing of the fruits prior to pressing.

The objective of the study was the estimation of selected apple cultivars for their suitability for the acquisition of natural juices with the method of pressing. The pressing was performed in a single cycle, with the use of a laboratory basket-type press. The scope of the study comprised the determination of pressing efficiency and of the quality parameters of apple juice obtained, such as acidity and the content of extract (^{o}Bx).

MATERIAL AND METHODS

The study was conducted on 12 cultivars of apples purchased from the Producer Group "Lubsad". The following apple cultivars were selected for the study: Boiken, Gala, Gloster, Golden Delicious, Elise, Idared, Jonagold, Jonagored, Ligol, Pinova, Rubin and Szampion. The tests were conducted on healthy material, without mechanical damage. Prior to the pressing, the apples were washed, excess water was removed, and then the apples were shredded into shavings using a shredder type MKJ250 (Spomasz, Nakło, Poland) with a standard shredding disc with apertures of 8 mm in diameter. Juice was pressed by means of a laboratory basket-type press of an oiriginal design, with diameter of 120 mm and volume of approx. 150 cm³ (Nadulski, Kobus, Wilczyński, Zawiślak, Grochowicz, Guz, 2016). Each measurement was made in six replicates. Material batches of 500 g were placed in fabric bags that were put into the press basket, and then loading was applied by means of a piston. After attaining a load of 40±1 kN the pressing process was interrupted. The expressed juice was collected in a container. After each measurement, the mass of the obtained juice was determined. Extract content in the juice was determined with the refractometric method (Polish standard PN-90/A-75101/02) using an Atago refractometer, and juice pH (PN-EN 1132:1999) was determined using a CP-411 pH-meter (Elmetron, Poland).

The pressing efficiency was calculated from the formula:

$$W = \frac{M}{M_p}$$

where:

W – pressing efficiency, %,
M – mass of juice obtained during pressing, kg,
M_p – initial mass of pulp, kg.

Statistical analysis of the results was conducted with the use of factorial analysis of variance ANOVA. The significance of differences was verified with the use of Tukey's LSD test.

RESULTS

The statistical analysis of the results demonstrated an effect of varietal traits on the efficiency of the process of juice pressing. It addition, differences were found in the content of extract and in the acidity of juices obtained from the particular apple cultivars.

The efficiency of juice expression from the studied apple cultivars varied considerably and amounted to 42.1-53.1% (Fig. 1). The levels of pressing efficiency achieved in the experiment are lower than values obtained in industrial conditions (72-83%). This is related to the fact that under the conditions of the experiment no enzymatic treatment was applied. In the course of the study it was noted that certain cultivars are resistant to juice pressing. During juice pressing from cultivars Boiken and Pinova it was observed

that solid particles passed through the fabric and, as a result, the juice obtained had the consistence of a pulp. The highest efficiency of juice pressing was obtained in the case of cultivars Idared, Gloster and Jonagold and the lowest in the case of cultivars Boiken and Pinova.

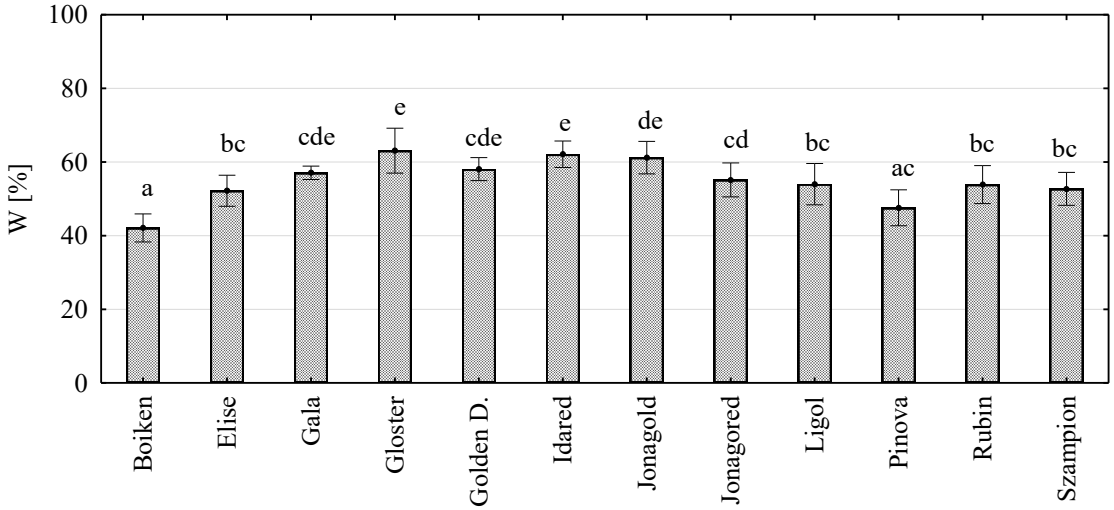

Fig. 1. Efficiency W (%) of the pressure extraction from the pulp depending on apple variety
a, b, c … – values marked with the same letter are not statistically significantly different (p>0.05)

The soluble solids content (°Bx) in the analysed apple juice varied from 10.2°Bx to 13.3°Bx and depended on the cultivar from which the juice was obtained (Fig. 2). The highest soluble solids content (°Bx) was noted in juice obtained from cv. Jonagored and the lowest in juice from cv. Ligol. All the juices were characterised by soluble solids content (°Bx) above 10°Bx, which means that in this respect they met the criterion of suitability for pressing.

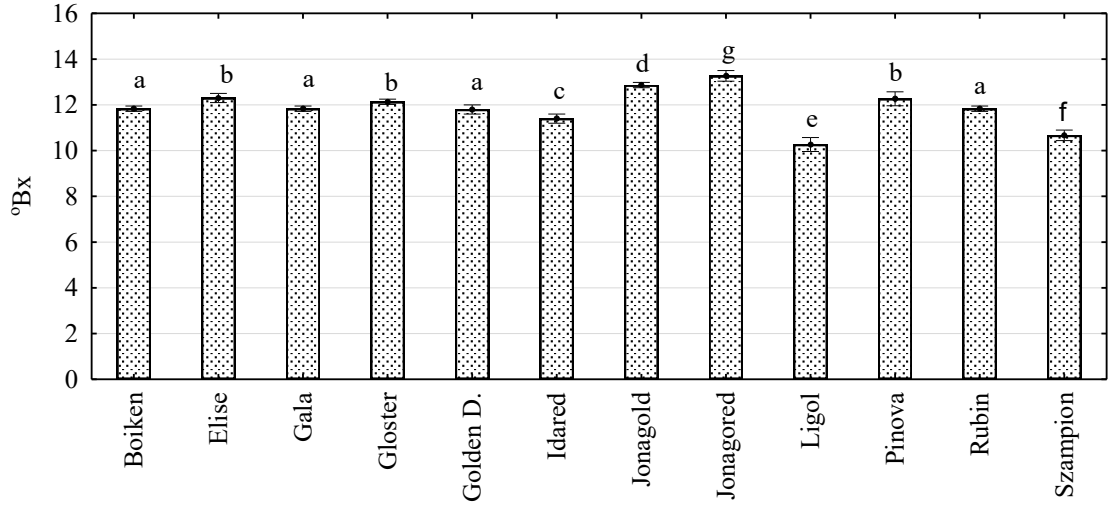

Fig. 2. The soluble solids content (°Bx) in the obtained juices depending on apple variety
a, b, c … – values marked with the same letter are not statistically significantly different (p>0.05)

The juices obtained in the scope of the experiment were characterised by varied acidity (Fig. 3).

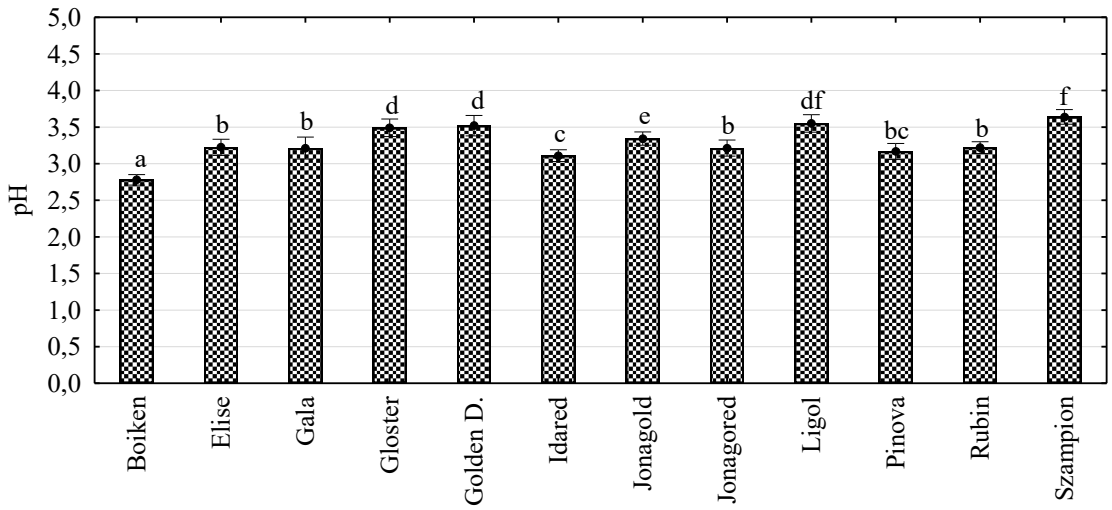

Fig. 3. Acidity (pH) of the obtained juices depending on apple variety
a, b, c … – values marked with the same letter are not statistically significantly different (p>0.05)

The lowest pH value was obtained in the case of juice from cv. Boiken and the highest pH was obtained for cultivars Ligol, Golden Delicious, and Gloster.

CONCLUSIONS

The results of the study indicate that the efficiency of pressing and the quality of the juice obtained are significantly affected by the varietal traits of the apples. The choice of suitable cultivars allows to achieve a high pressing efficiency and to obtain juice characterised by a high content of extract and high acidity. The highest efficiency of juice pressing was obtained in the case of cultivars Idared, Gloster and Jonagold and the lowest in the case of cultivars Boiken and Pinova. The highest soluble solids content (^{o}Bx) was noted in juice obtained from cv. Jonagored, and the lowest in juice from cv. Ligol. All the juices were characterised by soluble solids content (^{o}Bx) above 10°Bx. The lowest pH value was obtained in the case of juice from cv. Boiken, and the highest pH was obtained for cultivars Ligol, Golden Delicious and Gloster.

The choice of suitable apple cultivars for processing can significantly reduce the costs of juice acquisition in farm conditions, where generally no treatments augmenting the process of pressing (e.g. enzymatic treatment), typical in industrial fruit juice production, are applied.

The experiment performed within the scope of the study indicates that it is worthwhile to undertake further research in the aspect of estimation of the suitability of particular apple cultivars for juice pressing in farm conditions.

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TEXTURE CHANGES IN APPLE CULTIVARS DURING STORAGE IN DIFFERENT CONDITIONS

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Keywords: apple, texture, storage, time, fruit farm

ABSTRACT

In Poland, apples are stored in cold storage plants, with either normal or controlled atmosphere. Estimation of physical parameters permits the determination of the current state of the fruit and the prediction of allowable periods of commercial turnover after storage. The objective of the study was to characterise, on the basis of experimental studies, the firmness of the flesh and the skin strength in the puncture test of apple cultivars Ligol, Gloster, Golden Delicious, and Jonagored held in cold storage under different conditions. Apple storage conditions have a decisive effect on the preservation of the texture. In the course of cold storage of apples there takes place an unfavourable change in the analysed parameters of their texture The dynamics of changes in the analysed values characterising the texture was related to the varietal traits of the fruits.

INTRODUCTION

With apple harvest of over 3 million tons a year, Poland ranks among the largest producers of the fruit in Europe. In Poland, apples are stored in cold storage plants, with either normal or controlled atmosphere. Estimation of physical parameters permits the determination of the current state of the fruit and the prediction of allowable periods of commercial turnover after storage (Johnston, Hewett, Banks, Harker, Hertog 2001; Nadulski, 2009). In practice, the estimation of textural properties of fruit is conducted primarily with the use of empirical tests consisting, among other things, in the determination of fruit firmness with the Magness-Taylor method and of skin strength in the skin puncture test, as well as imitation application of the TPA test (Bourne, 2002; Surmaka-Scześniak, 2002). However, the textural properties of apples depend to a large extent on pre-harvest and post-harvest factors, and the time of harvest of the fruits has a significant effect on the storage capacity of the fruits and on their properties during storage (Saei, Tustinc, Zamania, Talaiea, Halld, 2011; Costa, Cappellin, Fontanari, Longhi., Guerra, Magnago, Gasperi, Biasioli 2012). In long-term storage of fruits, specific requirements concerning temperature, humidity and the amount of oxygen and carbon dioxide in the storage plant have to be met (Weber, Brackmann, Anese, Both, Pavanello, 2012). Non-observance of the technological regime during storage in cold storage plants with controlled atmosphere may lead to fruit damage (Saquet and Streif 2008). From the viewpoint of the producer, it is important to have fruits in commercial turnover before their firmness drops to a level that would be unacceptable to the consumer (Płocharski and Konopacka 1999). Therefore, it is necessary to acquire knowledge on changes in the textural properties of particular apple cultivars in the course of storage in cold storage plants with normal and controlled atmosphere.

The objective of the study was to characterise, on the basis of experimental studies, the firmness of the flesh and the skin strength in the puncture test of apple cultivars Ligol, Gloster, Golden Delicious, and Jonagored held in cold storage under different conditions.

MATERIAL AND METHODS

The experimental material consisted of fruits of four apple cultivars *(Malus domestica Borkh.*): Gloster, Golden Delicious, Jonagored, Ligol). The material originated from a specialist orchard farm belonging to the Association of Fruit Producers "Stryjno Sad". The material selected for the tests was of similar fruit size, healthy, without mechanical damage, from the harvests of the years 2011/2012.

The material used in the experiments was stored for 220 days in a cold storage plant with normal atmosphere (NA) and in a cold storage plant with reduced oxygen level (ULO). The first series of tests was performed immediately after the harvest, and subsequent tests at 30-day intervals. In the normal storage plant the temperature was maintained at 1.7-2.5°C and humidity at the level of 86-92%, while in the chamber with atmosphere with reduced oxygen level (ULO) the temperature was 1.6-2.2°C and the humidity was 90%-92%. The atmosphere consisted of the following gases with percentage rates of 1,6% - oxygen, 2,2% - carbon dioxide, and nitrogen.

The textural tests were performed with the use of the Texture Analyser TA-TX2, Stable Micro Systems Ltd. (Great Britain), equipped with measuring head with operation range up to 0.5 kN. The tests were made using a penetrometer with diameter of 11.1 mm and a cylindrical tip with convex face (conforming to the Magness-Taylor apparatus) for the penetration of apple flesh, and a penetrometer with diameter of 5 mm and a flat-faced cylindrical tip for the apple skin puncture tests. The penetration tests were conducted on fruits with a layer of skin removed to achieve penetration of 8 mm. The skin puncture test was made on the largest-diameter perimeter of the fruits, until the penetrometer penetrated the fruit flesh to the depth of 8 mm. Statistical analysis of the results was made using the software package Statistica 12.0 (StatSoft Inc., Tulsa, OK, USA), using the analysis of variance and regression analysis.

RESULTS

Apple storage in the storage plant with normal atmosphere caused a very big loss of fruit flesh firmness at the end of the period of storage (Fig. 1).

The greatest loss of firmness of 58.8% was recorded in the case of fruits of cv. Ligol, and the lowest – 47.9% - in the case of cv. Jonagored. The firmness of the flesh of fruits of cultivars Gloster and Golden Delicious decreased by approximately 55-56%.

Analysis of the graphs indicates that in the course of apple storage in the cold storage plant with controlled atmosphere there takes place a gradual decrease of the firmness of the fruits (Fig. 2). At the end of the period of storage in the cold storage plant with controlled atmosphere a 31.9% decrease of flesh firmness was noted in the case of fruits of cv. Gloster, 28.1% in the case of cv. Golden Delicious, 14.9% in the case of cv. Jonagored, and a 10.6% decrease of flesh firmness in the case of cv. Ligol.

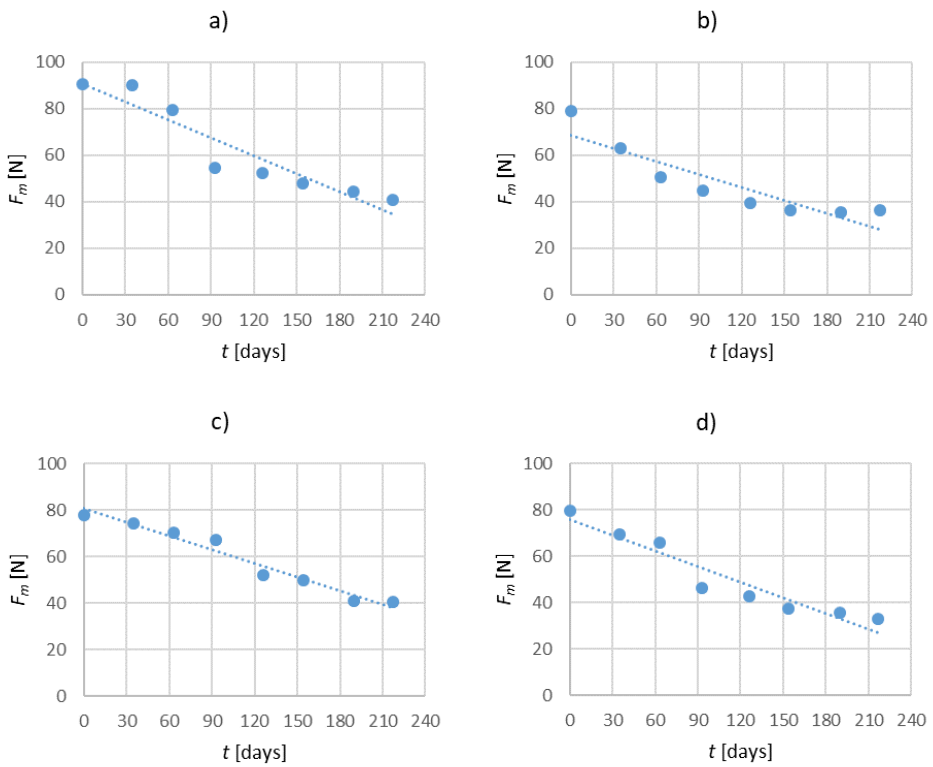

Fig. 1. Mean values of force F_m (firmness) for flesh tissue of apples of cultivars Gloster (a), Golden Delicious (b), Jonagored (c), Ligol (d) in relation to the time of storage in cold storage plant with normal atmosphere (NA)

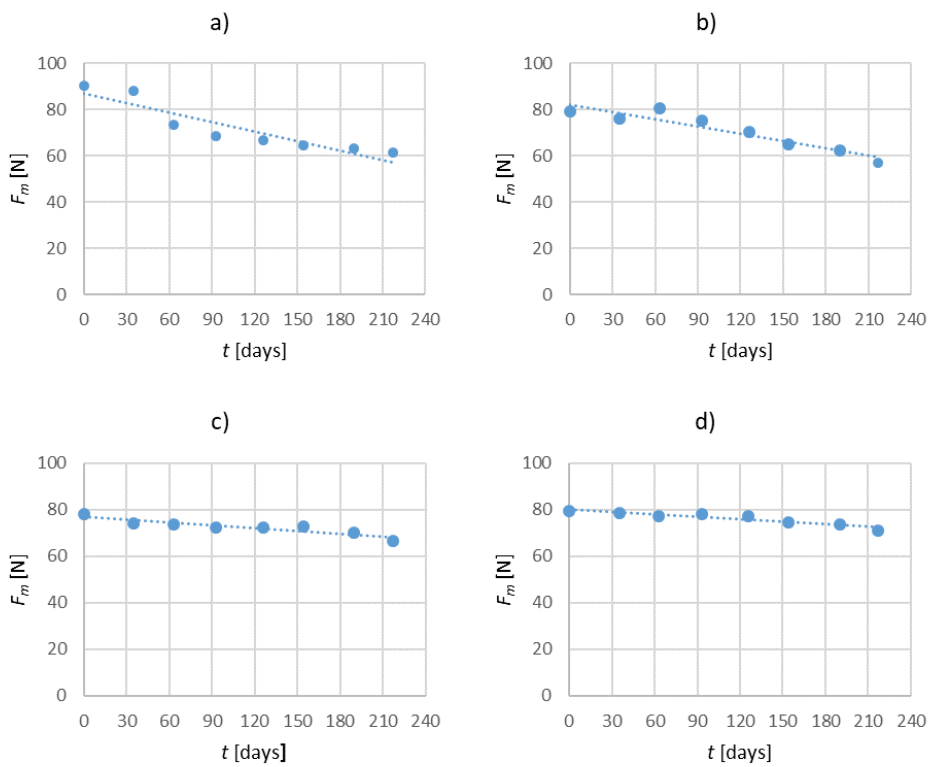

Fig. 2. Mean values of force F_m (firmness) for flesh tissue of apples of cultivars Gloster (a), Golden Delicious (b), Jonagored (c), Ligol (d) in relation to the time of storage in cold storage plant with controlled atmosphere (ULO)

In the course of fruit storage in the cold storage plant with normal atmosphere, a distinct decrease was recorded in the value of force required to puncture the skin (Fig. 3). At the end of the period of storage the value of the force required for apple skin puncture, in the case of all apple cultivars tested, decreased to the level of 17.3-19.9 N. The greatest decrease of skin strength was noted in the case of apples cv. Golden Delicious, for which it amounted to 48.6%, while in the case of the remaining cultivars the decrease was in the range of 32.6-39.7%.

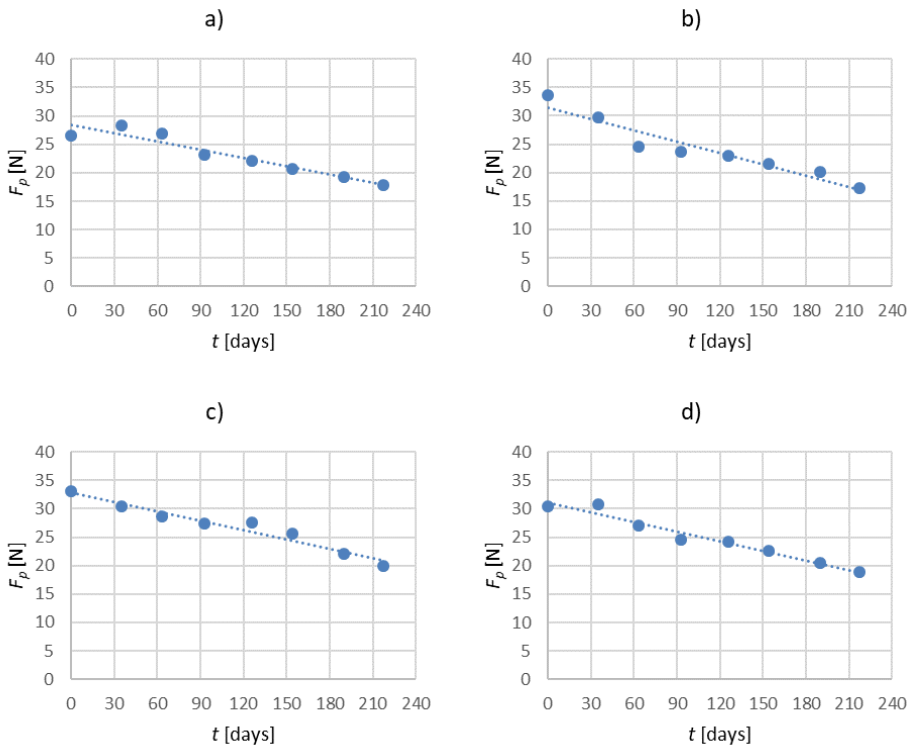

Fig. 3. Mean values of skin puncture force F_p for apples of cultivars Gloster (a), Golden Delicious (b), Jonagored (c), Ligol (d) in relation to the time of storage in cold storage plant with normal atmosphere (NA)

During fruit storage in the cold storage plant with controlled atmosphere the value of the force required for fruit skin puncture decreased only to a small degree (Fig. 4). The greatest decrease in skin strength was recorded in the case of cv. Gloster – 27.1% and cv. Golden Delicious – 21.1%, and the smallest in the case of cv. Jonagored – 13.5% and cv. Ligol – 13.5%.

At the end of the period of storage decidedly the lowest resistance to skin puncture was characteristic of the fruits of cv. Gloster – 19.3 N. The resistance to skin puncture noted for the other apple cultivars was at a fairly similar level and fell within the range of 26.1-28.6 N.

Irrespective of the conditions of storage, all the parameters of apple texture during the storage were described by means of linear regression equations, obtaining very good fit of the equations to measured values.

In conclusion, it can be stated that apple flesh firmness and skin puncture force depend significantly on the time and conditions of fruit storage. In addition, statistical analysis of the results showed that the range and character of changes in the parameters tested depended also on the varietal traits of the fruits.

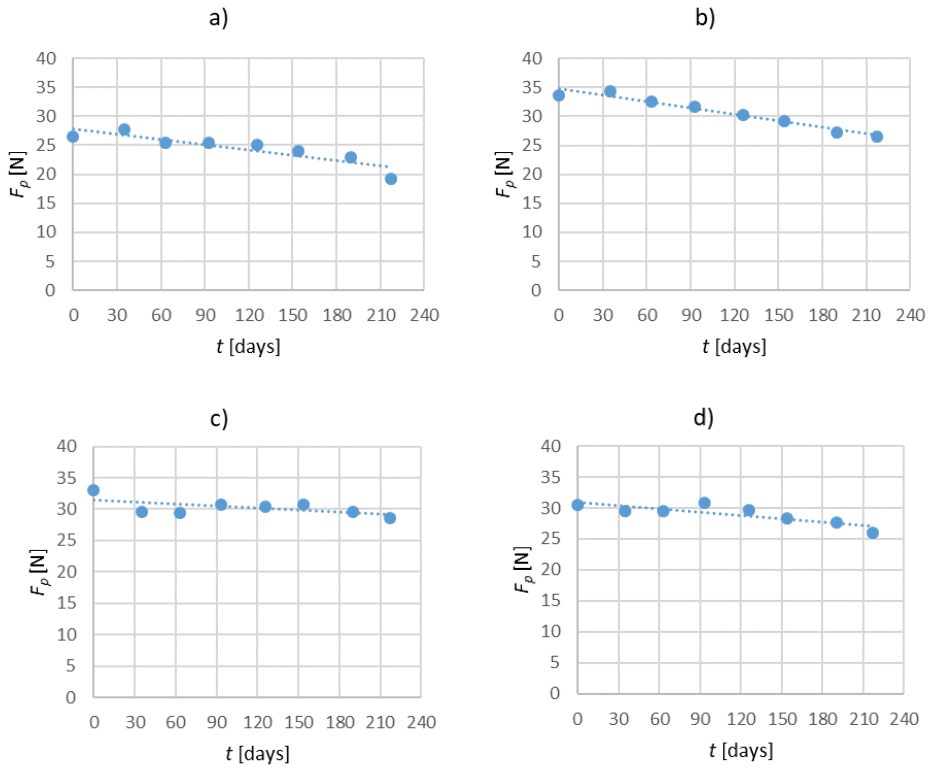

Fig. 4. Mean values of skin puncture force F_p for apples of cultivars Gloster (a), Golden Delicious (b), Jonagored (c), Ligol (d) in relation to the time of storage in cold storage plant with controlled atmosphere (ULO)

CONCLUSIONS

In the course of cold storage of apples, an unfavourable change in the analysed parameters of their texture takes place. Apple storage conditions have a decisive effect on the preservation of the texture. The range of changes in the values of the analysed texture parameters of apples stored in the cold storage plant with controlled atmosphere was decidedly smaller compared to the changes in the texture of fruits stored in the cold storage plant with normal atmosphere. The dynamics of changes in the analysed values characterising the texture was related to the varietal traits of the fruits. In the case of storage in the normal cold storage plant, among the apple cultivars under study the smallest range of changes in the analysed texture parameters was determined for cultivars Ligol and Jonagored. The dynamics of changes in the values of texture parameters of apples stored in the cold storage plant with controlled atmosphere depended on the varietal traits of the apples to a smaller degree. Relatively the smallest range of changes in the texture parameters of apples stored in the cold storage plant with controlled atmosphere was noted in the case of cultivars Ligol and Jonagored. In the course of apple storage in the cold storage plant with controlled atmosphere a constant gradual decrease in the values of the analysed texture parameters was observed throughout the period of storage, while in the case of fruits stored in the cold storage plant with normal atmosphere the greatest range of changes in the texture parameters took place in the initial stage of storage, after which the rate of the changes decreased notably.

Knowledge on the changes in apple texture during storage allows to empty the cold storage chambers at a suitable time and sell the fruits, which in effect reduces the costs operation of cold storage facilities at orchard farms.

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ASSESSMENT OF QUALITY CHARACTERISTICS OF BRIQUETTES PRODUCED FROM SELECTED WOOD WASTE

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Keywords: agro-energetics, biomass, briquettes, sustainability agriculture

ABSTRACT
The paper presents evaluation of the quality characteristics of briquettes produced from selected wood waste, whose use is part of a sustainable farming policy. The following types of wood waste were used in the study: poplar sawdust, poplar bark, oak shavings and oak bark. In order to crush the poplar and oak bark, a beater shredder was used. Briquettes were made using hydraulic piston briquetting machine. During the briquetting process, the working pressure was 8 MPa. Depending on the type of waste used, the briquettes produced differed in their qualities. Based on the analysis of the obtained results, it was found that the characteristics of produced briquettes were influenced by such factors as the type of raw material, its humidity and fragmentation. The best quality features characterized briquettes made of oak bark and the least advantageous of oak shavings.

INTRODUCTION

The Sustainable Agriculture Strategy fosters environmental protection in rural areas, which is linked to increased use of renewable energy sources. Wood waste is a valuable energy resource and they fit in this strategy. It can be used to produce electricity, heat, and liquid and gaseous fuels. Remnants of the trees, waste from sawmills or branches of orchards can be burned in the form of sliced wood, chips, and processed into pellets or briquettes (Hejft & Obidziński, 2015; Niedziółka et al., 2016). This allows full use of the raw material. This type of fuel is not harmful to the environment. Carbon dioxide, which is emitted to the atmosphere during combustion, is completely absorbed by plants reproducing biomass in the process of photosynthesis. In addition, wood is the fuel that leaves the minimum amount of ash after burning (Kachel-Jakubowska et al., 2013; Mc Kendry, 2002; Panwar et al., 2011).

Wood, which is a major part of biomass, is the most widely used renewable energy source in Europe. It occurs in the form of shavings from perennial trees (e.g. willow, poplar) as well as chips, sawdust and wood dust (Ivanova et al., 2014). The popular way to use wood fractions is to produce pellets and briquettes for energy purposes. In addition, the generation of energy from wood waste is profitable, because prices of these fuels on the market are competitive relative to fossil fuels (Frączek, 2010; Shawa et al., 2009).

Besides wood waste, straw and specially developed energy crops can be used for the production of heat. These raw materials are the biomass, which is included in renewable energy sources, including solar, geothermal, wind and river energy, agricultural biogas, and landfill and sewage treatment plants (Demirbas, 2004; Dreszer et al., 2003). Poland is characterized by the high potential of biomass used for energy purposes. It has considerable potential for development of agro-energy, especially based on the production of perennial energy crops. Hence, most biomass used for power generation is produced in the country (Kołodziej & Matyka, 2012; Niedziółka, 2014).

Solid biofuels made of plant biomass are of particular interest to distributed energy and to individual consumers. At present, professional energy is reluctant to use biomass as a fuel in power systems. This is caused, among others, by lower quality of this kind of fuel and also the instability of its supply. However, it is necessary to look for alternative fuels for the energy sector, hence the aim is to use different types of plant biomass for these purposes. New technological solutions are also sought, using plant fuels to produce electricity and heat. The existing technologies for the management of biomass surpluses from agricultural, forestry and orchard production are also being improved (Fournel et al., 2015; Huiling et al., 2013; Zhang et al., 2013).

The purpose of the study was to analyze the qualities of briquettes produced from selected wood waste in a hydraulic piston briquetting machine.

MATERIAL AND METHODS

The following wood waste was used for the production of briquettes: poplar sawdust, poplar bark, oak shavings and oak bark. The tree bark was crushed using a beater powered by an electric motor of 5.5 kW and equipped with a 10 mm mesh diameter sieve. For the briquetting of raw materials, hydraulic piston briquetting machine was used. During the briquetting process, the working pressure was 8 MPa and the double feed of the feeder to the briquetting compaction chamber, was applied.

The relative humidity of wood raw materials and their calorific value, based on calorimetric measurements, was determined using an iso-perybolic calorimeter. The moisture and heat content of the raw materials were measured in triplicate.

Measurements of physical features of briquettes included: diameter, length and weight. Samples of 10 briquettes were taken and three replicates were used for the measurements. The diameter and length of the briquettes were determined by means of a slide gauge with a measurement accuracy of ± 1 mm and their mass using laboratory scale with an accuracy of ± 0.1 g.

The bulk density of briquettes was determined on the basis of measurements of their physical characteristics including diameter, length and weight and then calculated according to formula (1):

$$\rho_w = \frac{4 \cdot 10^6 \cdot m}{\pi \cdot d^2 \cdot l} \ (\mathrm{kg \cdot m^{-3}}) \tag{1}$$

where: ρ_w – briquette bulk density ($\mathrm{kg \cdot m^{-3}}$),
m – mass of briquette (g),
d – outer diameter of briquette (mm),
l – length of briquette (mm).

Measurements of mechanical durability of briquettes were carried out on a test bench in accordance with standard PN-EN 15210-2:2011. The rotational speed of the cylinder was 21 rpm (± 0.1 rpm), a test time of 5 min, and a sample weight of 2000 g (±100 g). After the durability test, the briquettes were screened on a 31.5 mm diameter screen. The mechanical durability of briquettes was calculated according to the formula (2):

$$D_U = \frac{m_A}{m_E} \cdot 100 \ (\%) \tag{2}$$

where: D_U – mechanical durability of briquettes (%),
m_A – mass of briquettes after durability test (g),
m_E – mass of briquettes before durability test (g).

The results of the tested briquettes were subjected to statistical analysis using variance analysis and Tukey's test. For this purpose, the Statistica ver. 13.1 software was applied and the significance level was assumed at α=0.05.

RESULTS

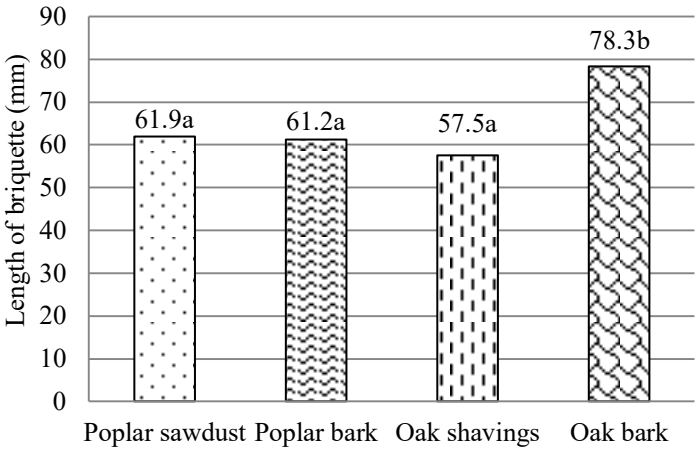
Prior to the wood waste briquetting process, the moisture content and calorific value were determined. Based on the results obtained, it was found that the moisture content of wood waste used for the production of briquettes ranged from 10.7% to 14.8%, while their calorific value was within the limits of 15.5-16.3 $MJ \cdot kg^{-1}$ (Table 1).

Table 1. Relative moisture and calorific value of wood waste

Kind of wood waste	Relative moisture (%)	Calorific value ($MJ \cdot kg^{-1}$)
Poplar sawdust	13.4	16.3
Poplar bark	12.6	16.1
Oak shavings	10.7	15.5
Oak bark	14.8	15.6

Source: own work

Diameter of the obtained briquettes was constant and was 50 mm. Figure 1 shows average lengths of obtained briquettes. The longest briquettes were made of oak bark (78.3 mm), much shorter of poplar sawdust (61.9 mm) and poplar bark (61.2 mm), while the shortest of oak shavings (57.5 mm). There were no statistically significant differences between the lengths of briquettes produced from poplar sawdust, poplar bark and oak shavings. On the other hand, statistically significant differences occurred between the length of these briquettes and the length of oak bark briquettes.



a, b, c: mean values marked with the same letter do not differ statistically significantly at the level α=0.05

Source: own work

Figure 1. Average length of produced briquettes

Figure 2 illustrates average mass of obtained briquettes. By analyzing the mass of biofuel produced, oak bark bricks were the heaviest (182.7 g), poplar sawdust - heavier (118.6 g), and poplar bark (110.2 g) and oak shavings (107.6 g) were the lightest. There were no statistically significant differences between the mass of poplar bark and oak shavings. In contrast, in other cases, statistically significant differences were observed between the mass of produced briquettes.

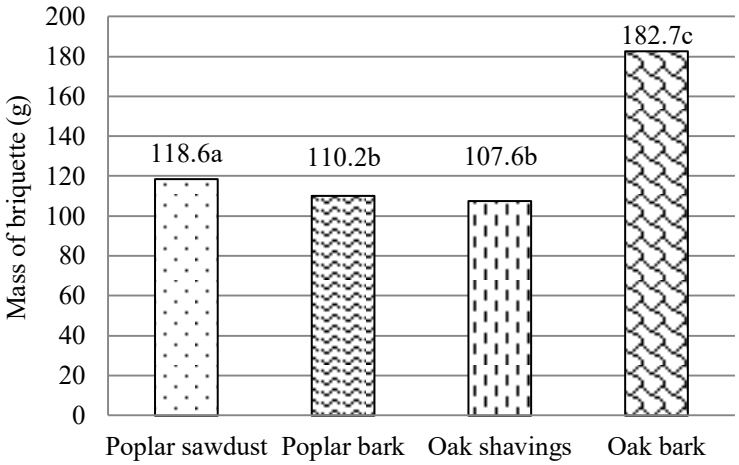


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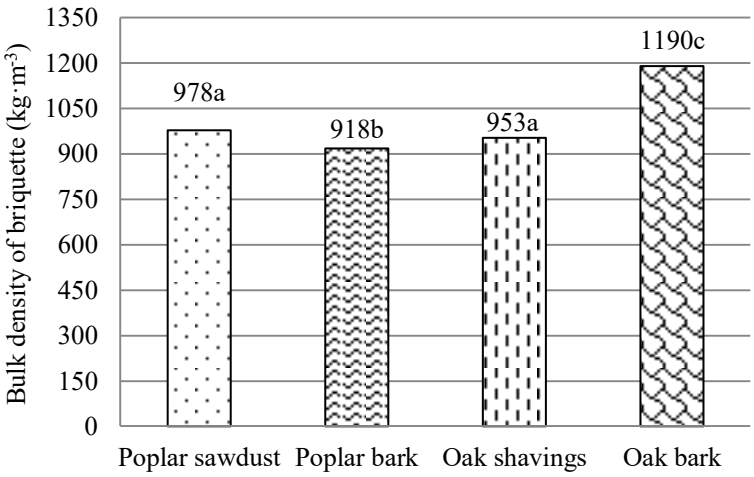
Figure 2. Average mass of produced briquettes

Figure 3 presents average bulk densities of briquettes produced. The highest density was characterized by oak bark briquettes (1190 $kg \cdot m^{-3}$). The density of briquettes made from poplar sawdust (978 $kg \cdot m^{-3}$) and oak (953 $kg \cdot m^{-3}$) was significantly lower than that of briquettes made from poplar bark (918 $kg \cdot m^{-3}$). There were no statistically significant differences between bulk density of poplar sawdust and oak shavings. In contrast, for other cases, statistically significant differences were found between densities of produced briquettes.

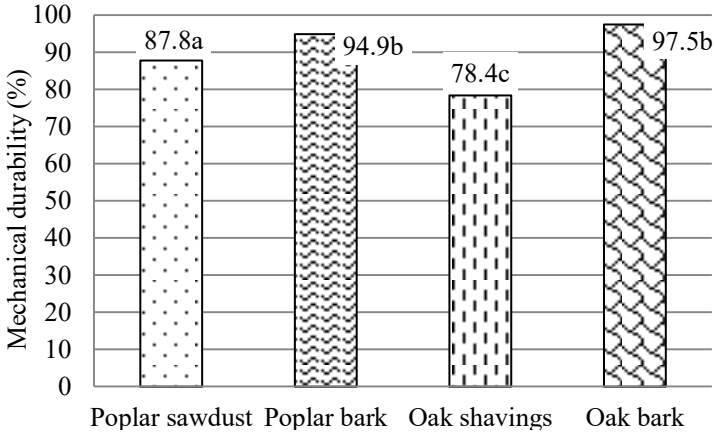


a, b, c: mean values marked with the same letter do not differ statistically significantly at the level α=0.05

Source: own work

Figure 3. Average bulk density of produced briquettes

Figure 4 shows the average values of mechanical durability of obtained briquettes. It was found that the largest indicator was showed by oak bark (97.5%) and poplar bark briquettes (94.9%), significantly less - of poplar sawdust (87.8%) and the lowest - of oak shavings (78.4%). There were no statistically significant differences between the durability of poplar bark and oak bark briquettes. However, in the remaining cases, statistically significant differences were found between durability of the produced briquettes.



a, b, c: mean values marked with the same letter do not differ statistically significantly at the level α=0.05

Source: own work

Figure 4. Average mechanical durability of produced briquettes

CONCLUSIONS

Based on the analysis of the obtained results, it was found that the characteristics of produced briquettes were influenced by such factors as the type of raw material, its humidity and fragmentation. The moisture content of wood waste used for the production of briquettes was varied. The lowest moisture content was characterized by oak shavings (10.7%) and the highest - oak bark (14.8%). The calorific value of briquettes from wood waste was slightly differentiated. The lowest heating value was obtained from oat shavings briquettes 15.5 $MJ \cdot kg^{-1}$, and the highest - from poplar sawdust 16.3 $MJ \cdot kg^{-1}$. Of the produced briquettes, the lowest bulk density was obtained for the briquette of the poplar bark (918 $kg \cdot m^{-3}$) and the highest for the oak bark (1190 $kg \cdot m^{-3}$). The results of mechanical durability tests showed that the lowest indicator was for oak shavings briquettes (78.4%), while the highest for oak bark briquettes (97.5%). The best qualities of briquettes were found in the case of agglomeration of oak bark, less favorable in the case of poplar sawdust and poplar bark, and the least favorable for oak shavings. Research indicates that the plant material analyzed can be a valuable source of energy. The use of these biofuels is conducive to the achievement of the objectives of sustainable agriculture policy.

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ANALYSIS OF PHYSICAL PROPERTIES OF DIETARY FIBER FROM APPLE WASTE

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Keywords: apple waste, pressure agglomeration, pellet from agri-food waste

ABSTRACT

The purpose of the present study was to determine the suitability of apple fibers (dietary fiber) as a raw material for granulate pellets production, as an aspect of waste management in sustainable agriculture processes. Apple fibers are a waste produced during the agri-food processing of apples. It is obtained from apple peas and can be further used as a diet supplement or for animal feed purposes, reducing the breeding costs. The material was moisturized with water and a mixture of water and milk powder to a moisture content of 16%. During the tests, the maximum pressure of the process was determined for all trials carried out. Density, absorption and activity of water in the resulting agglomerate and in the raw material were examined. Increasing the temperature of the pressure process from 20 to 50°C results in an approx. 50% increase in the density of the test mixtures. Higher density of the resulting granules was obtained using lower agglomeration pressure. The increase in density of the granulate influences the reduction of its water absorption (decrease of its moisture content and water activity). Increasing the density of apple fiber (from loose fiber) decreases moisture and water activity.

INTRODUCTION

Agricultural residues are the largest, in terms of mass, biomass feedstock in the Word, which is about 1.5 Gt of straw from cereal crops produced worldwide. According to Lu et al. (2014) densification (agglomeration) of biomass is considered important to achieve economical handling, transport, and storage procedures. Hejft (2002) claims that the main goal of agglomeration pressure processes is to obtain a compact and fragmentary product of a defined shape, geometric dimensions and properties. This process is influenced by many factors: the characteristics of the bulk medium, the way it is prepared for compacting, the type of device in which the process is implemented and the parameters of the agglomeration process. According to Janewicz and Kostrukiewicz (2016), the direct impact on the course and effects of the agglomeration process of a given bulk material is its susceptibility to densification and its ability to merge. These properties can be shaped by, for example, the use of binders. For example, Lu et al. (2014) investigated that with the addition of wood residue the tensile strength of the wheat straw pellets increased, other described experiments show that the density of wheat straw pellets was increased by adding bentonite and lignosulfonate. Ahn et al. (2014) concluded that the addition of rapeseed flour, coffee meal and lignin powder to larch or tulip tree particles increase the durability of obtained pellets. Whittaker and Shield (2017) reviewed factors affecting biomass pellet quality and they fund that starch or lignin-based binders can improve durability, particularly in feedstocks with lower lignin contents. Moreover, adding fat or oil-based binders might reduce the energy consumption of agglomeration, but the reduced friction may cause the pellets more elastic and less durable. Soleimani et al. (2017) state that pellets from spruce wood shavings or wheat straw with binders like glucose, fructose, sucrose or maltodextrin have higher density over 1200 kg/m^3 or even 1300 kg/m^3, where compared to the unit density of the pellets from the native biomass it was up to 1200 kg/m^3. Bai et al. (2017) obtained good quality pellets from biochar and 15% additive of peanut shell binder.

Similar research was conducted by Hu et al. (2015) where to biochar were added lignin, starch, calcium hydroxide, and sodium hydroxide. They found that starch was not suitable to be used as a binder cause of the low mechanical strength and density of obtained pellets.

The aim of the presented paper is to analyze the suitability of apple fibers (dietary fiber) as a raw material for granulate pellet production, as an aspect of waste management in sustainable agriculture processes. Apple fibers in the forms of pellets may be used as a diet supplement or for animal feed purposes, which would reduce the costs of agri-food production. Apple fibers were agglomerated in various temperature conditions from 20 to 50°C and using water or water and milk powder as a binder. The obtained pellets were examined on maximum agglomeration pressures, density, water absorption and water activity.

MATERIALS AND METHODS

The material used in the experiment was dietary fiber from apple waste. Apple fiber is a loose product used to produce from apple pomace pieces. Fiber production takes place through multi-phase cleaning, grinding, micronization and pasteurization. It is characterized by a high content of organic acids, vitamins, pectins and tannins. This means that it consists predominantly of soluble fiber. The apple fiber had moisture content of 8.1% and was mixed with water and water and milk powder to increase the humidity to 16%.

In the course of the tests of the densification process, determined were: the susceptibility to densification of dietary fiber from apple waste mixed with water and water with milk powder, by determining the maximum pressures densifying the material and the density of obtained pellets. Moreover, there was examined the water activity and water absorption of the raw material and produced pellets.

Tests of the densification process were carried out on a SS-3 stand, with the "open densification chamber-densifying piston" working system presented in the articles (Obidziński 2012a, Obidziński 2012b). The stand was modernized by using a heating band coupled with a temperature controller. Densification of the material was carried out by means of piston equipped with tensometric sensor allowing to record forces acting on the piston.

In the course of the tests, 20 samples were subject to densification in an open chamber with a diameter of 8 mm. The tests of densification of apple fiber waste were carried out at two input values, i.e.:

— $x_1 = z_w$ – binder type (water, water with milk powder),

— $x_2 = t_p$ - process temperature (20, 35 and 50°C).

The tests were carried out at a length of matrix openings of l_m = 20 mm by densifying waste samples with a mass of m_p = 0.7g.

Pellets density was determined, after 24 hours, by measuring the height and diameter of pellets using means of a caliper with an accuracy of ±0.02 mm and determining their mass using means of a WPS 360 laboratory scale with an accuracy of ±0.001 g. Density was calculated as the ratio of the mass of pellets to the sum of their volumes. Determination of the moisture content of material was performed pursuant to PN-76/R-

64752, prior to the densification process, using means of a WPE 300S moisture balance with an accuracy of 0.01%. Water activity of pellets was measured after 120, 240 and 360 hours of its storage in desiccators in various salinity conditions, using the AquaLab Series 3 apparatus, the methodology was before described in articles (Obidziński 2014, Obidziński et al. 2017).

RESULTS

Initial tests allowed to conclude that the tested apple fiber is characterized by bulk density of approx. 554.31 kg/m^3 and its water activity is 0.510. Table 1 presents the experimental data obtained during the agglomeration process of apple fiber. It was observed that in the case of density, the type of used binder did not affect it significantly in any process temperature. Completely different was in the case of the agglomeration pressures (fig.1.): it was found that water with milk powder as a binder requires greatly lower pressure to achieve a similar density as pellets produced from fiber and water. Moreover, increasing the process temperature had notably decreased the agglomeration pressure, while, as expected, the density increased.

Table 1. Results of granulate density tests and maximum pressures obtained during the pressure process of apple fiber agglomeration with the addition of various binders

Temperature [°C]	Pellet density [kg/m^3]		Maximum agglomeration pressure [MPa]	
	Pellet with water	Pellet with water and milk powder	Pellet with water	Pellet with water and milk powder
20	804.866	809.231	52.15	16.95
35	1003.259	1008.542	21.61	10.69
50	1202.922	1210.875	7.36	6.32

Table 2 presents results of pellet water absorption in various cases of binder used, NaCl concentration in a desiccators and pellet density. It has been found that pellets produced from apple fiber and water with milk powder are more susceptible for water absorption, especially at their low density. On the other hand, pellets with high density had a higher moisture content after the experiment which was, for example for water and milk powder as a binder approx. 13% for 1200 kg/m^3 and 10% for 800 kg/m^3: the higher density the higher water sorption during the agglomeration processes.

Table 2. Changes in pellet humidity during its for 360 hours storage in desiccators in various salinity conditions

NaCl concentration [%]	25			30			35		
Approx. pellet density [kg/m^3]	800	1000	1200	800	1000	1200	800	1000	1200
Change in pellet humidity (binder water and milk powder) [%]	1.3	0.5	0.3	-0.3	-0.4	-0.3	-0.4	-0.4	-0.5
Change in pellet humidity (binder water) [%]	0.9	0.9	0.2	-0.3	-0.4	-0.6	-0.2	-0.5	-0.6

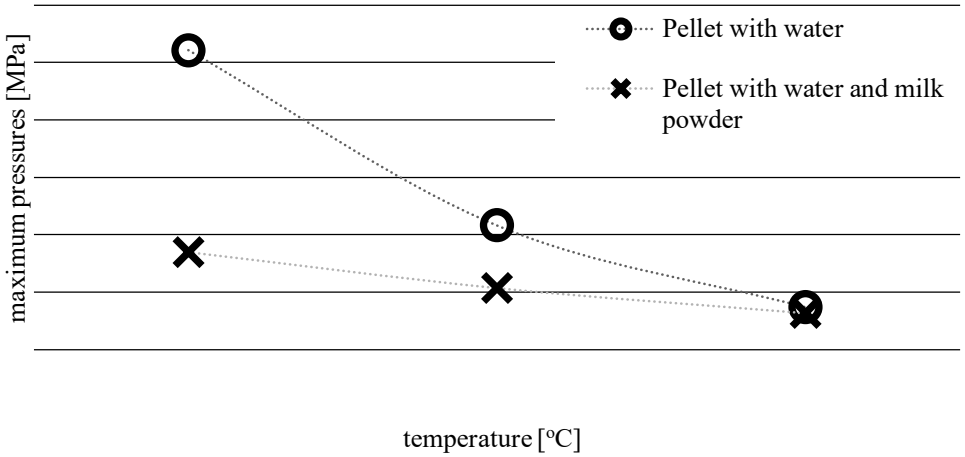

Figure 1. Influence of the temperature of the agglomeration process on the maximum thickening pressures obtained during the process of apple fiber agglomeration with the addition of various binders

In figures 2 and 3 are presented the effect of the residence time in the desiccators with various concentrations of NaCl.

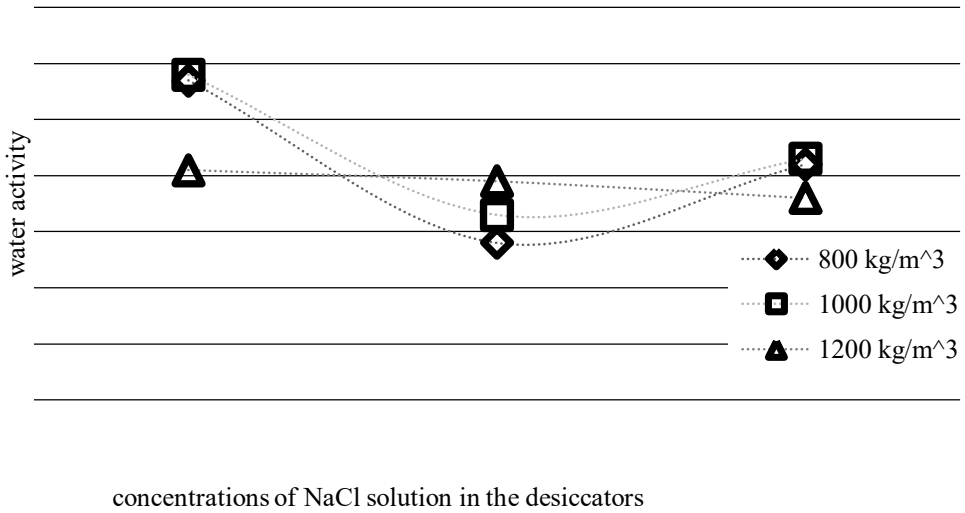

Figure 2. Effect of the residence time of a sample of apple-fiber granulate with added water and milk powder as binder obtained during the agglomeration pressure process and the density of tested granulate on water activity at different concentrations of NaCl solution in the desiccators (after 360h)

The analysis of figure 2 and 3 shows that the increase in density of granules from 800 to 1200 kg/m^3 influences the increase in water activity. For example, with a residence time of 72 hours in a desiccator and a concentration of 25% hydrochloric solution, increasing the density of granules with water from 800 to 1200 kg/m^3 influences the increase in water activity from 0.677 to 0.744.

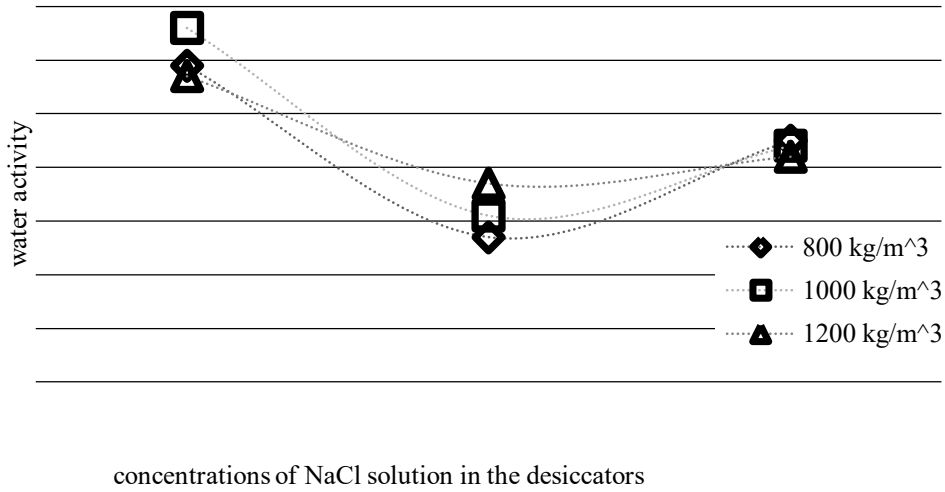

Figure 3. Effect of the residence time of a sample of apple-fiber granulate with added water as binder obtained during the agglomeration pressure process and the density of tested granulate on water activity at different concentrations of NaCl solution in the desiccators (after 360h)

Greater water activity was characterized by fiber granules with added water, less - with the addition of milk powder. The highest water activity values differ only 0.004. They are 0.740 for powdered milk granules and 0.744 for granules with water. They were recorded after 360 hours of storage, for a 1200 kg/m^3 granulate, in a 25% NaCl desiccator. The smallest values were recorded for granules of 800 kg/m^3, after storing 72 hours in a 35% NaCl desiccator. For powdered milk granules this value is 0.598, for water granules 0.615. The results conduct that only 800 kg/m^3 granules stored for 72 hours in a 35% NaCl desiccator are biological safety. Other specimens are exposed to fungus and yeast. Basing on the results obtained (table 2 and figure 2 and 3), it was found that increasing the density of apple fiber (from loose fiber, through the granulate obtained without pressure to the pressure granulate) decreases the increase in moisture and water activity during storage in the desiccator in the presence of NaCl solution.

CONCLUSIONS

Based on the results obtained, it has been found that increasing the temperature of the pressure compaction from 20 to 50°C results in a decrease in the thickening pressures in both, with water binder and powdered milk binder and increases the density of the resulting granulate. Thus, the pressure of the dietary apple fiber agglomeration with the water binder requires higher compaction pressures than in the case of thickening of the binder fiber with a solution of water and milk powder. The increase in the density of the granulate obtained by pressure agglomeration results in a decrease of its water absorption (decrease of its moisture content and water activity during the presence of NaCl solution). It was also found that the moisture content and activity of the loose fiber water increases with increasing the fiber's storage time in the desiccator (with NaCl solution): increasing the storage time of the loose fiber in the desiccator from 5 days to 15 days causes an increase in its moisture content and water activity. NaCl in the desiccator influences the decrease in water absorption of stored pellets. Water-based fiber granules exhibit higher moisture content and water activity during the presence of NaCl solution in relation to the powdered milk granulate at each density tested and at each NaCl concentration in the desiccator. Further processing of apple fibers, in the form of pellets, for diet supplement or for animal feed purposes will reduce agriculture production costs.

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THE USE OF MOLDAVIAN DRAGONHEAD BAGASSE WASTE IN EXTRUDED PRODUCTS

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Keywords: corn, Moldavian dragonhead, waste management, physical properties, texture

ABSTRACT

Dracocephalum moldavica L. residues after the cold oil pressing were added as supplementation to corn snacks in the amount of 5-30%. The experiment assessed the effect of addition of the dragonhead bagasse (oilcake) on the selected physical properties and texture of snacks. Directly expanded snacks were made with the extrusion-cooking technique at 14% of initial moisture of blends. The processing was carried out at 100 rpm, at the temperature ranged 115-140°C with a 3-mm forming die. The snacks were then tested to evaluate apparent and bulk density and the water absorption and water solubility indices, as well as the cutting force for texture. The increasing amount of dragonhead seed oilcake showed a significant impact on the physical properties of extrudates, lowering bulk density and water absorption, but increasing apparent density, water solubility and the cutting force of the enriched snacks. The application of dragonhead residues as an additive to corn crisps could be an effective way to limiting the oil waste after pressing and increasing the sustainability of waste management. A new range of nutritionally valuable snacks could be also introduced to the market.

INTRODUCTION

The Moldavian dragonhead (*Dracocephalum moldavica* L., Lamiaceae) is known as an herbal plant with specific properties, such as the presence of phenolic compounds, especially flavonoids (Yang et al. 2014). Primarily, the main raw material for medicinal purposes is the leaves and flowers of *Dracocephalum moldavica* used as infusion to treat stomach and liver disorders, headaches and congestion, coronary heart disorders and hypertension (Dastmalchi et al. 2007; Yang et al. 2014). There are some latest reports showing the application of dragonhead extracts as a therapeutic agent in many dysfunctions: cardioprotective, antiplatelet, neuroprotective, sedatives and anti-aging (Jiang et al. 2014; Gagoś et al. 2011). Dragonhead seeds are a good source of protein, lipids and fiber (Aprotosoaie et al., 2016; Dziki et al. 2013). Dragonhead seeds are also recognized as useful for the extraction of valuable oil. The seeds contain a high amount of fat (around 30%), in which 90% are unsaturated fatty acids, mainly omega-3 fatty acids. The plant has been confirmed as a good source of linolenic acid (59.4% in seeds after processing to obtain volatile oils) (Domokos et al. 1994). After obtaining oil by cold pressing, there are some residues left containing protein with an unchanged nutritional value, relative to the starting material (Hanczakowski et al. 2009). Taking these positive

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nutritional features of dragonhead seeds into consideration, the residues of cold oil pressing could be a valuable source of protein and unsaturated fatty acids. One of the useful waste management methods is extrusion-cooking. This HTST (high-temperature short-time) method is based on the thermal and mechanical processing of raw materials into food and feed products with unique characteristics. As regards the short-time treatment, extrusion-cooking is one of the most effective treatment methods which only slightly reduce the nutritional value of components. A limited destruction of the nutritional components and biologically active compounds (e.g. antioxidants) coupled with the improvement in starch and protein digestibility are just a few advantages of this process (Oniszczuk et al. 2015; Wójtowicz et al. 2017). These advantages make the extrusion-cooking suitable as a processing method of many food and feed products, e.g. crisps, pasta, breakfast cereals, instant products, flat bread, confectionery, and many others (Bouasla i in., 2016; Kręcisz and Wójtowicz 2017; Wójtowicz et al., 2015). The aim of this study was the application of dragonhead seed waste left after cold oil pressing in snacks and the evaluation of some selected physical properties and texture of snacks extruded with the various amounts of this additive.

MATERIALS AND METHODS

Corn grits (purchased from Lubella Sp. z o.o. Sp. K., Lublin, Poland) were used as the basic raw material. The *Dracocephalum moldavica* L. seeds were collected in 2016 and stored in dark conditions until tests. The seeds were pressed with a single screw oil press with the cold method to collect oil samples; the residue as bagasse waste (oilcake) was collected after pressing, stored in a refrigerator and then ground with the laboratory grinder LMN10 (TestChem, Radlin, Poland) to a granulation below 0.8 mm. Ground dragonhead bagasse was added to corn grits in the amount of 5-30%, mixed and moistened to the final blend moisture of 14%. The extrusion-cooking process was performed with the single screw extruder TS-45 (Metalchem, Gliwice, Poland) at L/D=12:1 and with the compression ratio of 3:1. The processing temperature ranged 115-140°C and the screw speed was 100 rpm. The snacks were shaped with a single-opening forming die of 3 mm in diameter. The obtained samples were dried at 40°C for several hours until the final moisture content of 6%. Selected physical properties of snacks were tested as well as texture. Apparent density was determined by substituting sand weight for extrudates volume and dividing it by sand density. Extruding bulk density (BD) was calculated as a mass (kg) of specific sample volume (m^3) using a measuring cylinder filled gently with snacks (Wójtowicz et al. 2017). The density measurements were reported as an average of five replications. The water absorption index (WAI) and the water solubility index (WSI) were determined by means of centrifugation (Bouasla et al. 2017) for each sample in five replications. The WAI was calculated as the amount of absorbed water (g) per g of dry sample. The water solubility index (WSI) was determined as solids recovered after the total evaporation of water at 105°C of supernatant obtained from the WAI analysis. Texture as cutting force (F_{max}) was tested with a Warner-Bratzler steel blade at the test speed of 500 $mm \cdot min^{-1}$ with Zwick BDO- FB0.5TH machine (Zwick GmbH & Co., Germany) in 10 replications. The obtained results were tested with the F-test and the Kruskal–Wallis one-way analysis of variance with the amount of additive as a variable factor was analyzed with Statistica (version 10.0, USA).

RESULTS AND DISCUSSION

Extrusion-cooking of corn snacks supplemented with dragonhead bagasse in the amount of 5-30% showed a significant effect on the tested physical parameters and texture of snacks. The apparent density values for snacks varied from 101 to 187 $kg \cdot m^{-3}$ (Fig. 1). There was a visible effect ($p_{\text{-value}}$=0.000, Table 1) of the growing dragonhead bagasse addition on the positive correlation coefficient (R^2=0.741). The addition of 5 and 10% of dragonhead oilcake lowered apparent density of snacks. A further increase in the amount of bagasse addition, up to 30%, resulted in a significant increase of the apparent density values, which could be the result of the increasing fiber, fat and protein content derived from dragonhead seeds oilcake waste.

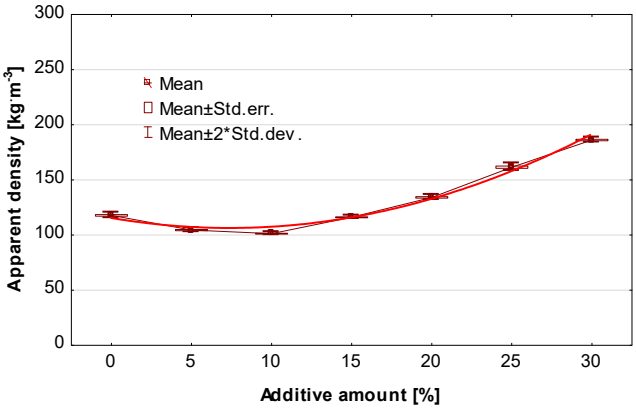

Fig. 1. Apparent density of extruded corn snacks with the addition of various amounts of dragonhead seeds bagasse waste

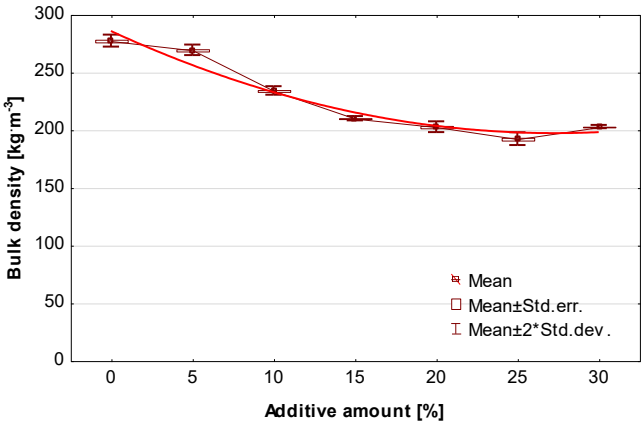

Fig. 2. Bulk density of extruded corn snacks with the addition of various amounts of dragonhead seed bagasse waste

Bulk density evaluated for corn snacks with the addition of *Dracocephalum moldavica* seed oilcake ranged from 188 to 271 $kg \cdot m^{-3}$ (Fig. 2). These values were lower than those reported for corn snacks. The addition of bagasse makes snacks less compact and well puffed, thus significantly ($p_{\text{-value}}$=0.000, Table 1) limiting bulk density. For directly expanded snacks, this behavior is desirable, and low bulk density is usually connected with the high expansion and good crispness of snack products. Increased application of oilcake waste from dragonhead seeds lowered bulk density with R^2=0.846.

The water absorption index of the extrudates is directly linked to the intensity of thermomechanical treatment during the extrusion-cooking process (Bouasla et al. 2017). The WAI of snacks based on corn and supplemented with the addition of dragonhead

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oilcake waste reached the values from 4.18 to 5.17 $g \cdot g^{-1}$. These values were similar or lower than in the case of corn snacks without any additives (5.13 $g \cdot g^{-1}$). A greater amount of bagasse waste lowered the water absorption of the tested snacks with R^2=0.699 (Fig. 3). Ground oilcake, rich in fiber, protein and fat, added to corn grits is likely to disturb the integration of components inside the extruder and reduce the processing intensity of ingredients. This effect was significant ($p_{\text{-value}}$=0.001) but the differences were limited (only 14% less than for corn snacks).

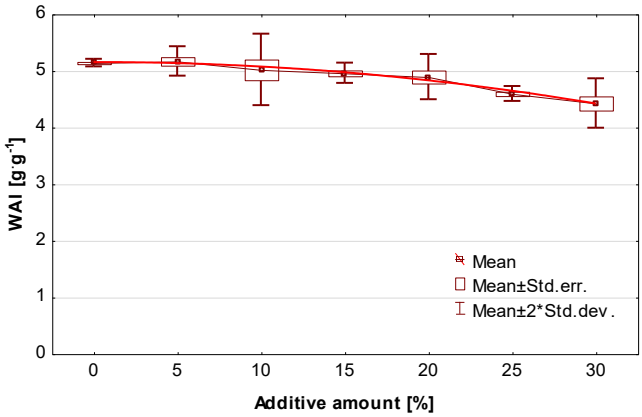

Fig. 3. The WAI of extruded corn snacks with the addition of various amounts of dragonhead seed bagasse waste

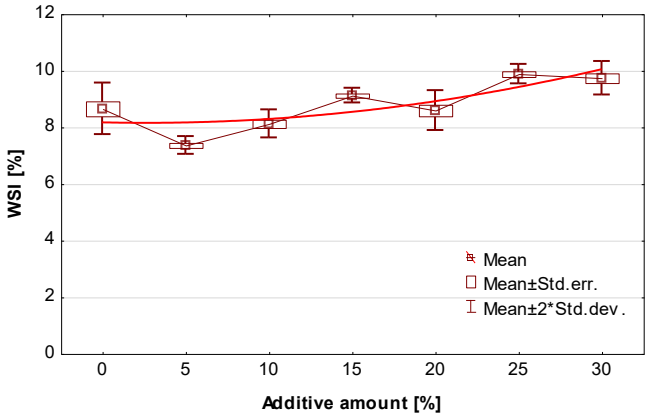

Fig. 4. The WSI of extruded corn snacks with the addition of various amounts of dragonhead seed bagasse waste

The results of the water solubility index of corn crisps supplemented with dragonhead seed bagasse waste ranged from 7.28 to 9.99% (Fig. 4). The differences between the means resulting from the supplementation were significant ($p_{\text{-value}}$=0.000, Table 1), but, as for the WAI, the WSI results were close: an increase of 37% was observed along with the growing amount of *Dracocephalum moldavica* seed bagasse waste in the recipe. The low values of water solubility reported for the tested extrudates showed a good integration of components during treatment and a low degradation of starchy components by thermomechanical treatment.

The cutting force measured for snacks supplemented with the Moldavian dragonhead ranged from 11.7 N for corn snacks to 15.4 N when 30% of the additive was used in the

recipe (Fig. 5). A significant rise in the amount of the additive (p_{-value}=0.00001, Table 1) translated into greater hardness of the supplemented snacks, but even a high amount of the additive produced snacks with proper texture. Increased hardness (around 31%) has no negative effect on the overall quality of the supplemented snacks.

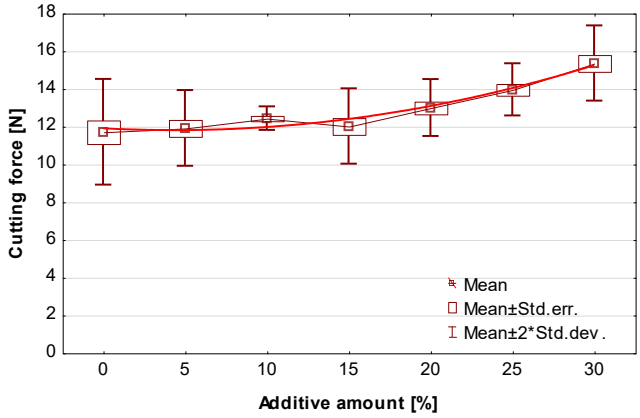

Fig. 5. The cutting force of extruded corn snacks with the addition of various amounts of dragonhead seed bagasse waste.

Table 1. A statistical analysis of the effect of dragonhead bagasse waste addition on the selected properties of extruded snacks

Parameter	Polynomial quadratic equation	F-test value	p-value	KW-H test value	p-value
Apparent Density ($kg \cdot h^{-3}$)	ρ_A=131.275-20.693A+4.159A^2	2341.148	0.0000	19.498	0.0034
Bulk Density ($kg \cdot h^{-3}$)	ρ_B=321.104-8.389A+2.974A^2	1378.032	0.0000	32.747	0.00001
WAI ($g \cdot g^{-1}$)	WAI=5.127+0.044A-0.021A^2	7.459	0.0010	14.961	0.0206
WSI (%)	WSI=8.295-0.193A+0.063A^2	30.048	0.0000	18.419	0.0053
Cutting Force (N)	F_{max}=12.261-0.489A+0.131A^2	10.062	0.00001	22.051	0.0012

A – additive amount; ρ_A – Apparent Density; ρ_B – Bulk Density; WAI – Water Absorption Index; WSI – Water Solubility Index; F_{max} – Cutting Force

As reported by Wójtowicz et al. (2017), the addition of *Dracocephalum moldavica* leaves increased bulk density, cutting force and breaking index of enriched snacks products compared with corn snacks. It was linked to the lower expansion and porosity of extrudates with an addition of fibrous components and increased bulk density of products with a high ash and fiber level (Altan et al. 2008).

CONCLUSIONS

The application of Moldavian dragonhead seed oilcake as an additive was found to be suitable for the processing of corn crisps directly expanded in the extrusion-cooking process that yielded ready-to-eat snacks. The research proved a significant impact of the amount of additive on texture and the physical properties of the supplemented snacks. The use of dragonhead seed oilcake lowered bulk density and the WAI and increased apparent density, water solubility and hardness of the tested snacks. The discussed results demonstrate a possibility of the application of dragonhead seed bagasse waste as a functional additive to corn snacks without any negative effect on the quality of extrudates. This makes the extrusion-cooking technique suitable for the sustainable management of waste products that offer an improved nutritional composition compared with conventional corn snacks.

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ENERGETIC EFFICIENCY OF SALIX VIMINALIS PLANTATION

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Keywords: willow, salix viminalis, EROEI, energetic efficiency

ABSTRACT
Energetic efficiency, based on a version of EROEI indicator, of salix viminalis plantation is estimated for realistic tillage technology. For different plantation sizes, different sets of machines are selected for performing agro-technical operations. Obtained results are dependent upon plantation size, and characteristics of technical devices applied. Potential values of energetic efficiency are rather high, but it has to be taken into account that the study is confined to the limited number of operations corresponding to strictly agricultural operations. Addition of other steps in production system is supposed to decrease final values.

INTRODUCTION

Biomass became considered as an alternative source of energy that might replace fossil fuels (at least for some time). This idea results of two factors: first is expectation of sc. "oil peak" – that implies possible shortages of resources. and the second widely discussed climatic effects of use of the fossil fuels. Exploitation of biomass seems to mitigate the both threads mentioned. The energetic use of biomass various origins (both wild or planted) requires inputs of energy on various steps of production. Therefore, it is important that sum of the energy inputs, given to all steps of production, does not exceed final amount of energy obtained from biomass. The effects of biofuel use for sustainability of agriculture have been recently discussed by Wasiak (2016). The characteristic describing energetic efficiency of particular energy producing system under the name EROEI was introduced by Cleveland et al. (1984), Murphy at al. (2010), Murphy et al. (2011) and also Zhang and Colosi (2013). The later Authors indicated, however that various calculation procedures being used might cause discrepancies in results and cause ambiguities of interpretation. Various analyses concerning energetic use of biomass were also published (cf. Field et al. (2007), Mediavilla et al. (2013), Arodudu et al. (2014) and Liu (2017). Recently also Pickard (2014) discussed the applicability of the EROEI to situations of modern technology and introduced some modifications. The following formula was proposed for any system used to convert some material resources onto energy:

$$EROEI = \frac{E_{out}}{E_{cr} + \sum E_{in} + E_{liq}} \tag{1}$$

where E_{out} – is the energy obtained at the end (exit) of the system, E_{cr} – is energy needed for creation of the system, E_{liq} – is energy needed for liquidation of that system. The E_{in} denotes one of many possible inputs of energy needed for subsequent steps of converting the particular resource or byproduct finally leading to energy. Obviously the EROEI indicator is a dimensionless quantity.

This formula was used by Wasiak and Orynycz (2014) as well as Wasiak and Orynycz (2015) in formulation of the model for energetic effectiveness of agricultural subsystem being the part of biodiesel production system. In this case it was assumed that energetic efficiency indicator, ε, is computed for already existing system, liquidation of which is not planned within the period of consideration. Therefore, the formula assumes form:

$$\varepsilon = \frac{E_{out}}{\sum E_{in}} \tag{2}$$

where meaning of symbols is the same as in Eq. 1.

The model is based on computation of contributions of energy consumption, by individual operations, E_{in}. For each operation a partial energetic efficiency, ε_i, can be defined as ratio of final energy obtained in form of biofuel to the particular value of any individual contribution:

$$\varepsilon_i = \frac{E_{out}}{E_{in}(i)} \tag{3}$$

and therefore:

$$\varepsilon^{-1} = \sum \varepsilon_i^{-1} \tag{4}$$

This approach enables recognition of the effects of contributions of individual technological operations on the final energetic effectiveness of production systems.

Slightly different approach is being used in agricultural community. The procedure introduced by Anuszewski (1987) was used by several authors e.g. Dobek (2007), Grzybek (2011) and others. The approach of those authors mainly differs from EROEI by taking into account the contribution of human work energy consumption.

Willow (salix viminalis) is one of the most popular plants (especially in Poland) that is used for energetic purposes. Analyses based on empirical studies performed by several authors e.g. Kwaśniewski (2010), Stolarski et al. (2011), Stolarski et al. (2016) show rather low values of energetic effectiveness, but evidently dependent upon technological and natural factors. The methodology used in those works corresponds to mentioned earlier Anuszewski's approach. Similar approach is also applied by Gallagher and Murphy (2013) to computation of energy balance of willow converted to biogas indicating promising possibility of such technology. The work contains detailed analysis of energy consumption in agricultural operations on willow plantation.

The present work contains preliminary computations of energetic efficiency based on purely technical considerations.

RESULTS AND DISCUSSION

The scope of the work is confined to only agricultural operations. It will be extended by separate computations of other components of production system, like drying, transport, converting into a specific fuel (pellet, briquette, gaseous fuel, etc.). The fuel consumption is estimated on the basis of assumption 192 g/kWh, and corresponding technical data of individual machines. The estimated values are approximately in agreement with the data reported in the book of Lorencowicz (2012). Machines are arbitrarily chosen according to the size of plantation. Results of computations presented here concern plantation size equal one and one hundred hectares. In this case the use of including 66 KM tractor KUBOTA M6040 was assumed. The choice of machines, as well as results of computation of consumed energy are shown in Table 1. It is seen that the most energy consuming operations are ploughing and cutting of crops. In the case of one-hectare planting of willow is assumed to be performed manually, and since we are interested in contributions in energy consumption only resulting from use of technical equipment, the energy contributed by human work is not taken into account.

Table 1. Energy consumption by individual operations on 1ha field

Operation	Machine	Specific fuel consumption	Operational capacity	Operation time	Fuel consumption	Consumed energy
		[dm^3/h]	[ha/h]	[h]	[dm^3]	[GJ]
Planting	Manual *)					*)
Ploughing	Plough Unia Grudziądz 100B	12	0.6	1.7	36.7	1.3
Cultivation	Cultivator Unia Grudziądz ARESL/S	11	1.6	0.625	7.5	0.3
Spraying	Sprayer Pilmet 300LM	8	4	0.25	2.75	0.1
Fertilization	Fertilizer spreader SIPMA RN 410 ANTEK	8	3	0.33	2.67	0.1
Cutting	Mower Husqvarna 555FXT	1.36	0.024	41.7	333.33	11.7
TOTAL						13.5

**) Human energy consumption for manual operations is not considered*

The other choice of much more powerful machines is presented for 100 ha field. The choice, as well as computed working time, fuel consumption and resulting energy consumption are shown in Table 2. In this case the use of tractor 186 KM FENDT 718 VARIO was assumed. Obviously, energy consumption in all individual operations is higher than in the case of one-hectare field. In the case of large field two variants are considered. The first is mechanical planting of willow cuttings, and the second – performing this operation manually. The energy consumption for the first case is estimated basing on operation time and fuel consumption, while for the second, the energy of human work is omitted. Results of energy consumption for both cases are reported in the Table 2. The column "Consumed energy" is split into two columns correspondingly containing data for the cases of mechanical and manual planting.

Agricultural operations are frequently accompanied with transport of various materials, and equipment. It can be transport of fertilizers, crop protection means as well as seedlings, etc. Practically, it concerns each operation. Such transport obviously consumes some energy, and should be included into calculations of energetic effectiveness. In the present work, this contribution is intentionally omitted in all operations, because transport energy consumption will be calculated for all operations as separate component.

The energy obtained from plantation is computed basing on the yield and low caloric value of final woody biofuel (pellet, briquette) in normal combustion (19 MJ/Mg i.e. 19 MJ per one metric ton).

Table 2. Energy consumption by individual operations on 100 ha field

Operation	Machine	Specific fuel consumption	Operational capacity	Operation Time	Fuel consumption	Consumed energy	
						Mechanical planting	Manual planting
		[dm^3/h]	[ha/h]	[h]	[dm^3]	[GJ]	[GJ]
Planting	Planting machine SPAPPERI TP	12	0.36	277.8	3333.3	116.7	*)
Ploughing	Plough	22.5	1.8	55.6	1250	43.8	43.8
Cultivation	Cultivator Agro Masz 5.6m	21	2.4	41.7	875	30.7	30.7
Spraying	Sprayer Pilmet EuropaXL 3000l	12	10	10	120	4.2	4.2
Fertilization	Fertilizer spreader AMAZONE ZA-M ultra	14	14	7.7	100	3.5	3.5
Cutting	Forage harvester Claas 940	55	2.4	41.7	2291.6	80.3	80.3
TOTAL						279.2	162.5

**) Human energy consumption for manual operations is not considered*

Finally energetic efficiency for this step of production system is obtained by division of the energy yield from obtained solid biofuel by the energy consumption.

As for the energy yield two values are considered as lower and upper limits of values usually obtained in practice, also in both cases of energy yield the values of energy efficiency are reported in two columns for mechanical and manual planting. It should be noted that, as mentioned earlier, mechanical planting for one-hectare field was not considered. The obtained results are rather high, and very different for small and big plantation. The later values might result of not good choice of devices used in small plantation (too much fuel consuming, too small operational capacity – especially for chosen mower).

Table 3. Comparison of energetic efficiency, ε, for 1 ha and 100 ha fields treated with various machines

Plantation size [ha]	Energy yield 300 [GJ/ha]		Energy yield 580 [GJ/ha]	
	Mechanical planting	Manual planting *)	Mechanical planting	Manual planting *)
1	-	22.22	-	42.96
100	107.5	207.7	207.7	356.9

**) Human energy consumption for manual operations is not considered*

The obtained values seem to be higher than those reported by other Authors, but it has to be recognized, that those are values of partial energetic efficiency (computed according to Eq. 3), in which the only part of production system is concerned. Operations like watering the fields, transportation of goods and equipment between and inside of fields, drying of crops, pelletizing, etc. are not considered, and those

operations surely will decrease the final energetic effectiveness of the whole production system. This study also does not consider indirect energy consumption (embodied energy), which also causes a decrease of energetic efficiency. All the omitted factors will be the subject of further studies.

CONCLUSIONS

Presented results of preliminary study show that energetic efficiency of willow plantation may strongly be affected by the choice of equipment used for performing agro-technical operations. It also depends upon size of plantation in that sense that it may be difficult to optimize choice of equipment for particular plantations areas. The resulting values of energetic efficiency are varying between about 20 and about 360 depending on size of plantation and choice of operating equipment. Those values appear to be rather high as compared to the results presented in the literature. The main goal of this work is, however, to recognize the role of subsequent steps of production in forming final energetic efficiency of production system. Taking into account Eq. 4 it is possible to predict that each subsequent step will decrease the total efficiency. It is also predictable, that the less efficient step will mostly affect the final result. Consequently, establishing individual contributions of subsequent steps will enable looking for those components of production system that require major improvements. In presented cases, as the most energy consuming appear operations like ploughing, mechanical planting or harvesting. The operations like: transportation of goods to the fields, watering, transportation of crops, etc. will be the subject of subsequent works. It also seems that improvement in technology of energetic exploitation of biomass may be the important step onto achieving higher energetic efficiency of the biomass derived fuels. It might be expected that direct combustion is not mostly effective use of willow biomass – what possibly can be improved by changing the technology of obtaining other than solid fuels from this biomass.

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SEPARATION AND CLEANING AS A MAIN PROCESS IN THE SUSTAINABLE FARM

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ABSTRACT
The paper presents the results of a study on evaluation of a selected group of physical properties of dry mixtures of juniper in relation to the process of their cleaning and separation using two types of cleaning separators. It has been shown that the course and the effectiveness of the process of separation of juniper berry-like cones from a dry mixture depends on the recognition of certain physical properties of the mixture as well as the type and parameters of the used separator devices. In addition, the most important geometric and dimensional characteristics of particular fractions obtained in the process of separation and cleaning of the mixture were specified.

INTRODUCTION

Common juniper (*Juniperuscommunis l.*) is a shrub, more rarely a tree with variable height and form. It occurs in central and southern Europe, Asia Minor, northern parts of Asia, Africa and in North America. In the food, pharmaceutical and cosmetic industries juniper berry-like cones are used in ground form or as extracts or as essential oils. To a lesser extent essential oils obtained from the needles and twigs are also used. Berry-like cones of common juniper are obtained from specimens growing in the wild, and hence plantations of this plant are not established. The content of essential oil varies depending on the origin of the raw material, the amount of sunshine, as well as climatic and soil conditions and it ranges from 0.7-0.8% in immature fruits to 2.85% in the berries harvested in warm and dry mountain areas. The berry-like cones with the highest content of essential oils are used as spice and raw material for the gin production, while those of inferior quality are designated to produce cosmetic oil and for pharmaceutical industry (Kozłowska 2002, Horabik 2001, Lorestani et al. 2012, Ożarowska et al. 1989, Tylek et al. 2002, Kuźnicka et al. 1987). Cosmetic industry adapted both fruits and essential oils obtained from juniper as valuable resources – they are ingredient of tonics, aftershave lotions, air fresheners, insect repellents, and as an important component of perfumes, both for men and women. Juniper wood is also known and appreciated - high content of essential oils deter pests. Temples were built of it and in wealthier homes there were wardrobes and boxes, which repelled tineid moths. Today the wood and its aromatic properties are used in food industry - the most expensive and the best cuts of meats and cold cuts are smoked in juniper smoke. The main final raw material are juniper berry-like cones that have to be separated and cleaned after harvest using sieve-pneumatic or vibratory separators (Dmitrewski 1981, Sobczak et al. 2012, Jurga 1997). Sieve separation is based on one of the basic characteristics for separating heterogeneous mixtures viz. geometric features such as thickness, width and length. The procedure relies on passing of the separated material through a single or a set of sieves of varied construction or shape of the holes under the two conditions determining the separation of a mixture - the separation will take place only when the dimension of the sieve holes lies within the range of the variation in the width or thickness of the particles

present in the mixture, and there is a movement of the mixture on sieve compliant with the principles allowing the fine particles to fall into the holes (Mazur et al. 2013, Krakowski 1997, Kośmicki et al. 1993, Dmitrewski et al. 1981). Pneumatic separation, besides the sieve one, is the cleaning method most commonly used in food industry. The process of separation takes place thanks to the air stream that is the factor causing the appearance of the differences in the aerodynamic characteristics of particles composing mixtures. By implementing a singular or multiple air streams it is possible to separate the raw material in terms of quality, as well as geometry, density and mass properties (Panasiewicz et al. 2012, Kośmicki et al. 1993, Krakowski 1997, Tylek 2003).

THE AIM AND SCOPE OF THE RESEARCH

The aim and tasks of the research concerned the detailed designation and assessment of selected groups of physical properties of dry granular mixture from which the juniper berry-like cones were separated. In addition, it was also to determine the geometric and mass characteristics of juniper berry-like cones in the context of juniper cleaning process and effective separation of all contaminants and other components undesirable from the technological point of view. The scope of work included the process of separation and cleaning of juniper berry-like cones performed on two laboratory separating and cleaning devices.

MATERIALS AND METHODS

Research material consisted of dried mixtures of juniper cones together with impurities collected from their natural environment using pneumatic devices, and then dried in convection drying process. Such mixtures along the desired, most valuable fractions such as juniper berry-like cones contained also a variety of organic and inorganic contaminants. Contaminations of biological origin were separated from the dried mixture; these included remains of damaged fruits, thicker needles, and pieces of twigs, as well as fine dusty debris created probably during the drying process and storage.

The division into dimension-based fractions was done using two sets of research stands, i.e. a SZ-1 laboratory sifter fitted with a set of sieves with round openings and drive providing back-and-forth motion and a laboratory vibratory sieve shaker RETSCH AS200 with variable acceleration caused by adjustable amplitude of vibration. Measurement and determination of selected properties were carried out taking into account the capability of smooth adjustment of the parameters of the cleaning and separation process (fig. 1). During the tests the moisture of the mixture and its tapped and bulk density were determined as well as the tipping and pouring angles and the granular composition.

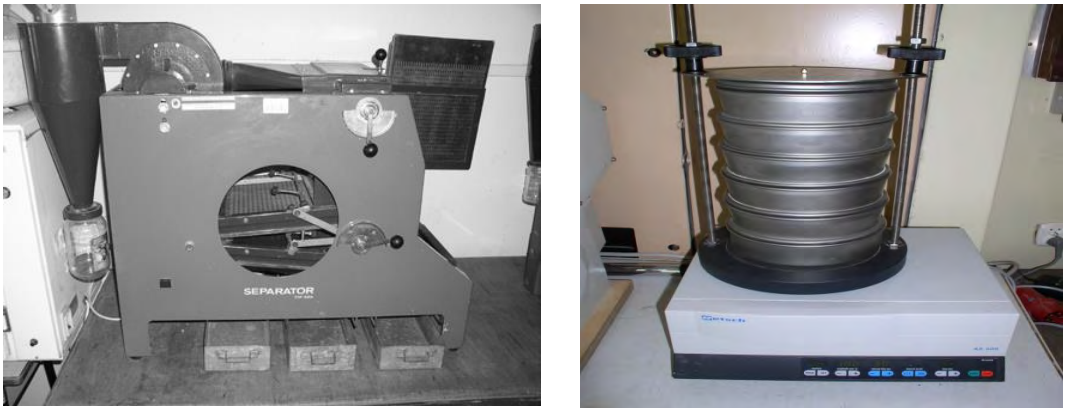

Fig. 1 Research stands for the determination of physical properties and conducting the process of separation and cleaning: pneumatic sieve sifter of SZ-1 type; laboratory vibratory sieve shaker RETSCH AS200.

RESULTS

The determination of physical properties of the individual components of the mixture was preceded by dividing them into size fractions. From the content of each particular fraction, the majority of which consisted of various impurities and unusable waste, the primary raw material was separated that constitutes the most valuable part of the processed undergrowth. Using the differentiation in the dimensions and shape of the particles of each fraction their moisture content as well as geometric and mass characteristics were determined. And so the average water content in the mixture (debris, berry-like cones) was 0.063 [kg/kg s.m^{-1}]. This confirms the correct preparation for and completion of the convection drying process of the mixture after it had been harvested. The average bulk and tapped densities of the material prepared for the research were 0.357 g cm^{-3} and 5.02 g cm^{-3} respectively. In the case of tipping angle, its lowest value for clean juniper berry-like cones was obtained for the size fraction ≥ 500 µm and 100-200 µm. This was respectively 24 and 52 degrees. Lack of contamination in these fractions of the mixture significantly eased dumping of berry-like cones with the shape close to spherical. A slightly greater angle of repose (56 degrees) was recorded for the fraction of debris, with identified tendency of a decrease in this value with the increase of particle size. The highest value of tipping and pouring angle was recorded in the case of the fraction containing juniper needles. By comparing the results of these parameters for particular fractions of the mixture, it must be stated that the debris and needle significantly increase the value of the tipping angle hindering the movement of berry-like cones on an inclined surface. The results of granular distribution of mixture of dried juniper cones obtained in the course of separation on two types of separators are presented in table 1 and 2.

Due to their dimensions, juniper berry-like cones remained on the upper screens of the vibratory sieve shaker having the mesh size of 5 and 4 mm. However, it was noted that during the separation process dry berry-like cones had been damaged by the metal wire sieves. This resulted in damaged scales passing through to smaller size fractions thus reducing the quality of the berry-like cones.

Table 1. The results of granular distribution of dried juniper cones mixture obtained on vibratory sieve shaker Retsch AS 200.

Fraction	RETSCH AS 200					
	I		II		III	
	Mass [g]	Percentage	Mass [g]	Percentage	Mass [g]	Percentage
> 500µm	37.244	37.25	24.143	24.26	35.834	36.00
400-500 µm	8.831	8.83	4.954	4.98	7.766	7.80
315-400 µm	1.92	1.92	2.016	2.03	2.294	2.30
200-315 µm	9.846	9.85	8.437	8.48	9.166	9.21
100-200 µm	12.247	12.25	12.878	12.94	12.457	12.52
50-100 µm	18.69	18.69	26.348	26.48	18.452	18.54
< 50 µm	11.222	11.22	20.723	20.83	13.567	13.63
Total	100	100	99.499	100	99.536	100

Table 2. The results of granular distribution of dried juniper cones mixture obtained on sifter SZ-1.

Fraction	SZ-1					
	I		II		III	
	Mass [g]	Percentage	Mass [g]	Percentage	Mass [g]	Percentage
> 500µm	45.860	46.33	46.210	46.58	43.070	43.39
400-500 µm	2.630	2.66	2.010	2.03	3.210	3.23
315-400 µm	0.500	0.51	0.320	0.32	0.700	0.71
200-315 µm	3.150	3.18	4.110	4.14	4.210	4.24
100-200 µm	11.649	11.77	11.800	11.89	10.830	10.91
50-100 µm	24.000	24.25	21.730	21.90	22.030	22.19
< 50 µm	11.197	11.31	13.030	13.13	15.220	15.33
Total	98.985	100	99.210	100	99.270	100

From the stand point of the technological relevance the implementation of the pneumatic sieve sifter produced much better outcome. In this case, the light pollution and mostly the needles were effectively separated, and most of them ended up in the size fractions of a mesh size smaller than 1 mm. The effectiveness of the separation of clean juniper berry-like cones from the mixture in the case of the sifter SZ-1 equalled to 48.07%, while in the case of the vibratory sieve shaker it was 39.71%.

DISCUSSION AND CONCLUSIONS

As demonstrated by the analysis of the test results an effective (100%) separation of impurities from the tested sample of dry mixture of forest undergrowth rendered very difficult. A significant number and amount of particular contaminants was characterised by properties very similar to the characteristics of the base species, and therefore was difficult to separate be it on the stand with pneumatic sieve sifter or the one with vibratory sieve shaker. This leads to a concussion that a mixture of undergrowth requires a special technological approach and the use of often peculiar and unconventional assembly of separating and cleaning machines. Moreover, when compared with cleaning cereal grains and seeds, the cleaning process requires to a greater extent the implementation of multiple repetitions (cycles) of the cleaning procedure, which increases the total duration of the process and its energy consumption.

Additionally, from the stand point of pneumatic separation, identification of selected group of physical properties of both the fraction of the base raw material, and the

fraction of contaminants was a very important stage of this research. The obtained results of research and the analysis thereof provided a valuable database and practical insights that should be taken into account when carrying out cleaning and separation into size fractions of this group of raw materials. The determined data regarding the characteristics of mixtures may be used as guidelines in setting up the parameters of the cleaning and separation processes in industry.

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INFLUENCE OF SURFACE TENSION OF WATER ON DROPLET SIZE PRODUCED BY FLAT JET NOZZLES

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Keywords:, adjuvant, droplet size, Volume Median Diameter, surface tension, flat fan nozzles.

ABSTRACT
The aim of the study was to check if the quality of water which was taken from different sources (used for plant protection treatments) influences the droplet size generated by agricultural nozzles. The experiment was done in the laboratory of the University of Life Sciences in Lublin (UP Lublin), and water from 3 different sources was used, demineralized water was used as reference water. There were two treatements of adjuvant (Superam 10AL): with and without adjuvant. The water quality was assessed on the basis of the change of surface tension. The surface tension was measured with a drop Shape Analizer DSA30 device. The Flat Fan, one of the agricultural nozzles widely used by farmers, was used in the study. The measurement was done with spraying pressure of the following values: 2 bar, 3 bar and 4 bar with three repetitions. The droplet size was measured with a laser diffractometer HELOS/R - Sympatec. The results show that using the adjuvant changed the surface tension for all the types of the water sources. However, this change was higher for the water from the farm well (source B) and the tap water from UP Lublin building (source C). This change in the surface tension alters in turn the drops size (Volume Median Diameter) depending on the average results of the spray patteren, but only when using 3-bar pressure.

INTRODUCTION
According to the EU Directive 2009/128 /EC on the sustainable use of pesticides, there is a need to reduce the impact of pesticides on the environment. Integrated protection involves the use of all available methods and ways to ensure safe and effective crop growth, and ensuring protection of the environment and human health, providing positive economic effects as well. Using the principle of sustainable use of pesticides should draw attention to the techniques used in the treatment of plant protection. The important issue here is the appropriate fit of the spraying techniques, taking into account the degree of plants coverage and the size of droplets produced by the agricultural sprayer. Therefore, in agricultural practice a standard ASAE S572.1 (2009) is the most often used standard for determining the droplet size produced by agricultural nozzles.

Flat fan nozzles and their operating parameters defining a plurality of standards and regulations have been extensively studied. Their technical condition and performance have a very big impact on the degree of coverage on the plants and this results in biological and economical effectiveness of the treatment as well as human and environment safety (Huyghebaert, 2015).

The droplet size has an important effect on the pesticide application process. For example, small size droplets have a tendency to drift and cause environmental problem. Subr et al. (2015) found that reducing the spraying pressure (from 3 to 2 and then to 1 bar) results in smaller drops size (VMD) in the center and edges of the spray pattern.

In agriculture, different types of water are used for crop protection activities depending on the location of the farm, and each of them has a different surface tension. Surface tension has influence on the quality of the produced spray droplets, which effects in turn

the degree of coverage on the plants surfaces. Therefore, the most appropriate droplet size for the spraying, and the dose of the adjuvant should be included on the label of a plant protection product (Czaczyk, 2014).

Decresing the surface tension of pure spray causes a decrease in the droplet size for three types of nozzles tested by Butler Ellis et al. (2001). However, the degree of this decrease which depends on the nozzle type is less than expected by spray formation theories. Massinon et al. (2017) observed an increase in the quantity of drops reaching a pre-wetted surface of bean and avocado as the surface tension of the spray decreased.

Butler Ellis et al. (1997), confirmed that the quality of the spray produced by flat-fan nozzles is influenced significantly by the liquid properties, the last one could be changed by adding the adjuvants. For example and according to their research, using the adjuvants influenced the variations of droplet size significantly, and also affected the spray fan thickness.

The aim of the study was to verify and determine how water taken from a different sources, with variable surface tension and with or without the adjuvant has an impact or changes the droplet size produced from agricultural nozzles.

MATERIALS AND METHODS

The water used in the test came from four different sources :

A: demineralized water obtained from the laboratory of the UP Lublin; B: farm well located in the village of Sosnówka; C: tap water from UP Lublin building; D: tap water from a farm located in the municipality of Sosnówka.

Surface tension was measured by using the device DSA30 Kruss by hanging drop. In this method, based on the obtained image and the drop shape analysis evaluates the surface tension. Before taking measurements to the software that controls the operation of device introduced the necessary data about the diameter of a needle dispensing measured drops (1.828 mm) and a density of analyzed samples (0.998 g / cm3). Then, each sample was taken after 10 measurements of the surface tension of injecting drops of a certain volume following the recommendations of the manufacturer (User Manual V1.92-03, 2004). A drop should be large enough to allow the weight to keep the needle tip and measurement of the value of surface tension. For water without adjuvant there were dispensed droplets with a volume of 28 ml while for the water to 100% the recommended dose of adjuvant droplet size allowing for measurement was 14 ml. Dispensing drops was carried out by the program control device.

Three TeeJet XR 110/03 nozzles were used to test the size of droplets. Before initiating the test, the flow rate of the nozzles was checked to be sure if it is the same like the nominal flow rate provided by the producer. The measurements of droplet size were done during the flow of the spray and with three repetitions for every position of the spray pattern. The used working pressure was 2, 3, 4 bar and it was gained from air pressurized water tank. The start and stop of the spray was controlled with a solenoid valve, and the position of the nozzle regarding the sampling area was controlled by an electro-mechanical positioning system and with the help of computer software.

The measurement of the droplet size was done by using laser diffractometer HELOS KR with a measuring range of 1 to 3500 microns. The nozzle was positioned in the axis of the laser light and moved every 20 cm intervals in both directions. The distance between the nozzle tip and the laser light was 50 cm.

RESULTS

The addition of adjuvant contributed to reduction of the surface tension of water from each source. However, it should be noted, that the percentage change in the surface tension was not the same in each case.The results of the measurements of surface tension are presented in the form of average values obtained during research.

Table 1. The surface tension for diferent types of water, with and without adjuvant

Water source*	Recommended dose of adjuvant	Droplet volume [µl]	Surface tension [mN/m]			
			Average	MIN	MAX	Standard deviation
A	0%	28	71.79	70.88	72.96	0.52
	100%	14	44.17	42.30	46.76	1.17
B	0%	28	71.56	70.34	72.39	0.53
	100%	14	36.26	34.16	38.45	1.23
C	0%	28	73.41	71.60	75.04	0.66
	100%	14	36.87	33.43	40.24	1.96
D	0%	28	73.83	72.43	75.01	0.58
	100%	14	48.88	42.03	54.50	3.33

**A: demineralized water-UP Lublin; B: farm well-Sosnówka; C: tap water-UP Lublin; D: tap water-Sosnówka.*

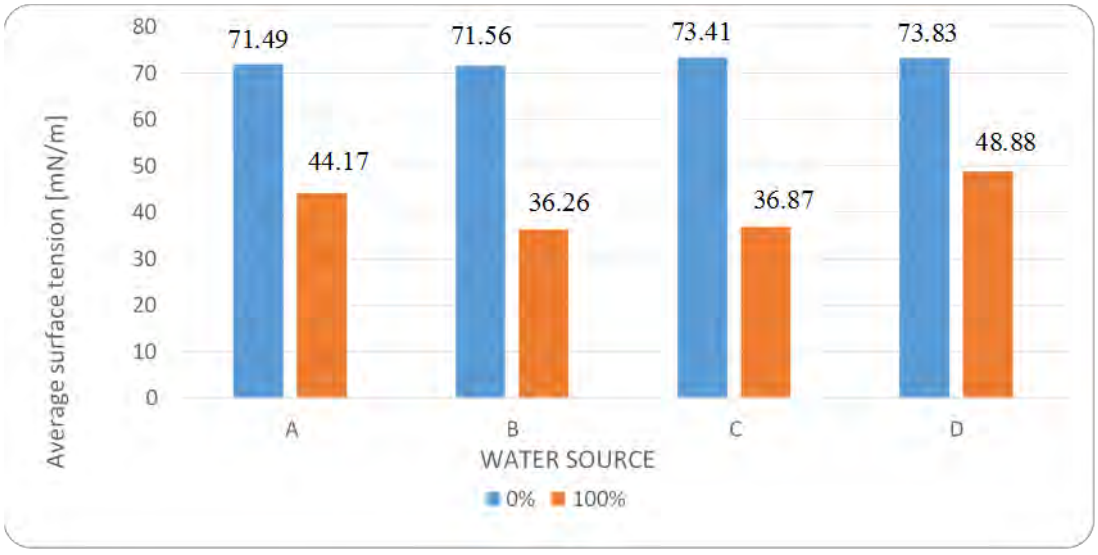

Figure 1. The average results of measurements of surface tension
**A: demineralized water-UP Lublin; B: farm well-Sosnówka; C: tap water-UP Lublin; D: tap water-Sosnówka.*

The average results (fig. 1) of the measurement of the surface tension of water without adjuvant were similar (ranged from 71 to 74). After the addition of the adjuvant. decrease in surface tension was observed. The largest decrease in surface tension after adding the recommended dose of the adjuvant was observed for the water from the source B and C. the decrease was almost half of the original value. Surface tension of water from the A and D are decreased by about 35% compared to the surface tension of water without the adjuvant.

The standard deviation of the water surface tension without the addition of adjuvant ranged from 0.52 to 0.66 (table 1). After using the adjuvant. the best value of the

standard deviation gained from using water from source A and reached a value of 1.17. while the worst value (value 3.33) was when using water D.

The obtained results show that the addition of adjuvant reduces the surface tension of water. and it is also reflected in the change in the droplet size produced by agricultural sprayers.The results of the measurements of volume median diameter are presented in the form of average values obtained during research.

Table 2. Mean values for the spray Volume median diameter (VMD). μm

Type of water	Working pressure. bar	Dose of adjuvant			
		0%		100%	
		On the center of spray pattern	Average of all the spray pattern	On the center of spray pattern	Average of all the spray pattern
A	2	205	252	196	240
	3	179	216	175	209
	4	171	198	168	192
B	2	212	234	193	228
	3	176	212	178	203
	4	168	190	164	187
C	2	208	238	196	234
	3	187	212	184	204
	4	179	198	168	190
D	2	202	238	195	234
	3	182	210	177	206
	4	169	189	164	188

**A: demineralized water-UP Lublin; B: farm well-Sosnówka; C: tap water-UP Lublin; D: tap water-Sosnówka.*

Table 2 presents the results of VMD with and without adjuvant with different position. pressure and water source. The higher changes in the VMD were when using adjuvant (which mean the surface tension is smaller) with pressure 2 and 3 bar with all sources of water when averaging the results of all the spray pattern. When using 4 bar pressure there was difference in the VMD for the results obtained from the center position and the averaged result of the spray pattern. However. there was no difference for the same pressure when adding adjuvant or without it.

The figure 2 shows the drops size distribution for normal water (B) without adjuvant. There was difference in the drops size distribution for almost all the size ranges between the averaged results and the results which were obtained in the center of the spray pattern. These differences come from the diversity of the drop size distribution of the flat fan nozzle spray cloud. for this results the difference comes from the different drops size in the center of the spray pattern and the edges of this pattern.

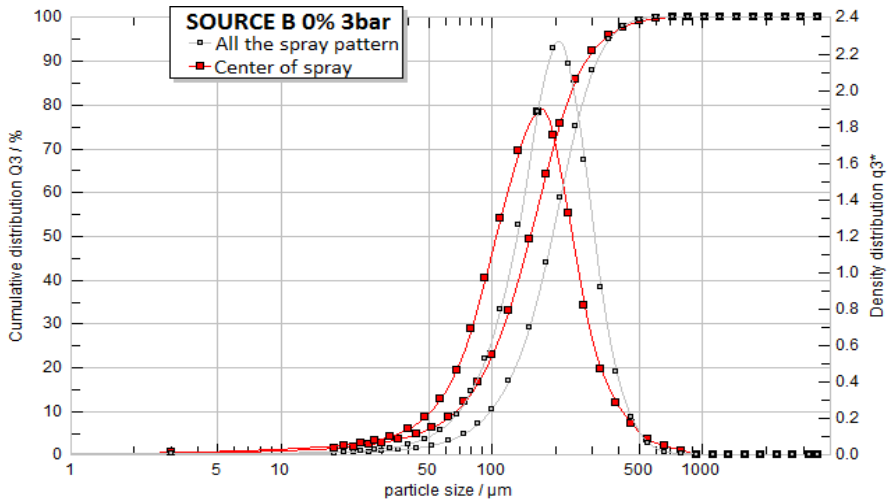

Figure 2. Distribution of droplet size produced by spray

Table 3 shows drops size distribution with and without adjuvant in different measuring positions for the water from the source B. Adding the adjuvant did not result in a big difference in the drops size distribution for all the size ranges. However. from table 2. adding the adjuvant produced smaller values of VMD in the center position only with 2 bar pressure. For the averaged results. the VMD was smaller when using 2 and 3 bar pressure. This mean the VMD did not change with 3-bar pressure with and without adjuvant and in the center position. This explains why the drops size distribution was almost the same with and without adjuvant in the center position.

Table 3. Droplet size distribution for different dose of adjuvant

	Measurement position	Droplet size distribution [%]										
		0 - 100	100 - 150	150 - 200	200 - 250	250 - 300	300 - 350	350 - 400	400 - 450	450 - 500	500 - 600	600 - 700
Water source: B dose of adjuvant: 0% Pressure: 3 bar	Average of all the spray pattern	10.82	18.57	23.94	20.51	12.75	6.25	3.39	1.70	1.05	0.67	0.21
	On the center of spray pattern	21.83	25.50	22.45	14.23	6.95	3.43	2.13	1.27	0.91	0.76	0.32
Water source: B dose of adjuvant: 100% Pressure: 3 bar	Average of all the spray pattern	10.10	19.48	24.83	20.51	12.32	6.08	3.41	1.74	1.07	0.44	0.02
	On the center of spray pattern	18.66	26.51	23.39	14.56	7.25	3.90	2.56	1.54	1.08	0.50	0.20

CONCLUSION

The study has shown that:

1- The use of the recommended dose from the adjuvant manufacturer has significant impact on the change of the surface tension, but only slightly reduces the diversity of the produced droplets in the different areas of the spray cloud. Best use of adjuvant can be observed by changing the VMD for the whole spray cloud.

2- Spraying with 2-bar pressure results in bigger differences of the VMD with all water sources and in the different ways of calculating VMD.
3- Using different water sources results in different values of VMD in the center of the spray pattern and in the averaged VMD of the spray pattern.
4- The VMD in the center of the spray pattern does not represent the VMD of the whole spray cloud due to the diversity of the droplets size within the spray cloud.

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FARMERS' AWARENESS IN THE FIELD OF OCCUPATIONAL SAFETY AND HEALTH IN SUSTAINABLE MANAGEMENT SYSTEM

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Keywords: work environment, farmers, occupational health and safety

ABSTRACT

Farming presupposes good acquaintance with the use of machinery, equipment, animal care and work schedules to safely perform duties on integrated farms. This is the reason why the farmers' knowledge of occupational health and safety, including the use and application of personal protective equipment, has become a subject of the research. A survey research was conducted among 90 farmers working on an integrated farm or being interested in such a system. Questions concerned harmful and hazardous factors in the work environment, the principles of safe working with animals, use of personal protection measures, knowledge and implementation of safety signs, pre-medical aid, and participation in training in innovative agriculture. The most active age group of respondents were farmers up to 50 years of age who were willing to participate in the study by providing exhaustive answers. Most of the farmers have a basic or secondary education and a large amount of their knowledge comes from their own experience. The greatest role in implementing the assumptions of the integrated management system plays the human factor together with its own state of awareness in the field discussed.

INTRODUCTION

A sustainable management system involves rational use of resources to reduce the negative impact of agriculture on the environment. Such a rational approach also presupposes a proper understanding of the working process and of the requirements related to it, in order to eliminate any risk to health and living conditions of the farmers. In a system of productivity-oriented farming based on precisely scheduled agronomic and animal husbandry practices, in addition to strict control of products and the environment, it is necessary to carry out activities related to occupational health and safety. (Kociszewski, 2011, Kostecka & Mroczek, 2007; Pawlak, et al., 2017; Pawlak & Nowakowicz-Dębek, 2015).

One of the major diseases that farmers are exposed to is an exogenous allergic alveolitis (EAA), which is caused by the inhalation of plant protection products. While trying to avoid poisoning and exposure to biological, physical and chemical agents, it is necessary to remember about appropriate preventive measures. The use of preventive measures requires thorough knowledge of the scope of their implementation (Brodzińska, 2012; Gawda et al., 2015; Nowakowicz-Dębek et al., 2016; Pawlak & Nowakowicz-Dębek, 2015; Pecyna, Pawlak, Maksym, Filipiuk, & Buczaj, 2016; Walusiak-Skorupy & Pałczyński, 2010).

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why the farmers' knowledge of occupational health and safety, including the use and application of personal protective equipment, has become a subject of the research.

MATERIAL AND METHODS

A survey research was conducted among 90 farmers working on an integrated farm or being interested in such a system. The anonymous questionnaire contained 22 questions divided into topical units regarding occupational health and safety in the field of agriculture. The surveys were conducted in Central and Eastern Poland among men and women of different age groups (up to 30 years, 30-50 years and over 50 years), (Fig.1). Net results were statistically analysed and are presented graphically.

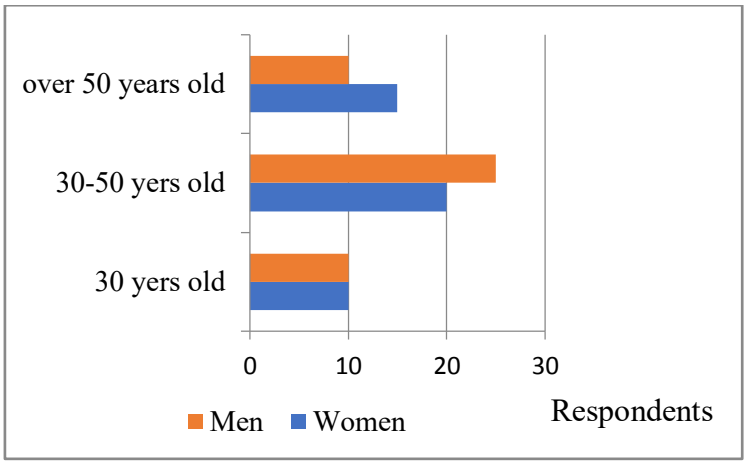

Fig.1. Age structure of respondents

RESULTS AND DISCUSSION

Questions in the first topical unit concerned harmful and hazardous factors in the work environment, the principles of safe working with animals and the use of personal protection measures. Both the youngest and the oldest age groups of farmers were not able to indicate and describe the harmful and dangerous factors that occurred in their work environment (Fig.2).

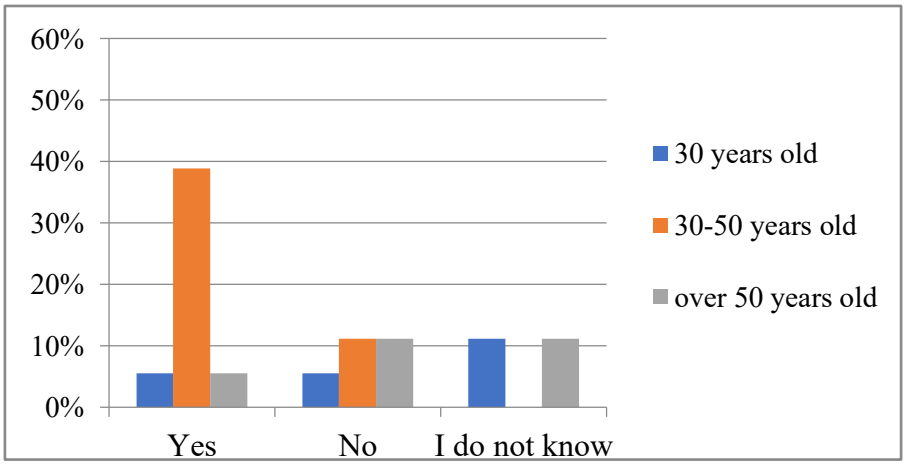

Fig.2.Dangerous and harmful factors in the work environment (% of respondents)

Principles of safe handling with animals are observed by farmers aged 30-50, while younger farmers don't follow these rules (Fig.3).

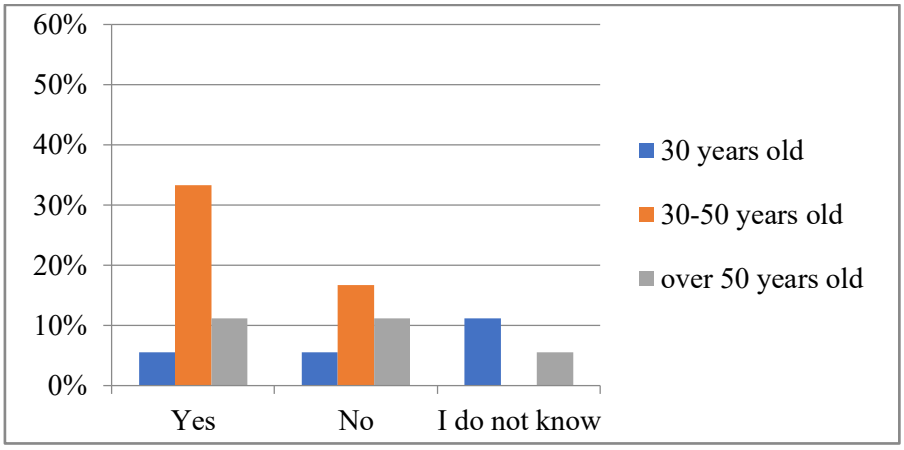

Fig.3. Safe handling of animals (% respondents)

Personal protective equipment is usually used by farmers up to 50 years of age. The oldest respondents have no habit of using personal protection (Fig.4).

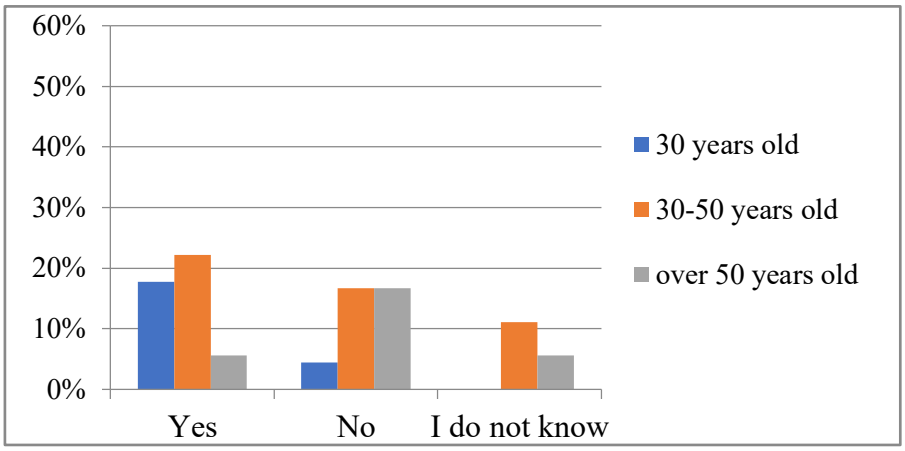

Fig. 4. Use of personal protective equipment (% of respondents)

The second topical unit of questions concerned the knowledge and implementation of safety signs, pre-medical aid, and participation in training in innovative agriculture. All respondents were familiar with the security signs used (Fig.5).

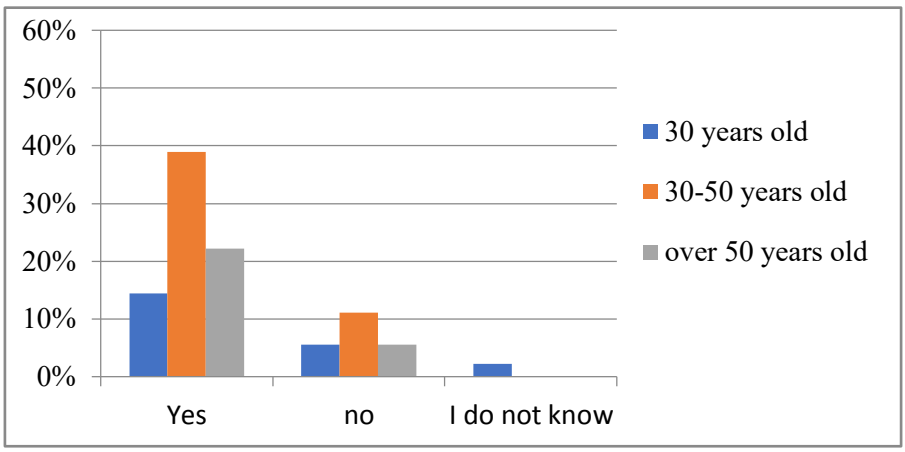

Fig. 5. Knowledge and use of safety signs (% of respondents)

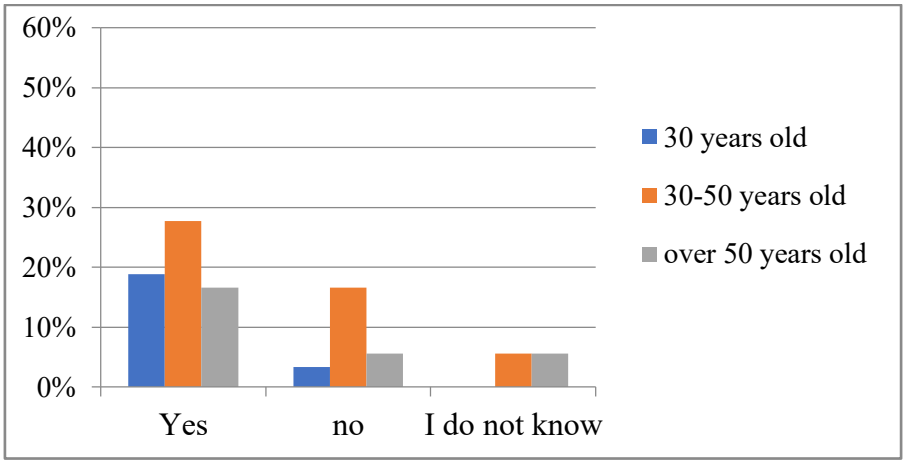

Fig. 6. Pre-medical assistance (% of respondents)

Farmers below the age of 50 had good knowledge in the field of pre-medical aid, although only the youngest were able to react appropriately and provide assistance in case of an accident (Fig.6). Farmers in the age groups of 30 and 30-50 were willing to increase their knowledge by participating in various training courses, being aware that they will need it for further work (Fig.7).

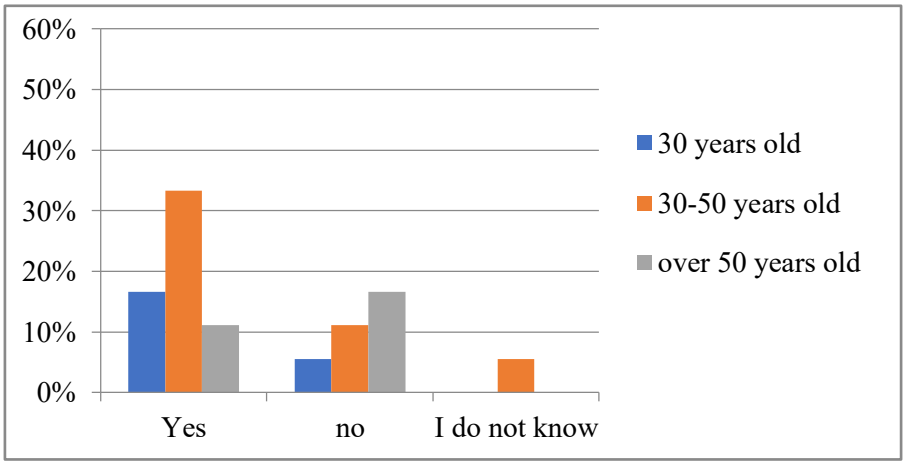

Fig. 7. Training in agricultural innovation (% of respondents)

Limitation of negative habits related to irrational management will reduce the deformation of the environment, while at the same time it will secure general obedience to the rules in the working environment.(Brodzińska, 2012; Gawda et al., 2015; Kałuża, 2009; Pawlak & Nowakowicz-Dębek, 2015).

Kostecka and Mroczek (2007) show that there is an increased interest in new ways of farming. In such a case, the agri-environment programs may be helpful, but the low level of education of farmers and the lack of knowledge in this area is an obstacle.

Similar results were obtained during the research. The greatest role in implementing the assumptions of the integrated management system plays the human factor together with its own state of awareness in the field discussed (Brodzińska, 2012; Kałuża, 2009). Therefore, it would be logical to arrange constant educational activity in rural areas that would make it inevitable to use the principles of good practice and to implement pro-environmental measures in order to maintain the integrated system and to guarantee safety of the farm workers.

CONCLUSION

In view of the growing problems regarding the rational management system connected with the state of the environment, there is a need to raise awareness about the ecology among people employed in agriculture. These activities should focus primarily on the prevention and elimination of anthropogenic threats mainly related to environmental chemistry. Most of the farmers have a basic or secondary education and a large amount of their knowledge comes from their own experience. The most active age group of respondents were farmers up to 50 years of age who were willing to participate in the study by providing exhaustive answers. The farmers surveyed indicate the need for a proper training related to their work environment. This is particularly important in view of emerging opportunities to use new funding and of implementing the rules for that purpose. Hence, the agricultural school teachers, as well as members of Agricultural Advisory Centres, are of great importance in broadening the knowledge of farmers related to the nature of their business.

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WATER PROTECTION AGAINST NITRATE AND PESTICIDES FROM AGRICULTURAL SOURCES – HISTORY OF ACTIONS TAKEN AT FARM SCALE IN WALLONIA (BELGIUM) FOR 15 YEARS

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Keywords: Nitrate Directive, Plant Protection Products Directive, water pollution, National Action Plan

ABSTRACT
Founded into the frame of EU regulations regarding nitrate and pesticides management, the Walloon structure PROTECT'eau aims to give farmers professional advices to implement good farming practices in order to prevent diffuse water pollution. The taken actions are the result of a strong collaboration between professional advisors, who provide technical and administrative support to farmers, and scientific partners, who produce regional references. Communication to the sector is another core activity of PROTECT'eau. It is indeed essential to make the objectives clearly understood to ensure a large application of the measures and achieve significant results regarding the quality of groundwater.

CONTEXT AND LEGISLATIVE FRAMEWORK

Nitrates and Plant Protection Products (PPP) are admitted to be the most significant diffuse water contaminants from agricultural activities. Consequently, the European Union has adopted several directives which establish a common framework for Member States to reduce and prevent pollution from these sources. The EU guidelines for achieving these common results are mainly included in three major directives: (i) the "Water Framework Directive" (Directive 2000/60/EC), which allows the evaluation and the management of bodies of water regarding their ecological and chemical status (it includes, among others, the monitoring of a list of contaminants, including nitrate and PPP)(EC, 2000); (ii) the "Nitrate Directive" (Council Directive 91/676/EEC), which forms an integral part of the Water Framework Directive and aims to prevent nitrates from agricultural sources polluting ground and surface waters and to promote the use of good farming practices (EEC, 1991); and (iii) the "Plant Protection Products Directive" (Directive 2009/128/EC) which aims to achieve the sustainable use of pesticides (EC, 2009).

Both Nitrate and PPP Directives promote the adoption of National Action Plans to set up their objectives and measures. Guidelines and targeted topics are provided in the texts. Their transpositions in Wallonia led to the development of two specific action plans: (i) the Walloon Program of Sustainable Nitrogen Management in Agriculture; and (ii) the Walloon Program of Pesticide Reduction Use. In order to manage and monitor agricultural practices, measures are structured around (i) Technical support to farmers, (ii) Communication to the sector and (iii) Scientific validation. The coordination is made by a non-profit organization, named PROTECT'eau, which was founded by the public authorities specifically for this purpose.

WALLOON ACTION PLANS

The Program of Sustainable Nitrogen Management in Agriculture (PGDA)

The Nitrate Directive was first implemented in Wallonia in 2001 and is known as the Program of Sustainable Nitrogen Management in Agriculture (PGDA). The current action program, in force since June 2014 (AGW, 2014), is the third version. Measures apply on a voluntary or compulsory basis. Requirements also depend whether the farm

is localized or not in the designated Nitrogen Vulnerable Zone (NVZ). NVZ represents 59 % of the Walloon territory and concerns around 68 % of the farmers. Behind these range of measures, the public authority has also developed a control procedure at farm level. The principle is based on the measurement of the amount of nitrate present in the soil after the harvest in the fall period, when crops do not take nutrients for their growth anymore. That nitrogen is, indeed, highly susceptible to leach during the winter. On field measurements are then compared to crop-specific references which are yearly determined from a network of 35 reference farms. These farms are geographically spread in order to be representative of Walloon soil conditions and types, and to the seasonal characteristics. The concerned farmers follow an established fertilisation program, based on a balance between crops requirements and soil supplies (see here under). During the fall, 5 % of the farmers from the NVZ are randomly selected in order to sample the soil of three of their parcels for further nitrate lab-analysis. Farmers enter in an observance program if their results are unfavourable. This instrument, named "Potentially Leachable Nitrogen", provides a control procedure based on the result.

Actions are divided into five topics and concern either legal Obligations (O), Voluntary good farming practices (V), led throughout Wallonia (W) or only in NVZ (NVZ). The legislation also rules the destruction and further management of permanent grasslands.

"Soil Binding Rate" and "Spreading contracts" (O, W): In order to monitor, as required, the amount of livestock manure applied to the land at farm-level, the public authority calculates yearly a "Soil Binding Rate" for each unit. This indicator attests that the amount of livestock manure valued as fertiliser does not exceed the specified amount of organic nitrogen per hectare. It takes into account organic nitrogen produced by the livestock and shipments of manure from one farm to another, through the establishment of "Spreading contracts". The specified quantities of organic nitrogen per hectare are fixed regarding the land use. It amounts to 115 kg N/ha for croplands and to 230 kg N/ha for pastures, with a maximum mean of 170 kg/ha at farm level in NVZ. The use of spreading contracts improved the geographical spread of livestock manures.

Spreading periods and conditions (O, W): The application of fertiliser should occur when crops require nitrogen, in order to prevent nutrient losses in water. The Walloon regulation provides periods when land application is prohibited. The calendar depends on the type of fertiliser, and, more particularly, on the basis of the fast-release nitrogen content of the product, the land localisation (in or out the vulnerable zone) and the land use (cropland or pasture). Land application of organic or chemical fertiliser is forbidden to water-saturated, flooded, frozen or snow-covered ground, for distance less than 6 meters from water courses, to steeply sloping (more than 15 %) or bare ground, and prior, during or after a legume culture (peas, beans, etc.). Some exceptions apply in non-NZV. They concern the application of solid manure to frozen, bare or sleepy sloping grounds.

Manure storage capacities (O, W): Each farm needs sufficient manures storage capacities in order to spread them during periods that allow an optimum valorisation and to avoid their application during environmentally hazardous periods. In Wallonia, the minimum required storage capacity was fixed to six months of production. Every breeder has to meet these standards, which required sector investments. Regulation also rules temporary on field storage of solid manure.

Sustainable fertilisation practices (V, W): Among measures that rely to "Good farming practices", farmers are strongly advised to plan fertiliser application in order to maximize nutrient uptake and to minimize losses. One measure of improvement concerns the application itself. Optimum climatic conditions such as a cloudy, humid, fresh and calm weather, associated whit efficient machineries (surface spreaders or sub-soil injectors), contribute significantly to reduce volatilisation and to uniformize the application. The spreading should, moreover, occur in periods during which crops development allows optimal nutrients uptake. "Sustainable fertilisation assessment" is another tool established and promoted to farmers. Fertilisation assessment is based on the balance between the foreseeable nitrogen requirements of crops and the nitrogen supply to the crops from the soil, corresponding to the amount of nitrogen present in the soil at the end of the winter, the supply through net mineralization of the reserves of organic nitrogen in the soil and of winter catch crops decomposition, in addition to nitrogen from livestock manure and other fertilisers (ECC, 1991). To be relevant, advices must rely on specific "Nitrogen supply factors" regarding the regional soil conditions and types, climate, land use and catch crop nature. A specific Walloon frame of reference is thus being built since the first program. Nitrogen fertilisation (organic + chemical) may not exceed 250 kg N/ha on croplands and 350 kg N/ha on pastures, with respect of the other legal dispositions.

Catch crop management (O, NZV; V, Non-NVZ): The maintenance of a vegetation cover during cold and rainy periods, allows to take up the surplus of nitrogen that remains in the soil after harvest which could otherwise be leached. The reasons why such excess appear have to be found in (i) the fact that the efficiency of fertilisation practices is not close to 100 %; (ii) an excessive fertiliser application due to a miss-evaluation of the requirements of the crops and/or the supplies from the soil (see here over); and/or (iii) a cultural accident that caused a drop in the expected yields. Catch crops sowing is obligatory for 15 years in NVZ. If that measure was first foreseen as an additional constraint, winter cover crops are now acknowledged for their numerous interests behind nitrogen catching, such as additional forage production, "green manure" effect, action on the soil structure, soil organic pool maintenance, erosion and weeds control, etc.

The Walloon Program of Pesticide Reduction Use (PWRP)

The European Directive aiming to achieve the sustainable use of PPP was transposed in the Belgian and Walloon legislations in 2013 (AR, 2013; AGW, 2013). The legal framework is, nevertheless, still in progress. The chapter regarding Integrated Pest Management came into force in January 2017 (AGW, 2016b, AM, 2017). The action plan includes the following major points:

Training: Professional users, distributors and advisors must be in possession of a valid "phytolicence" issued by the federal state afterwards initial or continuing training. Recognized training sessions are thus organised throughout the territory (AGW, 2016a).

Buffer zones and pesticide application equipment: The region established minimum buffer zones, near water courses (6 m) or road equipment to collect rain water (1 m). These buffer zones are additional to constraints regarding specific application obligation, determined by the Public Health authority while delivering the market authorization. Sprayers must be adequate, in good working order and minimize spray-drift.

Specific practices and uses: Aerial spraying is now forbidden and equipment's to minimize spray-drift are strongly recommended in some situations.

Handling and storage of pesticides: The legislation describes the main compulsory steps regarding the handling and storage of PPP.

- Storage: Storage has to occur in a specific room or closet, complying with security standards such as the record of an inventory with a close description of the products, the installation of retention facilities, the presence of pictograms, etc.
- Handling, dilution and mixing of products before application, filling and cleaning of the equipment: these steps have to occur either (i) on field, (ii) on a surface covered with grass, or (iii) on a surface covered with a waterproof material, mechanically and chemically resistant, with a specific drainage system to collect water contaminated with pesticides. Waste water must, finally, be treated in a proper treatment equipment. Every caution must be used during the filling of the tank in order to avoid any water backflow from the tank to the water source and any overflowing.
- Handling and remnants recovery: empty packaging must be rinsed, cleaned and dried before being stored in a closed bag, outside the storage room. Expired products must be clearly identified before recovery. Recovery is organised by approved agencies.
- Rinsing and disposal of tank mixtures: remaining tank mixtures might be spread on the concerned field or on a surface covered with grass, with respect of a minimum dilution of $1/100^{th}$.

Integrated pest management (IPM): This approach promotes low pesticide-input pest management, giving priority, whenever possible, to non-chemical methods (EC, 2009). Eight principles must be respected (AM, 2017): the application of good farming practices, the consideration of sanitary warnings, the respect of intervention thresholds, the use in priority of alternative control strategies, a careful choose of PPP, the re-consideration of doses and treatment frequencies, the application of anti-resistance strategies, the monitoring and the reporting of the success rate of the set of measures applied and the implementation of their traceability. Specialized professional organisations support the agricultural sector in Wallonia by monitoring crops for sanitary state. Their teams follow crops development in reference fields spread throughout the territory and determine the impact of climatic conditions and pest pressure on the cultivation. For each of their plots, they count and characterise the number of sick plants and check bugs traps. Regarding the results, sanitary warnings and intervention thresholds are published. Among all the IPM measures, none of them is totally new, except for the obligation regarding traceability.

DESCRIPTION OF ACTIONS MANAGED AT FARM SCALE

Nitrate and Pesticide action plans may somehow be seen as a long list of constraints. To ensure a large application of the program, it is therefore essential to strongly communicate and give technical support to the sector, so that they understand the objectives and the way to implement these measures. This is part of the missions of PROTECT'eau.

PROTECT'eau is one of the management structures created in the frame of the Walloon action plans. Founded in 2001 as a non-profit organisation, it is funded by the public

authorities. Its General Assembly brings together representatives of the agricultural, environmental and water sectors, in addition to the public authority. The operational organisation is, on the other hand, structured around three spheres of competence: (i) Technical support, (ii) Communication, and (iii) Scientific validation.

Technical support for farmers

PROTECT'eau is divided into 4 local units, each covering a specific geographical zone of Wallonia. Local technical support teams are composed of 3 professional advisors.

Both programs contain a lot of measures which details are sometimes difficult to handle. PROTECT'eau is a key partner to clarify these points. Most questions come over spreading calendar, catch crops obligations, buffer zones, etc. Administrative support mainly concerns the calculation of the Soil Linked Rate (see here over) and the completion of spreading contracts on the internet. Technical advices refer more often to the selection of the best available catch crops and the assessment of fertilisation levels. The lab-determination of plant-available nitrogen in the spring is used as an input in the calculation. At the end of the cultivation campaign, the "Potentially Leachable Nitrogen" is measured as an indicator of the accuracy of the past fertilisation level. Competences of PROTECT'eau also focus on storage facilities. Technical advisors help farmers to quantify their needed storage capacities, either for PPP waste water or livestock manure. Advise is made regarding the need of the farmer and the costs of the facilities. Advises also concern waste water treatment equipment and the use of spray-drifts.

Technical support teams and farmers rely on handy tools to provide advises or implement actions in a harmonized way. The staff works therefore continually, in collaboration with the scientific partners and the communication unit, on the development of new tools and technical sheets. To this day, PROTECT'eau has produced about 50 technical sheets, three technical guides and developed two online application. Since it was created in 2001, PROTECT'eau accompanied 8400 farmers and visited 19,000 farms. About 450 farmers were followed for fertilisation management in 2016, which represents 27,500 ha.

Communication

It is essential to widely and clearly communicate to the farmers in order to explain the objectives of the required measures and give advice for their best implementation. That work is done by the communication staff. Frequent agricultural press releases remind major scheduled points of the regulation. PROTECT'eau also releases twice a year its own magazine. Other events are organised such as information meetings, continuing training sessions, on field technical demonstrations. Public communication is also implemented in order to value efforts accomplished by farmers. In 2016, 61 press articles were published while 6 demonstrations days and 49 farmers meetings were, among others, organised.

Scientific validation

Scientific partners develop specific and regionally based, references and indicators. These regional data and information are then used as input in the technical sheets and tools developed by the technical support and communication staffs. The scope of their researches includes experiments on catch crop in order to determine best sowing rate

and date, forage value, best destruction techniques, nitrogen restitution dynamics, etc.; yearly monitoring of potentially leachable nitrogen throughout a network of reference farms; determination of fertilisation value of livestock manure; determination of the efficiency of treatments with sprayer equipped with spray-drifts; development of new PPP waste treatment equipment's; etc.

WATER QUALITY EVOLUTION

Due to the slow nitrate lixiviation rate (about 1 m per year) and the depth of groundwater bodies, the evolution of water quality is a very slow phenomenon. Nevertheless, the Nitrate action plan could be fully tested on a small catchment zone, in Arquennes. After 10 years of observation, while 6 were made of farmers technical support, the amount of nitrate in the groundwater body had diminished by 15 to 20 mg/l (Deneufbourg et *al.*, 2010). Eleven similar localised actions are in progress. They also aim to monitor the evolution of PPP concentration.

CONCLUSIONS

The evolution of water quality is a very slow phenomenon. Nevertheless, the application of the Nitrate and PPP action plans in, among others, catchment zones, with a close supervision of PROTECT'eau, has demonstrated the efficiency of the measures, when their application is generalized, and the relevance of the support of PROTECT'eau.

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THE CHARACTER OF HEAT EXCHANGE IN THE ELEMENT POWERED BY RENEWABLE ENERGY

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Keywords: renewable energy, solar energy, heat exchanger, solar collector, sustainable agriculture

ABSTRACT
Among other renewable resources of energy, solar energy has a small but dynamically increasing share. Solar irradiance is characterized by large variability, especially in the 24-hour cycle. Therefore, machines that use solar energy work in transient states. The character of heat exchange for the plate solar collector and the heat exchanger working in the hybrid system was investigated. The character of heat exchange turned out to be oscillatory for both machines mentioned above. The investigations of the heat exchanger model in laboratory conditions have been carried out to analyse the observed phenomenon in detail. The investigations confirmed the previously observed oscillatory character of heat exchange. As this phenomenon is unfavourable, working out methods of process control to stabilize the operation of these machines is highly recommended.

INTRODUCTION

Recently, technologies that facilitate renewable energy development have become increasingly important in global and European economy. Wysokińska (2012) presented the analysis of interdependencies between sustainable agriculture and renewable energy industry. In the coming years, the main issues related to sustainable development of global economy and its regions will be areas related to the improvement of energy efficiency, sustainable agriculture and renewable energies that facilitate rural areas development. Bartkowiak A. and Bartkowiak P. (2017), in turn, analysed the concept of sustainable agriculture in Poland, with regard to its regional specificity. Apart from an improved stock of machinery, they included in the analysis renewable resources of energy, and their growing role in sustainable agriculture development. According to GUS [Central Statistical Office of Poland] (2016) solid biofuels play a dominant though decreasing role as renewable energy resources [RER] (in 2011 84.89% of the total production of energy from RER, 72.22% in 2015), followed by liquid biofuels (an increase from 5.76% to 10.78% in 2015) and wind energy (an increase from 3.68% to 10.76%). Solar energy has less important though dynamically increasing share in the structure of RER (0.17% in 2011, 0.52% in 2015). The structure of generation and consumption of this kind of energy is specific, as in 2015 1655 TJ (88%) of solar energy was consumed by households, and only 230 TJ (12%) by trade and services. For households, over 4-fold increase in consumption was noted in comparison with 2011 (388 TJ). Therefore, the knowledge of proper use of devices and machines powered by solar energy is essential. RER rarely can work as separate machines. Usually, they must be connected to other, conventional sources of energy, which is related to the problem of appropriate control of the system. An example of control techniques related to anticipation of behaviour of a hybrid system made up of solar collectors and heat pump, used for plant cultivation air-conditioning, was described by Camacho et al. (2010). The system's main source of heat includes solar collectors with the area of 151 m^2, and an additional source of energy is a gas furnace with the power of 68 kW which is turned on, if necessary. Marshall (1999), in turn, made an attempt at defining the quality of the

hybrid system (system model and its sensitivity to parameters changes) that consisted of solar collectors, a heat exchanger, a circulator pump and a tank. A hybrid system used in the kitchen as a source of energy for cooking meals (a cooker) using solar collectors supported by LPG was presented by Prasanna and Umanand (2011). In this system, energy is transferred by the medium. Therefore, cooperation of the two types of energy, i.e. heat and electrical energy was considered. The described system, in which solar energy is complemented by gas fuel, and is sufficient for use in the kitchen, is described for conditions of strong and long-term insolation (India). Due to large variability and much smaller intensity of solar irradiance, described by e.g. Czekalski et al. (2012), this type of a system seems much less cost-effective.

MEASUREMENT STANDS AND MEASUREMENTS METHODOLOGY

One of the biggest problems related to solar energy utilization are variations of solar irradiance, both yearly and daily (Fig. 1). Rarely, there are days with the insolation illustrated by graph a); usually, there are days with higher cloudiness illustrated by graph b) and variations of cloudiness during the 24-hour day (c and d). Such variability results in the elements powered by solar energy constantly working in transient conditions. The method of predicting solar irradiance on an inclined surface with the use of artificial neural networks was worked out by Trajer and Czekalski (2005).

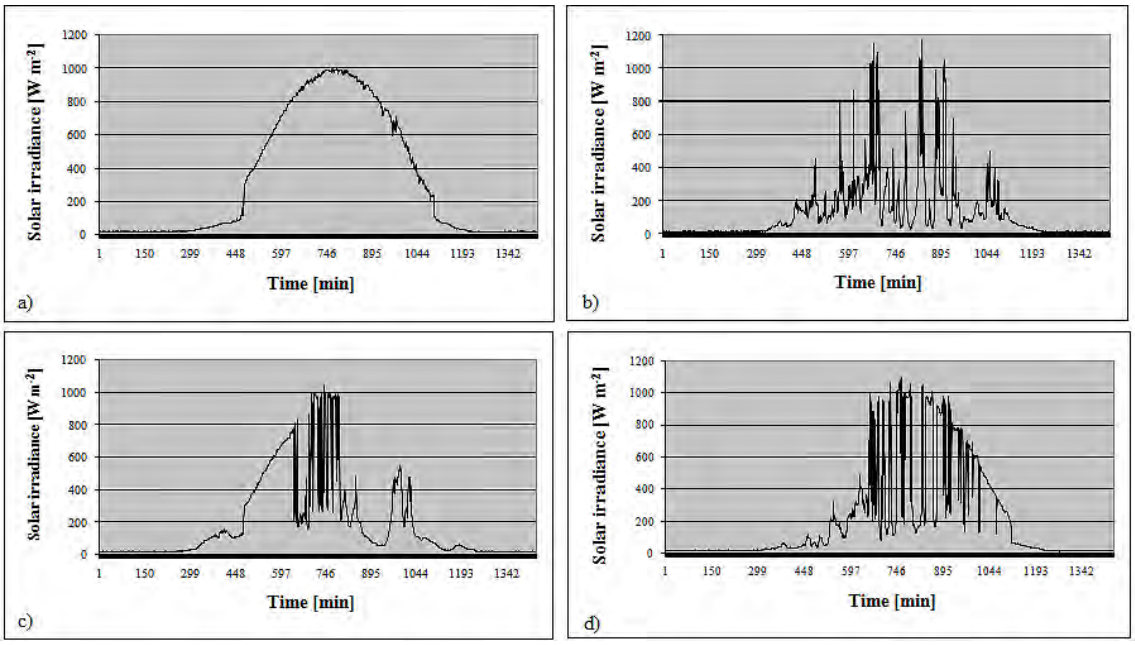

Figure 1. The daily variability of solar irradiance for days:
a) 10.05.2011, b) 13.05.2011, c) 22.05.2011, d) 03.08.2011.

The first group of examinations was performed using the experimental set-up 1 of the hybrid power system. Figure 2 presents a part of the system that comprises flat collectors, one of the tanks and heat exchanger. For the purpose of this study, measurements of the temperatures at the input to and at the output from the collector a) and from the exchanger b) will be used. Temperature measurements are taken every minute by thermometers PT 1000. The plate exchanger being analysed is the exchanger CB26 manufactured by Alfa Laval (soldered, 18 plates). The maximum heat power is 24 kW, and heat exchange surface area is 0.45 m^2. The flow in the exchanger is

variable, regulated by the delivery rate of the pump. On the primary side, the working medium is a mixture of water and glycol, and on the secondary side – water. The exchanger works in counter-current arrangement. The absorber of the solar collector Heliostar 200 has a total surface area of 34.6 m^2. Solar irradiance measurements were performed using pyranometer CM3 with the time constant of 18 s and the error of ±25 Wm^{-2} at irradiance of 1000Wm^{-2}.

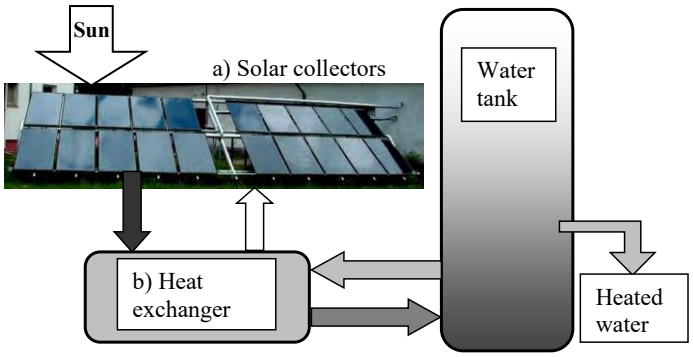

Figure 2. Fragment of the hybrid system in Budy Grabskie, measurement stand 1

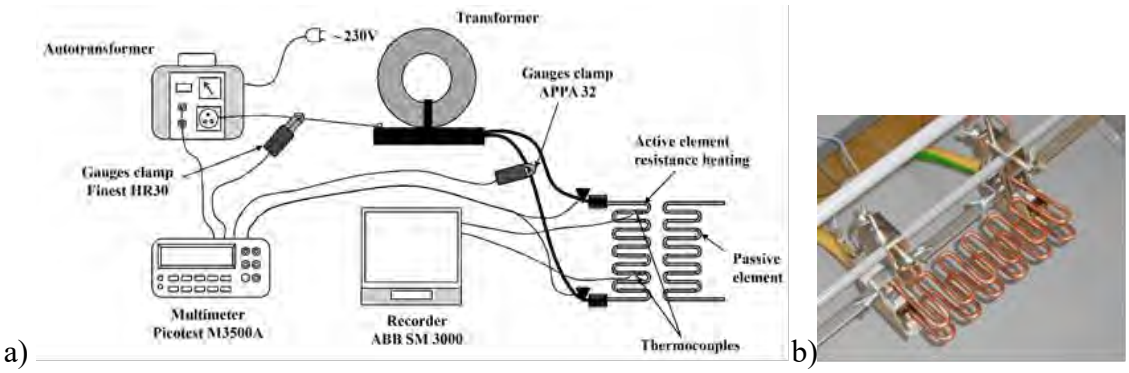

Figure 3. a) Diagram of the measurement stand 2 of the heat exchanger model, b) the positional relationship between the elements.

Another set of tests was performed at measurement stand 2, presented in figure 3. The heat exchanger is modelled by two elements: active, transferring heat and passive – collecting heat. The elements were made of copper rod with ϕ=5 mm. The active element was resistance heated, with air being the heating medium. Temperatures were measured every second in 6 points on both elements using coated K-type thermocouples (insulated, 0.5 mm tip). Screen Master 3000 recorder manufactured by ABB was used to record and archive the results. The maximum measurement error for thermocouples in the temperature range was ± 1.5°C, and the maximum error of the recorder ± 0.01%.

ANALYSIS OF RESULTS AND DISCUSSION

The results obtained in stand 1 were divided into two groups. The first group showed the variability of temperature obtained in the solar collector as a function of solar irradiance, and the second – variability of temperature at the output from the heat exchanger versus temperature at the input to the exchanger. Measurements, at measurement stand 2 involved only heat exchanger model, and were performed in order to determine the dependence of the temperature of the passive element (modelling the secondary side of the exchanger) on the temperature of the active element (modelling

the primary side of the exchanger). MATLAB with the System Identification Toolbox library was used to analyse all the obtained results. The necessity to precisely define the dependencies between the input and output values of the objects being studied required signal analysis allowing for investigation of the character of the element based on its STEP characteristics.

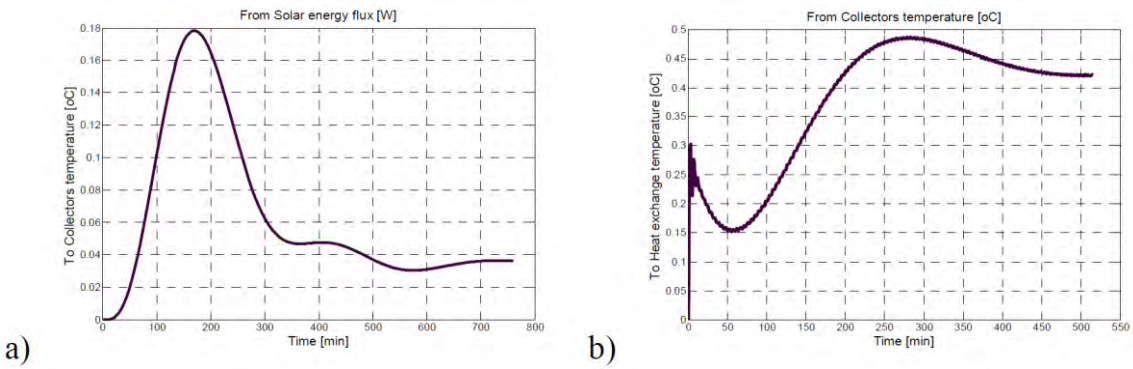

Figure 4. The STEP characteristics for:
a) solar collector (input: heat flux from solar energy, output: collectors output temperature),
b) heat exchanger (input: heat exchanger input temperature, output: heat exchanger output temperature)

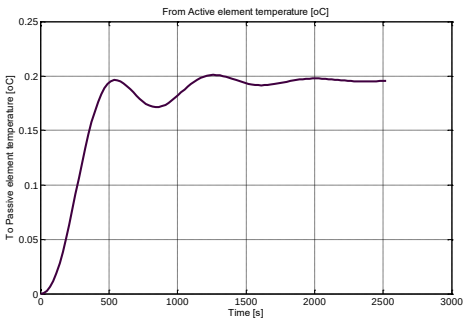

Figure 5. STEP characteristic for heat exchanger model
(input: active element temperature, output: passive element temperature)

Figure 4 presents STEP characteristics for a) solar collector and b) heat exchanger examined during the day with solar irradiance represented by figure 1 d. In both cases, oscillatory character of the investigated heat exchange was observed. For more precise determination of the degree of dependence of the observed character of unstable variability of irradiance observed in figured 1d, further examinations of heat exchanger model presented in figure 3b were performed. The resistance heated active element showed a stable rise in the temperature, to a greater extent corresponding to irradiance variability observed in figure 1a, and rarely occurring in reality. However, it proved that the analysis of the obtained results also revealed oscillatory character of the element being examined, with the STEP response of the element being presented in Fig. 5.

Oscillations in heat phenomena were also observed by other researchers. Problems of dynamic regulation of temperature was also studied by Wesołowski et al. (2011), indicating oscillations of temperature of the heating element for step change of the set-point temperature of the input function. Oscillations of temperature in transient states were also observed by Zerihun Desta et al. (2005) studying the course of heat exchange during the ventilation of a room. Espinosa-Paredes and Espinosa-Martinez (2009), Valle-Hernandez et al. (2011) and Espinosa-Paredes et al. (2011) wrote a series of

papers related to their many years' research and experiments. The authors analysed a nuclear reactor of BWR type (Boling Water Reactor). The analysis of processes occurring in the reactor led to the description of this reactor model by Espinosa-Paredes and Espinosa-Martinez (2009), and development of the equivalent electrical diagram, using thermo-electrical analogy by Valle-Hernandez et al. (2011). In this diagram, heat inductance occurs, which corresponds to the oscillations observed by Espinosa-Paredes and Espinosa-Martinez (2009). Oscillations of temperature were also observed during examinations of the plate heat exchanger dynamics by Obstawski (2012). Oscillations were also observed by Piotrowska and Chochowski (2012) for various types of exchangers, namely plate as well as shell and tube heat exchangers. Oscillations are an unfavourable phenomenon. Therefore, finding methods to counteract their occurrence is recommended. Such attempts were made by Díaz et al. (2001) by using a neural network to control the heat exchanger and for the purpose of elimination of oscillations, observed in transient states. Similar attempts, based on using neural networks for control of dynamic courses of heat exchange were made by Fichera and Pagano (2002), with consideration to their oscillatory character as well as Varshney and Panigrahi (2005), who described using a neural network for controlling heat exchanger.

CONCLUSIONS

There is a strong relation between sustainable farming and renewable sources of energy. At present, use of solar energy in Poland is small in comparison with other sources of energy, especially biofuels, but it shows a growing tendency, and its share in total renewable energy is increasing. The value of solar irradiance changes in a very dynamic and unpredictable way, with large variations being related not only to the season of the year or the time of the day but also to the current value of cloudiness. The devices that use solar energy work in conditions of large variability of input stream of heat. Transient states result in the changes of the character of their work. Oscillations of temperature were observed in the examined solar collectors combined with the heat exchanger. In order to assess whether the observed oscillations also occur for other values of parameters of heat exchange and their variability, investigations in laboratory conditions for the heat exchanger model were performed. The analysis of results of these investigations confirmed the occurrence of oscillations. Since they are unfavourable to devices in operation, it is recommended to work out models allowing to control the course of heat exchange and taking appropriate actions to avoid oscillations. These tasks may be realized with the help of e.g. neural networks.

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THE POSSIBILITY OF MAIZE STRAW APPLICATION AS A SUBSTRATE FOR BIOGAS PLANTS

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Keywords: maize straw, substrate, biogas production

ABSTRACT

The maize straw has a huge energetic potential. In Poland, the maize straw harvest can reach almost 5 million ha per year. With the good perspective for biogas market development in Poland, maize straw can become a good, reasonable substrate for biogas plant and avoid the conflict between food and biofuels production. This paper presents the potential for maize straw used as substrate for biogas plants. The results show that maize straw can be more effective for biogas productivity than maize silage. For 3 kinds of maize straw silage (from 4 analysed in total) the results of methane production were significantly higher (120.14 – 141.73 m^3/Mg FM) than in case of typical maize silage biomethane efficiency.

INTRODUCTION

In the last two decades, the development of renewable energy sources (RES) has been observed worldwide. Although renewable energy has been produced for more than a hundred years by hydroelectric plants, but it has only been since the 1990s that wind energy has spread, and after 2000 photovoltaics also. The prices of electricity produced by wind turbines or photovoltaic panels are falling successively and after 2020 the cost of generating the electricity from these installations will be lower than that of coal-fired power plants. The problem, however, is the instability of electricity produced from wind or sun. Photovoltaic panels, although unstable, are predictable during the 24-hour period (this is related to the movement of the sun in the sky). Moreover, an active change of their position relative to the sun can be used in order to increase their efficiency (Bugała et al., 2016a, Bugała et al., 2016b).

An alternative to fossil fuels and unstable RES is biogas production (Czekała et al., 2015; Pohl et al., 2012). It should be emphasized, that Poland is European leader in the development of modern biogas technologies, although the total number of installations does not exceed 300 (including 95 agricultural biogas plants - August 2017). The best Polish biogas plants work with real efficiency close to theoretical one, which diametrically differentiates them from wind power plants (efficiency 22-25%, off-shore at the sea up to 45%) or especially from photovoltaic installations (efficiency 10-16%). For example, the agricultural biogas plant in Jaromierz (Fig. 1) with the 1 MW of electric power, in 2016 produced 8499.5 MWh, which means efficiency at the level of 97% of theoretical efficiency.

What is also exceptional in Polish biogas plants (technologies Dynamic Biogas or ProBioGas) – it is the potential for fermentation of very large spectrum of substrates from agronomy and biowaste from agro-industrial sector. This increases the profitability of modern biogas plants because traditionally, those installations had to use mainly silages (i.e. German biogas sector uses every year over 60 mln tonnes of maize silage).

Fig. 1. Agricultural biogas plant (Dynamic Biogas technology) in Jaromierz

One of the most commonly used raw materials for biogas production are energy crops: maize silage, sunflower silage, cereal silage (Dach et al., 2014). In Europe, biomass from energy crops has a 35-40% share of substrate mixtures used in biogas plants (Rive et al., 2014; Cerbin et al., 2012). High yield of biogas from energy crops allows them to be widely used in high power biogas plants (> 1 MW). On the other hand, the raw material from energy crops accounts for 35-40% of the total cost of biogas production (Schievano et al., 2015), so that their use for biogas production is not profitable (Croce et al., 2016) and is not compatible with the principles of sustainable development. Moreover, the use of energy crops to produce biogas creates a conflict between food production and energy production (Croce et al., 2016). This is why sustainable biogas production can play a key role in the ongoing fight against global warming and climate change.

The method to reduce the cost of biogas production and its sustainable production is the use of substrates that are residues from agricultural production (Czekała et al., 2017). Recently, much attention is paid to lignin-cellulose waste materials. They are widely available and the purchase cost is low (Ferreira et al., 2014). Talebnia et al. (2010) show that lignin-cellulose waste is the largest source of raw material for energy production by anaerobic digestion. Agriculture can play a special role in providing lignin-cellulose substrates for biogas production, such as cereal straw, maize straw or rice straw. Since their cost is not high, their use is part of the sustainable production of biogas (Chandra et al., 2012a, b, c).

In the past ten years, worldwide, it has been observed 40% increase in maize grain production, which is currently 1030 million tonnes. In the European Union, total maize grain production in 2016 was 60.3 million tonnes and increased by 1.8 million tonnes in comparison with 2015 [Menardo et al. 2015, USDA 2016]. In Poland, maize grain production in 2015 was 3.16 million tonnes [CSO 2016]. That is why maize straw can be an easily accessible substrate for agricultural biogas plants (Zbytek et al., 2016). World production of maize straw is estimated at 230 million Mg. The highest amount of 150 million Mg of maize straw is produced in America, while in Asia it is 45 million Mg, in Europe 31 million Mg, in Africa 3.5 million Mg and 0.5 million Mg in Australia (Najafi et al., 2008).

The aim of this study is to analyze the possibility of maize straw using as a substrate for biogas plants, especially taking into account the most popular substrate in Europe –the

maize– as a reference point. In order to estimate better the potential of maize straw application for biogas plant sector, different kinds of straw silage (with large spectrum of dry matter content) have been tested.

MATERIAL AND METHODS

Tested material

The substrate for methane fermentation was silage from maize straw. We have analyzed 4 type of maize straw silages with completely different content of dry mass:

- CCS1: 31.35% of dry mass content;
- CCS2: 39.50% of dry mass content;
- CCS3: 62.90 of dry mass content;
- CCS4: 78.88% of dry mass content.

CCS1 silage was made of straw after harvest of Ambrosini maize variety from KWS company with FAO 220, stay green type. Harvested biomass contained 33% of dry matter. The yield of maize dry mass consisted of 53% of the flasks, 24% of the stem, 15% of the leaves and 8% of the flasks cover leaves. The maize straw was harvested by a field chopper with theoretical cutting length 20 mm. The straw was ensilaged in a flexible silo with length of 60 m.

The CCS2 silage was prepared from the straw directly after harvesting the maize grain PR39A79 from Pioneer with FAO 300. The dry matter content of the residue was 68% and dry matter content amounted 87.11%. The yield of maize dry matter consisted of 59% of flasks, 19% of stems, 14% of leaves and 8% of flasks cover leaves. The CCS2 silage was made up in a cylindrical bale wrapped in foil, CSS3 silage in elastic silo and CCS4 silage in a field prism covered with foil. The straw harvest was executed using New Holland 644 variable-compaction press and Pöttinger Jumbo 7200 Powermatic pickup truck.

Biogas research methodology

The maize straw samples were analyzed in Laboratory of Ecotechnologies at the Institute of Biosystems Engineering (PULS) – the biggest Polish biogas laboratory. The biogas efficiency analyzes were made according to German DIN 38414/S8 and VDI 4630 procedures – standard methods used in most of European countries. The final results were expressed in normal cubic meter per 1 Mg of fresh mass (FM), dry mass (DM) or organic dry mass (ODM) of the substrates (m^3/Mg FM). Before biogas analysis procedures, the samples were checked for dry mass and organic dry mass content within Polish Norms (PN-75 C-04616/01) and (PN-Z-15011-3).

The results obtained in this maize straw experiment were compared with the biogas efficiency of typical maize silage in order to analyze the energetic and economic usage of maize straw as the substrate for biogas production (Cieślik et al., 2016).

RESULTS

Maize straw silage of CCS1 had dry mass of 31.35%, and in visual and organoleptic evaluation it had a very similar appearance and smell to the typical maize silage from the whole plants (fig.1). In CCS1 silage the content of lactic acid amounted 1.08%, which was the largest content compared to other silages.

Fig. 1. Maize straw silage CCS1 had look and smell similar to typical maize silage

CCS4 silage had dry mass of 78.88% and in the visual and organoleptic assessment, it had crushed odor and was covered with mycelium. Between the tested silage - CCS4 contained the lowest level of lactic acid (0.17%) and acetic acid (0.2%).

Fig. 2. Maize straw silage CCS4 had look and smell comparable to composted material

Moreover, the analysis of pH has shown the big difference between the materials. The silage with the highest humidity had the lowest pH (3.95), however in contrary CCS4 (78.88% of dry mass) had pH over 6 (Tab. 1).

Tab. 1. Level of pH and concentration of Volatile Fatty Acids in analyzed silages

Maize straw ensilaged	pH	Volatile Fatty Acids [%]		
		Lactic acid	Acetic acid	Butyric acid
CCS1	3.95	1.08	0.61	0.07
CCS2	4.91	0.29	0.51	0.42
CCS3	4.52	1.07	0.68	0.03
CCS4	6.06	0.17	0.20	0.24

Analyzing the results of biogas productivities, for biogas plant holders, the most important is amount of methane produced from 1 Mg of substrate fresh matter. From this point of view, the best result was obtained for CCS3 material – 141.73 m^3 of CH_4 per Mg (Tab. 2). This is almost 40 m^3 more than in case of typical maize silage (app. 102 m^3/Mg). In case of 3 examined maize straw silages the methane productivity was higher than for typical maize silage. Only the most wet material (CCS1) had significantly lower methane productivity (59.68 m^3/Mg) than maize silage.

Furthermore, the obtained results show that more dry silages (CCS3 and CCS4) have higher biomethane productivity from fresh mass, which seems to be favorable for typical field conditions during harvesting period (usually maize straw has dry mass content over 50%).

Tab. 2. Biogas and methane yield from 1 Mg of tested material

Substrate	TS [%]	LOI [% TS]	Cumulative biogas yield [m^3/Mg]			Methane concentration [%]	Cumulative methane yield [m^3/Mg]		
			FM	TS	ODM		FM	TS	ODM
CCS1	31.35	98.17	114.47	365.14	371.94	47.98	59.68	190.37	193.92
CCS2	39.50	93.18	193.16	489.11	524.80	58.52	120.14	304.15	326.41
CCS3	62.29	92.94	239.96	385.24	414.50	56.67	141.73	227.53	244.81
CCS4	78.88	92.40	239.23	303.28	337.39	56.13	139.60	176.98	196.89

The cost of maize straw silage production (including harvest and transport) calculated for 6 different technologies within the project of the Ministry of Science 'The Technology of Harvesting and Storage of Maize Straw as an Energy Biomass and Structural Substrate for Composting" has started from 75 PLN/Mg of silage. This is clearly lower amount than in case of maize silage production (approximate cost – 110 PLN/Mg). It shows that maize straw silage can be much better substrate for biogas plant comparing with typical maize silage because of lower production costs and significantly higher biomethane productivity from 1 Mg of fresh mass.

CONCLUSIONS

1. The performed research experiments have showed the big difference in physic-chemical parameters between analyzed maize straw silages.
2. Except the material with the highest moisture (CCS1), all analyzed maize straw silages have clearly higher methane productivity from 1 Mg of fresh mass than typical maize silage. This causes that silages made from maize straw are very attractive substrate for biogas production.
3. In comparison with typical maize silage, maize straw silage can be much more effective substrate for biogas production due to lower production costs and significantly higher biomethane productivity from 1 Mg of fresh mass.

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COMPARISION OF PHYSICOCHEMICAL PARAMETERS OF RAPE SEEDS APPLYING THE INFRARED SPECTROSCOPY METHOD

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ABSTRACT
Technical progression in sustainable agriculture requires the need for search more and newer analytical methods in order to reduce time of analysis and to minimize costs routine of tests for the highest accuracy of the result. Infrared (IR) and near infrared (NIR) spectroscopy provides such possibility. The paper presents a method of measuring the basic quality parameters (moisture, content of protein, fat, damage and contamination of raw material) of winter rapeseed for cultivars: Abacus, Bellevue, and Adriana+Catana - concoction. Statistically significant differences resulting from various measurement systems between results obtained by means of sieve methods and infrared (IR), were observed. A three-dimensional way of measuring the seed shape used in three dimensional particle size analyzer (AWK 3D) suggests that it is more accurate than the measurement applying two-dimensional method used in the shaker with a set of sieves.

INTRODUCTION

Continuous high demand for winter rapeseed both for food and industrial production have contributed to the development of techniques providing a rapid assessment of this raw material. The pursuit of higher productivity should support the creativity and innovation of people primarily in the socio-economic sphere, including the field of science. The possibilities of testing the quality of products or raw materials dedicated for food and industrial purposes in every life aspect have advantages. Among them are: non-destructive and non-invasive analysis, short time preparation of sample for analysis, simple and fast routine procedure, high sensitivity of devices, improving labor safety, low costs etc. Winter rapeseed cultivars usually provide a higher yield than the spring ones. The average yield of seeds depend on the type of cultivars (hybrid or cross-bred lines), environmental conditions and the agronomic practices. However, the crop yields can vary between different countries in respect of the global trends (Calderini and Slafer, 1998; Nesi et al., 2008). High fat content with good-quality of proteins make this plant a valuable resource for food and oil industry (Casséus, 2009; Nesi et al., 2008). Assessment of raw materials is a very important step in quality control. This identification should certify that the raw material complies with a spectrum of quality parameters that allow its use for further storage and processing (Kachel-Jakubowska and Szpryngiel, 2006; Sujak and Kachel-Jakubowska, 2012). The most suitable rapeseed moisture without water and fat content for storage is in the range from 5 to 7%. High fat content, particularly in wet and damaged seeds, is readily degraded by enzymes and oxygen from the air. Following such process free fatty acids are formed and acidity of seeds increases. It contributes to accumulation of orthophosphoric and phytic acids, free amino acids, and reactive substances, that are toxic and structurally and functionally deforming the cells (Krasucki et al., 2002). Storage of damaged seeds reduce the efficiency of the extraction process. Moreover, significantly worsens the quality of oil obtained measured with the values of acidic and peroxide numbers.
The use of near infrared spectroscopy in the identity analysis reduces the analysis time. Assessment of test raw materials using NIR spectroscopy can be done in several ways:
- comparing the shape and intensity a substance spectrum with that of reference

standard purchased or obtained in similar conditions,
- comparing the intensity of absorbance at a particular wavelength,
- identification using the SIMCA (Soft Independent Modeling of Class Analogy) classifier (Vredenbregt et al., 2003).

The near infrared NIR (14 290 – 4 000 cm^{-1}) and far infrared spectrophotometry FIR (700 – 200 cm^{-1}) finds its great interest. The analysis is based on the principle proving that even a very simple molecule can have a very complicated spectrum (for the unknown sample), which is compared with the spectrum of a reference sample (Silvestein et al., 2005). The IR and NIR spectroscopy differ mainly in the range of the spectrum and a method for sample preparation. NIR analysis uses radiation from 10 000 – 4 000 cm^{-1}, providing information on physicochemical properties and physical status of the sample. The use of spectroscopic techniques in the analysis of food products is widely applied among others to identify the quantity of determined constituents, detect falsifications, determine the botanical origin or control the quality changes in the process of heating and storage e.g. by measuring the moisture, fat and protein contents of raw materials.

The aim of the study was comparison the characteristic parameters of rapeseed such as: external dimensions, contaminants and injuries, moisture, protein and fat contents determined using the new IR and NIR spectroscopy methods with values of these characteristics obtained by traditional methods.

MATERIAL AND METHODS

Material to study consisted of 2 kg samples of three selected of winter rapeseed crops cultivars (Abacus; Bellevue; Adriana+Catana - concoction) carried out in 2014-2015 by individual farms located in the villages Kurów (Puławy District), Małków (Hrubieszów District) and Wólka Kańska - Kolonia (Chelm). Farms were randomly selected to eliminate any similarities between the obtained material. The selection was aimed at achieving maximum sample diversification to obtain reliable results between methods under consideration.

The obtained samples of research material were stored in laboratory conditions, hermetically sealed in plastic bags in order to compensate the seed moisture at a constant ambient temperature of 20°C. Moisture analysis for comparative purposes was carried out applying common methods that use moisture analyzer (manufacturer: Radwag, model: Max 50/1/WH) and resistance grain moisture meter with sample fragmentation (manufacturer: Dramański, model: Grain Master GMS). The third measurement of water content in examined samples was performed using Omega G analyzer (manufacturer: Briuns Instrument) using near infrared radiation NIR (Dz.U. 2004.20.178).

The fat content in seeds was also measured with Omega G analyzer for rapid and accurate analysis of whole seeds applying NIR technique as well as Instalab 700 analyzer that measures the test material using near infrared NIR-T. This device also allows to determine the protein content in seeds.

Analysis of the seed size, the quantity of contaminants, and seed injuries, was carried out in accordance with PN-R-66160 (1991) by distinguishing between useful (injury, moldy) and useless (organic impurities, stem fragments, etc.) as well as was based on a random sample of 1000 seeds, for which measurements were made in triplicate for each of the three samples. Sieve analysis used shaker (manufacturer: Multiserw-Morek, model: LPzE-2e) and a set of sieves with mesh diameters: 3.00, 2.00, 1.00, 0.50, and 0.315 mm. Particle size analyzer was used (manufacturer: KAMIKA, model: AWK 3D) equipped with an electronic measuring unit with two independent lanes measuring particle size distribution also including meter. The dosing seeds system transmits the

analyzed material to the vibrating chute with a variable vibration amplitude regulated by an electric motor and ultrasound power.
The test results were processed using AWK 3D software applying Zingg classification based on the proportions between three seed dimensions related to the longest dimension - length (a), medium (b) – width, and the shortest (c) - thickness. It was assumed that:

- Seeds with proportions b/a > 0.67 and c/b > 0.67 recall sphere. For b/a = c/b = 1, it is an exact sphere,
- Seeds with proportions b/a > 0.67 and c/b < 0.67 recall disc,
- Seeds with proportions b/a < 0.67 and c/b > 0.67 recall rod,
- Seeds with proportions b/a < 0.67 and c/b < 0.67 recall blade.

The tests were performed in triplicate and then arithmetic means were calculated. The statistical analysis was carried out using Statistica 10 software using T-Student test and calculating standard deviations.

RESULTS

Results of the sieve analysis are shown in Tables 1 and 2. The sieve analysis isolates five seed fractions of different sizes. Referring to the sieve analysis carried out on a shaker with 0.315 mm mesh, there were no rape seeds but impurities in a form of fine particles after harvesting. Sieve of 0.5 mm mesh in addition to the contaminants isolated single seeds. The highest percentage of seeds of all cultivars tested was observed on a sieve with the mesh size of 2 mm, which retained the largest amount of Bellevue cultivar (94.71%). For Abacus and Adriana+Catana cultivars the results were comparable (approximately 75%). According to the analysis carried out using AWK analyzer, it can be concludes that there was no seed fraction which remained on the sieve of less than 0.315 mm mesh in all three cases. Presence of impurities and individual seeds was also noted on a sieve of 0.5 mm mesh. The largest share in samples of evaluated cultivars was made up by seeds larger than 1 mm (13.68% to 55.55%) and larger than 2 mm (49.06% to 85.95%). Share of other fractions was negligible. The statistical analysis aimed at comparing the two methods showed statistically significant differences between both methods for all three rapeseed cultivars in groups of sieve having 2 mm and 1 mm mesh (Table 1). Values in cultivars Bellevue and Adriana+Catana were not taken into account due to the absence of seeds on the 0.315 mm sieve.
Significantly greater share of seeds were observed in traditional method on 2 mm mesh sieve than in the IR method. In the case of sieves having 1 mm mesh, it was observed an inverse relationship with larger seed shares in IR method rather than the traditional method (Table 2). This phenomenon can be explained by a more accurate three-dimensional measurement of seeds in the case of the IR method. In traditional method the measurement is carried out only in two dimensions. Therefore, depending on the setting of seeds passing through the screen, there is the possibility of passing a material with different shape than a sphere. This situation can cause a remarkable measurement error when using the traditional method (sieve). Based on this the total volume of seeds and maximum dimension were calculated. Table 3 shows the distribution of rape seeds shape as percentage distribution seeds taking into account their shape. The issue of contamination and injuries to the seeds is widely discussed due to its particularly negative impact on technologies for oil production and its subsequent stabilization. This distribution is provided in Table 2, which shows the quantity and percentage of seeds referring to the shape of analyzed material. In all cases the highest share was reported for a spherical shape representing the range from 92% to 98%, while the

smallest - blades being presumably a natural product described as the seed contamination (with irregular and unidentified shape) ranging from 0.3 for Abacus to 1% for Bellevue. These contaminants were within acceptable limits in fat industry for which in the case of raw rapeseed the pollution level should be about 8%, and for technological about 6%. The disc and rod-shaped seeds were considered damaged or halved. The smallest share of these parameters has occurred for Abacus 1.2%; for Adriana+Catana 4.43% and 6.45% for Bellevue cultivar. No moldy seeds were found.

Table 1. Statistical analysis of rape seeds distribution on sieves (a – AWK 3D, b - LPzE-2e)

Sieve	Statistical parameter						
	Mean	Variation	Observations	PPC	Mean difference	df	t Stat
Abacus							
0.315a	0.040	7.230	3	-0.84856	0	2	-0.65085
0.315b	0.123	0.045	3	-	-	-	-
1a	22.785	4.295	3	-0.99705	0	2	-8.44171
1b	49.236	11.279	3	-	-	-	-
2a	77.158	4.293	3	-0.99989	0	2	8.342866
2b	50.630	11.802	3	-	-	-	-
Bellevue							
1a	50.058	85.753	3	1	0	2	9.461749
1b	5.058	0.857	3	-	-	-	-
2a	94.716	0.980	3	-0.28367	0	2	2.842431
2b	88.063	13.398	3	-	-	-	-
Adriana+Catana							
1a	24.161	0.759	3	0.963104	0	2	-9.08512
1b	38.980	13.356	3	-	-	-	-
2a	75.721	0.760	3	0.97015	0	2	8.376323
2b	60.680	15.595	3	-	-	-	-

Table 2. Percentage distribution of rape seeds on sieves using LPzE-2e shaker and AWK 3D analyzer

Sieves (mm) / Cultivar	0.315	0.50	1.0	2.0	3.0	0.315	0.50	1.0	2.0	3.0
	LPzE-2e shaker					AWK 3D analyzer				
Abacus	0.006 ±0.05	0.001 ±0.05	26.1 ±20.74	73.8 ±19.99	0.04 ±0.09	0	0.01 ±0.02	49.2 ±3.3	50.63 ±3.4	0.37 ±0.2
Bellevue	0.005 ±0.12	0.15 ±0.32	5.06 ±8.71	94.71 ±8.51	0.069 ±0.01	0	0.02 ±0.01	11.73 ±3.3	85.95 ±3.6	0.35 ±0.2
Adriana+ Catana	0.01 ±0.06	0.09 ±063	24.16 ±9.26	75.72 ±9.88	0.02 ±0.02	0	0.02 ±0.01	38.98 ±3.6	60.68 ±3.9	0.37 ±0.3

Table 3. Distribution of rape seeds shape using AWK 3D analyzer: b/a = 0.67; c/b = 0.67; c/a < 0.33

Abacus			Bellevue			Adriana+Catana		
Shape	Quantity (pcs)	%	Shape	Quantity (pcs)	%	Shape	Quantity (pcs)	%
Sphere	978	98.49	Sphere	919	92.55	Sphere	941	94.67
Disc	6	0.6	Disc	41	4.13	Disc	26	2.62
Rod	6	0.6	Rod	23	2.32	Rod	18	1.81
Blade	3	0.3	Blade	10	1.01	Blade	9	0.91

This distribution can be also presented by graphic form using the Zingg classification. The classification is based on the proportions between three dimensions of seeds by means of a quantitative system. Figures 1 shows the distribution for one of three

cultivars (Abacus), dividing the analyzed material into four basic classes: spheres located in the upper right corner of the graph, discs in the upper left corner, rods classified in the lower right corner and blades having unidentified shape of contaminants in the lower left corner of the graph.

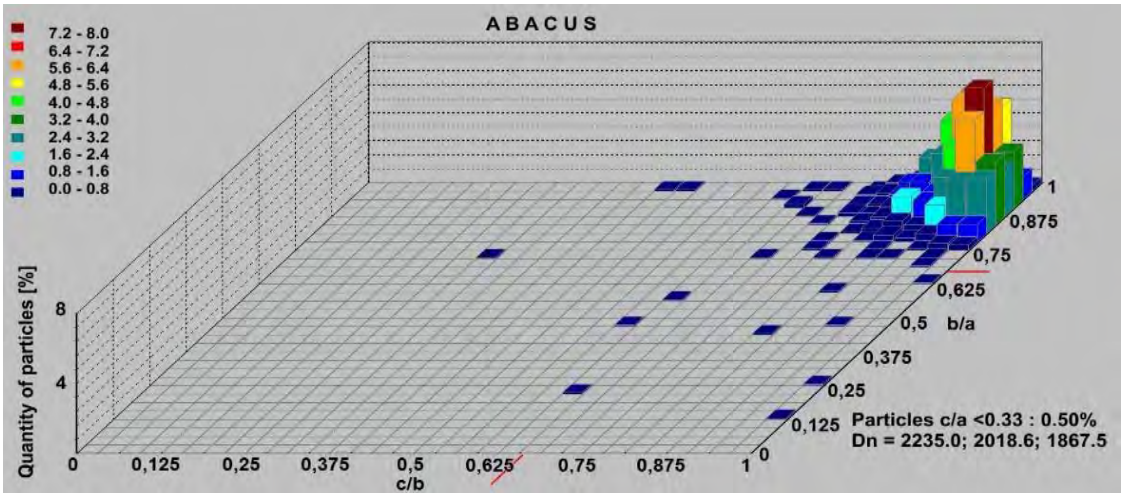

Figure 1. Quantitative distribution of rape seed particles according to Zingg classification for Abacus cultivar

Many farms and fat processing plants use electronic devices to allow rapid analysis of one or more parameters of seed quality. To determine the percentage concentration of such constituents as water, protein or fat, the reflective or transmissive in near infrared (NIR) analysis or in cases where moisture of portable instruments for obtaining fast results, may be used. Table 4 shows the results of rapeseed moisture measurement using three different devices. The samples of rapeseed revealed water content at the level between 6% and 6.5% for the moisture meter Dramiński, between 6.2% and 7.3% for moisture analyzer and 6.2% to 7.2% for Omega G. All tested seeds were characterized by optimal moisture acceptable for Fat Processing Plant in a range of 6-9% (Szczoła, 2006). Statistical analysis of the moisture results for analyzed rape seeds samples showed no statistically significant differences between used methods of moisture content measurements.

Table 4. Results of protein, fat and moisture content in rapeseed for three cultivars

Cultivar / parameter	Protein [%]	Fat – OMEGA G [%]	Fat – 700 [%]	Moisture [%]		
				OMEGA G	dryer - weight	dryer - Dramański
Abacus	20.40	43.87	45.23	7.20	6.98	6.50
Bellevue	21.90	42.63	44.60	7.40	7.35	6.20
Adriana+Catana	22.30	44.00	44.53	6.20	6.19	5.97

Table 2 shows also results of fat and protein contents in different rapeseed cultivars. The lowest protein content characterized Abacus cultivar - 20.4%, and the highest the hybrid Adriana+Catana - 22.3%. The level of fat determined using a near infrared showed values in the range from 43.0% to 44.5% for Omega G and from 44.5% to 45.0% for Instalab 700. For fat content values using two devices and for three rapeseed cultivars, statistical analysis showed no significant differences.

CONCLUSIONS

The use of spectroscopy in the infrared NIR and IR is becoming an increasingly popular method enabling rapid determination of the basic parameters of the chemical

composition, both in industrial analytics and research. There are no specific contraindications for the use and preparation of models (samples) for qualitative and quantitative analysis using these spectra.

Based on the performed analyses, it can be concluded that:

1. Statistically significant differences resulting from different measurement systems between results obtained by means of sieve methods and infrared (IR) were observed. A three-dimensional way of measuring the seed shape used in AWK suggests that it is more accurate than the measurement applying two-dimensional method used in the shaker with a set of sieves.

2. All tested cultivars were characterized by optimum moisture contents ranging within 6.0-7.5%. The greatest differences were found for results in the case of resistance method of moisture which was damaging for seeds.

3. The largest amount of contaminants and damaged seeds were noted in Bellevue and Adriana+Catana cultivars which amounted to 7.45% and 5.34% respectively.

4. The highest percentage share of rapeseeds for all cultivars was observed on sieve with 2 mm of mesh, that collected largest quantity of Bellevue seeds (94.71%).

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ASSESSMENT OF THE INTEGRATION OF MECHANICAL WEEDING FOR WEED CONTROL IN SUGAR BEET-GROWING

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ABSTRACT
The aim of this research was to evaluate the potential of mechanical weeding for the cultivation of sugar beet by comparing four weed control programmes (one chemical, two mixed (chemical and mechanical) and one mechanical). Under the dry conditions of 2017, the mixed conditions displayed the best effectiveness (more than 97%), using less herbicide and costing €30/ha less than the chemical scheme, while producing a yield identical to that obtained with fully chemical protection. Conversely, the mechanical programme was ineffective (69%), especially on weeds in the crop row (23% effectiveness only); while its cost was lower (€180/ha), it led to a loss of sugar yield of 18.9% compared to chemical weed control.

INTRODUCTION

Plant protection products have a recognised impact on the environment (air, soil, surface water, groundwater and seawater pollution), and are toxic to varying degrees (Calvet et al., 2005). Herbicides are applied to plants at an early stage of development, and are therefore more easily transported to surface water and groundwater. According to the key indicators for the Walloon environment (DGARNE, 2014), pesticides are detected in two-thirds of groundwater quality control sites, and the active substances found in higher concentrations are all herbicides. Representing 36,679 ha of land in 2016, beet is an important crop in Wallonia, but makes heavy use of pesticides (mainly herbicides): an average of 6.5 kg of active substances per hectare (Lievens and al., 2014). The control of weeds is essential in beet-growing, as the plant's slow juvenile growth leads to strong competition from weeds which potentially has a significant impact on yields of up to 90%. More specifically, there are number of problems associated with the herbicide solutions used for beet-growing, including the appearance of resistance, in particular in fat hen (*Chenopodium album*) (Mechant and al., 2008) and spreading orach (*Atriplex patula*) (De Cauwer et al., in press), and the reduction of available active substances and authorised doses. In response to these problems, one solution for farmers is integrated weed management, in which various approaches to managing weeds are combined. In this context, mechanical weeding is a clearly identified technique which has benefited in recent years from developments which facilitate its implementation, such as camera or GPS guidance, increased working widths and the introduction of equipment for working on the crop row itself. Trials have shown that it is possible to control weeds in integrated systems combining mechanical weeding and phytosanitary treatment, even for beet-growing, which is highly demanding in terms of weed competition (ITB, 2011, Kunz et al., 2015). However, problems remain due to lack of flexibility in the application of treatments, observed crop losses and lack of effectiveness (Pottier M., 2012; Colomb et al., 2011; ITB, 2011). Questions may be legitimately asked about the cost of implementing these practices. The available studies show variable results depending on

whether direct costs and/or some indirect impacts are taken into account (ITB, 2011; ITAB, 2012). Considerable variability is also observed according to the pedoclimatic conditions.

The objective of the trial was to evaluate the potential of mechanical weeding for the cultivation of sugar beet in order to provide farmers with information on the effectiveness and cost of combined weed control in Walloon pedoclimatic conditions.

MATERIAL AND METHOD

The trial was set up on 27 March 2016 (variety BTS990; inter-row distance 45 cm; row width 18.6 cm) on a plot located in Autre-Eglise. Four weed control programmes in four blocks with four passes per block were compared; the crops were treated identically in all other respects (Table 1).

Table 1. Description of the weeding treatments

Weeding treatments	09/04/17	20/04/17	27/04/17	9/05/17	16/05/17	23/05/17	31/05/17
M0 – Untreated	/	/	/	/	/	/	/
M1 - Chemical	FAR 1	FAR 2	FAR 3	/	FAR 4	FAR 5	FAR 6
M2 - Mixed 1	FAR 1	FAR 2	FAR 3	/	FAR 4	Hoe with stars	/
M3 - Mixed 2	FAR 1	FAR 2	FAR 3	Hoe	/	Hoe with stars	/
M4 - Mechanical	/	/	/	Hoe	Hoe + rotative weeder	Hoe with stars	/

Given the dry conditions, there was no application of pre-emergence herbicides (due to the ineffectiveness of soil active herbicides. The FAR (Fenmedipham Activator Radiculair) treatments are listed in Table 2. Four different modes of action were used in this scheme.

Table 2. Description of the FAR treatments (products and quantities)

FAR description	Doses/ha et products*
FAR 1 (sowing + 12 days)	0.8 l Be + 0.5 l G
FAR 2 (+ 11 days)	1 l Be + 0.6 l P + 15 g S
FAR 3 (+ 7 days)	0.5 l Bv + 0.2 l T + 0.6 l P + 15 g S + 0.05 l Vsc + 0.5 l H
FAR 4 (+ 20 days)	0.6 l Bv + 0.2 l T + 0.6 l P + 0.1 l Vsc + 0.5 l H
FAR 5 (+ 7 days)	0.6 l Bv + 0.2 l T + 0.6 l P + 0.15 l Vsc + 0.5 l H
FAR 6 (+ 7 days)	0.5 l Fr + 0.5 l Vsc

*Be : Betanal Elite (91 g PMP-71g DMP-112 g ethofumesate) – G: Metatron (700 g/l metamitron) – P: Chlordex (430 g/l chloridazon) – S : Safari (50% triflusulfuron-methyl) – Bv : Belvedere (160 g/l phenmedipham +160 g/l desmedipham) – T : Ethomat (500 g/l ethofumesate) – Vsc : Venzar (500 g/l lenacil) – Fr : Frontier Elite (720 g/l dimethenamide-P) – H : Vegetop (812 g/l esterified oilseed rape oil).

Weed pressure was low: in June, the total average pressure was 16.2 weeds/m² on average in non-weeded controls, with an observed variability in the plot of 6.1 to 30.0 weeds/m². For the mechanical weeding, two machines were used. The first of these was a hoe mounted with a camera (3 m, brand Carré, model Econet) which weeded between rows

by means of triangular coulters and Lelièvre blades. In order to work on the crop row, the hoe could be equipped with stars when the beet stage made this possible (>6 leaves). The second machine used was a 6 m rotative weeder (Einböck, Aerostar rotation model), consisting of teeth mounted on inclined discs fixed on independent suspended arms; this weeder worked over its entire width independently of the crop rows. The weed population was monitored throughout the season at each weed control intervention by conducting counts in 0.50 m² sample squares distributed at random in the different conditions as well as in the non-weeded controls. The latter were distributed evenly throughout the plot to allow for the spatial variability in the distribution of weeds. In total, 96 sample squares were evaluated at each count for the total number of weeds and the number of weeds in the crop row and between the rows (with both species and stage being recorded). The number of beets was also counted after emergence, after each pass of a mechanical tool and at the end of the weeding season. Effectiveness (%) represented the evaluation of the treatment's action on the weeds. It was calculated by comparing the number of weeds counted for a defined condition with the untreated control. This was done in each sample square, for the total number of weeds as well as for the weeds located in the crop row and between the rows, using the following formula:

$$Ef_{P1} = 100 - (100 \times \frac{AdvP1}{AdvT})$$

Where: *Ef* = effectiveness of plot 1 in %, *AdvP1* = number of weeds/m² in plot 1, and *AdvT* = number of weeds/m² in the nearest untreated control.

Selectivity represented the impact of weed control on the beet, and was evaluated by calculating the % of beet losses compared to a previous situation.

For each block and in each condition, 6 m x 4 rows (10.8 m²) of beets were manually topped and lifted. The samples thus obtained were weighed before and after washing and analysed in order to determine the yield and quality of the beets (mellasigenic elements), and in particular their sugar content. Each weed control programme was subject to a cost calculation. This included the use of the machinery (the cost of the tractor, driver and machine) and the cost of the products. All calculations were carried out using the Mecacost software program (www.mecacost.cra.wallonie.be, Rabier et al., 2008). The assumptions used for the calculations are presented in).

Table 3).

Table 3. Parameters used for the calculation of the weeding costs

Parameters	Assumptions UA : Annual Utilization – Perf : Performance
Labour cost	20 €/h
Hoe (3 m)	Price: 33 000 to 43 000 (with stars) € - UA: 100 ha/year - Perf: 1,6 ha/h
Rotative weeder (6 m)	Price: 14 000 € - UA: 100 ha/year - Perf: 3,5 ha/h
Sprayer (27 m-trailed-3000 litres)	Price: 45 000 € - UA: 800 ha/year - Perf: 7 ha/h
Depreciation	On the technical lifetime of the machine regarding its specific annual utilization

RESULTS AND DISCUSSION

The two mixed conditions (M2 and M3) were the ones that worked best, with similar effectiveness scores of 97.75% and 97.28%. This is explained by the conditions in spring 2017, which did not restrict the use of mechanical tools and made it harder to control the more developed weeds (> 2 leaves) with herbicides, a situation that was successfully remedied with the use of the hoe to destroy weeds up to the six-leaf stage.

Table 4. Total, row and inter-row effectiveness (mean in %, n=16), in June for the four weeding treatments ± standard deviation (%)

Weeding treatments	*M1- chemical*	*M2- Mixted 1*	*M3 – Mixted 2*	*M4 - Mechanical*
Effectiveness (total)	90.52 ± 24.18*[a]	97.75 ± 3.68***[a]	97.28 ± 3.05***[a]	69.71 ± 19.65[b]
Effectiveness (row)	92.23 ± 9.63***[c]	94.74 ± 7.85***[c]	90.68 ± 10.31***[c]	23.70 ± 21.87[d]
Effectiveness (inter-row)	89.80 ± 19.46[f]	98.95 ± 4.17*[e g h]	100.00 ± 0.00 **[e] *[g]	97.68 ± 3.61*[e h]

Means quoted with different letters are significantly different at the level p<0.05 (*), p<0.001 (**) or p<0.0001(***)

The chemical treatment condition achieved an effectiveness of 90.52% which, although disappointing, can be explained by the specific conditions encountered during the year. The cold, dry weather at the beginning of the season led to very slow beet development and caused the weeds to harden off; this was then followed by a sudden rise in temperatures combined with very rapid new weed emergence and development. The effectiveness of the completely mechanical condition was not acceptable, with an average of 69.71%, significantly or very significantly different from the other three conditions.

A comparison of row and inter-row effectiveness shows that row effectiveness was lower. For condition M4, this was extremely problematic, with an effectiveness of 23.70% in the crop row, but 97.68% between the rows (a very significant difference from M1, M2 and M3 in the row). It is thus clear that the limitation of mechanical tools lies in their ineffectiveness against weeds situated in the row. It is hard to strike a balance between the reasonable development of beet and weeds with a view to destroying the latter without damaging the main crop.

The failure to perform a late application of soil acting herbicides (M2, M3 and M4) had no impact on weed development after June. A count conducted on 1 September revealed no difference from the situation in June. This may be explained by the particularly dry conditions and the incorporation of the soil acting herbicides preventing late emergence of weeds (e.g. lenacil) as early as FAR3.

With regard to selectivity, there were no significant losses of beet observed, regardless of the treatment. Used correctly (in terms of speed and settings) and at the appropriate stages, mechanical weeding tools do not result in beet losses. However, they do limit performance, because the speed is reduced (3-4 km/h for the hoe), and the opportunities to use the tools are also reduced because it is necessary to wait until the beet is sufficiently developed and the weather is ideal (dried soil and drying weather for three consecutive days).

The cost of the different weed control schemes is presented in Table 5. The chemical programme was the most expensive (€320/ha), mostly due to the product cost (79%). The mechanical condition (M4) had the lowest cost (€180/ha), due to the different number of passes required (three, compared with six for the chemical condition) and the fact that no herbicides were purchased. It should be noted that the manpower cost required for manual catch-up weeding was not taken into account.

The two mixed programmes had similar costs (€290/ha), because one hoeing pass (€51/ha) costs almost the same as spraying with herbicide (€53/ha).

Table 5. Costs for the different weeding treatments in €/ha

Weeding treatments	*Products cost €/ha (% total)*	*Machines cost and labour €/ha (% total)*	*Total cost €/ha*
M1 - Chemical	252 (79%)	68 (21%)	320
M2 - Mixed 1	187 (65%)	102 (35%)	289
M3 - Mixed 2	149 (51%)	142 (49%)	291
M4 - Mechanical	0 (0%)	180 (100%)	180

In terms of the yields measured for the four conditions, there were no significant differences between M1, M2 and M3, either for the net yield in kg of beet per hectare or kg of sugar/ha. However, the yield obtained for totally mechanical weeding was significantly lower than for the other three (Table 6). Differences in effectiveness do not necessarily result in a difference in yield, since the impact of weeds will depend not only on their numbers but also on their development. Thus, the lower effectiveness of chemical weed control did not have an impact on yield since the weeds were at less developed stages. This was not the case for M4, where weeds were not slowed down in their development and where the vast majority (83%) were in the heading-flowering stage (BBCH 58-60) in June.

Table 6. Net yields (beets and sugar) for the four weeding treatments

Weeding treatments	*Net Yield (kg of beets /ha)*	*Sugar yield (kg sugar/ha) (%M1)*
M1 - Chemical	96 111	18 508 (100%) [a]
M2 - Mixed 1	95 081	18 105 (97.82%) [a]
M3 - Mixed 2	95 301	17 941 (96.93%) [a]
M4 - Mechanical	77 292	15 007 (81.09%) [b]

Means quoted with different letters are significantly different at the level $p<0.05$.

CONCLUSION

The results of this trial show that it is possible to integrate mechanical weeding in chemical schemes in a very satisfactory manner in order to reduce the use of herbicides. In this trial, were the conditions including the use of mechanical tools to replace two or three rounds of spraying that proved the most effective, obtaining an identical yield to that obtained with completely chemical protection at slightly lower cost. The fully mechanical solution is not currently adequate; the problem lies exclusively in weed control in the crop row. This weed control scheme resulted in a sugar yield loss of almost 19% compared to chemical weed control, and will probably have an impact on future weed growth on the plot. A solution needs to be found that will make it possible either to

take a more aggressive approach and thus accept the destruction of beets (denser seeding), or to increase the time lag between the beet stage and the weed stage. Another possibility is the combination of spraying directed at the crop row and hoeing between rows. As the weather conditions have a significant impact on plant development and the possibility of mechanical intervention, these results are specific to the year 2017. It is therefore important to continue this type of trial in order to carry out an evaluation over several years.

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ASSESSMENT OF THE BALANCE OF GREENHOUSE GASES IN THE PRODUCTION OF RENEWABLE BIOMASS FROM SHORT-CYCLE ENERGY PLANTATIONS OF WILLOW

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Key words: greenhouse gas emissions, bioenergy, short rotation coppice, willow

ABSTRACT
Greenhouse gas control it is the key aspect for climate protection. As climate regulation became inevitable, companies started adopting more proactive strategies. One of the effective methods for greenhouse gas emission calculation is based on life cycle analysis. A carbon footprint is defined as the sum of greenhouse gas emissions caused by an organization, event, or product and is expressed in terms of CO_2 equivalents. The investigations were devoted to greenhouse emission assessment during life cycle of willow wood production from short rotation coppice plantations. In accordance with results about 48% of carbon dioxide gas from all life cycle of willow was emitted during wood harvesting and transportation to energy plants.

INTRODUCTION

The most important aspect of the Kyoto Protocol is the flexibility to achieve the set limits on greenhouse gas emissions. The basis of this system is the "bubble" principle, used in the US to control emissions of sulfur dioxide. In accordance with the Directive of the European Parliament and Council in the EU member states, from January 1, 2005, trade in greenhouse gas emission quotas began. According to the state's needs to reduce greenhouse gas emissions, the operator in a certain region is given the number of quotas that operators can throw into the atmosphere. If the operator emits less than the established quota, the difference between the established quota and the actual emission can be sold. Regression modeling of the dependence of greenhouse gas emissions on the consumption of primary fuel and energy resources and economic development of the sectors was used to forecast greenhouse gas emissions.

At present, more and more producers are joining the so-called "carbon clubs", whose goal is to reduce greenhouse gas emissions (Renato et al, 2015). This trend is due to number of reasons. Whereas in the early 1990s, corporations sought to block regulation of climate change-related issues, from the time they recognized such regulation in number of international instruments, they sought to develop an adaptive strategy. The companies saw new prospects for the market, improved reputation and production development in connection with climate regulation. In such circumstances, the most important issue is determining the amount of greenhouse gas emissions applied to the production of a particular type of product. Currently, one of the topical issues for businesses in the field of carbon strategy is the uncertainty of national policies in the field of greenhouse gas emissions regulation. One of the most effective methods is the calculation of the so-called "carbon footprint," based on the evaluation of the product life cycle. This approach is used by companies of various types of activities: industrial,

energy, agricultural. Thus, studies were conducted to estimate greenhouse gas emissions in the production and use of electric vehicles. One of the sectors of agricultural production that accounts for a significant amount of greenhouse gas emissions is the production of beef (Subramaniam et al 2015). The purpose of the research performed in Brazil was to calculate the "carbon footprint" per kilogram of live weight. At the same time, various methods of obtaining products were taken into account (Ruviaro et al 2015). The need to estimate greenhouse gas emissions in the production of agricultural products and to develop new approaches aimed at reducing emissions is noted in a number of other publications (Hertwich et al, 2009; Tilman et al, 2011; Ruviaro et al, 2012). Gas emissions from renewable energy sources are not taken into account when calculating quotas. Nevertheless, it is necessary to take into account those greenhouse gases that are emitted during the life cycle of obtaining an energy resource. In this regard, the methods of "carbon footprint" have been actively disseminated in assessing the effectiveness of renewable energy sources. Large hydro power plants are the main source of electricity production on a renewable basis at present. The method for analyzing the life cycle and calculating the "carbon footprint" is the most effective for estimating the potential reduction of greenhouse gas emissions in the construction and operation of hydroelectric power stations (Zhang et al, 2015). Studies have shown that the low-carbon status of large hydropower plants is currently somewhat overvalued, and certain adjustments are needed to correct the situation in the future.

One of the most promising sources for obtaining thermal energy is biomass. To obtain biomass, it is also necessary to spend a certain amount of fossil fuel, which implies the emission of greenhouse gases. The Life Cycle Assessment (LCA) method was used in a number of studies related to various sources of biomass to generate energy, for example, algae (Lima et al, 2015).

These and other studies have shown that it is necessary to search for new approaches and technologies that allow reducing the amount of greenhouse gases in obtaining biomass (Dovi et al, 2009). One of the promising directions is the production of energy from the biomass of short-cycle tree plantations: willow, poplar, eucalyptus, etc. A study of the potential of fast-growing subspecies and hybrids of willow, poplar, aspen, miscanthus and other plants is being actively conducted in several countries (Sweden, Finland, Canada, Poland, and others) (Schweier et al, 2012). In this connection, a particular interest is caused by willow, as a plant capable of growing under conditions of high moisture content, on different types of soils characterized by different levels of fertility. The natural conditions of central and Eastern Europe make it possible to consider willow as a promising crop for the creation of commercial energy plantations. In accordance with the decisions of the Kyoto Protocol, greenhouse gas emissions from the burning of energy crops, as well as from other sources of biomass that are produced on a renewable basis and used for energy production, are not taken into account when establishing carbon credits. The purpose of our research was to estimate greenhouse gas emissions in the process of growing willow on energy plantations. The obtained results will allow to estimate the real decrease in the amount of greenhouse gases when using willow wood as biofuel in comparison with traditional energy carriers.

METHODS OF RESEARCH

Plantations of fast-growing willow were laid in the ecological conditions of the Republic of Belarus. According to the results of research carried out in different agroclimatic zones of country (Grodno, Mogilev, Minsk and Brest oblasts), the yield of

willow in Belarus was 9-12 t of dry wood per year, which corresponds to the indicators achieved in the USA or Sweden.

The study of the morphological parameters of willow plants, to assess the dynamics of their growth and development in the field, was carried out according to the adopted methods (Dospechow 2012). The yield of willow was determined by weighing in continuous harvesting in the plots. The results of measurements of morphological parameters and yields of willows from each plot were processed by the method of variance analysis. The moisture content in willow wood and the specific heat of combustion were determined in laboratory conditions. Emissions of greenhouse gases were determined according to accepted international and national methods (Global Warming 1995).

RESULTS AND DISCUSSION

With a three-year cycle of wood production, the following results were obtained in experiments at the best sites: Developed peatlands: 9.9 t of wood per hectare in terms of one year and 10 percent moisture; Loamy sod-podzolic soils: 12.5 t of wood per hectare; Degraded peat-bog soils: 10.9 t of wood per hectare in terms of one year and 10% moisture.

Based on the results of the measurements the technology of cultivation of willow was adapted to specific soil and climatic conditions. The technology formed the basis for the development of technological maps for cultivation of crops, which in turn were used to perform economic calculations (Table 1).

Table 1. Technological map of obtaining willow wood. The area is 1 hectare

Technological operation	Fuel consumption, l	% of the total
Soil cultivation	57.4	12.67
Stubble abrasion (6-8) cm	8.6	1.90
Preparation of the working solution of the herbicide	0.9	0.20
Transportation of water in the field and filling of the sprayer	1.8	0.4
Loading in a vehicle of mineral fertilizers	0.2	0.04
Transportation and application of P and K fertilizers	0.79	4.15
Plough land plowing	18.8	4.15
Loading of mineral nitrogen fertilizers into the vehicle	0.1	0.02
Loading of mineral nitrogen fertilizers into the vehicle	5.3	1.17
Cultivation with harrowing	3.6	0.79
Transportation and application of nitrogen fertilizers	10.9	2.41
Landing	13.4	2.96
Planting cuttings	13.4	22.61
Care of plantings (7 cycles)	96.6	21.32
Loading in a vehicle of mineral fertilizers	1.4	0.31
Transportation and application of P and K fertilizers	25.2	5.56
Loading of nitrogen fertilizers in the vehicle	0.7	0.15
Transportation and application of nitrogen fertilizers	25.2	5.56
Application of herbicides	47.7	10.52
Plantation cleaning (7 cycles)	217	47.88
Wood harvesting with loading and grinding	133	29.35
Wood transportation	84	18.53
The plowing of the plantation	118.8	26.21
Plot of land	18.8	4.15
Total	453.2	100

When growing willow, greenhouse gas emissions are associated with the use of diesel fuel for performing technological operations.

When burning diesel fuel, the main greenhouse gas that is released into the atmosphere is carbon dioxide. The structure of fuel consumption and carbon dioxide emissions according to technological operations is shown in Figure 1.

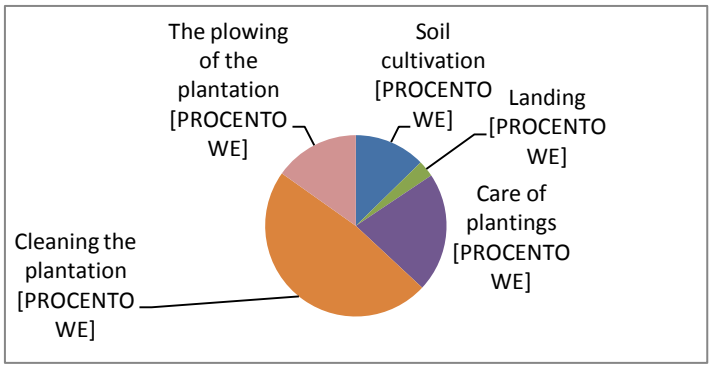

Figure 1. Structure of carbon dioxide emissions in the production of willow biomass according to technological operations

Cleaning is the most costly operation in terms of fuel consumption (Raucci et al 2015). Based on the results of the assessment conducted for 55 farms, over the course of 3 years, greenhouse gas emissions from technological operations were distributed as follows: harvesting and processing residues - 36%, fertilizer application - 16%, liming - 13%, pesticide use - 7%.

When growing willows, more significant cleaning costs are associated with a relatively high crop yield. A significant impact on greenhouse gas emissions of technological operations related to the harvesting of short-cycle crops has been noted in other publications (Berhongaray and Ceulemans, 2015). At the same time, it is stressed that special attention should be given to such a technological operation as weed control. In particular, it is from this aspect that the carbon balance in the soil largely depends. In our studies, an estimate of the emissions associated with soil carbon during the cultivation of willow on short-cycle plantations was not carried out.

The average calorific value of willow wood installed in our experiments was 18500 J/kg. This means that in terms of a year from one hectare of plantation, you can get 4.4 t of equivalent fuel, which is equivalent to about 3.9 thousand m^3 of natural gas and 3.2 t of heating oil.

In accordance with the obligations of the Republic of Belarus on the UN Framework Convention on Climate Change and the current market in the EU ETS system, the cost of one ton of carbon dioxide can be about 15 euros (Subramaniam et al, 2015).

Thus, replacing fossil fuel with willow wood as an energy carrier will potentially allow about 4,000 euros per hectare of willow plantation over the entire life of the will, if the mechanism for trading carbon credits at the local level is implemented. Of course, this approach will serve as an additional incentive for wood producers for energy purposes from short-cycle plantations.

CONCLUSION

The receipt of any kind of renewable energy is associated with the use of fossil fuels (diesel, gasoline, natural gas, etc.). One of the most effective methods for estimating

greenhouse gas emissions in the production process is the LCA method. The research proves the effectiveness of such an approach for estimating greenhouse gas emissions in obtaining wood for energy purposes from short-cycle willow plantations. The main amount of emissions is associated with the use of diesel fuel in the cultivation of plantations. Calculations carried out taking into account the optimal planned plant life (22 years from the moment of planting) showed that the main carbon dioxide emissions (48%) are related to such a technological operation as harvesting and transportation of wood. Reduce emissions is possible when optimizing the logistics of these technological operations. In particular, the organization of movement of harvesting equipment, optimization of cleaning, loading and transportation schemes, etc. Of great importance is the distance from the plantation of willow to the consumer (thermal power plant). From one hectare of willow, taking into account its yield and specific heat of combustion, it is possible to obtain 4.4 tons of equivalent fuel, which is equivalent to about 3.9 thousand m3 of natural gas and 3.2 tons of heating oil. The amount of CO_2 emissions from burning willow wood for energy purposes will be 12,467 tons. For the entire service life (in terms of plantation area of 30 hectares), emissions associated with the consumption of diesel fuel will total 734 t. When replacing natural gas with an equivalent output energy, the amount of wood willow is a positive CO_2 balance of 11,733 t. The cost of a quota for emissions of one tonne-equivalent of CO_2 is currently on the international market of about 15 euros. Replacement of fossil fuels with willow wood is thus both environmentally and economically justified, both at the country level and individual energy producers. The implementation of this approach at the local level will serve as an additional incentive for wood producers for energy purposes from short-cycle plantations.

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OUTSTANDING ISSUES OF MOTOR CAR RECYCLING IN TERMS OF ENVIRONMENTAL IMPACT MITIGATION

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ABSTRACT
Due to the intensive growth of the importance of all activities in the field of ecology and rational economy, the article presents an attempt to develop a comprehensive model of the dehumidification process of LPG and CNG gas cylinders. The recovery of the gases from gas cylinders in the circumstances of the Polish economy will lead to an improvement of the work and environmental safety and to increase the recovery rates.

INTRODUCTION

Changes in the construction of agricultural working machines and vehicles, and improving recycling techniques affect the growth of the importance of product recycling at the expense of energetic recycling, which is less economically viable.

Due to the fact that recycling issues are of great ecological, economic and material importance, it is necessary to adopt a global policy to increase the relevance of that issue. It is also important to include issues related to the forecasting and controlling of recycling processes, depending on the amount and type of utility waste and the technologies and applications used in the country (Gaballah I. Kanari N. 2001, Upper Z., Sobczak J. 1995, Mc Donough WJ 1994, Schuster D.M. et al. 1993).

Efficient disposal management of solid waste arising from any type of motor cars in Poland is still an outstanding issue, although first acts of law regarding motor cars were enforced in 2005. Imprecise and amended law and related regulations still fail to effectively address the aforementioned outstanding issue, and inaction will result in deterioration of living standards for the contemporary civilisation, damage of natural environment and landscape as well as development of civilisation disease.

The essence of recycling is most of all withdrawal of a variety of natural resources from operational use in the manner that will ensure the maximum shortening of the technological cycle of products – which is driven by economics – and mitigation of hazards in reuse – which is driven by ecology (Wojciechowski 2012). The said measures should aim at the „closed-loop material cycle", for instance, that is an economic objective and should be subject to the following criteria, according to Wojciechowski (2012):

- development of the recycle and recover technology at the stage of designing,
- solid waste prevention in the production or manufacturing processes,
- promotion of low-emission and waste-free production,
- it should aim eventually at energy recovery,
- development of safe technologies for hazardous substances,
- improvement of unification and cohesion of solid waste disposal management law and related regulations,
- development of the comprehensive education programme.

Given the current automotive industry growth forecast, there is an imminent need for improvement of any of the recycling system elements. According to the figures published by the Central Statistical Office (Transport 2001) it is estimated that in 2020 approximately one billion of motor cars will be driven on Earth and 30 years later this number will double.

Further to the above, the related literature more and more frequently refers to varied strategic approaches to the recycle management (Merkisz-Guranowska 2005, Tomczyk 2005, 2006 and 2009, Wojciechowski 2012, Wojcieszak 2012), that aim at substantial improvement of recycle and recovery efficiency in terms of their broad meaning from the point of view of both comprehensive and primary targets.

STUDY OBJECTIVE AND SUBJECT MATTER

The study objective is to present the scale of the outstanding issue of the recycle of LPG-driven and CNG-driven motor cars in terms of systemic drying cylinders out of fuel for the purpose of subsequent recycling.

Procedures of improvement of efficiency of drying and re-classifying solid waste such as LPG and CNG cylinders, originating from motor cars withdrawn from the road, constitute the subject matter of the study.

The authorities of European countries have set up institutions that take care to reduce waste and air pollution and minimize energy consumption. These efforts are aimed at rational exploitation of human and material resources by the promotion of sustainable development and the reduction of disparities in that matter between the world economies, ie the EU, Japan and the United States.

Given the observation of Lublin industry sector dealing with disassembly of motor cars, among others, the increasing size of the problem of recycling mainly LPG cylinders and few CNG cylinders draws attention. This was confirmed by the surveys conducted in the period from 2012 until 2014 among 9 vehicle disassembly stations located in the Lublin Region. None of the surveyed vehicle disassembly stations was equipped with a drying device for this type of gas cylinders, and each of them collected from 350 to 470 kg of liquid gas cylinders of 160116 waste code classified as hazardous solid waste on the annual basis. The price and the impossibility to neutralise such a cylinder to classify it as 160117 waste code pertaining to ferrous metal, after having dried it, are the major reasons for the failure for vehicle disassembly stations to be equipped with drying devices for gas fuel.

In the Polish market two drying devices for LPG and CNG cylinders originating from motor cars withdrawn from the road are available to be compliant with the standards governed by Directive 2000/53/CE:

- manual ones, in the case of which an employee needs to make all necessary connections and run the process of draining gas out of a cylinder and nitrogen rinsing of a cylinder as well as burning this mixture in a torch (the cost of such a device amounts to PLN 35 000),
- automatic ones in which subsequent processes are independently run after a cylinder is placed in a chamber (the cost of such an automatic drier amounts approximately to PLN 75 000).

A drier pumps LPG out of a motor car cylinder into a standard cylinder, for instance of 11 kg in weight, and concurrently runs nitrogen rinsing of a cylinder. In the case of CNG, it is just possible to burn gas out in a torch. Such a system allows gas to be removed from a motor car cylinder as well as to get rid of remaining gas by means of controlled burning. In the course of emptying a cylinder, it is concurrently being nitrogen-rinsed, nitrogen being supplied from an external source. The aforementioned process allows motor car cylinders to be recovered in conformity with law and related regulations.

The advantage of such a device - when you have come into possession of it - is the opportunity to use LPG that has been pumped out, for instance as fuel for fork lifts or heating halls in the winter season. It is vital that well-trained personnel is exclusively authorised to operate this type of devices.

There are few enterprises that render services of reclassifying gas cylinders, which is automatically making them eligible for scrapping cylinders and recovering ferrous metal under the solid waste code 160117. The cost of such services ranges from the net amount of PLN 5 to 10 per cylinder – depending on the number of cylinders supplied, furthermore a vehicle disassembly station loses scrap metal, fuel and incurs expenses on top of that - which is discouraging. In the case of not more than 50 cylinders, those prices are normally higher. Since the number of cylinder that a vehicle disassembly station obtains is usually not more than 20 gas cylinders per annum, higher costs brings about bad practices such as discharging gas or pumping it into other cylinders by means of forbidden or hazardous procedures. Even when a vehicle disassembly station resolves to deliver cylinders of the solid waste code 160116 down to such an enterprise, it may face being charged with hazardous waste transport irregularities. In consequence, such a type of practices bring about considerable hazards arising from seemingly dried cylinders that still contain vestigial quantity of gas and are transported with other scrap metal by means of transport that are not fit for that purpose. Given the above, the figures of the quantity of recovered LPG are imprecise.

Taking into consideration the fact that motor cars dating back to the period of boom in gas installations in Poland – namely the period from 1994 until 2004 – are only now beginning to be delivered to vehicle disassembly stations and the fact that gas installations are becoming more and more popular, the number of recycled LPG cylinders may be expected to double or triple. CNG has only recently begun to develop mainly to the intention to generate savings in the urban passenger transport services in larger cities and in some of commodity transport sectors. Given all the vehicle types registered in Poland in the number of 23 million (Wheeled Transport 2015), LPG-driven vehicles account for 13%: passenger cars - 2,8 million, trucks - 0,18 million, truck tractors - 0,0015 million, buses - 0,0008 million, special vehicles - 0,0038 million.

According to the forecast by the National Solid Waste Disposal Management Plan (2002), in 2006 in Poland approximately 0.5 million of motor cars withdrawn from the road should have been recycled on the annual basis, and only 0.15 million of them were actually recycled. We currently recycle 0.4-0.5 million of motor cars withdrawn from the road on the annual basis (Statystyki according to SI CEPIK 2015), and as the forecast suggests we should recycle approximately 0,8 million of motor cars withdrawn from the road on the annual basis. So, from the statistical point of view, each vehicle disassembly station in Poland should process approximately 750 of motor cars

withdrawn from the road on the annual basis, and the surveyed stations in the Lublin region recycle as little as 20% of that number (Table 1.). Furthermore, two out of the surveyed vehicle disassembly stations operating in Lublin wound up their business operations in 2014. It is the consequence of numerous problems that, according to Wojcieszak (2012), have come hitherto down in Poland - as far as the recycling of motor cars withdrawn from the road - to: illegitimate disassembly of used motor cars in the grey market, inefficient system of disassembly subsidies, difficulties in obtaining recovery and recycle certificates as well as falling prices of recycled materials in result of the financial crisis – which directly influences profitability of the recycling business model.

Table 1. Exemplified quantity of solid waste originating from disassembly of motor cars subject to recycling of products or materials, according to the figures available from vehicle disassembly stations on the annual basis (own paper on the grounds of Marczuk et al. 2015)

Type of Solid Waste	Weight of Solid Waste [Mg]	Weight of Solid Waste Subject to: [Mg]	
		Recycling of Products	Recycling of Materials
Plastic	7.435	0.624	6.811
Glass	3.426	0.41	3.016
LPG Cylinders	0.432	0	0.432

According to Wojcieszak (2012) there are also at least three reasons for that state of play that vehicle disassembly stations cannot be blamed for:

- no relevant supervision of the state authorities over their operations and competence overlap among numerous institutions in that respect,
- dramatically high and relatively continual growth of imports of used motor cars from abroad with the concurrent decrease in the number of new cars bought,
- dramatically high and relatively continual fall of expenditures incurred on research and development, which causes sluggishness in that field.

Rising costs of recycling due to dispersed automotive industry are also indicated by Romański and Kowalczyk (2010).

CONCLUSIONS

The aforementioned problems with drying LPG and CNG cylinders also incorporate themselves into the inaccessibility of relevant systems and technologies of specific types of solid waste disposal management, which is underlined by Wojciechowski (2012).

In the case of problems with gas cylinder drying, one should comply with the strategy recommended by a number of authors in respect of operations of vehicle disassembly stations in terms of the recycling system as a whole in Poland (Wojciechowski 2012, Merkisz-Guranowska 2005).

The research that has been conducted in recent years indicates a number of conclusions and procedures in connection with intended research on LPG and CNG cylinder recycling:

- establishment of 4 or 5 gas cylinder drying mobile centres in Poland, that will leave scrap metal and recovered fuel with vehicle disassembly stations, possible implementation of co-financing programmes coming forward with financial assistance of 70% to be allocated to the acquisition of drying devices,
- marketability of recovered LPG, which may additionally increase financial gains of vehicle disassembly stations; stations may use recovered gas for their own purposes.

Implementation of the above will have a positive impact upon the indicators of the sustainable development in its broad sense:

- economics – increasing the quality of generating units will allow to enjoy a better price and consequently improve financial figures;
- law and administration – the obligation to increase the percentage share of recycled materials;
- sociology – ecological awareness rising;
- engineering – the BRD rise linked with newer motor cars driven on our roadways, equipped with active and passive safety devices in terms of standard equipment, that also give feedback to safety measures when it comes to the roadway engineering infrastructure.

Moreover, as the rise in the complexity of the materials and systems used also in agriculture, new technologies to ensure sustainability and high recycling rate of such components, machines and vehicles will be required (Jody B. J. et all 2010).

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NEW APPROACH TO FULFILL ART 8 OF DIRECTIVE 2009/128: A RISK ASSESSMENT PROCEDURE FOR PESTICIDE APPLICATION EQUIPMENT

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Keywords: pesticide application equipment, inspection, risk assessment, guidelines, exemption.

ABSTRACT
All pesticide application equipment in professional use shall be subject to inspections at regular intervals according to the EU Directive 2009/128/EC on the sustainable use of pesticides. Article 8.3 allows the Member States to derogate from the mandatory inspection at regular intervals or to apply different timetables and inspection intervals for certain types of pesticide application equipment based on a risk assessment for human health and environment and an assessment of the scale of use. In order to fulfill Article 8.3, a risk assessment protocol was developed in Belgium within the framework of the SIRA-APESTICON project. It is then applied on the Belgian equipment in use. Therefore, risk is evaluated for the human health and the environment. The assessment is based on technical parameters subject to inspections, their occurrences and severities, but also on national scale of use of the PAE types. Results are expressed at different scale levels: the defect, the machine and the country. They also can be used to help in elaboration of new inspection protocols. This new procedure offers guidelines about the necessity to carry out an inspection of every PAE in use.

INTRODUCTION

The EU Directive 2009/128/EC on the sustainable use of pesticides requires that Member States (MS) shall ensure that all Pesticide Application Equipment (PAE) in professional use shall be subject to inspection at regular intervals (Art. 8.1 and 8.2). However, Article 8.3 of the Directive allows the MS to derogate from the mandatory inspection at regular intervals or to apply different timetables and inspection intervals for certain types of PAE based on a Risk Assessment (RA) for human health and environment and an assessment of the Scale of Use. The RA process should demonstrate the usefulness of the inspection to significantly decrease the risk of the use of the PAE. The Belgian method from the SIRA-APESTICON project defines the risk by a combination of two factors: 1. the severities of harm on exposed subjects and 2. the occurrences of hazard. In the context of this work, harm is the consequence of technical defects: over-dosage, under-dosage, or injuries induced by the use of PAE during the pesticide applications. Occurrences of defects are defined by PAE technical inspection. Risk is calculated for the health of the operator, the health of the consumer and for the environment. This paper shows an overview of the results for Belgium.

MATERIALS AND METHODS

Risk is the result of the combination of occurrence and severity of harm: In this case, occurrence is relative to PAE technical defect. They were extracted from the data of 2011, 2012 and 2013 of the Belgian inspection services. Harms result of the hazard and of the way of exposure. In this case, this can be over- or under-dosages or injuries induced by the use of PAE presenting technical defects. Values of severities of harm

were defined based on an international enquiry submitted in particular to European experts from the SPISE (Standardized Procedure for the Inspection of Sprayers in Europe) community.

The risk calculation was made using two methods to combine the severity of harm and the occurrence: "Defects only" or "Defects + residual risk". Formulations are given in Table 1. The "residual risk" is the risk induced by potential undetectable (at the inspection) small deficiencies combined with the risk inherent to the use of PAE even without any defect. Risks are calculated at three different scales: 1. the defect individually, 2. the entire machine (sum of defect's risks) and 3. the country or for all machines of a given PAE type on the national territory, thanks to the factor of scale of use. These scales of use were based on a combination of the frequencies of use (obtained by a national enquiry) of the different PAE types and the weight (kg) of pesticide potentially applied. Sales of active substances in Belgium (kg) were selected for the years 2011, 2012 and 2013 from the Eurostat database. An estimation of the human part of risk (behaviour of the operator) can be added to the technical risk to obtain a total risk of pesticide application. Therefore, the partition between the technical part and the human behaviour part of risk (% of a total risk) was determined by an enquiry submitted to European experts. Each risk calculation is performed "before" and "after inspection". In one hand, "Before inspection" illustrates the presence of a defect, above tolerance level of inspection and without defect correction. In another hand, "After inspection" illustrates a defect repaired regarding the inspection tolerance level or an absence of defect. The objective is to evaluate the potential risk reduction induced by the inspection.

Table 1. Calculations used to apply the RA in Belgium. Two methods: Defects only and Defects+residual risk. Scales: defect, machine, Belgium, Belgium+human part. Two situations: before technical inspection and after technical inspection

Method	*Calculation before technical inspection*	*Calculation after technical inspection*
"Defects only" at the scale of the defect	*occurrence** $\text{severity}_{\text{before}}$ = $Risk_{defect.before}$	*occurrence** $\text{severity}_{\text{after}}$ = $Risk_{defect.after}$
"Defects only" at the scale of the machine	$\sum Risk_{defect.before}$ = $Risk_{machine.before}$	$\sum Risk_{defect.after}$ = $Risk_{machine.after}$
"Defects + residual risk" at the scale of Belgium	$(\sum Risk_{defect+resi.before})$*scale_of_use = $\text{Risk}_{\text{Belgium.before}}$	$(\sum Risk_{defect+resi.after})$*scale_of_use = $\text{Risk}_{\text{Belgium.after}}$
"Defects + residual risk" at the scale of Belgium, + human part	$(Risk_{defect+resi.before})$*scale_of_use*partition_human_vs_technical_part = $\text{Risk}_{\text{Belgium+human.before}}$	$(Risk_{defect+resi.after})$*scale_of_use*partition_human_vs_technical_part = $\text{Risk}_{\text{Belgium+human.after}}$

RESULTS AND DISCUSSION

Defects only, scale of the defect

At the scale of the defect, risk values are very useful to elaborate new inspection protocols. As they are defined before and after inspection, they inform about the risk reduction obtained by the inspection of every individual parameter. Differences in risk values are observed between defects meaning that some defects give harms more severe than others and/or that some defects occur more often than other. For a given defect, the risk varies from a PAE type to another with the variation of occurrences between PAE types. The defects for which the risk before inspection is close to zero could be exempted from inspection. By example, for the pressure deviation because of a defect in

a section, the risk is below 0.025 before inspection. The defects that present the biggest risks should be inspected. For example, the readability of the tank content indicator has risks values around 1 before inspection. The decision about inspection of a defect can also be influenced by the risk reduction induced by inspection. For example, the risk reductions induced by the replacement of an absent tank filling strainer are among the most important (-67% for the operator). In another hand, for example the nozzles individual flow rate has lowest risk reductions (-37% for the operator).

Defects only, scale of the machine

A direct effect of inspection can be observed with the method "defects only". Analysis at the scale of the machine could be useful to evaluate the risk for the operator who is exposed to only one machine at a time. A graphic illustration is given for knapsack sprayers in Figure 1. Variations of risk values can be noticed between subjects at risk. Relative risk reduction are calculated on the risk "after inspection" as a percentage of the risk value "before inspection". The type of defects listed can influence the final risk value because the severities of harm can be higher for some defects than for other defects and because the occurrence can also be higher. The risk reductions at the scale of the machine have to be subject of attention because they directly reflect the effects of a technical inspection. In the case of Belgium, a clear effect of inspection is observed on risk results (risk reduction of about 63%; Figure 1). For decision making, a maximum level of risk could be defined for the operator safety and another maximum level of risk can be defined for exclusion of inspection. Before to be fixed, the maximum values should be subject of discussion by decision makers with taking account of the other risk results (at the scale of the country), of the scale of use and, when justified, of the toxicity of substance applied.

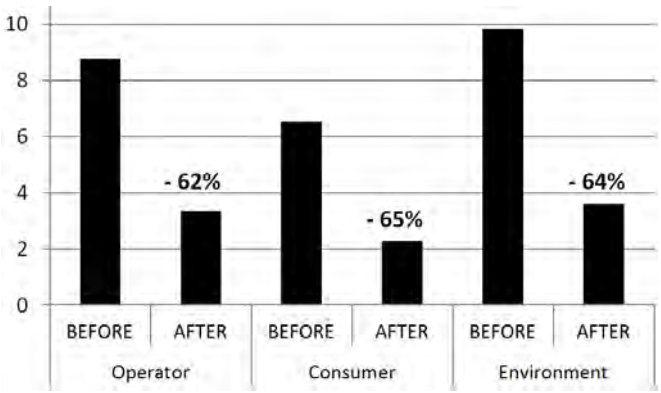

Figure 1. Results of risk calculation in absolute values for Knapsack sprayers. Risks for the operator, for the consumer and for the environment. Scale of the machine, method "defects only". BEFORE=before inspection; AFTER=after inspection. Risk reduction between BEFORE and AFTER are indicated in percentage.

Defects + residual risk, scale of Belgium (technical risk)

The advantage of the analysis of technical risk at Belgian scale is to obtain a global view on the total technical risk for one PAE type or to compare different PAE types (Figure 2). The differences of risk values between PAE types are mainly due to the scales of use that are specific to each PAE type. In Belgium the field crop sprayers have the biggest scale of use with 78% of the total scale of use. The orchard, knapsack and fixed and semi mobile sprayers have scales of use corresponding respectively to 5%, 7% and 4% of the total. Percentages of risk reductions with the method ("Defect

only+residual risk") are smaller (~10%) than with the method "Defects only" (~65%). This observation is explained by the fact that "residual risks" is equally distributed between "before" and "after inspection" and take a big part in the total risk. Absolute values of risk are above 10 000 (results of calculation haven't standard unit). The national scale is interesting concerning the risk for the consumer and the risk for the environment because they are targeted by pollution related to broad crop surfaces. For decision making, a maximum level of risk can be tolerated excluding inspection of certain types of PAE.

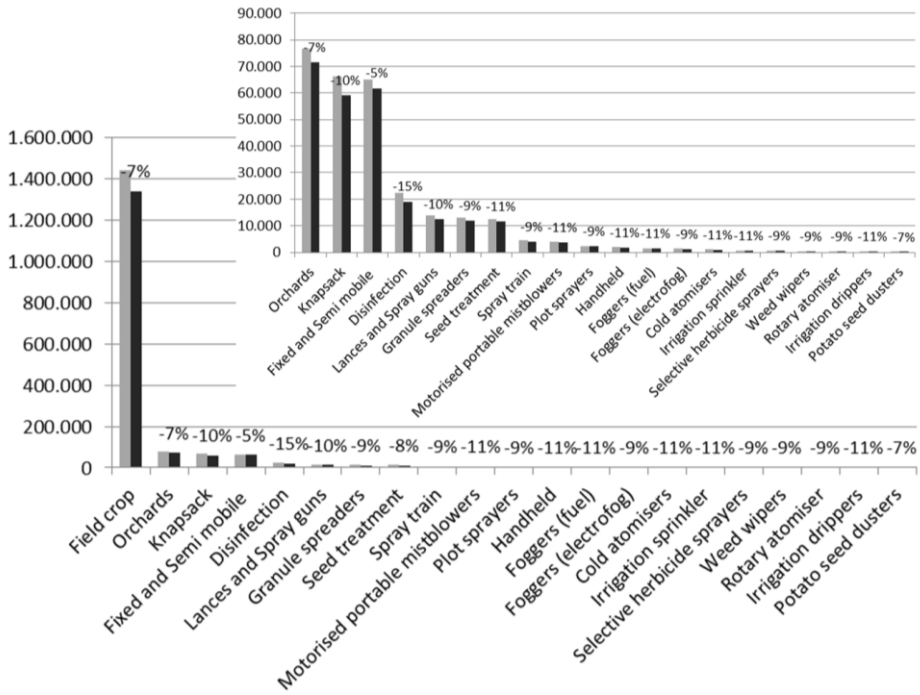

Figure 2. Risks calculated by the method "Defects only+residual risk" at the scale of Belgium for different PAE types (technical risk). Risk values are average of risk for the operator, risk of the consumer and risk for the environment. Grey: risk values before technical inspection; Black: risk values after technical inspection; Values in percentage: risk reductions between the risk before and risk after technical inspection

Defects + residual risk, scale of Belgium (technical and human part of risk)

This last method of risk calculation is interesting to compare pesticide application of the different PAE types (Figure 3). That is the most complete, including defects and residual technical risks, scale of use and human behaviour part of risk. As previously, differences in risk values between PAE types are mainly due to the scale of use. However, risks related to pesticide application are, for some PAE types, more dependent of user's behaviour (e.g.: knapsack sprayers). For other PAE types, as spray train or irrigating systems, the technical part of risk is more dominating. The percentage of risk reduction is very low (~5%) because the residual risk and the human part of risk are added equally to the risks value before and after inspection. The partition between human and technical part of risk could justify the inspection in order to significantly reduce the total risk.

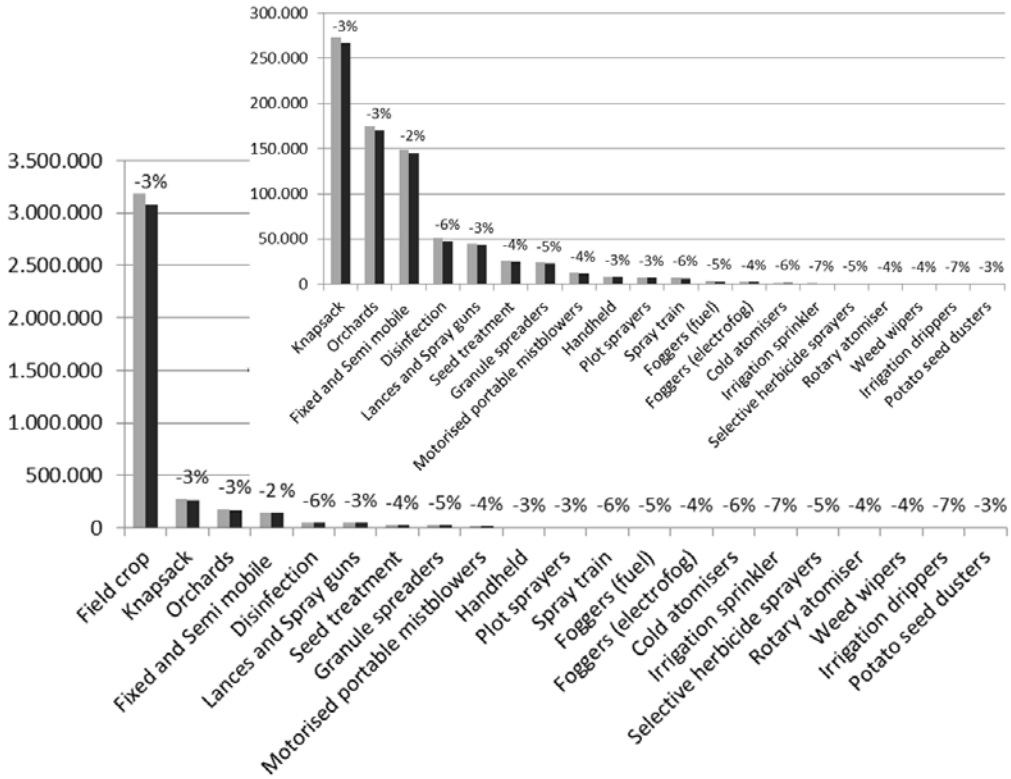

Figure 3. Risks calculated by the method "Defects only+residual risk" at the scale of Belgium for different PAE types and added to the human part of risk (technical risk + human risk). Risk values are average of risk for the operator, risk of the consumer and risk for the environment. Grey: risk values before technical inspection; Black: risk values after technical inspection; Values in percentage: risk reductions between the risk before and risk after technical inspection

CONCLUSION

Results of the method applied in Belgium illustrate the effects of inspection of each PAE type and the variation of scales of uses between all of them. Risks can be calculated for an unlimited number of PAE types. Risk reductions give indication on potential efficiencies of inspection for all PAE types. It distinguished different targets (operator, consumer, and environment) and the results can be obtained at different scales of calculation (the technical defect, the machine or the scale of the country).Absolute values of the risk increase with the scales of calculation. They are around 0-1.5 for the scale of the defect, until 13 for the scale of the machine, until 1 500 000 for the scale of Belgium and until 3 250 000 for the scale of Belgium with the addition of the human part of risk. Risk reductions expressed in percentage are similar trough all PAE types but absolute values of reduction are proportional to absolute value of risks that vary between PAE types. These last are mainly due to the complexity of the PAE and its inspection protocol when analysis is made at the scale of the machine. On the other hand, they are mainly due to scale of use when analysis is made at the scale of Belgium. Risk values and risk reduction values at every step of the risk assessment are strong theoretical basis to support decision making. Regarding risk results, PAE types already inspected in Belgium are those for that inspections are the most useful (field crop, orchard, fixed and semi mobile, disinfection equipment).

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CONSUMERS' PERCEPTION OF FOOD QUALITY AND SAFETY IN TERMS OF BUYING PROCESSES

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Keywords: food quality and safety, buying processes, consumers' perception, sustainable agriculture, sustainable consumption

ABSTRACT

Food safety and quality is a global and multidisciplinary notion that has an impact upon both food industry companies and consumers. Sustainable agriculture and consumption are not currently just fashion, and the consumer relationship with the product is very important because it is not enough to produce responsibly - consumer awareness of the production should also be increased. A consumer deciding to choose a specific product should be aware of why he has made a purchase. There are many determinants that can convince him for specific products; some of them are quality and safety. These two issues seem to be inextricably linked to the idea of sustainable development. Nowadays consumers' awareness of food products choices is noticeably rising, thereby the study aims at researching and assessing consumers' perception of food quality and safety and the related impact upon buying processes. The results arising from the study have made it plausible to state that contemporary consumers perceive themselves as individuals who are aware of safety and quality of food products they buy, and top quality food is associated by them most of all with the lack of preservatives, quality certificates, and a producer's assurance that a food product is 100% organic.

INTRODUCTION

Food serves the basis for human existence and has a direct and considerable either positive or adverse impact upon health condition. According to Stewart (1987): „Diet (…) is the major source of nutrients but it may be the substantial source of hazards arising from infectious, toxic, and pharmacologic substance". Thus, food quality and safety is essential for consumers, food and agriculture industry companies as well as the economy as a whole.

As far as consumers are concerned, awareness of food safety and quality is noticeably rising and in consequence the awareness of related processes and buying choices is rising, too. On the other hand, food producers are characteristic of top quality and safety food assurance systems and food standard compliance systems, that are becoming top priorities. It is so important for a food product quality, that reaches the final consumer, to be the outcome of various factors and processes undertaken by a food producer; the following is of utmost importance: quality of raw food ingredients used for food production purposes, food production technology, application of relevant additives, selection of sub-operations, and choice of adequate process parameters (Nowak 2011). Nowadays this issue is becoming more and more significant, on the one hand, due to a high growth rate of the food industry and mass food production technological advancement and globalisation process, and on the other hand - due to intensive education of society in the area of food products safety and related impact upon human health and conduct as well as natural environment.

Food safety and quality is the global, multidisciplinary and multidimensional; notion addressing both collective and individual features. Thereby they are hard to be defined in an unbiased manner - especially in terms of quality. However, the related literature includes a number of attempts to address that issue; some of the authors reckon that

food products quality may be analysed mainly in terms of technical, mental, and marketing aspect, which first of all means the degree of wholesomeness (dietary value, energy value, nutritious value, and health safety), sensoric attractiveness (for instance, shape, size, hue, taste, scent, consistence, texture) and disposability (food product sustainability, easy-to-use food, easy-to-prepare food, etc.). By contrast, food products safety is based on 4 fundamental pillars – the so-called safety criteria, namely: physical, chemical, microbiological, and information safety.

Consumers' perception and assessment of food products quality is subjective, however, Gutman (1982) has drawn attention to 3 major approaches: information economics approach, hierarchical approach, and integrated approach. According to Karaszewski (2006), a buyer perceives quality through the prism of various factors, for example, production quality, affordable price, sustainability, usability, accessibility, easy-to-use, etc. Furthermore, Kijowski and Wysłouch (2003) state that a consumer cannot assess food quality at the moment of buying food products; a consumer's choice is driven only by sensory perception indicators. These are the food producers, that are accountable for food products safety and quality, inter alia, by means of implementation of effective quality management and assurance systems, and state authorities - by means of enforcement of relevant food law and related regulations as well as appointment of supervisory bodies.

Thus, the study aims at researching and assessing consumers' perception of food quality and safety and the related impact upon buying processes, with particular regard to aspects of producer responsibility for the goods they manufacture. An increasing number of consumers is paying attention to the way goods are produced, whether they are produced according to responsible business policy, respect for animals, plants, lack of waste, and, for example, the philosophy of the FAIRTRADE brand, with respect for human dignity, decent pay for work, appropriate social conditions and transparent business relationships between partners. These are important issues, especially decisive for the purchase choice among an increasing number of consumers.

MATERIAL AND METHODS

A questionnaire survey, in which 200 people participated, was conducted in order to assess consumers' food quality and safety and related impact upon buying choices. Random sampling was applied – simple random sampling formula (without replacement). The questionnaire survey was conducted in 2016.

The survey questionnaire was used as the survey tool, that had been designed deliberately for the purpose of this study. It contained closed-ended questions that had been formulated in such a way as to avoid supplementary comments.

For the purpose of demographic and social characteristics of the surveyed population, the questionnaire was supplemented with an annex that included questions, inter alia, about sex and age. 95 men (accounting for 44% of the surveyed population) and 121 women (56%) participated in the questionnaire survey. 4% respondents were not older than 18 years old, 59% - at the age ranging from 19 to 25 years old, 18% - at the age ranging from 26 to 35 years old, 12% - at the age ranging from 35to 55 years old and 7% - at the age above 56 years old.

RESEARCH RESULTS AND DISCUSSION

For the purpose of achieving the study objective, the results of the questionnaire survey were analysed and elaborated upon in the descriptive and graphic form (Fig. 1).

Those surveyed were requested to define the notion „high quality food" – they had 10 answers to choose from, and could choose not more than 3 answers. As it has turned out, the majority of contemporary consumers associate high quality food with the lack of preservatives (84% response rate), quality certificate (74%) and a producer's assurance that a food product is 100% organic, which means that it has been produced by an organic food farm in conformity with organic food production standards - without artificial fertilizers, chemical plant protection products, and antibiotics – in compliance with high quality standards (52%). It also bears noting that high quality food is rather associated with food products of Polish origin (38%) and not with food products produced abroad (1%). Consumers do not associate high quality food with modern packaging at all (0% response rate) and rarely associate them with long best before dates (6%), well renowned brands (8%) and high prices (9%). That may prove that well known producers, modern packaging or high prices are not necessarily the factors that account for a high quality food product.

Respondents were subsequently asked which packing marks convince them most of safety and good quality of a food product they had bought. That question was alike the previous ones. The obtained results have allowed to confirm the previously received information – the marks, that correlate with the proven food safety and quality, are regarded as: „No Preservatives" (65% response rate), „Natural Ingredients Only" (48%), „100% Organic Product" (36%), „Polish Product" (30%) „Top Quality Ingredients" (24%).

Due to the fact that consumers declared the top quality food was influenced by the certification procedures to a great extent, they were asked subsequent questions concerning the food safety and quality assurance systems. Unfortunately, respondents' knowledge of that was not best as 31% of them declared not to know any of the systems referred to in the question. Other persons regarded the following as the most significant to guarantee top quality and safety food: HACCP System (45% response rate), GHP/GMP (Good Hygienic Practice/Good Manufacturing Practice) – 25% as well as ISO 2200 standard (11%).

The resulting figures confirm the conclusions arrived at in result of the survey on food product consumers' perception of food quality and safety and recognition of quality marks and certificates as conducted by other authors. Grębowiec obtained similar results (2015) – the following systems turned out to be best known among consumers: HACCP, ISO 9001 and ISO 22000, and less known – IFS and BRC standards. Whereas as many as 37,5% of respondents had never heard of any of those systems.

Issanchou (1996) or Wilcock et al. (2004) also indicated the need for further intensive consumers' awareness raising after having obtained their results – especially food product consumers – by means of professional education and reliable information. It bears noting, however, that knowledge on health is noticeably improving amongst Polish contemporary consumers, which in consequence causes knowledge on nutrition and rational diet to improve in result of the health education of society (Grzybowska-Brzezińska 2010). It seems to reflect general trends in the global food market.

According to Szwacka-Mokrzycka (2013) and Grębowiec (2015), factors, that pre-condition buyers' choices, include economic, marketing, social, and psychological factors. However, in the food product market in Poland, especially those food products that satisfy the basic needs of a human body, economic factors (most of all a product price and disposable income per household member) and social factors (nutrition customs and habits) count most. In the contemporary food market marketing factors are also important determinants such as: skillful product policy (diversified product offer, product packaging), price policy and publicity measures. However, it bears noting that consumers' buying choices cover a system of cohesive responses related to decision making and normally result from the influence of the aforementioned determinants upon buyers' choices - the influence being varied and aiming at varied targets.

Thus, in order to study determinants that pre-condition food buyers' choices, subsequent questions were asked to respondents, to what extent they took into consideration the following factors in the course of buying food: packing marks referring to quality, ingredients, best before dates, price, brand, promotion, friends' opinions, others – which out of those they considered to be the most important and which ones did not influence buying processes at all. Analyses of the results were conducted on the grounds of the gender grouping variable (Fig. 1). Identification of criteria that consumers follow in the process of market decision making allow food industry companies to prepare a tailored product offer satisfying consumers' expectations and preferences (Augustyńska-Prejsnar 2014) and the very consumers – to avoid or mitigate risks of bad choices in the process of buying, which is reflected not only in economic but also social affairs (for instance, in health care).

a) b)

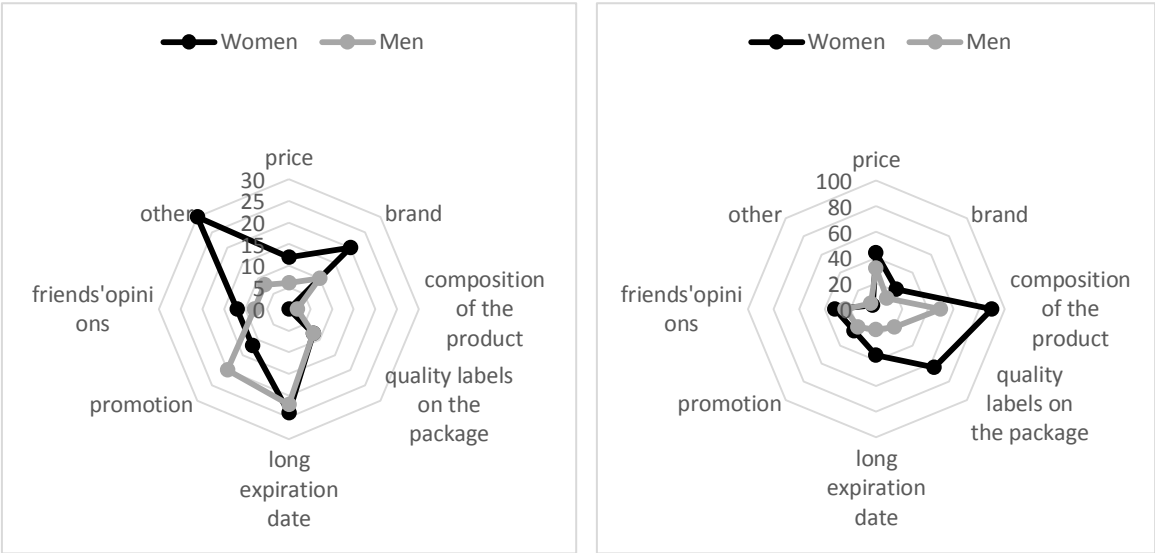

Fig. 1. Buyer's choice factors in consumers' opinion: a) key, b) least important

According to the figures presented by means of the Figure 1, respondents – notwithstanding they indicated in response to the previous questions that both food quality and food safety mattered to them and that they paid attention to food product packing marks – they regarded the following buyers' choice factors as the most important ones: among other factors that had not been referred to in the question, long best before sates, and brands (female), and additionally promotion (male). On the other

hand, they regarded the following factors as the least important in the course of food product buying decisions: ingredients price, and packing quality (for both women and men).

CONCLUSIONS

The results arising from the study have made it plausible to state that contemporary consumers perceive themselves as individuals who are aware of safety and quality of food products they buy, and top quality food is associated by them most of all with the lack of preservatives, quality certificates, and a producer's assurance that a food product is 100% organic. Whereas it is not necessarily associated with a well-known producer, modern packaging or high price. Furthermore, consumers have declared that they pay attention to packing marks, especially those referring to food safety and quality (for instance, „No Preservatives", „Natural Ingredients Only" or „100% Product Organic") since they repeatedly convince to make buying choices. Although consumers associate top food quality with inter alia quality-certified food, they are not too familiar with food quality and safety assurance and management systems – almost 1/3 of the surveyed are not familiar with any of those systems. However, the HACCP system has turned out to be most well identified.

The study results have also made it plausible to state that notwithstanding the fact that contemporary consumers consider themselves to be aware of food safety and quality, they pay attention mostly to brands, long best before dates, and promotion when making decisions to buy food products whereas quality and safety, namely: ingredients or product marks do not matter much to them in the course of buying processes. That is indicative of the need for further intensive health education of society and awareness rising to the extent of health, diet, consumers' choices and sustainable consumption.

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TESTING THE UNIFORMITY OF SPRAY DISTRIBUTION UNDER DIFFERENT APPLICATION PARAMETERS

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Keywords: spray distribution, coefficient of variation (CV), spray angle, agricultural nozzles

ABSTRACT
The study was conducted to determine the differences between commonly used nozzles TeeJet XR110-03 (new and used) during the testing of field boom sprayers on an electronic table (spray scanner) as they were affected by spraying pressure. The tests were carried out at three working pressures (2.0, 3.0 and 4.0 bar) and the uniformity of spraying, the liquid flow rate of the spray nozzles mounted on the field boom and the number of nozzles beyond the tolerance were determined. The spraying angle was also measured which could influence the coefficient of variation (CV) of the spray distribution. The results showed a poor CV value (more than 10%) as the operating pressure decreased for the new nozzles while they were (CV values) under 10% for the used nozzles at all the range of test pressure values. This suggests that the spray distribution uniformity test depends on the sprayer boom setting and operating factors more than on the work life of the nozzles.

INTRODUCTION

Ensuring a uniform placement of the applied materials (pesticide) to the target (pest) is an important task for the sprayer operator which requests careful setting for the sprayer. This factor (spray distribution) which is expressed by the coefficient of variation (CV, %) could influence obtaining the required (maximum) efficiency of chemical crop protection with minimum costs and environmental contamination (Višacki et al., 2016). According to ISO 5681(1992), the transverse distribution defined as "Variation in volume or mass of spray liquid or granular deposited over the treated area transverse to the direction of travel" and the spray angle "Angle formed close to a spray nozzle by the edges of the spray". The CV is an indicator for the differences in the total measured spray deposit, the measured CV value from the field deposit must be 15% or less when applying pesticide on soil, grass, or weed surfaces (Willcutt and Smith, 2010). The same threshold (CV=15%) was proposed by Herbst and Wolf (2001) as a performance limit for dynamic spray distribution. On the other hand, the laboratory CV value is usually smaller (numerically) than the value which was measured under the field condition (Smith, 1992). ISO 16122-2 (2015) set a threshold for the uniformity of the spray distribution within the total overlapped range, the coefficient of variation (CV) according to this standard must be 10% or less.

Dorr and Pannell (1992) found in their study that more profit sensitivity of herbicide dose non- uniformity happened due to the nozzle design, the wind, boom roll, etc. than those which happened because of the boom overlapping (or the contrast) in successive circuits of the field. They reported that the estimated cost of the herbicide non-uniformity was as high as 25% of net returns in some scenarios. This non-uniformity of the spray distribution will cause less or over dose transfer of the pesticide to the target which, in turn, will affect the pesticide application process efficiency. The agricultural nozzles are the part which has the main effect on the spray distribution, besides the

settings which were associated with those nozzles like nozzles height, nozzles spacing, spray angle and atomizing pressure etc. Because of their fan shape spray, flat fan nozzles need to be completely overlapped to gain uniform amount of spray under the nozzle tip (over the target) and also on the edges of the spray. This overlapping is affected by the spray angle of the nozzles which, in turn, is affected by the atomization pressure. However, increasing the last factor (pressure) does not ensure constant uniformity of the spray distribution for some types of nozzles (injector nozzles) in comparison with flat jet nozzles as stated by Višacki et al. (2016). There are other factors which affect the spray distribution in the dynamic mode (during spraying) like the vibration of the sprayer boom due to the field ground unevenness and the wind direction. Luck et al. (2015) reported an improvement in the CV values of the spray pattern uniformity when spraying at higher pressure values or at mid-range metering stem positions for the variable-orifice nozzle. The objectives of this paper were:

1) Study the influence of several variable application parameters on the uniformity of spray distribution (coefficient of variation (CV)) and spray angle for flat-fan nozzles (new and used) mounted on sprayer boom under laboratory conditions.

2) Determine if the evaluation of the nozzles performance depending on the test of spray distribution will represent the nozzle physical state and give an indicator to replace the nozzles according to the sprayer inspection procedure.

MATERIALS AND METHODS

All the spray distribution tests were done when the sprayer boom was static and with fixed height and spacing of nozzles. New and used (having more than 10% increase in flow rate than the nominal one) Flat fan nozzles were utilized in the test; their features and the boom setting are detailed in Table 1. The laboratory boom sprayer with electronic adjustment of pressure and sections work on/off was used in the experiment. An electric pump was used to transfer the tab water from the tank to the boom and pressurized it with 2.0, 3.0 and 4.0 bar pressure (within the recommended pressure from the manufacturer).

Table 1. Features of the test nozzles and their setting on the boom

Nozzle	Spraying Systems Co.®, TeeJet XR 110-03
Boom working width	6 m
Nozzles spacing	0.5 m
Boom height	0.5 m
Number of nozzles	12
Nominal flow rate	1.18 l/min at 3.0 bar
Application rate*	300 l/ha

* Manually input to the patternator software

The coefficient of variation (CV) used to assess the uniformity of the spray transverse distribution; it was calculated by dividing the standard deviation of the collected water in every patternator tube under the boom by the average value of the total collected water (ISO 16122-2, 2015).

$$CV = 100 \times \frac{s}{\bar{x}}$$

where:

$$S = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

$$\bar{x} = \frac{\sum x_i}{n}$$

CV: coefficient of variation, expressed as percentage;
x_i : the volume of liquid in the ith tube;
n : the number of grooves;
S : the standard deviation of the volumes collected in the grooves;
$\bar{x}$: the average/mean volume collected per groove.

The electronically driven test bench "Sprayertest 2000" was used to measure the distribution uniformity and total sprayer output parameters (Figure 1). The device has a table (2.12 m width with 20 measuring glasses) which contains a number of 20 V shaped channels. The table is fixed to a test coach which automatically moves on aluminum rails (18 m long). During the test and by online radio transmission, the data are displayed on a PC monitor. The device is accompanied with software (OWFB 1.0) to show graphically the spray distribution and calculate the CV, average flow rate of the nozzles, total output of the boom, as well as to calculate the required travelling speed of the sprayer to gain a manually input application rate (set to 300 l/ha for all the test). The spray angle was measured by taking high-resolution photos of the spray with the help of LED light at different atomizing pressure. After this and with the help of software with protractor tool, the angle between the spray boundaries was measured.

Figure 1. Sprayer test 2000 patternator and the laboratory sprayer boom used in the test

RESULTS

Randomly chosen photographs of the boom spray distribution when spraying with new and used nozzles at 3.0 bar pressure are shown in Figure 2.

RESULTS

Randomly chosen photographs of the boom spray distribution when spraying with new and used nozzles at 3.0 bar pressure are shown in Figure 2.

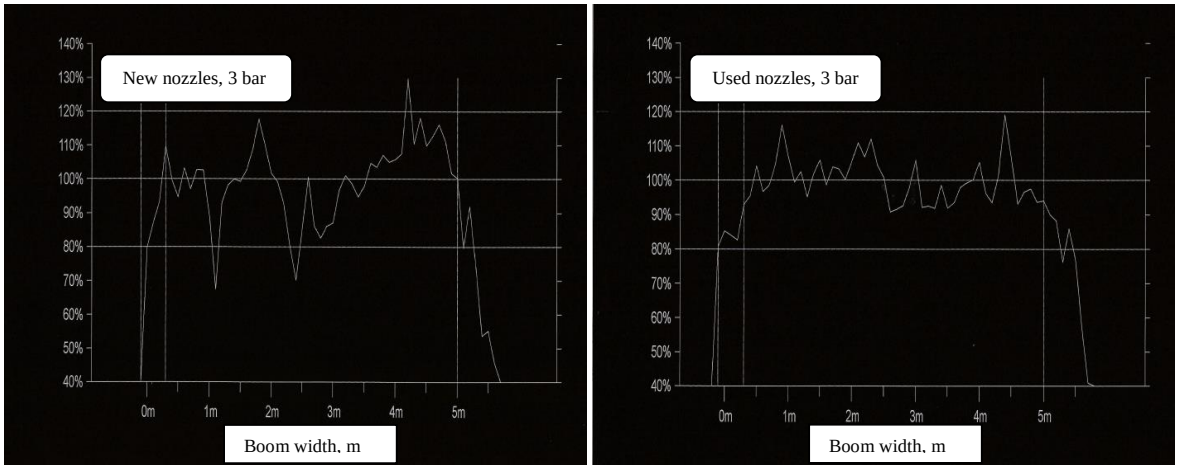

Figure 2.Spray distribution for new and used nozzles at 3.0 bar pressure, the vertical axis shows the collected values compared to the mean value

The previous figures indicate clearly that more new nozzles were out of tolerance than used nozzles. However, this number decreases as the spraying pressure for the new nozzles increased as shown numerically in Table 2. The number of used nozzles which were out of tolerance was the same for the three values of pressure (one nozzle only), and also the CV value was almost the same when using 3.0 and 4.0 bar pressure. Table 2 also shows the clear difference between the new and used nozzles concerning the flow rate (averaged value) which was increased as the spraying pressure increased for both new and used nozzles. This difference in the flow rate made the software to give higher spraying speed values (theoretical calculation) for the used nozzles than the new ones to keep the application rate (300 l/ha) in the same value.

Table 2. The results of the spray distribution uniformity test

Nozzles	Pressure, bar	Flow rate, l/min (SD)	CV, % (SD)	Number of nozzles out of tolerance	Required traveling speed, km/h
New	2.0	0.81 (0.03)	13.6 (0.8)	6	3.70
	3.0	0.98 (0.05)	12.1 (0.7)	5	3.70
	4.0	1.17 (0.03)	9.4 (0.8)	2	5.30
Used	2.0	1.08 (0.03	6.9 (1.4)	1	4.72
	3.0	1.36 (0.04)	7.4 (1.0)	1	5.86
	4.0	1.54 (0.06)	7.5 (0.9)	1	6.62

From Figure 3 we can notice the CV value for the new nozzles spray was decreased as the spraying pressure increased and finally it becomes within the allowed limits according to the

From Figure 3 we can notice the CV value for the new nozzles spray was decreased as the spraying pressure increased and finally it becomes within the allowed limits according to the sprayer inspection standard (ISO 16122-2, 2015) when using 4.0 bar pressure for the test. On the other hand, the used nozzles CV value was within the allowed limits when using all the test pressure values.

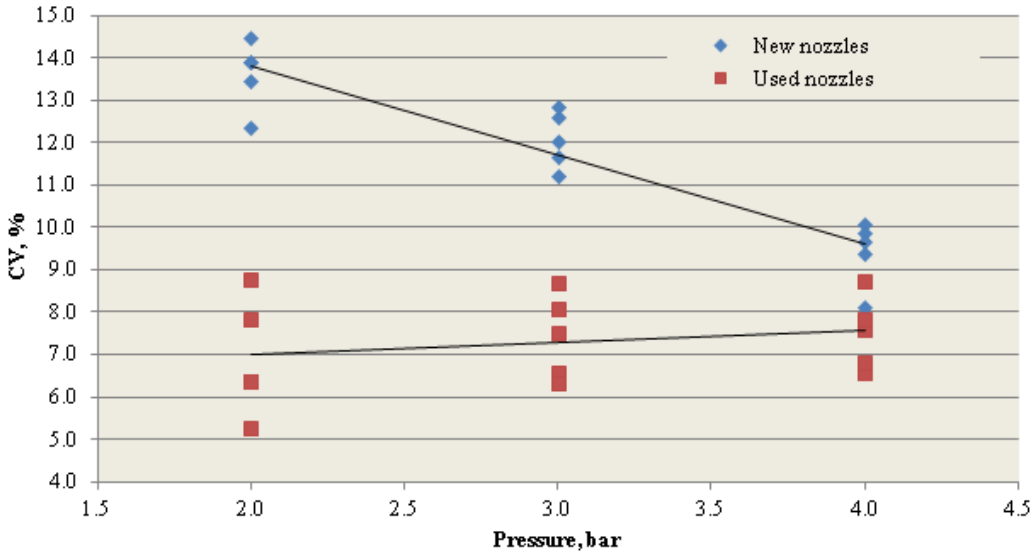

Figure 3. Coefficient of variation (CV) for new and used nozzles at different atomizing pressure

This change in the CV values for the new nozzles (poor values or over 10% as the operating pressure decreased) probably results from the effect of spray angle which was changed due to the increase in pressure as well (Figure 4).

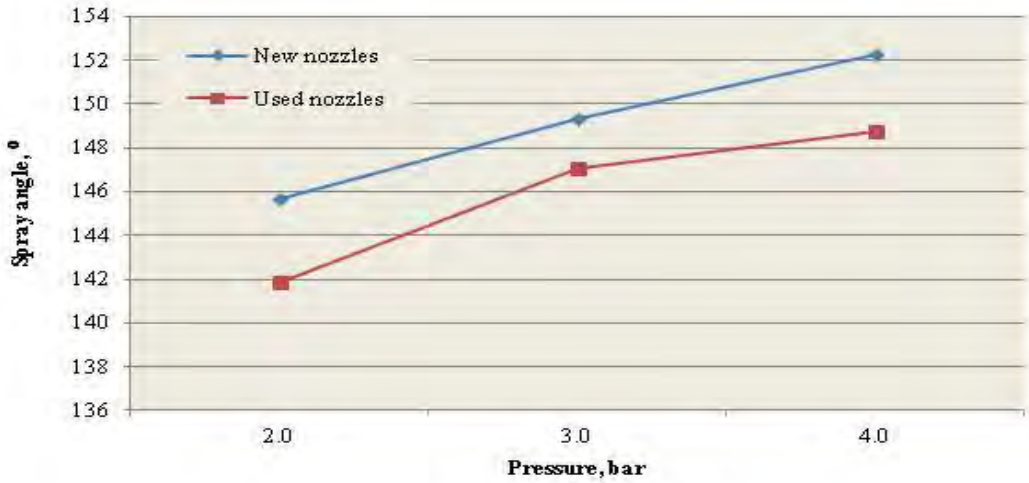

Figure 4. Effect of atomizing pressure on the spray angle

This implies that there is some specific setting for the nozzle and the boom where the CV value reaches the lowest value. In contrast, if all factors influencing this setting were not matched to reach the lowest spray distribution CV value, this test (uniformity of distribution test) could produce wrong information concerning the situation of the sprayer. The results of the used nozzles make this clearer, those nozzles were out of the limits according to the flow rate (it must be less than 10% increase than the nominal

flow rate). However, from the distribution uniformity test, we can see that those nozzles were within the allowed CV limits for the sprayer inspection and for all the used spraying pressure.

CONCLUSIONS

From the results and within the scope of this study, the following can be concluded:

1. The spray distribution CV values are higher than 10% for new nozzles at 2.0 and 3.0 bar pressure and less than 10% at 4.0 bar pressure. The CV values depend more on the setting and adjustment of the sprayer working parameters than on the physical condition of the nozzles.

2. Depending on the spray distribution uniformity test during the sprayer inspection procedure will result in acceptance of nozzles set which are used and are out of the flow rate tolerance limits, within the range of pressure used in the test.

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POSSIBILITIES OF DESIGNATING SWARDS OF GRASSES AND SMALL-SEED LEGUMES FROM SELECTED ORGANIC FARMS IN POLAND FOR FEED

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ABSTRACT
Proper management of plant nutrients has a fundamental effect on the amount and quality of crop yields and on maintaining soil fertility. Under organic production conditions, with limited fertilization, deficiency of some elements in soil may occur, which translates into a change in the chemism of cultivated plants. The aim of this paper was to assess the quality of a sward from selected organic farms in the context of using it for feed purposes. 55 organic farms were selected for the research; 25 of those farms additionally had conventional animal production. Sward samples of mixed grasses and small-seed legumes were collected from each farm. Content of elements that are the most determinant on the suitability for feed (N, P, K, Na, Ca, Na) was determined in the plant material. The results of the conducted research indicate that sward from grasses and small-seed legumes from the studied organic farms had too low content of macroelements and of most microelements, and the biggest problem was too low content of phosphorus, potassium and calcium. The animal production farms were found to have a higher content of phosphorus, calcium and potassium in sward as compared to farms without animals. Feeding cattle only with roughage obtained from the studied lands could pose a risk to the health of the animals and their productive abilities owing to the unfavorable chemical composition.

INTRODUCTION

The idea of organic farming is a result of intensification of food production and the negative effect of farming on the natural environment that is associated with this production. Increasing plant production capacity involves increasing the amount of used fertilizers and chemical pesticides, intensification of soil degradation processes and unfavorable changes in agricultural landscape (Niemiec et al. 2015; Lorenz and Lal 2016). Intensive animal production leads to local contamination of the environment as a result of storing natural fertilizers and feeds. The most frequently described problems associated with concentration of animal production include local odor nuisance, the risk of microbiological contamination, and pollution and contamination of surface and underground waters. In addition, intensive farming of animals leads to problems associated with managing animal health and imposes the use of a higher amount of allopathic veterinary medicines. Ethics, which has recently been gaining in significance, is an important aspect of food production (Carlsson et al. 2007, Kuboń at al. 2010). The increasingly aware consumer seeks products that are of verifiably better quality but that have also been produced using environmentally-friendly technologies, respecting animal rights and workers' rights. There are many quality systems (both private and currently operating in the EU) in the market which are optionally implemented by farmers (Higgins et al. 2008). Organic farming is one of the most restrictive systems. Its goal is to return, as much as possible, to the original methods of food production with limiting the use of external means of production to the maximum (Niemiec at al. 2016). The purpose of such an approach is to generate high quality products, both in sensory terms and in terms of chemical composition. Processes that are used to produce organic

products should, as much as possible, use natural productive capacities of ecosystems and processing techniques which do not alter the properties of the product and do not reconstruct its features that have been lost as a result of processing. In animal production, it is important to ensure well-being of animals in inventory buildings and to provide them with activities resulting from behaviorism. Organic animal production ecological should be based on selecting animal breeds resistant to diseases and unfavorable climatic conditions, and managing their health is associated with ensuring proper living conditions for animals and feeding at a level that meets the nutrient demand of animals. Due to reduced fertilization on ecologically used areas, there is a risk that the quality of feed produced under ecological management conditions will not meet the requirements laid for good quality feeds.

The aim of this paper was to assess the quality of a sward from selected organic farms in the context of using it for feed purposes.

MATERIAL AND METHODS

To achieve the objective established in 2016, research was conducted in 55 organic farms. All the farms had been subjected to a system of control and certification of the certification body, and based on the inspections performed in 2015 they met the requirements of the EC Regulation No. 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No. 2092/91. All the farms had been converted. The studied farms were located in Dolnośląskie (17), Lubuskie (13), and Warmińsko-Mazurskie (25) provinces. Among the studied farms, 25 had conventional livestock production. All farms with animal production were located in Warmińsko-Mazurskie province. The area of the studied farms ranged from 30 to 90 ha. A sample of sward from the first crop was collected from each farm, from a randomly selected field. On all fields from which samples were collected, a perennial mix of grasses and small-seed legumes was grown, with different share of legumes. The share of legumes resulted from changes in the species composition of the sward which were caused by habitat and climatic conditions. The collected samples of sward were dried, homogenized and subjected to analysis. Content of elements that are the most determinant on suitability for feed (N, P, K, Na, Ca, Na) was determined in the plant material. The plant samples were subjected to dry mineralization in an open system in a muffle furnace at 450ºC. Then they were diluted in nitric acid solution. The analytical sample was 3 g dry matter. Concentration of the studied elements in the obtained solutions was determined by atomic emission spectrometry, on an Optima 7600 manufactured by PerkinElmer. Total nitrogen content was determined by elemental analysis method, using Elementar vario MAX cube elemental analyzer.

RESULT AND DISCUSSION

Organic fertilization on ecologically cultivated soils leads to an increase in soil fertility, enables proper plant feeding and makes it possible to maintain good soil culture (Niemiec et al. 2017). From the point of view production technology, maintaining ruminants, where feeding is based on the grazing system, is regarded as organic animal production which poses the fewest problems. Procuring feed from pastures is the most energy-efficient form of animal production. Maintenance of pastures is also beneficial from the point of view of carbon sequestration and reducing dispersion of nitrogen in the environment (Anglade et al. 2015).

Phosphorus is a strategic element in organic farming and its deficiency is often observed, which is associated with lack of fast soluble fertilizers containing this element that are approved for use in organic farming (Barszczewski et al. 2007). The mean phosphorus content in sward biomass from the organic farms without animal production was 0.123% and ranged between 0.0713 and 0.215% (Tab. 1). Sward biomass from farms with animal production contained, on average, 0.169%. The lowest phosphorus content in samples from this group was at the level of 0.123%, whereas the highest was 0.252% (Tab. 1). Phosphorus content in the studied sward, both from farms with animal production and from the ones without cattle breeding, was too low from the point of view of intending the sward for feed. Good quality feed for dairy cows should contain at least 0.3% of this element. In the case of beef cattle breeding, phosphorus content above 0.17% should suffice (Mc Dowell, 1996). When phosphorus content in feed is too low, there can be problems with animal health associated with the limited ability to move, osteopathic lesions, and with problems with reproduction (Eisenberg et al. 2014). The problem of macro element deficiency in cattle eating feed from one source was emphasized particularly by Mc Dowell (1996) and McNamara et al. (2017). In such cases, it is necessary to supplement elements whose amounts in feed are insufficient, or to change the fertilization level for crop production with a better chemical composition (Alvarez-Fuentes et al. 2016). The range of optimal magnesium content in feed for beef cattle fluctuates from 0.05 to 0.25% (Mc Dowell, 1996). Too low content of this element in feed leads to increased animal sensitivity to stress, muscle tremors, numbness, irritability, anxiety. Zielińska et al. (2014) determined the amount of this element in sward of organic agricultural lands fertilized with manure at a level slightly below 0.2%. Kulik (2009) recorded similar amounts in sward of traditional grass crops with small-seed legumes. Mean magnesium content in the studied samples of sward which are intended for feed amounted to 0.178% and no significant changes between the studied groups of farms were detected (Tab. 1). The determined amounts of magnesium are sufficient to satisfy the physiological requirements of cattle.

From the point of view of animal health and productivity, calcium content in feed is very important. Hypocalcemia is a very common problem associated with the management of dairy cow health. Hypocalcemia can be associated both with a low amount of this element in feed and with the impairment of mechanisms of its absorption. Symptoms of calcium deficiency are associated with animal weakness, apathy and lack of appetite. Calcium content that covers the nutrient requirements of dairy cows should not be lower than 0.43%, whereas in the case of beef cows – 0.17% (McDowell, 1996). The results of the performed analyses point to a very low calcium content in the sward from organic farms. The mean content of this element in the sward from farms with animal production was 0.326%, whereas in farms with only plant production it was much lower and amounted to 0.266% (Tab. 1). Kulik (2009) reported that calcium content in the sward of mixed grasses and legumes was at the level exceeding 0.6%, while Zielińska et al. (2014) reported that calcium content in the sward from organic pastures ranged from 0.3 to 0.7%. Potassium is an element whose deficiency in cow diet occurs rarely. However, on account of a substantial variability of its amount in plants, potassium has a major effect on the shape of ionic ratio in feed (Rérat et al. 2009). The mean potassium content in the studied samples was 0.499% and ranged between 0.254 and 0.891% (Tab. 1). The optimum amount of potassium in feed for cattle should be approximately 2% (McDowell, 1996) All the studied samples had potassium content that should have disqualified them as a feed material. There was no

statistically significant difference in the content of this element in plant biomass from both research groups. The determined potassium content was several times lower than that recorded by Kulik (2009) in a sward of mixed grasses and small-seed legumes.

Sodium content in the studied samples of sward varied within a wide range from 0.007 to 0.100%. A higher content (by approximately 40%) of this element was observed in the sward obtained in animal production farms. Cattle feed should contain this element in the amount of approximately 0.1% (McDowell, 1996). In most cases, the determined amounts of sodium are too low and cannot meet the animal requirement for this element. Zielińska et al. (2014) recorded that sodium in the sward from organic pastures was in the amount of approximately 0.1%. Sodium is a very important element in cattle diet, and under conditions of high animal productivity one cannot meet animal requirements for this element through feed alone; its supplementation in the form of salt-licks is required (Granzin and Gaughan, 2002).

Feed quality from the point of view of its chemical composition is assessed not only based on content of elements in it, but also on the ratio between them. The optimum mass ratio calcium to phosphorus (Ca:P) in feed should range from 1.3 to 2.0 (McDowell, 1996). The value of the Ca:P mass ratio in the sward from individual farms ranged between 1.146 and 4.614 (Tab. 1). Half of the samples from farms without animal production had improper quantitative ratio between the studied elements. In farms with animal production, more beneficial relationships between phosphorus content and calcium content were observed. In 20% of cases the Ca:P ratio was too high. Results obtained by Zielińska et al. (2014) in the sward from organic pastures were similar to the results observed in our research. Too high quantitative ratio of Ca:P leads to a reduction in phosphorus absorption by the animal organism even with its high amount in feed. The ionic ratio of K:(Ca+Mg) is another parameter that shapes the quality of feed. The value of this parameter should not be lower than 1.6 and should not exceed 2.2 (Falkowski et al. 2000). The results of the conducted research indicate that none of the samples of sward meets the criteria for a good quality feed from the point of view of the ionic ratio of potassium to the sum of calcium and magnesium. Too low values of this coefficient were observed in all cases. Its average value for all the samples was approximately 0.9, and there was no difference in individual research groups. The very low value of the ionic ratio of K:(Ca+Mg) resulted from the low potassium content in the studied samples. Under conditions of managing the production of organic roughage, potassium deficiency can often take place, particularly after a longer use of such lands (Rérat et. al. 2009).

Table 2. Statistical parameters of the studied sward quality parameters

Parameters	unit	without animal breeding				farms with animal production			
		min	max	mean	median	min	max	mean	median
P	%	0.071	0.215	0.123a	0.123	0.113	0.252	0.167b	0.176
K		0.254	0.875	0.465a	0.458	0.334	0.891	0.535b	0.526
Ca		0.139	0.356	0.266a	0.294	0.190	0.501	0.325b	0.294
Mg		0.125	0.231	0.172a	0.174	0.145	0.254	0.183a	0.179
Na		0.007	0.056	0.022a	0.023	0.008	0.100	0.029a	0.023
Ca:P	-	1.146	4.614	2.319	2.124	1.358	4.436	2.060	1.976
K:(Ca+Mg)		0.402	1.525	0.882	0.827	0.469	1.306	0.882	0.771

The results of the conducted research indicate that plants cultivated according to the principles of organic farming have a poor feed value. Low phosphorus, potassium and calcium content is the most determinant of poor feed quality. These elements are very important for animals, and their deficiency may result in health problems in bred animals. Feeding animals with feed only from the studied farms could lead to a reduction in their productivity and problems associated with managing their health. Chemical composition of the studied samples from farms with animal production is more beneficial than of those from farms without animal breeding. They are characterized by a higher content of almost all of the studied macroelements. None of the farms applies fertilization on certified lands, but in farms with animals grazing takes place periodically. Grazing animals are a source of readily available elements, which translates into botanical and chemical composition of sward (Assmann et al. 2014). The studied farms have organic plant production and parallel plant production in the traditional system. Such a strategy is connected with additional subsidies for organic production, which improves the condition of the entire farm (Wahlhütter et al. 2016). Feed produced on certified lands is intended for conventional animals which are additionally fed with traditional feeds (both roughages and concentrates). Moreover, most of the farms use mineral additives. Therefore, no health problems are observed. There are few organic farms with organic animal keeping in Poland (Cupiał et al. 2013). This is not beneficial from the point of view of the development of organic farming. However, under conditions of organic animal production, when feed is produced on farmers' own fields, the amount of available elements may decrease permanently. Permanent positive effect of organic agriculture, which lies at the basis of its ideological assumptions, would require implementing a rational fertilization policy.

The results of the conducted research indicate that biomass of plants from organic grass crops with small-seed legumes has improper chemical composition from the point of view of using it for feed purposes. Lack of mineral fertilization and a considerable reduction in the use of external means of production in organic farming generate a high risk of permanent negative balance of plant nutrients. This can lead to a disturbed homeostasis of agroecosystems and disturbed quantitative relations of elements in plant biomass (Nowak et al. 2015, Craheix et al. 2016).

CONCLUSIONS

1. The sward from grasses and small-seed legumes from the studied organic farms had too low content of macroelements and of most microelements.

2. The studied feed had wrong mass ratio Ca: P and ionic ratio K:(Ca+Mg).

3. The animal production farms were found to have a higher content of phosphorus, calcium and potassium in sward as compared to farms without animals.

4. Feeding cattle only with roughage obtained from the studied lands could pose a risk to the health of the animals and their productive abilities owing to the unfavorable chemical composition.

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FORMULATIONS OF PLANT OILS USED IN CROP PROTECTION IN SELECTED EU MEMBER STATES

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ABSTRACT

An overview of lists of plant protection products used in organic farming in the European Union was carried out in 2017. For the analysis, the lists of products approved for organic farming protection from 8 European Union Member States were used: Belgium, Czech Republic, France, Germany, Hungary, Italy, Luxemburg and Slovakia.

It was found that in all the analysed Member States 10 different plant oils were recommended for use in organic farming. Nine of 10 were placed on the market as the only active substance of the plant protection products, in addition to 4 cases where plant oils were registered in the mixtures. There were very significant differences among the Member States as to availability of plant oils, as 6 out of 10 are registered in 1 country only. The plant oils registered in more than one Member State were rapeseed oil, mint oil, orange oil and fennel oil. Plant oils were registered for use in 7 different formulations. Emulsifiable concentrate was definitely the most popular among the formulations.

INTRODUCTION

Integrated pest management (IPM) – obligatory in all European Union member states from the beginning of 2014 - emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems. Following implementation of integrated pest management, alternative approaches or techniques, such as non-chemical alternatives to pesticides, should be promoted in agriculture. Therefore the study results regarding microbial products used in agriculture rise particular interest (Matyjaszczyk 2015a, Lamichhane et al. 2017). Biostimulants (Kocira et al. 2015, Kocira et al. 2017, Miziniak and Matysiak 2016) and preventive measures of pest control are also used in integrated pest management (Bocianowski et al. 2016, Walczak, Tratwal and Bocianowski 2015, Matyjaszczyk 2011, Matyjaszczyk 2015b, Jankowski et al. 2016).

Plant oils can be an interesting alternative to chemical active substances, as some of them have proven activity against crop pests (Bakkali et al. 2008; Isman 2000; Batish et al. 2008; Souguir at el. 2013). Plant protection products containing plant oils as an active substance are already placed on the market of European Union member states and some of them are qualified for use in organic agriculture.

The aim of the study was to compare the availability and the formulations of products containing plant oils recommended for use in agriculture in selected Member States of the European Union.

MATERIAL AND METHODS

An overview of lists of products to protect organic farming in the European Union was carried out in 2017. For the analysis, the plant protection products containing plant oils approved for use in organic farming were considered. The data came from 8 European Union Member States: Belgium, Czech Republic, France, Germany, Hungary, Italy, Luxemburg and Slovakia. Material for the study came from the official websites dedicated to organic farming within the Member States.

In the remaining Member States either there were no official lists of plant protection products designed for organic farming (Denmark, Estonia, Greece, the Netherlands, Ireland, Latvia and Romania), obtaining information about such lists was very difficult (e.g. Spain and Portugal), or the lists were available but contained no plant protection products with plant oils (Croatia, Lithuania, Poland and United Kingdom).

RESULTS

Table 1 illustrates the fact that there are very significant differences in the availability of registered products containing plant oils among the analysed Member States. The most often registered for use in organic crops protection are rapeseed oil, mint oil, orange oil and fennel oil. There are also registered formulations containing plant oils in mixture with another active substance. During the research, it was noted that in all analysed member states, there were together 10 different plant oils recommended for use in organic farming. In nine cases, plant oil was the only active substance of the plant protection products. Additionally, in 4 cases, plant oil was registered in the mixtures with another active substance: *Pongamia pinnata* oil with linseed oil, as well as rapeseed oil in mixtures with respectively azadirachtin, lecithin and pyrethrins), as presented in table 1.

Taken together the plant oils listed in table 1 were registered for use in 7 different formulations. Emulsifiable concentrate (EC) is definitely the most often used among them. The other formulations listed in table 1 are emulsions: oil in water (EW) as well as water in oil (EO), oil to be applied in undiluted form (AL), oil dispersion (OD), soluble concentrate (SL) and hot fogging concentrate (HN).

The following plant oils were placed on the market in more than one formulation: rapeseed oil (4 different formulations), mixture of rapeseed oil and pyrethirins (2 formulations) and orange oil (2 formulations).

Table 1. Plant protection products containing plant oils approved for use in organic farming and their formulations in the analyzed European Union countries.

Plant oils in plant protection products	Country	Formulation*
Fennel oil	Czech Republic Slovakia	EC
Gillyflower oil	Italy	EC
Mint oil	Belgium France Germany Italy	HN
Orange oil	Belgium Slovakia	SL
	Germany	EW
Pinus oil (pinole)	Slovakia	EO
Pongamia pinnata oil	Czech Republic	EC
Pongamia pinnata oil, linseed oil	Czech Republic	EO
Rapeseed oil	Belgium France Luxemburg	AL, EC
	Czech Republic	EC , OD
	Hungary	EC
Rapeseed oil, azadirachtin	Luxemburg	EC
Rapeseed oil, lecithin	Czech Republic	EC
Rapeseed oil, pyrethrins	Belgium Czech Republic	AL, EC

Plant oils in plant protection products	Country	Formulation*
	Germany Luxemburg	
Soybean oil	Czech Republic	EC
Sunflower oil	Hungary	EC

*Formulation codes are explained in the text

CONCLUSION

The following plant oils (in alphabetical order) are available for the protection of organic crops in the analysed European Union countries: fennel oil, gillyflower oil, linseed oil, mint oil, orange oil, pinus oil, *Pongamia pinnata* oil, rapeseed oil, soybean oil and sunflower oil. However from the point of view of particular Member State, the availability is much worse, as none of them is registered in all of the eight analysed Member States and 6 out of 10 are registered in one Member State only.

The plant oils were registered for use in 7 different formulations. Emulsifiable concentrate is definitely the most often used among them. The most often registered for use in organic crops protection are rapeseed oil, mint oil, orange oil and fennel oil.

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RENEWABLE ENERGY SOURCES USED FOR AGRICULTURAL PURPOSES AS EXEMPLIFIED BY A RURAL MUNICIPALITY

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Keywords: renewable energy sources, sustainable agriculture

ABSTRACT
The aim has been to assess social acceptance and the opportunity to use renewable energy sources by rural area residents, as exemplified by the rural municipality of Dołhobyczów. The results of the questionnaire survey on renewable energy sources used by farmsteads have been presented. Solar energy (solar collectors, solar dryers) is most often used in this area. Some farmers have come into possession of biomass boilers in their farmsteads.

INTRODUCTION

Renewable energy sources play a key role for current global greenhouse gas emission reduction strategies, as well as, to some extent, for fossil fuel replacement projects (Stolarski et al. 2015; Burg et al. 2016; Obidziński et al. 2016). Actions aiming at using new arrangements in the production or manufacture industry and energy management industry, including renewable energy sources, contribute to the achievement of the objectives set out in the climate and energy package (3x20%) enforced by the European Parliament in 2007 (Zarębski et al. 2015; Zając et al. 2017). The agreement made by seven EU Member States for the aforementioned purposes makes the European Union a top leader for changes in the global economy.

Agriculture is the sector that has a considerable impact upon natural environment as well as living standards, and thus constitutes the area in which the sustainable development-oriented actions are needed. (Szubska-Włodarczyk 2012). The idea of the sustainable development imposes reconciliation of two opposite targets such development, progress, economic growth on the one hand and balance, security, and natural environment protection on the other (Mystkowski 2005). Development of the renewable energy sources industry may be the opportunity for rural areas to develop sustainably. These are local sources of renewables, so they may contribute to improvement of energetic security by means of decreasing fossil fuel exports. Creation of new jobs, particularly in small and medium-sized enterprises, and regional development promotion is still another advantage arising from the renewables development. Furthermore, production of biofuel in agricultural areas, for instance, allows to use severely polluted soil that is not fit for growing edible plants (Gotowska, Jakubczak 2011).

The aim has been to assess social acceptance and the opportunity to use renewable energy sources for rural area residents, as exemplified by the rural municipality of Dołhobyczów. The results of the questionnaire survey on renewable energy sources used by farmsteads have been presented. The results indicate whether the surveyed respondents make use of this type of energy, which of the renewables they are most interested in, and which technology is most feasible to develop in the surveyed area.

MATERIAL AND METHODS

The survey was conducted in the rural municipality of Dołhobyczów that is located in the south-eastern part of the Lubelskie Voivodeship, in the area of Hrubiewszowski District. The survey was conducted by means of the questionnaire including open-ended and closed-ended questions concerning renewable energy used in farmsteads, development prospects in the surveyed area, and benefits arising from the renewable energy sources.

The survey was conducted among the farmers in the municipality of Dołhobyczów. That was a direct survey in which the incidental community participated. The survey was conducted for the group of 140 people and its results have indicated the profile of respondents in terms of sex, age, education, and size of a farmstead. The majority of the surveyed have farmsteads of 5-10 ha in area (31,5%) and 10-30 ha in area (31,5%). Those having farmsteads of 30-50 ha in area (4%) and above 50 ha in area (4%) are the minority. The majority of the surveyed grow cereal (48%), and sugar beat (16%), vegetables (mainly beans) and fruit (10%) and corn (3%) are grown to a lesser extent. 6% of them grow other crops - oilseed rape is mainly grown. Farmsteads running animal husbandry are in minority: 12% of farmers breed cattle, and only 3% breed swine, and 2% breed poultry.

RESULTS AND DISCUSSION

On the basis of the resulting figures arising from the survey, it has been plausible to state that the majority of respondents make use of charcoal boilers (94%) in which wood is burnt as substitute fuel apart from charcoal in their farmsteads. As few as 6% of the surveyed respondents make use of biomass boilers and burn wood (6%) and wooden chips (1%), whereas none of them makes use of gas boilers or oil boilers. The majority of the respondents do not have renewable energy sources facilities/installations (71%). Amongst the surveyed farmers, 20% of them make use of solar collectors for warming up water, 6% of them have biomass boilers and as few as 3% of them have solar dryers in their farmsteads. None of them uses other renewable energy sources. The respondents are most interested in solar energy (63%). Lower interest is_aroused by: wind energy (20%), biomass (8%), biogas (5%) and production of biodiesel for own purposes (4%). None of the respondents has been interested in water energy or heat pumps.

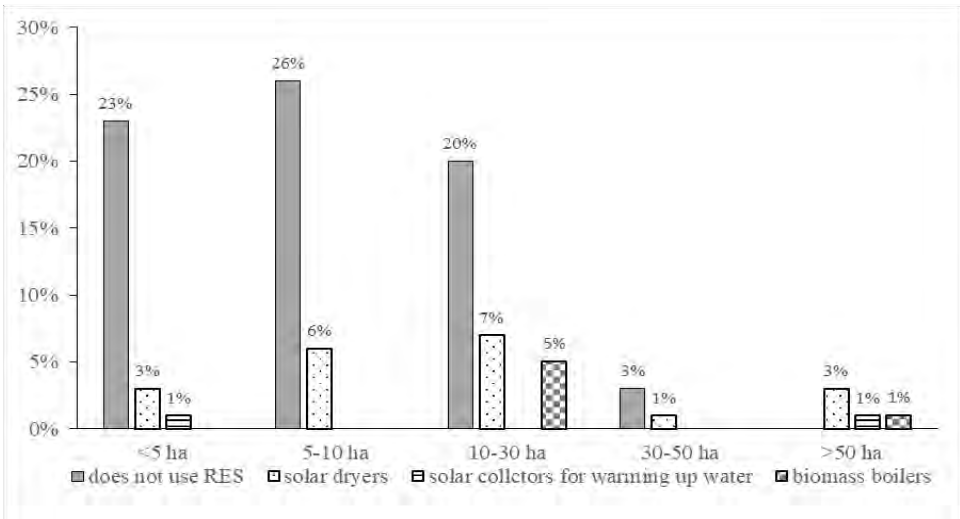

Fig. 1. Renewable energy sources facility/installation and size of farmsteads [own study]

As it has been presented in the Fig. 1, renewable energy sources are most often used by owners of farmsteads of 10-30 ha in area (7% of solar collectors for warming up water, 5% of biomass boilers). Each of the surveyed farmers who owns a farmstead of above 50 ha in area has a renewable energy source facility (3% of solar collectors, 1% of solar dryers, 1% of biomass boiler).

The majority of the surveyed respondents think that the use of renewable energy sources has a positive impact upon the natural environment protection (37%) and brings about energy savings (32%). Fewer respondents have ticked the response concerning the dependence on rising fossil fuel prices (12%), local/regional development (6%), energy security and gradual independence from external sources (6%) and greenhouse gas emission reduction (6%). As few as 1% of respondents have stated that the use of this type of energy does not bring any benefits.

CONCLUSIONS

Development of the renewable energy sources industry may contribute to development of rural areas. It contributes to creation of new jobs, agricultural production diversification and in consequence - to structural changes in agriculture. Furthermore, it results in positive changes in the agricultural background and natural environment, aiming at the global sustainable economic development (Gotowska, Jakubczak 2011; Maj 2015; Szyszlak-Bargłowicz, Zając 2015). In Poland the use of renewable energy sources is regularly growing in the rural areas. This is the effect of numerous economic, energetic, and ecological factors as well as our commitments shared under agreements made by international organisations in the European Union.

The surveyed farmers from the Municipality of Dołhobyczów are interested in renewable energy sources, however they use them to a very limited extent. Due to easy application, it is mainly solar energy and, according to respondents, solar energy is regarded as most likely to develop in the area of the municipality. Apart from solar collectors, biomass boilers and solar dryers are also used for warming water. As far as solid biofuel for boilers is concerned, mostly wood and less often wooden chips are used as fuel for boilers.

Farmers are indeed aware of the benefits arising from the use of renewable energy sources. The majority of them think that the use of this type of facility has a positive impact upon natural environment and furthermore, it brings about energy savings. Farmsteads of above 50 ha in area may be the examples for the fact that all of those surveyed have had renewable energy sources facilities (mainly solar collectors used for warming water, solar dryers and biomass boilers).

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NEURAL MODELLING FOR THE ANALYSIS OF CHANGES IN SELECTED FEATURES OF PLANT PRODUCTS

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Keywords: neural modelling, classification, quality assessment, sustainable agriculture

ABSTRACT
The work investigates possibilities of plant products quality assessment by means of neural networks. A quick method of plant products assessment was proposed based on the correlations occurring between selected features of plant products and neural modelling. This approach facilitates sustainable agricultural production, which often requires making decisions based on approximate but quick assessment of the quality of produced or processed products. The method of quality assessment is presented using changes in the features of pumpkin being dried as an example. Changes in selected features of chemical composition and colour were analysed, including correlations between them. Initial analysis involved cluster analysis, which allowed for grouping data into cases characterized by similar quality. Based on the analysis, a neural model was developed, which, based on easily obtainable features, allowed for classification of products according to their quality features. This approach was positively verified based on the results of chemical composition and quality assessment performed using statistical analysis of data.

INTRODUCTION

Methods used for the assessment of plant materials include organoleptic and laboratory tests. The first method involves assessing a given object by using one's own senses: sight, smell, taste, feel or hearing, while the second mainly involves assessing an object by means of appropriate equipment and analysis of physicochemical and microbiological features. Both methods are usually time-consuming and expensive. Therefore, attempts are made to improve the assessment process. In order to achieve this, other, easily obtainable features of the product are used, e.g. image features such as geometry, colour and texture, which may be correlated with other features of plant products, or dependencies between ultrasonic wave propagation and selected features of the product, Ratajski, et al (2014). This forms the base for a neural model, which allows for the assessment of product quality based on these easily measurable features.

MATERIALS AND METHODS

A database containing 39 cases of research results for three different varieties of dried pumpkin: *Ambar, Amazonka* and *Justynka* was used for the analysis, Sojak et al (2016), Król (2017). The pumpkins were dried by three methods: convection, tunnel and hybrid method. Input data used for the analysis of changes in pumpkin features being studied were chemical composition (dry mass, total and reducing sugars, lutein, lycopene and beta carotene) as well as colour discriminant in the CIE system *L, a, b*, Hunter (1948).

The dataset was analysed using cluster analysis in order to find and classify similar cases, homogeneous in terms of features. Objects belonging to the same group should be as similar as possible to one another and as different as possible from objects belonging to other groups. The classification was based on *k-means* algorithm, Hartigan (1975). Chemical composition and colour discriminants parameters were used as classification variables.

Subsequent stage of the analysis involved developing a neural model to identify similar groups of cases (of similar quality) using only three different colour discriminants in the CIE_ *Lab* system. A multilayer perceptron networks (MLP type) with the following architecture 3:k:1(4) was used, in which the number of neurons k in the hidden layer was optimized. In the approximation problem, this number, according to Heht-Nielsen (1991), should not exceed 2n+1, where *n* is the number of neurons in the input layer. The network was trained using error backpropagation algorithm using a *bootstrap* technique Efron (1982) for the development of neural models. In comparison with an ordinary random sampling (Monte Carlo method), bootstrap avoids problems of generalization resulting from finiteness of the set of cases.

RESULTS AND DISCUSSION

The results of cluster analysis performed in *Statistica Pl version 12.5* (www.statsoft.pl), indicated four clusters, fig. 1.

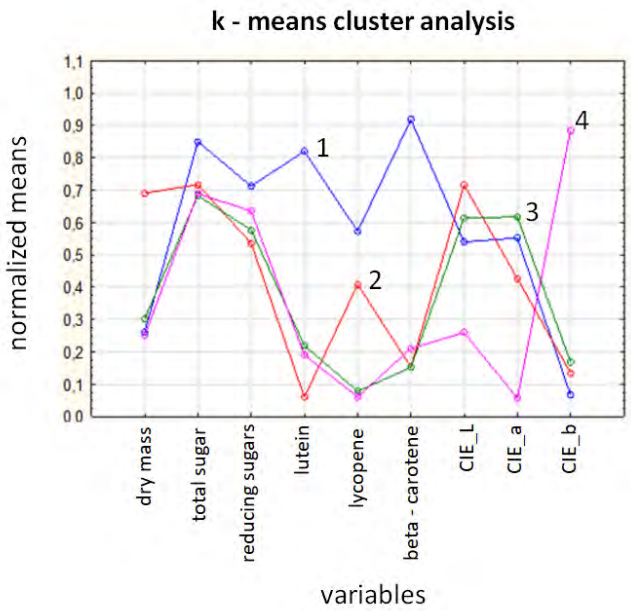

Fig.1. The results of cluster analysis for 39 cases of dried pumpkin

Cluster 1 consists of 3 cases and is characterized by the best quality features – the highest content of the examined elements (except dry mass). The second cluster consists of 9 cases and groups cases with the highest content of dry mass and lycopene. The third, and the biggest cluster, consists of 21 cases and is characterized by higher content of lutein and lycopene than the fourth cluster (which consists of 6 cases), which groups cases of the lowest quality in terms of examined features. The latter two clusters may be treated as one since the differences in chemical composition are minimal.

Table 1 shows the results of the analysis of variance *ANOVA (ANOVA* – testing significance of differences between means Ahrens (1970)) for input data describing chemical composition and colour discriminants.

Table 1. Analysis of *ANOVA* variance in the pumpkin classification task: number of clusters 4, total number of training cases: 39

Feature	Intergroup. SS	df	Intragroup SS	df	F	*p -value*
dry mass	70.7	3	50.50	35	16.3410	0.000001
total sugar	374.3	3	8035.23	35	0.5435	0.655729
reducing sugars	10.3	3	272.52	35	0.4428	0.723855
lutein	178233.8	3	65736.80	35	31.6321	0.000000
lycopene	2509.6	3	1340.47	35	21.8421	0.000000
beta-carotene	17406.2	3	6106.26	35	33.2563	0.000000
CIE_L	414.6	3	529.11	35	9.1423	0.000132
CIE_a	51.8	3	36.92	35	16.3633	0.000001
CIE_b	6689.8	3	519.28	35	150.2997	0.000000

Table 1 shows that variables "total sugars" and "reducing sugars", for which *p-value* is equal more than 0.05, are of the least significance.

The performed tests suggest that the most optimal structure of the network in the classification task, Trajer et al (2012) is *MLP 3:4:1(4),* fig. 2.

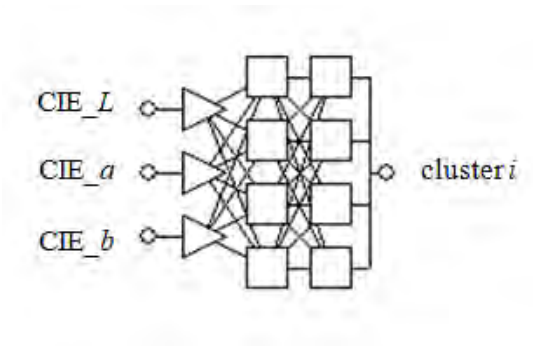

Fig.2. Neural model of the assessment of pumpkin quality

The description of the obtained network is presented in table 2.

Table 2. Parameters of the neural network for pumpkin quality assessment

Network name		Quality (training)	Quality (testing)	Quality (validation)	Training algorithm	Error function	Activation (hidden)	Activation (output)
MLP:3-4-4		95.0	100.0	100.0	BFGS 25	Entropy	Tanh	Softmax

Sensitivity analysis allowed for defining the degree of importance of each colour discriminant. Colour discriminant CIE_b, which describes share of yellow or blue (shades of yellow are positive values, and shades of blue are negative values) had the greatest impact on the results of classification, table 3.

Table 3. Results of sensitivity analysis of a neural model for the assessment of dried pumpkin quality.

MLP 3-4-4	CIE_b	CIE_a	CIE_L
Value of error	235.9761	41.84554	27.23396

The developed model for the assessment of dried pumpkin quality allows for fast monitoring of quality changes. The gains chart for the four analysed quality classes, fig. 3, graphically indicate the correctness of classification. Gain is defined as: *Gain = (Expected Response Using Predictive Model)/(Expected Response From Random Mailing)*, Brandenburger and Furth (2009). Gains chart is a graphical presentation of the usefulness of the model for predicting the value of dependent categorical variable assuming two values. Gains charts may be used for most methods used for predicting the object assignment to a given class (in case of two or more classes). When a modelled categorical variable assumes more values, we may create gains charts separately, for each category.

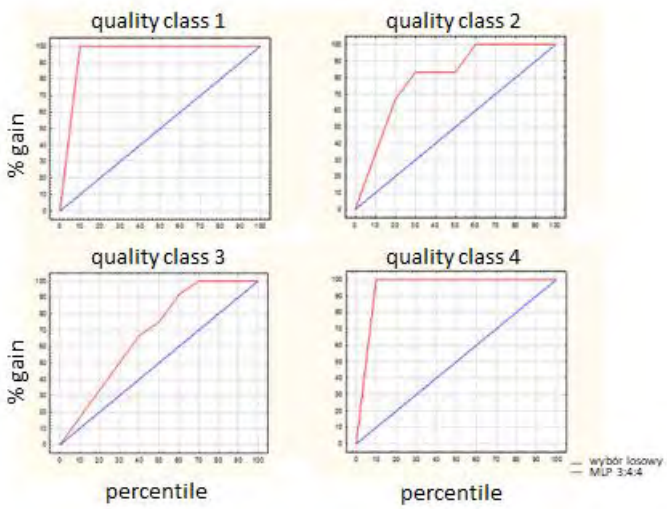

Fig. 3. Gains graph for the identified four quality classes of pumpkin

The correctness of classification of pumpkin was also confirmed by analogical results obtained using statistical data analysis: three classes in which similar cases were identified, Sojak *et al* (2016).

CONCLUSIONS

The developed neural model, based on easy to determine colour determinants in the CIE_*Lab* system allows for obtaining quick assessment of the product being examined. Training quality is equal 95%, i.e. the correctness of classification performed by the network is good. The performed sensitivity analysis showed that the most significant variable in the model was CIE_*b* – discriminant of yellow colour. Cluster analysis of 39 cases of dried pumpkin showed that the data may be divided into 4 sets (clusters), which identify four groups of pumpkin cases of similar quality. The developed MLP *3:4:1(4)* model allows for efficient classification of pumpkin into different groups of quality based on colour discriminants only, which is also indicated by positive verification of the developed neural model. This approach facilitates sustainable agricultural production, enabling quick assessment of the quality of manufactured or processed products.

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APPLE TREE YIELD ANALYSIS USING DATA MINING

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Keywords: apple tree yielding, Data Mining, sustainable gardening production

ABSTRACT
The paper analyses an orcharding farm that specializes in apple trees production. Based on the data for the period of 2008-2014, the authors analysed the main factors that might have impact on apple yield. A computer system for assessment of apple trees cultivation efficiency that aids in making appropriate decisions allowing for obtaining the highest yield, was proposed. The system was developed using selected Data Mining techniques such as cluster analysis and Kohonen networks. The system may be useful for decision support in sustainable horticulture production, and thus contributes to the development of sustainable agriculture. Although its quality is acceptable it still requires improvement using a bigger dataset.

INTRODUCTION

Orcharding is one of horticulture production divisions, characterized by unique requirements, considerable obligations as well as both thorough and specialized knowledge. Fruit farmers must meet extremely high quality norms set by consumers' and food processing industry's requirements, related to taste, fruit firmness, abundance in vitamins and minerals, and appealing look encouraging the consumer to buy and eat particular fruits. To obtain yields of high quality and quantity, it is important to possess universal soil, climatic and cultivar-related interpretation, which determines the quality and quantity of yields. In order to efficiently produce safe, high quality food, and simultaneously protect and improve natural environment, as well as achieve farmer's social and economic living conditions (sustainable agriculture), it is important to comply with the highest standards set by experience and practice, supported by specialist knowledge in areas related to orchard maintenance, Zaliwski (2007). Running an orchard is an extremely costly and long-term undertaking. Numerous decisions related to selection of the area, cultivars, storage facilities and sale. Every year, many hectares of new orchards are grown, and since it is permanent crop, all the above factors that have impact on positive or negative results of these actions ought to be rationally analysed, which is best done with the help of appropriate decision support system. Such a computer system requires a regularly updated database to work properly. Appropriate combination of these elements (information + a processing system) may, in effect, bring satisfactory results, Bielecki (2001). This work presents a conception of such a computer system to support decision-making related to obtaining the best yields in sustainable apple production.

APPLE TREE YIELDING

In order to reach the highest production goals, it is necessary to correlate the knowledge of parameters that play a decisive role and have impact on their effectiveness. The above knowledge allows for taking effective actions, which result in high yields. The most crucial factors that have impact on apple yielding include: rootstock, cultivar, tree age, spacing distance between trees as well as soil class and irrigation, Pietrzycka (2016). Other important yielding factors comprise weather and climatic conditions, selection of appropriate plant protectants and fertilization. Thorough knowledge and appropriate use of these factors may contribute to sustainable apple trees cultivation.

Rootstock – is a plant used for shield budding of cultivars. Starting a modern orchard requires selection of an appropriate rootstock. Rootstocks for apple trees can be divided into four categories: dwarf, semi-dwarf, semi-standard and standard, with the standard being the largest and the dwarf being the smallest, Czynczyk (2012). In Poland, soils are mostly luvisols.

Therefore, dwarf rootstocks such as M9, P22 or P59, Rejman (1997) are not appropriate. Better results on lighter soils, with lower content of humus are obtained with semi-dwarf rootstocks, i.e. M7, M26, P60 or P14 – they are appropriate for orchards grown in lower lying areas.

Cultivar – most species of orcharding plants have numerous cultivars, which differ in yield, frost- and disease-resistance, ripening time, and utility value, Pieniążek (1995). Production value has largely depended on the market and consumers, and these factors have a significant influence on the selection of cultivars by farmers, Sobiczewski (2013). Only cultivars, for which the demand is stable and high, are profitable. They include such varieties as Alwa, Boskoop, Gala, Idared, Lobo, Szampion, Ligol, Gloster, Decosta, Empire, Mutsu, Golden Delicious, Jonagold, Red Prince.

Irrigation – providing trees with appropriate amount of water, especially in critical phases of development allows for high and good quality yields. It is estimated that for optimal growth and yielding, orchard plants require yearly precipitation of 700-850 mm. However, due to the fact that such values are rarely reached, it is necessary to consider the possibility of installation of artificial watering system when starting and orchard.

Spacing between trees – the best spacing is 1500-3000 dwarf trees or 1000-1500 semi-dwarf trees per hectare, Sobiczewski (2013). Decreasing the spacing between trees by planting over 3000 per hectare significantly increases the cost of planting material, and may also result in fruit quality deterioration, and make pest and disease protection of trees more difficult. In a popular row system of planting, dwarf apple trees are planted with the spacing of 1.0-2.0 m between the trees and 3.5 m spacing between rows, while for semi-dwarf apple trees, the spacing between the rows should be 4.0 m, and the spacing between trees in a row – 1.5-2.5 m.

Soil class – arable lands are divided into 9 valuation classes, with the following symbols: I, II, III a, III b, IV a, IV b, V, VI and VI Rz. When choosing the plot of land to start an orchard, it is necessary to consider land configuration, soil fertility, and underground water level.

Trees age – when planning to start an orchard it is necessary to consider the fact that full tree productivity is reached in a specified time interval. For apple trees, the full yield stage falls for years 5-14. In extremely favourable conditions, the trees may be kept until they are 20 years old but it must be remembered that 15-20-year old trees the yield is lower.

MATERIALS AND METHODS

The dataset contains 175 cases obtained from observations at the turn of 2008-2014, Pietrzycka (2016). The most important factors determining the quantity and the quality of yields, namely, cultivar, rootstock, number of trees per hectare, soil class, irrigation, and trees age, were selected for analysis. The study involved 16 different cultivars of apple trees. In order to simplify the model, based on cluster analysis, which uses EM (*Estimation Maximization*) algorithm Witten and Frank (2000), the cultivars were divided into two groups. The cultivar was described by the following characteristics: fruit size, sensitivity to frost and diseases, harvest date and bloom dates, table 1.

Table 1. Results of classification of apple cultivars

Apple cultivar	Fruit size	Sensitivity to diseases	Sensitivity to frost	Harvest date	Bloom date	Classification results
Idared	3	2	1	1	1	**2**
Gala	1	2	3	1	2	**1**
Szampion	3	3	3	3	2	**1**
Ligol	3	2	1	2	3	**2**

Apple cultivar	Fruit size	Sensitivity to diseases	Sensitivity to frost	Harvest date	Bloom date	Classification results
Gloster	3	2	1	3	3	**2**
Jonagored	3	2	2	2	2	**1**
Decosta	2	2	2	2	1	**1**
Mutsu	3	1	3	3	2	**1**
Lobo	2	3	1	1	3	**2**
Alwa	1	3	1	3	3	**2**
Empire	2	1	2	3	2	**1**
Golden D	2	2	3	3	3	**2**
Boskoop	3	1	1	3	2	**1**
Red Prince	3	3	3	2	1	**1**
Rubinstar	3	2	2	2	1	**1**
Elize	1	2	2	3	2	**1**

The following rootstocks are used in the plantation: M26 labelled 1 and M9 – 2. Irrigation can be assigned two values in the model, namely 0 and 1, 0 denotes no irrigation, and 1 – irrigation exists. Soil classes were divided into 5 categories, see table 2.

Table 2. Soil classification

Assigned value of soil class	Soil class	Description of soil classes
1	IIa	Good soils
2	IIIa, IIIb	Quite good soils
3	IIIb, IVa	Medium quality soils, better
4	IVa, IVb	Medium quality soils, worse
5	IVb, V	Poor soils

Kohonen networks (*Self Organizing Map*) were used to analyse the yield, Kohonen (1982). The input variables include the cultivar, rootstock, number of trees, soil class, irrigation and trees age, and the output layer consists of 169 (13x13) neurons that make up a topological map, Fig. 1.

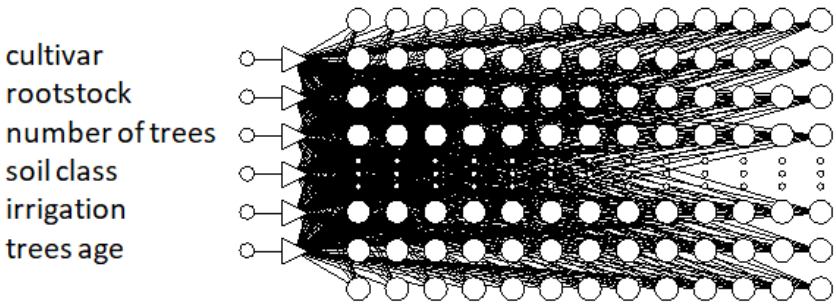

Fig.1. Kohonen network for the analysis of apple yields

When developing a topological map, the number of neurons should be approximately the same as the number of the cases being analysed (here 175), but it should not be greater than this number as the resultant 'empty' cases might have a negative impact on classification quality.

RESULTS AND DISCUSSION

The system was developed using Kohonen network and data analysis software *Statistica 12.5* StatSoft, Poland. The network's ability to activate neighbouring neurons acquired during learning process when similar input data is input, allows for interpretation of input signals set

as a map mapping topological relations between input data in the space of input signals. The topological map (fig. 2) shows winner neurons (number of *i*-th case denoted as 'vi').

	v97		v78		v54 v63	v45		v75	v77		v50	v44
			v90	v86					v71		v53	
v42	v41		v94	v98			v74		v65		v59	v56
v40	v39						v72					
v38		v161			v145		v136			v8	v11	
v37	v36	v106			v147	v134		v140				
		v154	v158				v142	v144		v113	v116	
v25 v 28			v153		v162 v168		v171	v167				
v22		v152	v156		v170		v173	v169	v163		v32 v35	v29
		v151	v148									
v1 v43						v80			v132	v131		v15
v2	v3								v130	v129		v18
v4	v5			v96	v99	v91	v79 v87		v127	v128		v20

Fig.2. A topological map that shows apple trees yielding classification results.

Individual regions of the map were shaded depending of the quantity of yield, table 3.

Table 3. Yield quantity denotations

Yield quantity [1000 kg]	Yield rank	Colour shade on the map
(0-20)	very low	
<20-35)	low	
<35-50)	average	
<50-65)	satisfactory	
more than 65	high	

The results of sensitivity analysis for this model indicating the rank of individual input variables are presented in table 4.

Table 4. Sensitivity analysis for the apple trees yielding classification model

Predictor:	Cultivar	Rootstock	Number of	Soil class	Irrigation	Age
Rank	2	1	4	5	3	6
Error	0.418	0.427	0.306	0.204	0.308	0.147
Quotient	16.85	17.186	12.309	8.219	12.42	5.908

The functioning of the developed system for supporting decisions regarding the assessment of efficiency of apple trees cultivation and yield may be considered correct although its quality requires refining. The growth index *p,* Trajer et al. (2012), used for the assessment of the classification, has the value of $p = 0.526$, which indicates that the system requires refining. Growth is defined as a percentage of positive hits in the set of positive classifications *PTK* to the percentage of positive hits in the whole set of data *PTD*, formula (1):

$$p = \frac{PTK}{PTD}, \tag{1}$$

The efficiency of the system requires improvement such as the use of larger dataset and selection of better predictors. Based on sensitivity analysis it was determined that the importance of factors that have impact on yield quantity is as follows (in descending order of

importance): rootstock, cultivar, number of trees per area unit, soil class, irrigation and trees age.

CONCLUSIONS

The developed computer system, based on selected decision variables, allows for satisfactory support of decisions related to obtaining the best yields in sustainable apple production, which was confirmed by both the results of logical and empirical verification. The decision variable, i.e. apple cultivar, requires refining as grouping the cultivars in the study by using cluster analysis into two groups only, poorly describes the variability of this parameter. The improvement of the system efficiency might be obtained by analysing a greater number of cases, which would also consider other factors significant for this orcharding production. Numerous empty fields on the topological map indicate that the quality of the system might also be improved by optimizing the size of the map. Sensitivity analysis indicates that the most significant factors that have impact on yield quantity include rootstock and apple tree variety, which is confirmed by information contained in relevant literature and empirical observations.

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SUSTAINABLE AGRICULTURE – DEVELOPING COUNTRIES PERSPECTIVE

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Keywords: sustainable agriculture, developing countries, knowledge, participation, cooperation

ABSTRACT
The paper discusses the factors affecting the sustainable agriculture and its adoption in the developing countries. It argues the importance of economic aspect of sustainable agriculture and the necessity of meeting farmers expectations in terms of production and output. An introduction of realistic learning framework promoting sustainable agricultural practices, with active participation and cooperation, is also introduced and debated.

INTRODUCTION

Agriculture is critical for human welfare and economic growth. That applies to both developed and developing world. However, it has a particular significance in countries where people still live in extreme poverty with subsistence agriculture as their main source of food and income. Typically, in most developing countries, people depend on farming for their livelihood (Toenniessen, Adesina & DeVries, 2008).

With the increasing world population, especially in the developing countries, global food demand is projected to double over the next 50 years (Hunter et al., 2017); with many authors calling for production increases of 60%–100% by 2050, based on two recent food-demand projections (Tilman et al., 2011, Alexandratos & Bruinsma, 2012). Need to increase agricultural productivity and food security in a sustainable manner poses a huge challenge, especially in areas now referred to as developing countries. It is difficult to imagine that those areas will move towards, so called, developed countries.

Increasing presence in the media issues related to climate change, usable land for agriculture, availability of water and waste management brought a lot of attention to the environmental aspect of sustainability. However, it is crucial to remember about the other fundamental elements; economic sustainability and social sustainability.

It may be hard to comprehend, for those who do not realize the conditions of living in the developing countries, but for smallholder farmer living in some rural area of Africa, Asia or South America the food production is the most important aspect of agricultural activity. His awareness of the ecological issues may be either low or not existent, whereas his concern is solely related to practical problems of his equipment and activities. Such farmer is still using mainly animal power and manual labour for farming, hence his concern may be with proper harness for his donkeys (Barro, Kondombo & Yelemou, 2017; Getnet et al., 2014), adequate plough for his oxen (Loukanov, Uziak, Michálek, 2005) or proper hand driven equipment for food processing (Uziak & Loukanov, 2007). In addition, many traditional agricultural systems and techniques stood the test of time. They document successful and resilient indigenous agricultural strategies and by itself represent an example of sustainable system (Altieri & Toledo, 2011). In that context, sustainable agriculture may be reflected upon differently.

DEFINITION OF SUSTAINABLE AGRICULTURE

Food and Agriculture Organization of the United Nations (FAO) defines sustainable agriculture development as '*the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner to ensure the attainment and continued satisfaction of human needs for present and future generations.*' (FAO, 1995). In fact, in an agricultural context the concept of sustainability came by much earlier. One of the earlier definitions specifies a sustainable agriculture as a system that, '*over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fibre needs; is economically viable; and enhances the quality of life for farmers and society as a whole.*' (American Society of Agronomy, 1989).

From this statement numerous definitions emerged, but the concept surrounding agricultural sustainability remains the same.

Improving agricultural sustainability appears to be one of the most important goals for the near future for most of the countries and has become an international agenda. In that context, several studies have been performed on the environmentally non-degrading, resource conserving, socially acceptable, technically appropriate and economically viable agricultural practices. However, sustainable agriculture has different meanings for different people. Even most precise statement on the meaning of the sustainable agriculture may, and will, produce numerous definitions and practices. For some, it means continuing present farming methods; for others, the focus is on ecological integrity at the expense of any other concerns.

In many developed nations, the concept of sustainable agriculture blends basic economic concerns, conservation, and maintenance or improvement of the resource base. The motivation is derived primarily from environmental and ecological concerns.

In developing countries, farmers' immediate concerns include improving crop yield, increasing crop diversity, and increasing income rather than concern for the environmental issues.

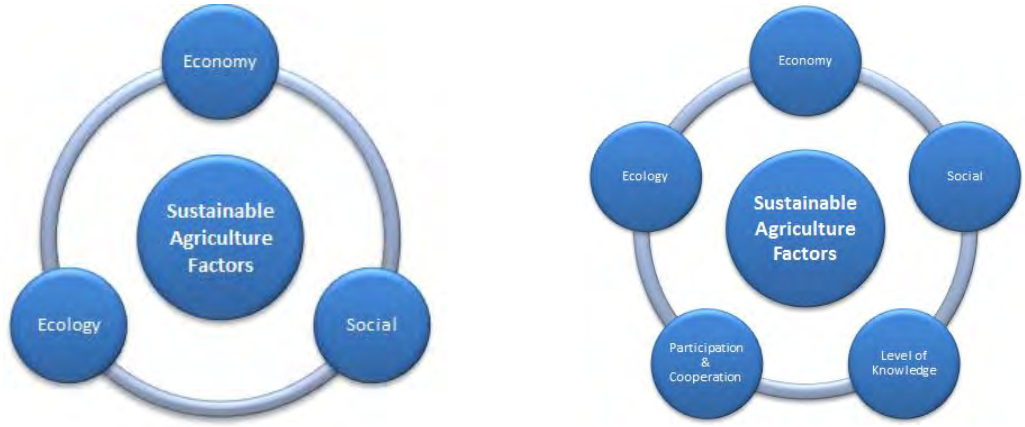
Consequently, it is important to define the concept of sustainable agriculture in the context of the society in which it exists.

FACTORS OF SUSTAINABLE AGRICULTURE

Traditionally, it is considered that sustainability centres on three pillars: environmental, economic and social. The impact of the activity is considered by, so called, 'Triple Bottom Line (TBL)', i.e. society (people), the environment (planet) and economic value (profit) – Fig. 1(a) (Norman & MacDonald, 2004; Flint, 2013).

In the three pillars mentioned above, in agriculture system certain factors can be emphasized (Table 1).

The three main goals form a sustainable agricultural system are often affected by other underlying factors. It is more realistic that in some cases, especially in the developing countries, to specifically separate two additional factors; participation and cooperation, and also the level of knowledge - Fig. 1(b). It has been proven that the level of education and participation, both play crucial role as factors of the sustainability of agricultural (D'Souza, Cyphers & Phipps, 1993; Den Biggelaar and Suvedi, 2000; Bosshaq, Afzalinia & Moradi, 2012).



(a) traditional (b) revised

Figure 1: Factors of Sustainable Agriculture

It can be argued that the level of knowledge, which is directly related to level of education, is most likely a decisive factor and superior to the participation. Techniques that are essential for making agriculture sustainable, such as sustainable agronomical operations-orientation (Saifi & Drake, 2008), including use of advanced irrigation systems, technologies of integrated management of pests combining administration, decrease in the consumption of chemical fertilizers and move toward consuming organic fertilizers and supporting biological variation, can only be achieved with high level of knowledge. Knowledge gives understanding, awareness, responsiveness and consciousness, crucial factors in comprehension and application of proper agricultural solutions. However, participation, which can be considered as part of the social factor in the sustainable agriculture, call for special consideration. It is also directly related to knowledge (participation in training and extension classes), as it may be one of the only way for local farmers to acquire information and know-how. However, participation should be read together with cooperation and collaboration, as taking part in regional and local social activities related to sharing and empowering people, producing new capacities, learning native knowledge, and generally increasing understanding and grasp of practical aspects of sustainable agriculture (Uphoff, 1991; Lorencowicz & Uziak, 2014). That also calls for support system not only showing the values and benefits of sustainability in agricultural system, but also enhancing production resources of the farming community that leads to improvement of life quality.

Table 1. Elements of Sustainable Agriculture

Environmental dimension	Social dimension	Economic dimension
• environmental integrity • physical resource base • management of human consumption • applied technology	• social acceptability & justice • human settlements • enhanced quality of life • intergenerational equity • human relationship to nature	• economic viability & opportunity • disassociate environmental degradation & economic growth • increased & stabilized productivity • manageability of the system • political desirability of the system

Webster has also emphasized that the improvement of economic conditions of farmer is the most tangible and objective manifestation of advantage of any system which the farmer welcomes (Webster, 1997). The income from the land is, without any doubt, the most, if not the only, concern of some poor smallholder farmer in rural area of almost

any developing country. Primary, the farmer wants to satisfy his own needs and, possible, sell the surplus produced.

CONSTRAINTS TO IMPLEMENTING SUSTAINABLE AGRICULTURE

The adoption rates of the sustainable agriculture in developing countries is very low (Andersson & D'Souza, 2014; Adenle, Azadi & Manning, 2017; Thierfelde et al., 2017) despite examples of successful adoption of conservation agriculture (Erenstein et al., 2012). The major reason for such situation can be attributed to the fact that simply the need for food in those countries is not met, and that it is certainly the required condition for a transition to more sustainable agriculture. Foremost, practising of the sustainable system has to improve food production to satisfy consumption needs of the farmer's family. The next step is the possibility of selling the surplus to customers.

A vast range of factors are listed by different authors as constraints to sustainable agricultural development in the developing countries. Some authors group them as internal and external (D'Souza, Cyphers & Phipps, 1993), some as biophysical and socio-economic (Rusinamhodzi, et al, 2014).

Unfortunately, the major constraint for better implementation of practices of sustainable agriculture is political, as the current practices applied in the developing countries do not bring the enough increase in the production. A '*tale*' of long-term environmental degradation is not an argument for a farmer who is struggling to feed his family. Therefore, there is a need for economic incentives from the policymakers; whether such approach is '*sustainable*' itself is separate question.

There is also a dramatic need for education creating and/or improving awareness and willingness of farmers to participate. Hence, extension services, community training, lacking in developing countries, is a second major constraint.

Another factor, often not recognized, is the political and social instability. Civil wars, or simple fights for natural resources, such common in developing countries, put a problem of sustainable agriculture out of the picture. The same applies to HIV/AIDS, tuberculosis, malaria, cholera and other pandemics ever-present in developing countries. Such tragedies create, if not political, at least social crisis. Once again, the sustainable agriculture looks like a distant issue not worth considering.

CONCLUSIONS

Most sustainable agriculture attempts in the developing countries are donor-funded and have no mechanism of surviving after the funds for the project dry out. Farming practices are not actually promoting procurement of essential agriculture inputs. The activities of majority of projects are limited to meeting the subsistence needs (Munthali, Mkandawire & Tembo, 2012).

Majority of smallholder farmers regularly, if not constantly, face numerous challenges and constraints linked to variety of issues, mainly related to limited resources (land, water, funds, labour) and limited access (knowledge, information, inputs, technology, opportunity). In such circumstances, the general importance of economic motivations in facilitating sustainable farm management cannot be overemphasized.

It is unrealistic to expect an awareness and understanding of long term environmental challenges within rural population in the developing countries. However, since any long-lasting and viable solution requires, that sustainable agriculture must be based on

the needs of local farmers and meeting his expectations, the emphasis should be on providing farmers with tools and techniques to improve their economic conditions. This factor should be the main concern of agricultural policies and agricultural innovation must improve yields, decrease environmental degradation, and be accessible to smallholders.

Learning framework, promoting sustainable agricultural practices should actively educate farmers about the link between these farming practices and biodiversity conservation; such promotion should put special emphasis on benefits for local communities. In general, there is a need to build human capital, so more farmers are more likely to adopt new technologies. Learning activities should be associated with active participation and cooperation, as only factual experience, in successful sustainable agricultural practices improving quality of life, can be indeed effective in accepting and implementing new agricultural approach.

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INFLUENCE OF SUBSIDIES ON TECHNICAL EQUIPMENT AND EFFICIENCY OF FAMILY FARMS

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Keywords: technical equipment of holdings, amount of subsidy, economic size, holding income, sustainable agricultural production

ABSTRACT

The aim of the study was to determine the influence of subsidies on the technical equipment of holdings. The level of technical equipment of holdings, considering the amount of subsidies, economic size and income, in the period before and after receiving subsidies, shows a growing tendency. The greatest changes were noticed in the group of holdings with subsidies within 100–150 thousand PLN (number of tractors of a power over 50 kW – an increase by 450% pcs·100 holdings^{-1}). In all the studied groups, the highest increase (by about 200%) was noted in the number of tractors with a power over 50 kW. An increase in in the economic size (ESU - Economic Size Unit) and in the level of generated income has a significant influence on the level of mechanization of holdings. The efficiency of support technical equipment is considerably higher in groups of holdings with the highest values of the criteria of division than in groups with lower values of the division criteria. The evaluation of the relationship between received funds and the technical modernization of the holdings under study, in the context of sustainable development, allows us to conclude that social sustainability is present in small holdings.

INTRODUCTION

Factors of production are always connected with human labour, they are referred to as the productive forces of the production process which are present in the relations between means of production (capital) and labour power (labour). That is why labour (mh – manhours, or labour-hours) and the workplace (of a person) have to be assisted by technical equipment to achieve high efficiency of mechanization of agricultural production (Kocira and Sawa 2008). The technical condition and the structure of means of mechanization in given (organizational-economic) conditions of production shape the production process and define management efficiency in agriculture, which is a significant factor for farmers when they make decisions concerning investment purchases and sources to finance the said purchases. (Sawa 1994, Wójcicki and Pawlak 1996). As shown by numerous studies, the level of agricultural technical equipment of holdings, including the quantity, type, value and efficiency of machines and the power of tractors, varies greatly between individual holdings, even those with similar scope of production (Tabor 2004, Muzalewski 2007). Diversified holdings, with mixed directions of production, usually require diversified machines (Strategia... 2008). Differences in the number of tractors and agricultural machines are, first of all, the result of a disproportion between the development and the economic size of individual entities. In Biłgoraj County, the factor which influences the level of technical equipment of holdings is the particular form of mechanization of principal field work. The are no well-developed mechanization services and most farmers aim to achieve self-sufficiency with respect to agricultural equipment, and holdings make use of external services only when harvesting (Strategia... 2008). The possession of their own machine is a guarantee of its availability, which is especially important in unfavourable weather conditions.

The introduction of another new machine to the holding should contribute, among others, to an improvement in the organization of production, productivity and promptness of field works, quality of machine work. It should also improve work conditions and safety of operators as well as decrease the unfavourable environmental influence of agricultural machinery (Muzalewski 2008, Wasąg 2008).

THE AIM, SCOPE AND METHODOLOGY OF THE STUDY

The aim of the study was to determine the influence of subsidies on the technical equipment of holdings. 70 agricultural holdings from Biłgoraj County were studied in the period before and after receiving subsidies from EU funds (purposive sampling). The period is different for individual holdings because in the years 2004-2009 they received different forms of subsidies. The period under analysis was a minimum of two years before and two years after receiving subsidies based on business plans filed by farmers with the Agency for Restructuring and Modernization of Agriculture in the years 2004-2009 (Plan… 2004; Sektorowy… 2004; Program… 2007). In order to assess the condition of agricultural technical equipment, the sample of holdings was divided on the basis of the amount of subsidies, their economic size and their income. The study contains empirical data from completed undertakings, presenting the level of ownership of major machines and equipment in the base year (before subsidies) and in the target year (after subsidies). The indicators are grouped into: level of technical equipment per holdings (pcs·100 holdings^{-1}) and technical equipment per farmland area (pcs·100 ha^{-1} AL - Agricultural Land). The level of agricultural sustainability in the holdings under study was evaluated in the social context (Sawa et al., 2006).

RESULTS OF THE STUDY

The level of means of mechanization of holdings, considering the amount of subsidies (table 1) in the period before and after subsidies, shows a growing tendency. The highest level is present in the group with subsidies up to 50 and from 50 to 100 thousand PLN in the number of tillage machines and tools, respectively: 121.4 and 180.0 pcs·100 holdings^{-1} and in total tractors: 50.0 and 72.9 pcs·100 holdings^{-1}. These groups also show a significant share of, respectively: tractor trailers 34.3 and 48.6 pcs·100 holdings^{-1} and spraying machines 30.0 and 40.0 pcs·100 holdings^{-1}. Holdings both of smaller sizes and receiving lower subsidies (up to 50 thousand PLN) in comparison with holdings with subsidies over 150 thousand PLN have better means of mechanization – tractors and tillers, respectively: 50.0 and 47.1 and 121.4 and 84.3 pcs·100 holdings^{-1}. The highest change in the level of means of mechanization of holdings in the target year as compared with the base year was noted in the group of holdings with the amount of subsidies from 100 to 150 thousand PLN (number of tractors of a power over 50 kW – an increase by 450% pcs·100 holdings^{-1}).

An evaluation of the conversion level of total tractors in holdings according to their economic size and to their income (tables 2 and 3) shows an increased level of the holdings' equipment, respectively up to 8 ESUs (16.8 pcs·100 holdings^{-1} AL) and up to 10 thousand PLN (22 pcs·100 holdings^{-1} AL). Whereas the percentage increase in the level of equipment in those holdings in the target year is the highest in the group from 16 to 40 ESUs (65) and over 50 thousand PLN (66). However, in the whole studied group, all groups have the highest increase (ca. 200%) in the number of tractors with a power over 50 kW, which can indicate the use of higher efficiency machines and tools. Whereas, holdings of smaller economic sizes (up to 8 and between 8 and 16 ESUs)

purchased currant harvesters, which supports their aim (defined in the business plan) to increase of machine efficiency (table 2). The level of mechanization of those holdings was several times higher than the bigger ones in individual groups of technical equipment. Sawa (1998) made similar findings, which can evidence the continuing tendency towards an irrational use of equipment and towards generating maintenance and operating costs. However, this increases the comfort and quality of work and reduces the number of, for example, drives of combined cultivators in fields. Due to the specificity of the county under study, in which small holdings prevail, a situation like this is a sign of social sustainability.

A multidirectional analysis of these holdings confirms that a growth in the economic size (ESU) and in the level of generated income have a considerable influence on the level of mechanization of those holdings. An exceptional situation arises when the income of holdings is taken into consideration (table 3), in which case its increase is accompanied by a clear decrease, e.g. in the total number of tractors from 22.0 pcs·100 holdings^{-1} AL (with income up to 10 thousand PLN) to 4.8 pcs·100 holdings^{-1} AL (with income over 50 thousand PLN).

Table 1. Changes in the equipment of farms with tractors and major agricultural machinery considering the amount of subsidies

Specification	Agricultural equipment (pcs·100 holdings^{-1}) in holdings with respect to the amount of subsidy											
	< 50			50–100			100–150			> 150		
	by	ty	change, base year = 100	by	ty	change, base year = 100	by	ty	change, base year = 100	by	ty	change, base year = 100
Total tractors, including:	42.9	50.0	117	41.4	72.9	176	14.3	27.1	190	30.0	47.1	157
– up to 30 kW	10.0	10.0	100	18.6	21.4	115	2.9	2.9	100	4.3	4.3	100
– 30–50 kW	21.4	27.1	127	11.4	21.4	188	8.6	8.6	100	7.1	7.1	100
– over 50 kW	11.4	14.3	125	11.4	30.0	263	2.9	15.7	550	18.6	35.7	192
Tractor trailers	31.4	34.3	109	35.7	48.6	136	19	21.4	115	44	50	113
Other trailers and manure spreaders	20.0	20.0	100	27.14	37.1	137	4.3	4.3	100	14	21	150
Reloading equipment	14.3	18.6	130	5.7	21.43	375	4.3	10.0	233	19	26	138
Machines and equipment:												
– tillers	98.6	121.4	123	140.0	180.0	129	53	77.1	146	61	84.3	137
– ridgers	11.4	11.4	100	25.7	25.7	100	2.9	2.9	100	4.3	4.3	100
– fertilizer and lime distributors	21.4	24.3	113	27.1	35.7	132	13	15.7	122	17	20.0	117
– seed drills	24.3	25.7	106	28.6	34.3	120	11	15.7	138	19	27	146
– sprayers	22.9	30.0	131	28.6	40.0	140	10	14.3	143	14	22.9	160
Combine harvesters	8.6	8.6	100	12.9	12.9	100	1.4	1.4	100	11	14.3	125
Balers	17.1	20.0	117	18.6	24.3	131	5.7	5.7	100	10	15.7	157
Root crop harvesters	5.7	5.7	100	5.7	5.7	100	1.4	1.4	100	5.7	5.7	100
Currant harvesters	2.9	4.3	150	1.4	2.9	200	–	–	–	1.4	2.9	200
Feed making machines	4.3	4.3	100	7.1	15.7	220	1.4	4.3	300	15.7	15.7	100

by – *base year (before subsidies),* ty – *target year (after subsidies)*

Table 2. Equipment of farms with tractors and major agricultural machinery with respect to economic size

Specification	Agricultural equipment (pcs·100 ha^{-1}AL) in holdings with respect to economic size (ESU)											
	< 8			8–16			16–40			> 40		
	by	ty	change, base year = 100	by	ty	change, base year = 100	by	ty	chang, base year = 100	by	ty	change, base year = 100
Total tractors, including:	10.7	16.8	157	10.8	15.2	141	3.4	5.6	165	2.9	4.1	141
– up to 30 kW	6.8	7.5	110	2.7	3.0	111	0.8	0.7	88	0.4	0.4	100
– 30–50 kW	1.7	5.2	306	6.1	7.2	118	1.3	1.3	100	1.3	1.3	100
– over 50 kW	2.2	6.2	282	2.0	5.8	290	1.3	4.2	323	1.2	3.1	258
Tractor trailers	10.8	9.2	85	7.9	10.4	132	4.1	4.8	117	4.5	4.3	96
Reloading equipment	2.1	3.9	186	4.3	6.4	149	1.6	3.0	188	1.0	1.9	190
Machines and equipment:												
– tillers	39.6	43.1	109	29.7	36.1	122	12.3	15.6	127	5.7	6.8	119
– ridgers	7.6	6.3	83	6.0	5.5	92	1.0	0.9	90	0.4	0.4	100
– fertilizer and lime distributors	7.4	8.1	109	6.0	7.5	125	3.7	3.9	105	0.6	0.9	150
– seed drills	7.7	7.5	97	6.7	6.9	103	2.8	3.7	132	0.4	1.2	300
– sprayers	6.2	10.3	166	7.1	7.8	110	2.8	3.7	132	0.7	1.7	243
Combine harvesters	2.3	1.8	78	2.9	2.5	86	1.0	1.1	110	0.9	0.7	78
Balers	2.0	1.8	90	6.0	6.5	108	2.0	3.3	165	1.0	1.2	120
Root crop harvesters	1.2	1.2	100	2.3	2.0	87	0.5	0.4	80	0.2	0.2	100
Currant harvesters	0.7	1.1	157	0.3	0.3	100	0.0	0.0	0	0.3	0.6	200
Feed making machines	2.0	2.5	125	1.5	2.6	173	0.6	0.5	83	2.1	2.3	110

by – *base year (before subsidies),* ty – *target year (after subsidies)*

Table 3. Equipment of farms with tractors and major agricultural machinery with respect to holding income

Specification	Agricultural equipment (pcs·100 ha^{-1}AL) in holdings with respect to income (K PLN·holdings^{-1})											
	<10			10–20			20–50			>50		
	by	ty	change, base year = 100	by	ty	change, base year = 100	by	ty	change, base year = 100	by	ty	change, base year = 100
Total tractors, including:	14.4	22.0	153	10.1	13.7	136	7.1	9.5	134	2.9	4.8	166
– up to 30 kW	6.9	8.1	117	3.5	3.5	100	2.0	1.9	95	0.4	0.3	75
– 30–50 kW	5.7	9.5	167	4.1	5.1	124	3.3	3.9	118	1.1	1.1	100
– over 50 kW	1.8	5.5	306	2.5	5.9	236	1.8	3.8	211	1.5	4.9	327
Tractor trailers	8.5	9.3	109	10.7	12.3	115	5.9	6.7	114	4.0	4.7	118
Reloading equipment	4.3	5.8	135	3.4	5.6	165	0.6	3.3	550	2.4	3.7	154
Machines and equipment:												
– tillers	46.6	53.5	115	28.5	36.5	128	19.1	22.9	120	12.1	11.4	94
– ridgers	10.8	10.4	96	5.1	4.4	86	0.8	0.8	100	1.7	0.8	47
– fertilizer and lime distributors	8.7	10.1	116	6.6	7.4	112	3.6	5.0	139	2.8	3.1	111
– seed drills	8.4	9.1	108	6.9	7.7	112	3.2	3.7	116	3.4	3.0	88
– sprayers	10	13.8	138	5.5	7.2	131	3.8	5.4	142	2.2	2.2	100
Combine harvesters	2.2	1.6	73	2.3	2.3	100	2.1	2.1	100	1.1	1.0	91
Balers	5.3	4.4	83	5.0	6.0	120	2.8	4.9	175	1.6	2.1	131
Root crop harvesters	2.3	1.9	83	2.2	2.2	100	0.4	0.4	100	0.6	0.5	83
Currant harvesters	0.5	0.5	100	0.0	0.0	0	1.2	1.8	150	0.1	0.1	100
Feed making machines	1.6	2.9	181	1.4	2.6	186	0.6	0.9	150	0.8	1.0	125

by – *base year (before subsidies),* ty – *target year (after subsidies)*

SUMMARY

The level of mechanization of holdings with respect to the amount of subsidy, their economic size and income in the period before and after receiving subsidies, shows a growing tendency. The highest level is in the groups, respectively: from 100 to 150 thousand PLN·holdings^{-1}, over 40 ESUs and from 20 to 50 thousand PLN·holdings^{-1}. Holdings of smaller sizes, which at the same time received lower subsidies (up to 50 thousand PLN), in comparison with the ones with subsidies over 150 thousand PLN have a higher level of mechanization – tractors and tillers: 50.0 and 47.1 and 121.4 and 84.3 pcs·100 holdings^{-1}. The greatest changes in the level of mechanization of holdings in the target year with in comparison with the base year was noted in the group of holdings with the amount of subsidies between 100 and 150 thousand PLN (number of tractors with a power over 50 kW – an increase by 450% pcs·100 holdings^{-1}). In all the studied groups the highest increase (ca. 200%) was noted in the number of tractors with a power over 50 kW, which can indicate the use of more efficient tools and machinery. In groups of holdings with the highest value of the division criteria, the efficiency of support machinery is considerably higher than in groups with smaller values of the division criteria. For example, in holdings with the amount of subsidy up to 50 and over 150 thousand PLN and with economic size of up to 8 ESUs and over 40 ESUs, the change in the percentage of spraying machines was, respectively: 31 and 66% and 60 and 143%.

A multidirectional analysis of these holdings confirms that an increase in the economic size (ESU) and in the amount of subsidies has a considerable influence on the level of mechanization of holdings. The evaluation of the relationship between received funds and the technical modernization of the holdings under study, in the context of sustainable development, allows us to conclude that social sustainability is present in small holdings. It increases the comfort and quality of work and reduces the number of, for example, drives of combined cultivators in fields. Support programs for agriculture from EU funds are an important and effective factor in the shaping of technical modernization of family holdings.

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THE EFFECT OF TRANSPORTATION CHOICES ON ENERGETIC EFFECTIVENES OF RAPESEED PLANTATION

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ABSTRACT
The computer modelling is applied to the analysis of the effect of choices of transportation means, and transport organization on energetic effectiveness of biodiesel production system. In general, needs of transport of harvested crops decreases energetic effectiveness of the production system. Production processes occurring in the whole production system should not consume more energy than the amount that can be obtained in form of final biofuel. Consequently, estimation of the effects caused by various contributing processes, e.g. transportation of biomass between production subsystems, is important for drawing conclusions concerning optimization of the production process.

INTRODUCTION

Biofuels produced out of biomass become important part of liquid fuel industry. They are considered as, at least partial replacement of fossil fuels. It is important that production processes occurring in the whole production system should not consume more energy than the amount that can be obtained in form of final biofuel. Otherwise no gain of energy is achieved. Typical for biofuel production system is coupling between agricultural and industrial subsystems. Moreover, agricultural production is distributed on relatively large area as compared to industrial production. This situation causes needs for transportation of crops between the plantations and industrial processing facility. The present paper presents results of numerical analysis of various choices of transportation means as well as organization of transport with respect to transportation contribution to energetic efficiency of the production system.

Energetic efficiency can be considered as one of the most important characteristics of biofuel production systems, and production processes occurring in that system. Cleveland at al. (1984) have introduced EROEI “Energy Return on Energy Invested” as quantitative measure of energetic efficiency. It was defined as a ratio of energy delivered by some production system to the total energy that have to be consumed in production processes, to deliver the above mentioned amount of energy. Unfortunately, as was indicated by (Murphy at al.2010), various calculation procedures, and several modified definitions are used, causing some ambiguities that have been discussed by Murphy at al. (2011), and also Zhang and Colosi (2013). Recently, the definition that have been introduced by Pickard (2014) was used by the present Authors, in a series of papers: Wasiak and Orynycz, (2014), Wasiak and Orynycz (2015), Orynycz and Wasiak (2014), Wasiak and Orynycz (2015) applying mathematical modelling to estimation of energy efficiency dependence upon several factors determined by methods of production used in agricultural subsystem of rapeseed biodiesel production.

Since biofuel production systems, are usually composed of separated subsystems, having different characteristics, but connected to each other by fluxes of masses or energy, it seems important to establish a way of separate estimation of energetic efficiency of such subsystems, and investigation of subsystem’s interactions determining the total energetic efficiency of the production system. It was shown by

Wasiak and Orynycz (2016) that for a production system the total energy efficiency can be expressed as:

$$\varepsilon_{tot} = E_{fuel} / \Sigma E_{i,j} \quad (1)$$

where the energy fluxes going into a given i-th subsystem are numbered by index *j*. The partial energetic efficiency of any subsystem can be written as follows:

$$\varepsilon_j = E_{fuel} / \Sigma E_i \quad (2)$$

It can be easily discovered that the numerator of the expression given by Eq. , and Eq. 2, is the same, while the denominators differ. The numerator is the final amount of energy obtained from the system (delivered out of the system). Consequently, for the case when all partial efficiencies, related to contributing energy expenses in subsystems, are computed as rations to the same value of final energy yield of the whole production system than the energy efficiency of the whole system is expressed by the following rule:

$$\varepsilon_{tot}^{-1} = \Sigma \varepsilon_j^{-1} \quad (3)$$

The same formulas are applicable to the set of technological operations or processes occurring in the production system. It has to be taken into account that all partial, as well as the final, total efficiency should be computed for the same amount of resource. For the case of biofuel production systems, the procedure might refer to particular mass of crops or to particular plantation area, and the same span of time.

The aim of the present paper is to investigate relationships between energetic efficiency of transport between agricultural and industrial subsystems as function of characteristics of transportation means for different plantation sizes. The same dependencies are computed for two cases, namely transportation of rapeseed grain and transportation of raw oil being pressed directly in plantation. Several plantation sizes, as well as several plantation sizes are considered. As characteristics of transportation means the load capacity and fuel consumption are taken into account. The fuel consumption is taken as independent variable varying between different limits specific for the type of vehicle. The data concerning fuel consumption are taken from various catalogues of vehicles as well as publicly available tests, and driver's opinions.

RESULTS AND DISCUSSION

Numerical computations are performed with the use of a computer program Microcal ORIGIN and data on fuel consumption of various transportation means collected from various sources. Results of computed energetic effectiveness are presented as functions of fuel consumption taken within the limits, reported for particular transportation means (trucks and cisterns). Computations were performed for two cases, namely transport of rapeseed grain or transport of raw oil pressed at the plantation. Grain yield is assumed as 3000 kg/ha, and correspondingly oil yield is taken as 1100 kg/ha, and the yield of biodiesel amounts to 380 dm^3/ha. The low calorific value of biodiesel fuel is taken as 35 MJ/dm^3. The distance that has to be driven between plantation and industrial facility is 100km. Table I shows the number of vehicles (or courses of one vehicle) needed for transport of grain harvested on various sizes of plantation for several sizes of vehicles. Obviously in the cases of large vehicles and small plantations, the capacity of the vehicle is not utilized in full.

Table I. Number of vehicles needed for transportation of rapeseed grain between plantation and industrial facility as a function of plantation size, and load capacity of the vehicle.

Load capacity [kg]	Plantation area [ha]									
	1	2	3	4	5	6	7	8	9	10
	amount of crop [kg]									
	3000	6000	9000	12000	15000	18000	21000	24000	27000	30000
	number of vehicles									
2000	2	3	5	6	8	9	11	12	14	15
5000	1	2	2	3	3	4	5	5	6	6
10000	1	1	1	2	2	2	3	3	3	3
20000	1	1	1	1	1	1	2	2	2	2
30000	1	1	1	1	1	1	1	1	1	1

An example of results of partial energetic efficiency of transport computed according to Eq. 2, is shown in Fig. 1. The figure presents energetic efficiency of transportation of grain from plantation area 10 hectares

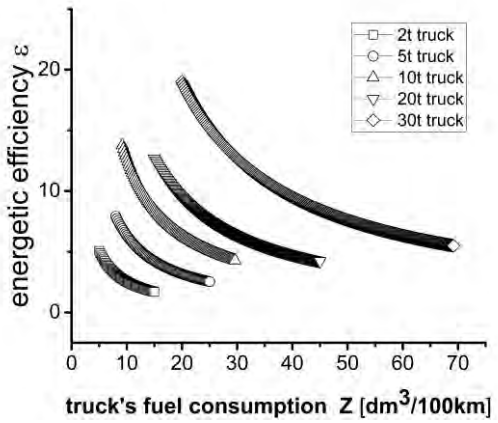

Fig. 1. Energetic efficiency for transportation of rapeseed grain harvested from 10ha field, and crop yield 3000 kg/ha by means of trucks of various load capacity.

As it is seen in Fig. 1, in all cases energetic efficiency decreases with an increase of specific fuel consumption, [dm^3/km], the character of the dependence is very similar for all types of vehicles. lowest energetic efficiency is observed in the case of smallest vehicle. This result is mostly due to the fact, that the use of small vehicle requires larger number of courses (vehicles). It has to be pointed out, however, that the same value of energetic effectiveness can be reached by different vehicles at different values of fuel consumption. Therefore, in some situations it may be that the use of bigger vehicle offers better efficiency, while in other cases the result might be quite opposite. Consequently, in the practical situations, each case has to be analysed individually.

Fig. 2, in turn, shows similar dependencies for 10 tons truck used for transportation of grain from various sizes of plantation. Again, obviously, the decrease of energetic efficiency is observed with an increase of vehicle's fuel consumption. The highest

values of energetic efficiency are reachable for small plantation area. This effect is also due to an increase of number of trucks (or courses of one truck) needed to transport whole crop. In this case also the individual choice of the vehicle (its specific fuel consumption) decides on the energetic efficiency of transport operation (since equal energetic efficiencies for different fields can be achieved at different fuel consumption values)

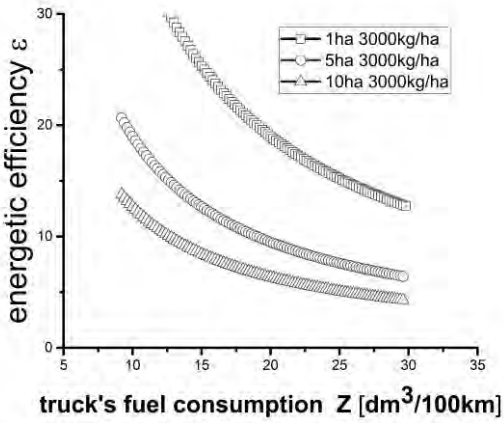

Fig. 2. Energetic efficiency for 10t truck transporting crops from fields differing in area for the crop yield 3000 kg/ha

An interesting feature can be observed in Fig. 3 showing the dependence of energetic effectiveness of transport as a function of the ratio of mass load capacity, L, of the truck to its specific fuel consumption, Z. As it is seen, a linear relationship for each field size is observed. Energetic efficiency increases with an increase of the ratio ξ=L/Z.

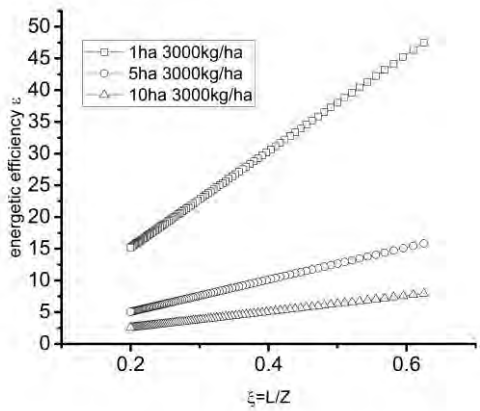

Fig. 3. Energetic efficiency for 10t truck transporting crops from fields differing in area, giving the crop yield 3000 kg/ha as function of the ratio of load capacity to fuel consumption.

Similar calculation performed for tor the case of another organization of production processes, i.e. localization of the process of pressing oil at plantation followed by transportation of oil shows the same character of dependencies. An example of results is shown in Fig. 4.

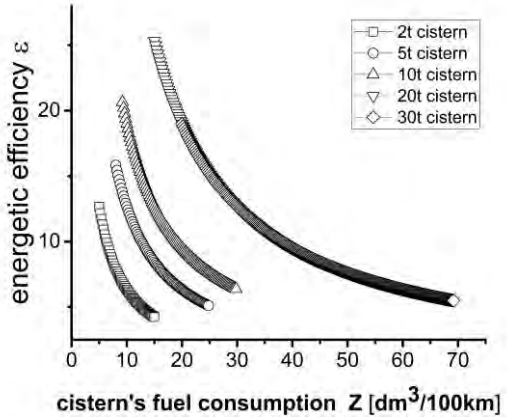

Fig. 4. Energetic efficiency for transportation of rapeseed oil harvested from 5ha field, and crop yield 3000 kg/ha (1100 kg/ha of oil)

The dependencies are very similar to those shown in Fig. 1., it seems that at lower fuel consumption limits the energetic efficiency in this case is slightly higher than for the case of grain transportation. Plots for 20t and 30t cistern mass capacity practically overlap, what results of the same number of vehicles needed for transportation of oil from plantation of the size chosen.

Direct comparison of energetic efficiency dependencies for both transportation strategies is shown in Fig. 5.

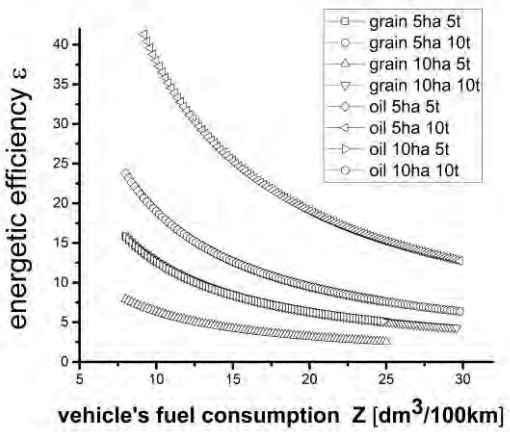

Fig. 5. Comparison of transport energetic efficiency for transportation of rapeseed grain and rapeseed oil harvested from 5 ha, and 10 ha field fields, and crop yield 3000 kg/ha (1100 kg/ha of oil) using vehicles of 5 t and 10 t mass capacity.

For those cases, the highest energetic effectiveness for all values of fuel consumption exhibits the dependence for the case of 10t cistern transporting oil from 5ha field. The curve below is formed by coincidence of the dependencies for oil transport cases: 5t vehicle - 5ha field, and 10t vehicle -10ha field. The third curve (from the top) results from coincidence of several cases, while the lowest corresponds to the case of transportation of grain grown on 10ha field by means of truck of 5t capacity.

Similar linear relationship as shown in Fig. 3 can also be seen in the case of transportation of oil. The slopes of the dependencies obtained by linear regression tend to be larger for oil transport rather than grain.

CONCLUSIONS

The energetic effectiveness of transport may strongly contribute to the total energetic effectiveness of rapeseed biodiesel production system. Results of performed model computations show that partial energetic effectiveness of transportation processes depends mainly upon the appropriate choice of the transporting vehicle, especially with respect of its characteristic ratio of load capacity to fuel consumption. Obviously fuel consumption of particular vehicle might depend upon road situation, style of driving, etc. The vehicle also should be correctly chosen with respect of plantation size, and type of crop being transported.

Intuitively, transportation of smaller amount of oil, rather than grain obtained from the same field should lead to better values of energetic effectiveness, it seems however, that incorrect choice of the vehicle might spoil the expected gain in effectiveness. The dependencies of energetic effectiveness upon the ratio of load capacity to fuel consumption suggest that this later characteristic may be the tool for choosing appropriate vehicle. The choice, however, has to be optimized with respect to plantation area (or the amount of the crop that has to be transported.

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ASSESSMENT OF EFFICIENCY OF AN AGRICULTURAL TRACTOR ENGINE FOR DIFFERENT ROTATIONAL SPEEDS

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Key words: agricultural tractor, sustainable agriculture, compression-ignition engine, engine test stand, efficiency of engine, rotational speed

ABSTRACT
Within the framework of this paper efficiency of the S-4003 engine Ursus C-360 tractor was evaluated in terms of variation of its rotational speed. The proper use of the engine operating parameters according to various agrotechnical conditions is consistent with the concept of sustainable agriculture, which assumes rational management and the least harm to the environment. Higher engine efficiency results in less fuel consumption. Engine tests were performed on a dynamometer bench at the engine test stand, based on load characteristics, for the speed range from the maximum torque (1600 rpm) to the rated one (2200 rpm), at every 150 rpm. The fuel (Ekodiesel Ultra D) calorific value was determined using the KL-12 calorimeter produced in Poland. It was found out that the highest efficiency of the tested engine was achieved for the intermediate speeds from 1750 to 1900 rpm.

INTRODUCTION

Conventional heating plants as well as thermal power plants constitute primary environmental hazards but from the point of view of anthropogenic environmental hazards, transport, especially wheeled transport is also considered to be hazardous. This primarily results from substantial consumption of fuel. Fuel consumption expenses often account for over 50% of total costs incurred by transport enterprises (Black 2002, Stead 2001, Zamboni et al. 2015). Agricultural transport (food products transport and animal husbandry transport) is strictly connected with safety and environmental protection concerns (Bauer et al. 2010, Garcia-Alvarez et al. 2013, Krautzberger and Wetzel 2012, Vanek and Sun 2008). Moreover, transport-related issues are subject to the law and related regulations in force in the European Union. This is related to the issue of competition among carriers, labour conditions. vehicle technical standards and related energy consumption (Behrends et al. 2008, Burski et al. 2016, Drewes et al. 2003).

Advancing development of the automotive market and related increase in fuel consumption rates and alongside emission of toxics contained in combustion gases cause progressive degradation of natural environment (Zając and Węgrzyn 2008). In the case of compression-ignition engines, high concentration of pollutants caused by combustion gases is not only the case with urban agglomerations but also rural areas. This is merely this type of engine that, alongside heavy trucks, is commonly used for agricultural tractors and machinery. Catalytic combustion is the most effective way of reducing emission of gases and particulate matter contained in combustion gases. Measurable ecological benefits as well as advantageous basic engine performance indicators (fuel consumption, power output, torque) are achieved by means of intra-engine „operations" such as, for instance, relevant regulations, type and features of fuel

or engine operational parameters tailored to driving conditions (rotational speed, load) (Merkisz et al. 2005, Wasilewski and Krasowski 2015).

Sustainable agriculture promotes a rational use of natural resources at the least possible negative environmental impact. Engines of agricultural vehicles are characterized by a high degree of nuisance to the natural environment, mainly due to their inadequate technical condition, but also to the specifics of field works. Hard and diversified operational conditions in the case of agricultural tractors require operating speed, namely the most efficient ration of engine rotational speed to the load (type of operations performed) alongside lowest possible fuel consumption and highest possible rated nominal power. Therefore, efficiency, that is directly proportional to nominal power and inversely proportional to time-limited fuel consumption, is particularly significant engine performance indicator:

$$\eta_e = \frac{3{,}6 \cdot 10^6}{g_e \cdot W} = \frac{3{,}6 \cdot 10^3 \cdot N_e}{G_e \cdot W} \tag{1}$$

where:

η_e – efficiency,
ge – unitary fuel consumption, g/kWh,
Ge – hourly fuel consumption, kg/h,
Ne – effective power, kW,
W – fuel calorific value, kJ/kg.

In order to meet the ecological goal of sustainable agriculture, in addition to proper farming practices and the best use of the tractor engine operating parameters, there is a need to replace older agricultural tractors with newer, more economical and environmental friendly. Undoubtedly such activities are time-consuming, but as in every field of economics also in agriculture the priority is environmental protection.

TEST STAND AND STUDY METHODOLOGY

Ursus C-360 agricultural tractor's S-4003 four-cylinder engine, mounted on a dynamometer bench at the engine test stand workshop in the Power Engineering and Means of Transport Department of the University of Natural Science in Lublin, underwent the study tests. The engine at issue has the combustion system with direct fuel injection into a toroidal cavity on the piston head. The Fig. 1 presents the study test stand diagram.

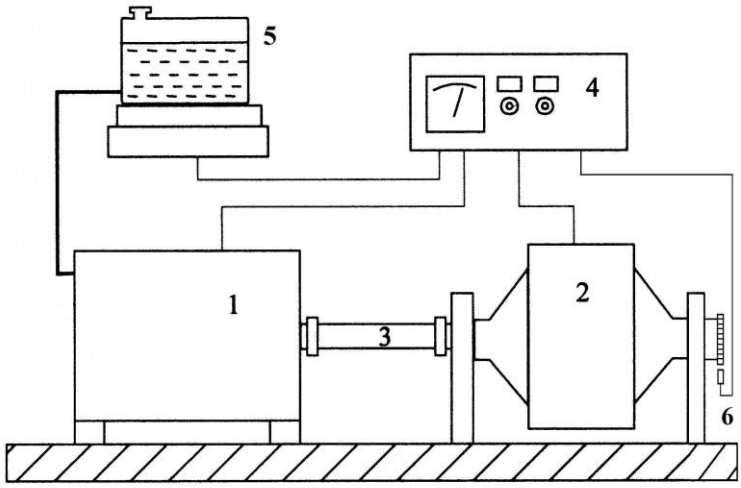

Fig. 1. The diagram of the test stand: 1 – combustion engine, 2 – electric brake, 3 – transmission shaft, 4 –control panel, 5 – fuel consumption measurement system, 6 – inductive sensor

The electric brake type K1 - 136 B – E (asynchronous ring generator), that has also been used for switching on the ignition of the engine at issue, is the essential part of the dynamometer bench. Load variations were effectuated by changing the current for the brake switchboard through the liquid resistor.

The inductive sensor aligned with the N05 digital meter was used for measuring the rotational speed of the engine.

Fuel consumption was measured by means of weighing with the use of the electronic balance type TP-30B that allows to measure fuel dose consumption time automatically.

Calorific value of fuel, that is indispensable for computing efficiency of an engine, was defined by means of KL-12 calorimeter made in Poland.

Engine measurements were performed on the grounds on load characteristics in terms of varied rotational speed within the range from the maximum torque (1600 rpm) to the rated speed (2200 rpm), at every 150 rpm. In the course of defining respective load characteristics in respect of every single rotational speed, the effective power and time-limited fuel consumption were measured. Then the efficiency have been calculated following the formula 1.

STUDY RESULTS AND ANALYSIS

The Fig. 2 presents the results of the η_e efficiency experiments for S-4003 tractor's engine in the function of N_e effective power alongside rotational speed variable, and the Table 1 theoretical relations corresponding to the aforementioned experiment resulting figures defined on the grounds of the regression analysis curve. The relevant equation formula was chosen on the basis of the value of the determination coefficient R^2, F-Snedecor test functions for the purpose of testing accuracy of the model and significance levels of respective elements of the regression function (t-Student's tests).

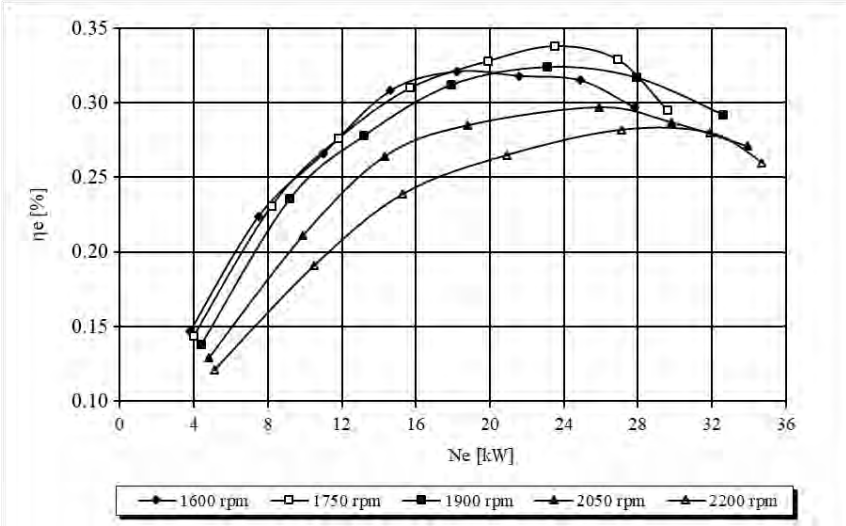

Fig. 2. Variations of efficiency η_e for S-4003 engine in the function of N_e effective power alongside rotational speed variable

Calorific value of fuel, that is indispensable for computing efficiency of an engine, was defined by means of KL-12 calorimeter made in Poland. Ultra D Ekodiesel was the fuel that underwent the study tests. Its calorific value stood at $W = 42887$ kJ/kg.

Table 1. Regression equation formula and R^2 determination coefficients that define efficiency η_e for S-4003 engine alongside varied rotational speed

Engine rotational speed	Regression equation formula	R^2 Determination coefficient
1600 rpm	$\eta_e = -0.00062N_e^2 + 0.025429N_e + 0.062816$	0.9952
1750 rpm	$\eta_e = -0.00059N_e^2 + 0.025591N_e + 0.052261$	0.9936
1900 rpm	$\eta_e = -0.0005N_e^2 + 0.023717N_e + 0.050387$	0.9919
2050 rpm	$\eta_e = -0.00043N_e^2 + 0.021151N_e + 0.041336$	0.9929
2200 rpm	$\eta_e = -0.00033N_e^2 + 0.017986N_e + 0.03843$	0.9967

The analysis of the aforementioned relations has indicated as follows:

1. Efficiency reached the highest value to the extent of medium engine load, and it is inversely proportional to the unitary fuel consumption. Its peak values for the engine rotational speed variations under consideration to the extent of the effective power were kept within the range of N_e = 20-27 kW.
2. The peak value of the efficiency of the engine under consideration within the range of the rotational speed variations from the maximum torque (1600 rpm) to the rated speed (2200 rpm) corresponded with 1750 rpm. It amounted to $\eta_e = 0.338$ and corresponded to the power $N_e = 23.5$ kW.
3. The top mean value of the operational efficiency of the engine was reached to the extent of maximum load alongside the rotational speed at 1750 rpm ($\eta_e = 0.275$), and rose by 17.3% as compared to the lowest rated speed ($\eta_e = 0.234$).

4. In the case of higher load (N_e > 20 kW), 30% of efficiency was obtained for the speed at 1900 rpm, which was not much lower (by approximately 1.5%) than the peak value of the efficiency.
5. High values of the determination coefficient (R^2>0.99) proved accurate alignment of theoretical relations with the experiment resulting figures.

CONCLUSIONS

The study has proven a considerable impact of S-4003 tractor's engine rotational speed upon the efficiency of the engine. The engine proves the peak value of the efficiency when the rotational speed is lower than the rated speed and higher than the peak torque. Higher efficiency of the engine is related to the decrease in the unitary fuel consumption (optimal operations of the engine), which is particularly required for vehicles that are operated in volatile and harsh conditions, namely tractors, among others. Tractors' engines are often operated with substantial load, for instance, in the course of extreme deep ploughing. Improving of the engine efficiency is one of the fundamental challenges that constructors of modern diesel engines are to face at. It makes them cost-effective and low-emission. Such actions strictly correspond to sustainable agriculture with the least environmental harm as a priority.

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ANIMAL WELL-BEING BIOLOGICAL HAZARD ASSESSMENT FOR TRANSPORT LOGISTICS IN SUSTAINABLE AGRICULTURE IN THE REPUBLIC OF POLAND

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Keywords: sustainable agriculture, animal well-being, transport logistics, biological hazard, correlation analysis

ABSTRACT

This paper presents the findings of the cattle well-being in transport audit conducted in the period from 2007 till 2012. Respective veterinary check-ups were audited: upon dispatch, upon arrival, at rest, sale (at markets or cattle collection points), and in-transport checks. The number of cattle heads subject to the audit, the number of cattle heads that proved irregularities and correlations between those numbers in the previous years were analysed. Moreover, the audit of the percentage share of the animals that had proven irregularities has allowed for accurate assessment of irregularities occurrence rate. Positive correlation between the percentage share of the cattle heads that proved irregularities and the audit years has been found.

INTRODUCTION

Animal well-being assurance is one of the most significant issues for the sustainable agriculture. The well-being must be understood as animals' condition of physical and mental health achieved in harmony with natural environment (Kołacz 2005).

Animal and food products transport development is strictly connected with the natural environment protection and security (Bauer et al. 2010, García-Álvarez et al. 2013, Krautzberger and Wetzel 2012). Other transport issues are additionally subject to the law and legal regulations in force in the European Union. This is the case with the competition among carriers, employment conditions, vehicle technical standards and related energy consumption rates as well as terrorism threat anticipation and possible loss cuts (Black 2002, Burski et al. 2016, Drewes et al. 2003, Stead 2001).

Animal and food products transport is a specific kind of transport that has required diligence and technical and sanitary standards compliance (Raiten and Aimone 2017, Barlow et al. 2015). Therefore, there is the need for defining current hazards in transport of this kind in respective Member States in the European Union, alongside the veterinary standards compliance. This is the aim of this publication in which wheeled means of animal (cattle) transport have been scrutinised in the context of completed audits and related irregularities that have been found in the recent years in Poland and the correlation analysis that has been carried out.

FINDINGS OF CATTLE WELL-BEING IN-TRANSPORT AUDIT

The findings of the number of the cattle heads audited in terms of animal well-being in the period from 2007 until 2012 at respective transport stages have been displayed in the Figure 1.

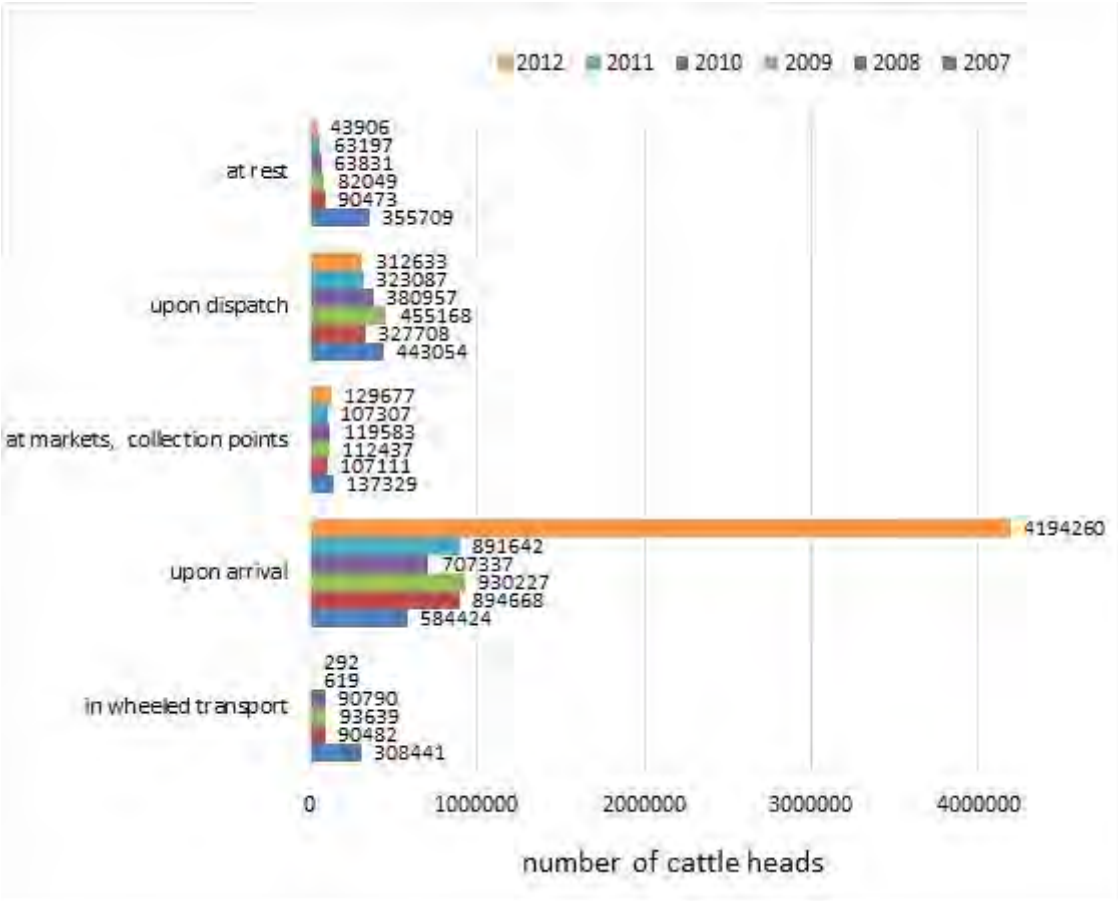

Figure 1. Number of cattle heads that was subject to means of transport audit in the period from 2007 till 2012 (own study based on Integrated Multiannual…, 2007-2012)

The number of cattle that was subject to the wheeled transport audit fell in the majority of cases in consecutive years (except for the year 2009): from 308441 in 2007 down to 292 in 2012 (Figure 1). The largest number of cattle heads i.e., 4194260 were audited upon arrival in 2012. The number of animals audited at markets or cattle collection points was more or less steady in the audited period and amounted to 107111 pieces in 2008 up to 137329 in 2007. The number of cattle heads that were subject to check-ups during rest fell in consecutive years and in the case of audit upon dispatch - beginning with 2009.

The number of cattle heads that proved irregularities found in the means of transport audit has been presented in the Figure 2.

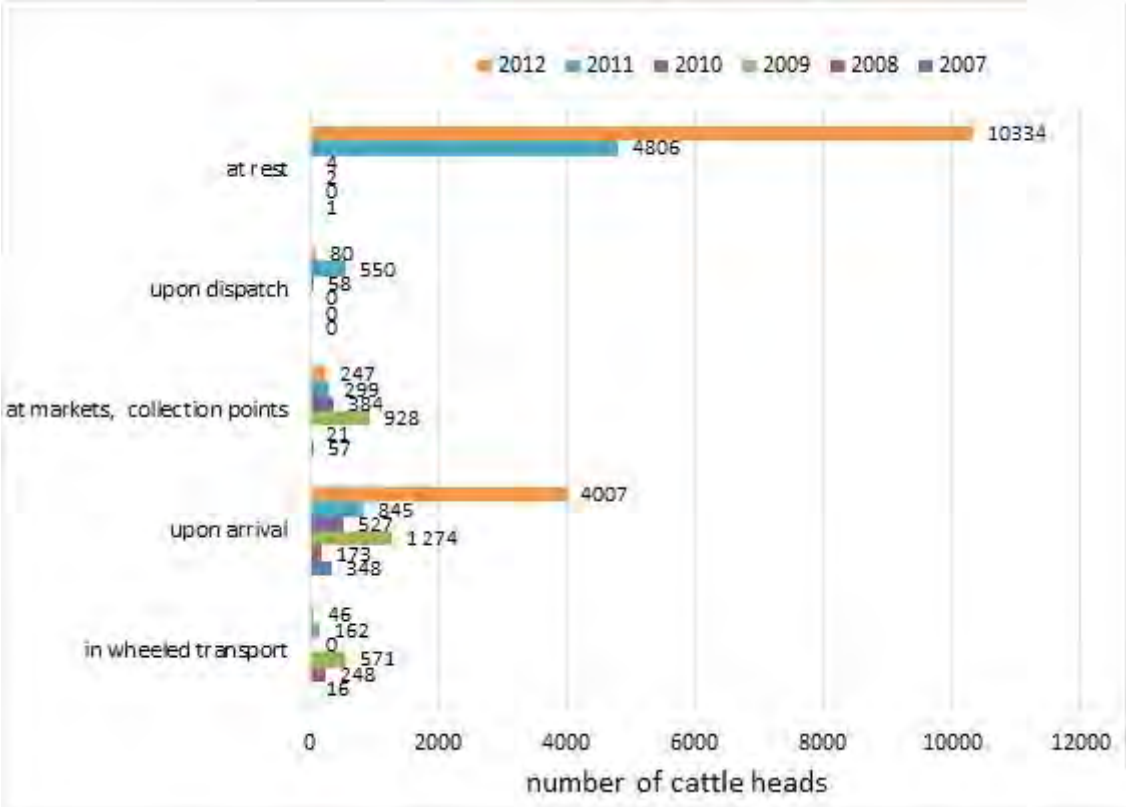

Figure 2. Number of cattle heads that proved irregularities found in means of transport audit in the period from 2007 until 2012 (own study based on Integrated Multiannual…, 2007-2012)

The change in the number of cattle heads that proved irregularities did not indicate a clear tendency (Figure 2). Upon arrival in 2012 irregularities were found for the largest number i.e., 4007 of cattle heads. In the case of audits carried out at markets and animal collection points, the number of animals that proved irregularities fell beginning with 2010. It bears noting that in the period from 2007 until 2009 no irregularities were found among the audited cattle upon dispatch. During the remaining period, the largest number of irregularities were found in the years 2011 and 2012 (4806 and 10334 cattle heads, respectively) whereas in the remaining years irregularities were found for just few cattle heads or were not found at all (in 2008).

CATTLE AUDIT FINDINGS CORRELATION ANALYSIS

Interdependences between the number of cattle heads subject to the audit, the number of cattle heads that proved irregularities and the years of audit have been presented by means of the correlation coefficients (Table 1) alongside the audit venues.

The strong negative correlation between consecutive years and the number of cattle heads subject to the audit in transport has been found (Table 1, r = -0.86). No significant correlation between the number of audited cattle heads and the number of cattle heads that proved irregularities has been found (r = -0.17).

The analysis of the audit upon arrival has indicated the moderate positive correlation between consecutive years and the number of cattle heads subject to the audit (r = 0.68)

as well as consecutive years and the number of cattle heads that proved irregularities (r = 0.73). The correlation between the number of cattle heads subject to the audit and the number of cattle heads that proved irregularities has been found positive and extremely strong (r = 0.97).

Table 1. Correlation coefficients (r)

audit	examined feature	years	number of cattle heads that proved irregularities
in wheeled transport	number of cattle heads	-0.86	-0.17
	number of cattle heads that proved irregularities	-0.17	
upon arrival	number of cattle heads	0.68	0.97
	number of cattle heads that proved irregularities	0.73	
at markets, collection points	number of cattle heads	-0.13	-0.28
	number of cattle heads that proved irregularities	0.20	
upon dispatch	number of cattle heads	-0.63	-0.47
	number of cattle heads that proved irregularities	0.52	
at rest	number of cattle heads	-0.75	-0.40
	number of cattle heads that proved irregularities	0.83	
total	number of cattle heads	0.56	0.87
	number of cattle heads that proved irregularities	0.84	

The number of audited cattle head upon dispatch fell, which corresponds to the negative and moderate correlation between consecutive years and the number of audited cattle heads (r = -0.63).

The analysis of the audit at rest has indicated the strong and negative correlation between the number of cattle heads and consecutive years (r = -0.75) as well as the strong and positive correlation between the years and the number of cattle heads that proved irregularities (r = 0.83).

After having summed up the number of audited cattle heads in consecutive years, the positive and moderate (r = 0.56) correlation between the number of audited cattle heads and consecutive years as well as the strong positive correlation between the number of cattle heads that proved irregularities and consecutive years (r = 0.84) have been found. The correlation between the number of audited cattle heads and the number of cattle heads that proved irregularities has been positive and strong (r = 0.87).

The percentage share of the cattle heads that proved irregularities, namely the quotient of the number of cattle heads that proved irregularities and the number of cattle heads subject to the audit has been additionally analysed. The correlation coefficients between consecutive years and the percentage share of irregularities have been computed. The results have been presented in the Table 2.

Table 2. The percentage share of cattle that proved irregularities and correlation coefficients (r) for the percentage share and consecutive years

audit	2007	2008	2009	2010	2011	2012	r
in wheeled transport	0.01%	0.27%	0.61%	0.00%	26.17%	15.75%	0.74
upon arrival	0.06%	0.02%	0.14%	0.07%	0.09%	0.10%	0.46
at markets, collection points	0.04%	0.02%	0.83%	0.32%	0.28%	0.19%	0.19
upon dispatch	0.00%	0.00%	0.00%	0.02%	0.17%	0.03%	0.52
at rest	0.00%	0.00%	0.00%	0.01%	7.60%	23.54%	0.79
total	0.02%	0.03%	0.14%	0.07%	0.48%	0.31%	0.80

The highest percentage share of irregularities amongst the cattle (Table 2) has been found in the case of the audit in wheeled transport in 2011 (26.17%) and in 2012 (15.75%) as well as in the years 2012 and 2011 for the audit at rest (23.54% and 7.60%, respectively). The correlations between the percentage share of irregularities and consecutive years have been found positive. The strong correlation has been found between the consecutive years and the percentage share of irregularities in the case of the audit in wheeled transport (r = 0.74) and at rest (r = 0.79). The correlation between the percentage share of irregularities and total consecutive years for the total number of audited cattle heads has been found very strong (r = 0.80).

CONCLUSIONS

The study that has been conducted indicates that the number of cattle heads that were audited fell in the consecutive years. The audits upon arrival (slaughter-houses, abattoirs) were the exceptions to have posted the rising number of audited cattle heads in the period from 2007 until 2009 and 2010 till 2012. The largest number of audited cattle heads was reported for the audit upon arrival.

No uniform tendencies have been spotted in the case of irregularities referring to animal well-being. The largest volume of irregularities was found at the place of rest in 2012.

The analysis of the correlations between the number of audited cattle heads and the number of cattle heads that proved irregularities and the consecutive years of the study has provided for an interesting outcome. There is a very strong negative correlation between the consecutive years and the number of audited cattle heads (r = -0.86) in transport as well as at rest (r = -0.75). Furthermore, most often positive (except for the audit in wheeled transport) correlations between the number of cattle heads that proved irregularities and the consecutive years have been found. The strongest correlations have been found for the audit at rest and upon arrival.

The analysis of the percentage share of cattle heads that proved irregularities has provided for unambiguous assessment of the irregularity occurrence rate. The highest percentage share of irregularities has been found for the audit conducted in 2011 and 2012 in wheeled transport and at rest.

The resulting figures of the correlation analysis conducted to the extent of the cattle well-being are very much interesting and should serve the basis for assessment of the outstanding issue under consideration since there are significant differences in the assessment of well-being among the audit upon dispatch, upon arrival, and in transport. Explanation of this phenomenon should be the subject matter of the audit of veterinary authorities since it has an impact upon animal quality features that are so essential in terms of assessment, consumption merits, and animals themselves. A similar analysis should be conducted for other animals – maybe transported in smaller numbers – sheep, chicken, geese, etc.

Familiarity with the factors that have the impact upon animals' well-being may not only be the faults occurring within the framework of domestic transport but may also be the target of the impact of terrorism threats in international terms – biological, chemical, radiological hazards. It is currently one of the most important issues in terms of global threat for vehicle inspection authorities, the police, veterinary authorities.

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NEW TECHNICAL SOLUTIONS FOR PRECISE AND SAFE APPLICATION OF PLANT PROTECTION PRODUCTS

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Keywords: Field crop sprayer, direct injection, automation, assistance systems, pesticide application manager

ABSTRACT
The technical development of field crop sprayers have reached a high level. Due to automation and assistance modern sprayers are able to achieve very high application quality combined with low risks for environment and operator as well as high efficacy. But, the requirement to spray plant protection products as homogeneously as possible all over the field runs out of date. Due to possibilities arising from precision farming and digitalization of agriculture the idea of site specific application moves closer to realisation. Therefore two technologies are necessary, direct injection and sensor systems for weed, pest and disease detection. Moreover, the efficacy and safety of plant protection can be still raised by looking on the whole process of plant protection, meaning to integrate planning, preparation and documentation besides the application itself. The article gives an overview about the state of the art of field crop sprayers and their technical development.

INTRODUCTION

"How to spray a tiny amount of active substance in a precise and even way all over the size of the fields?" This was the dominant question for constructing plant protection machinery in the past decades connected with the intention to avoid environmental impacts on non-target areas. Concerning this matter the technical development was mainly focussed on even lateral distribution and a reduction of drift measures by using the tools of mechanical engineering. Due to the options arising from precision farming and digitalization of agriculture the technical potentials have been enlarged a lot. Within the last few years these tools offered a lot of possibilities to improve different particular aspects of the spraying process in order to make the application of plant protection products (PPP) even more precise and to avoid associated risks. Today, the system of the application of PPP is in transition. The actual keywords of technical development in the area of field crop sprayers are "site specific application" and "automation" with regard, not only to particular aspects, but to the entire process of plant protection.

FIELD CROP SPRAYERS: STATE OF THE ART

In modern field crop sprayers a lot of functionalities have been automated so far (e.g. Herbst, 2016 & Wegener, 2015). There is machinery available on the market having GPS-guided section control with individual nozzle switching. The proper operation of every single nozzle and its droplet spectrum can be controlled automatically as well as nozzle changes due to distance regulations near buffer zones for example. There are assistance systems controlling the optimal target distance of the boom and its adoption to the ground orientation (Horsch, 2015). Other systems are supporting trailed sprayers in order to keep the tractors track even under difficult field conditions such as slopy terrains. Along curves the application rate can be automatically adjusted within the sections of the boom in order to have a more even lateral distribution (Dammann, 2015). Latest developments even allow the compensation of an uneven longitudinal distribution caused by vibrations by using position sensors in the boom combined with nozzles operating with pulse width modulation. After application the field crop sprayer

can be cleaned running through an automated and assisted cleaning procedure whereas the remaining quantities of PPP are minimized by using compressed air in the piping system in before. Mixing and loading have become more secure since there are Close Transfer Systems available on the market (Agrotop, n.d.), preventing the operator coming into direct contact with PPP. In order to assure best efficacy of PPP even the temperature and pH level of the spraying water can be monitored by sensor systems, again keeping the operator away from coming directly into contact with the PPP. Category 4 cabins according to EN 15695-1, being able to eliminate dusts, aerosols and vapors, are offered, being a substitute/supplement of personal protective equipment.

All these features mentioned so far are examples of automation of known functionalities or new types of technical solutions improving the application of PPP, saving PPP, reducing drift or enhancing the operator protection. But, all of them have in common that they have been developed by focussing more or less on a single aspect of application.

SITE SPECIFIC APPLICATION

Site specific application is one of the most important challenges in plant protection in order to save larger amount of PPP in the fields which automatically would have a positive environmental and economical impact. In order to realize this two requirements have to be satisfied from a technical point of view. First off all, there is a need to gather enough site specific information about pest and disease status of the field crops which should be treated with PPP. This is a question of sensing and information technology. Second, it needs a field crop sprayer being able to apply different kind of PPP independently from each other at the same time. This is a question of direct injection technology.

Looking on the market, there have been several attempts to realize site specific PPP treatments on the field. On Agritechnica 2015 for example the Amazone company presented the "AmaSpot" system, which was based on "greenseeker" technology and pulse width modulation, being able to implement a site specific application on basis of simple "yes/no" decision (Amazone, 2016). But, this system only works for total herbicide application on stubble fields and is not able to fulfil the requirements for PPP application under other conditions, because the sprayer has e.g. no direct injection system, allowing to mix just the amount of spray liquid which is really needed.

Other field crop sprayer prototypes with direct injection system being constructed within the last 30 years always had the following problems: too long delay times until the concentration of PPP is accomplished/depleted at the last nozzle of the boom, when the sprayer is switched on/off, insufficient dosage accuracy of PPP during spraying, problems to clean the system properly after utilization and/or inadequate area efficiency of the whole process of spraying (Krebs et al., 2015).

Also presented on Agritechnica 2015 was a new prototype of a field crop sprayer with a direct injection system that solves all the problems mentioned before. It was designed, built and tested in practice in a joint research project between the Herbert Dammann company and the Julius Kühn-Institute. The prototype which was developed is able to keep the dosing quantity within a range of ±7% for any liquidly formulated PPP. It works without any delay time, can be automatically and completely cleaned after spraying and its area efficiency is comparable to conventional sprayers. It is able to apply up to three different PPP separately from each other using a separate nozzle line

for each direct injection system (Krebs et al., 2015). Nevertheless, there are some restrictions for practical use: Solid formulated PPP can only be applied so far using conventional tank mixtures within the prototype sprayer. The possibility for section control is limited when using low dose levels of PPP (<0,5 l/ha) at slow forward speeds (≤6 km/h). If more than one nozzle line is in use the amount of spraying water is doubled or tripled (Wegener et al., 2016). Practical tests have shown, that this may have an impact on the time needed until a PPP is taking effect. But, there was no difference concerning the efficacy of the PPP treatment during the field tests (Pohl et al., 2017).

Regarding the necessary requirements for site specific application operating sensor systems for pest and disease detection still seem to be the biggest problem. All sensors on the market so far are for weed detection. But, these known camera based solutions are either based on already mentioned "greenseeker" technology or on such systems with weed identification, which are not able to cover the whole working width of a sprayer. In this context it will be exciting to see, what new solution will be presented on Agritechnica 2017.

PROCESS BASED SOLUTIONS

Due to increasing digitalization of agriculture huge amount of data is available. This can be used in order to improve the efficacy of the whole process of plant protection. In this case, not the application itself, but also planning, preparation and documentation is included. A first attempt to interlock different steps of the process "plant protection" was presented on Agritechnica 2015: Pesticide Application Manager (PAM).

The PAM systems allows automatically to take specific distance requirements to buffer zones into consideration (Scheiber et al., 2013). Therefore, national plant protection obligations were incorporated in a web based application, which can be used in future by farm management information systems (FMS/FMIS) in practice. First FMS/FMIS which include a virtual interface to the PAM data service will be presented on Agritechnica 2017. The system works as follows: The required field data concerning field borders and surrounding structures have to be collected once and are transferred into the FMS/FMIS. When the operator decides to plan a specific pesticide application he starts to send relevant data (field coordinates, crop plant, PPP chosen, etc.) to the PAM-Service, which is calculating an application map in ISO-XML format including all specific distance requirements which have to be followed. This map is fed into the computer system of the machine and will serve as basis for the application. In a next step the operator starts the application in the fields and the machine is recording the process automatically. The calculated map and the documentation of the process can be transferred back into the FMS/FMIS after the application is done (e.g. Figure 1).

This kind of process management can help the farmer to better plan, exercise and document his plant protection application by connecting knowledge, consultancy, practice and machinery. For the future the integration of further information concerning e.g. growth stage, specific weather conditions, online application data etc. will contribute to lower the risks, save PPP and increase the economical benefit of plant protection measures.

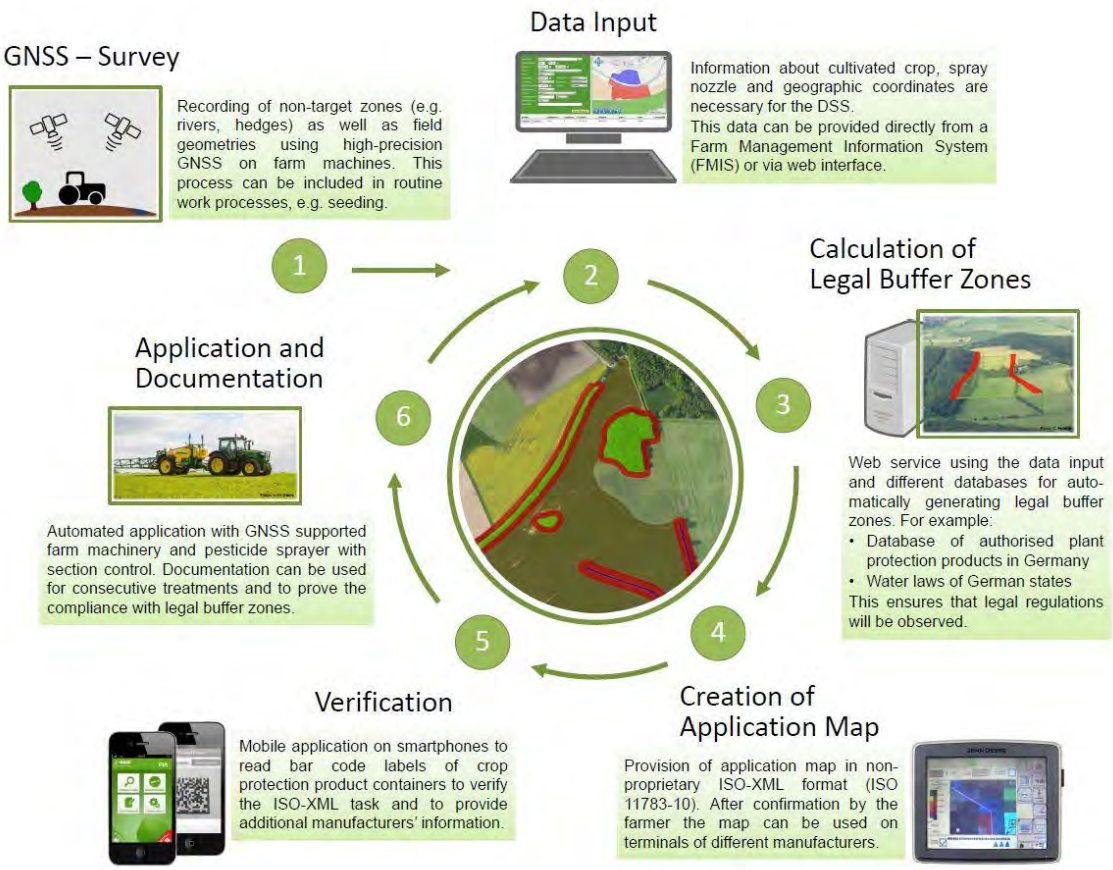

Figure 1. Decision support system of the pesticide application manager (ZEPP, 2015).

CONCLUSION

The development in plant protection technology in direction of saving PPP, lowering risks for the environment, increasing the efficacy and operator safety has reached a high standard. Modern field crop sprayers are able to spray PPP precisely with the same concentration all over the field. Due to automation nearly every feature of a sprayer can be assisted which gives the operator the opportunity to concentrate on controlling the process of application. The challenge for the future will be to overcome the equal treatment of the fields in terms of site specific application. First technical approaches are in development or even on the market. In order to further increase the efficacy of plant protection the possibilities given by precision farming and digitalization are enormously if the whole process of plant protection is in the focus of ambitions. But, a key component for future development of this approach is to find economical and practical sensor systems being able to detect weeds, pests and diseases in the fields.

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THE EFFECT OF ULTRASOUND ON THE RHEOLOGICAL PROPERTIES OF APPLE JUICE

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Keywords: ultrasound, rheological properties, apple juice, energy consumption

ABSTRACT

In this paper, the effect of ultrasonic treatment on the rheological properties of apple juice (Idared variety) was studied. The juice was treated with ultrasonic waves for 5 and 10 minutes relative to the untreated sample. The tests were conducted using rotational viscometer at shear rates ranging from 40 to 140 s^{-1} at constant temperature of 20°C. There was no influence of ultrasonic treatment on the rheological character of apple juice. The rheological behaviour of untreated apple juice had the characteristics of non-Newtonian fluids. The value of the flow index was less than 1, indicating its pseudoplastic character. Because the ultrasonic treatment doesn't change the structural properties it can be used for mild preservation of apple juice. This technology of juice processing allows to reduce the energy consumption, what contributes to the rational management of energy resources.

INTRODUCTION

The scientists and government organizations around the world are working to promote and implement alternative agricultural practices that maximize the benefits of sustainable agriculture. These actions are accompanied by attention to reduce energy consumption during processing, transport and production of goods with limited or no waste (Tilman et al., 2002).

Therefore, solutions are being sought based on the available technologies, which aim to improve economic growth, while minimizing the impact on the natural environment (Altieri 1995; Urbaniec et al., 2016).

The alternative may be new ultrasound-based technologies, which due to the acceleration of many processes (Kobus 2008; Cai et al., 2016) and reduction of energy consumption allows them to obtain higher quality products, and reducing or eliminating adverse effects on the environment (Cintas 2016; Draye and Kardos 2016).

Currently, research is performing on the use of ultrasound energy for gentle preservation of fruit juices (Rojas et al., 2016). The sound waves can inactivate enzymes and microorganisms by denaturing or breaking down of protein structures (Kwiatkowska et al., 2011). Ultrasonic treatment can have a substantial impact on the rheological properties of the liquid (Bot et al., 2017). Rheological characteristics are important in transport, storage and structural changes in the liquid (Kobus 2015).
The aim of the study was to investigate the effect of ultrasound on the rheological properties of apple juice.

MATERIAL AND METHODS

The research material was apple juice from the Idared variety. The juice was obtained after crushing on a laboratory basket press. To test the juice was filtered to remove pulp particles.

The process of ultrasonic treatment was carried out using an ultrasonic generator Sonic VC 750 with power of 750W and the head having a diameter of 19.05 mm. A sample of

60 ml of apple juice was treated for 5 and 10 min at ultrasonic intensity of 1.16 $W \cdot cm^{-3}$. Rheological properties were measured using Brookfield viscometer (Brookfield Engineering Laboratories: model LVDV-II + PRO). A sample of 16 ml of apple juice was used in ULA-baker for all experiments. The tests were conducted using rotational viscometer at shear rates ranging from 40 to 140 s^{-1}. By using a water bath (Brookfield TC-502P) the temperature was kept constant value on 20°C. The viscosity curves and flow curves were determined on the basis of the computer software (Rheocalc 3.1).
In addition, changes in the extract content and temperatures after wave treatment were measured. All experiments were carried out in three replications. The relationship between shear stress and shear rate was determined using the Ostwald-de Waele model described by the following equation:

$$\tau = k \cdot \gamma^n \tag{1}$$

where:

τ – shear stress (Pa),
k – consistency coefficient ($Pa \cdot s^n$),
γ – shear rate (s^{-1}),
n – flow behaviour index (-).

RESULTS

Figure 1 shows temperature changes of apple juice during ultrasonic treatment depending on the treatment time. In both cases the temperature increases gradually to reach respectively a value of 75 °C after 5 min and 85 °C after 10 min.

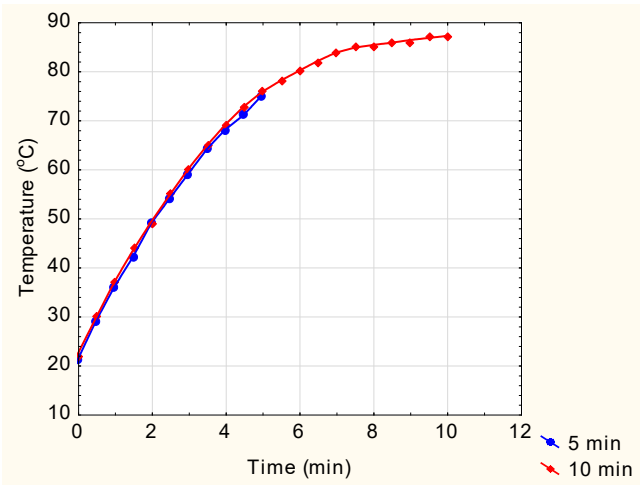

Fig. 1. The influence of ultrasound on the change in temperature apple juice

Table 1 shows the content of the extract for the raw juice and after the ultrasonic treatment. It showed an increase in sugar content, with increasing treatment time. But this effect may be caused by evaporation of some amount of water from the sample due to the increase in temperature.

Table 1. The content of apple juice extract before and after ultrasonic treatment

Kind of treatment	Extract content (°Bx)
Raw juice	7.950±0.05
5 min US treatment	8.125±0.43
10 min US treatment	8.725±0.43

In Fig. 2 and 3 were shown flow and viscosity curves for three samples of tested juices.

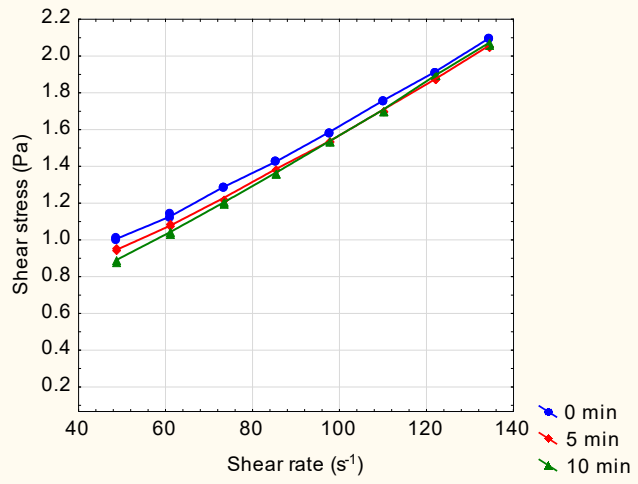

Fig. 2. Flow curves for apple juice depending on the applied treatment

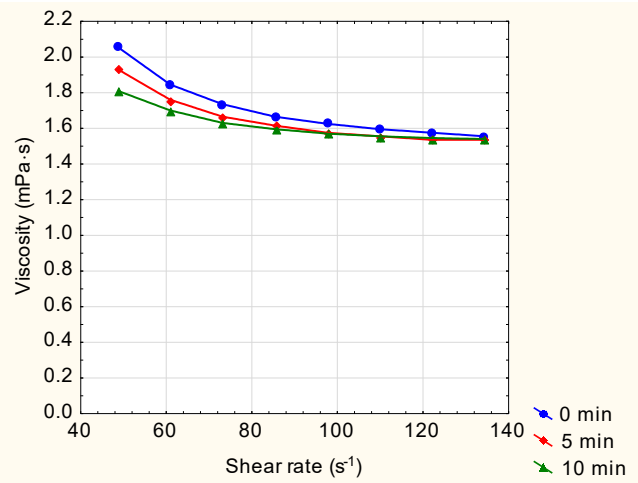

Fig. 3. Viscosity curves according to apple juice depending on the applied treatment

On the basis of the shape of the flow and viscosity curves, it can be concluded that the tested juice exhibits non-Newtonian behaviour.

In table 2 were presented values of consistency coefficient and flow behaviour index for the tested juices. Due to the fact that juices exhibited non-Newtonian behaviour Ostwald-de Waele model was applied to calculate its rheological properties.

Table 2. The rheological properties of the Ostwald-de Waele model for juice, depending on the treatment

Kind of treatment	Consistency coefficient ($Pa \cdot s^n$)	Flow behaviour index (-)
Raw juice	0.04960 [a]	0.7589 [b]
5 min US treatment	0.05188 [a]	0.7547 [b]
10 min US treatment	0.04569 [a]	0.8177 [b]

a, b the same letter for each parameter in column are not significantly different at a confidence of 95% (Tukey's test, $p<0.05$)

The value of the flow index are different from the 1 which indicating the non-Newtonian liquid character. All the values of flow behaviour index are below 1 supporting the pseudoplastic behaviour of tested juices. Statistical analysis showed no significant effect of ultrasonic treatment on the consistency coefficient and flow index.

CONCLUSIONS

Research on the influence of ultrasonic treatment during 5 and 10 min on rheological properties of apple juice versus control (raw juice) was performed. Untreated juice exhibited non-Newtonian liquid properties. The ultrasonic treatment didn't change rheological behaviour of apple juice. There was also no statistically significant effect of ultrasonic processing on the values of consistency coefficient and the flow index of the tested apple juice.

It can be concluded that sonification at this level of intensity doesn't effect on changes in structural properties of juice. The results of the study indicate that the applied ultrasonic intensity can be used to gentle apple juice preservation. This mild way of juice processing allows to reduce the energy consumption, what is important for the sustainable use of energy sources in the food and agriculture sector.

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THE ANALYSIS OF THE CONNECTION OF TWO TOOLS OF A MODULAR DEVICE FOR SOIL APPLICATION OF THE DIGESTATE

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Keywords: sustainable agriculture, digestate, modular device, connection of tools, forces

ABSTRACT
The issue of connecting two collaborating tools in the scope of determination of forces occurring in the hitch of the tools was discussed. The analysis was carried out at the example of a modular device for soil application of digestate. In one working pass the device enables to organize a work enabling evenly spreading the digestate at the soil surface, mixing it and covering with soil. Finite Element Method (FEM) numerical methods have been used for the development of a construction which allowed, among others, the determination of loads at the point of the tools connection. Carrying out experimental research in real conditions of operation, stress distribution and force values occurring in connection were determined. The force values obtained were verified with computer analysis carried out at the 3D model of the device, demonstrating the correctness of the assumptions made.

INTRODUCTION

Care for soil environment and in particular the content of humus in soil is one of the assumptions of sustainable agriculture. The increase of humus in the soil may be obtained, among others, by means of the use of natural fertilizers, including, among others, digestate. In order to enable this process while meet the requirements for the use of natural fertilizers, a modular device for subsurface injection of digestate was elaborated. The principles of ecodesigning, ergonomics and work organization in sustainable agriculture were implemented when elaborating the construction of the modular device (Bohdal et al., 2014; Kukiełka et al., 2016). The set consists of a manure spreader and a trailed disc harrow. The device offers the possibility of work organization enabling the simultaneous transport, spreading and mixing of digestate with soil. A bracket with a transport hitch developed according to the principles of ergonomics, mounted to the spreader frame, was used to connect both machines. This type of attachment ensures the transfer of loads generated by the aggregated disc harrow. The disc harrow is equipped with a drawbar ended with an eye. High strength requirements are set for connections of such kind, subject to variable and different operational loads. In order to define the level of loads at the point of connection, Finite Element Method (FEM) numerical methods were applied (Savaidis and Vormwald 2000; Maggi et al., 2005; Rakowski and Kacprzyk 2005; Wang 2012; Kosterski et al., 2016). They are commonly applied in the Industrial Institute of Agricultural Engineering, in the scope of elaboration of the construction of agricultural machines working with variable operating loads (Szczepaniak and Pawłowski 2005; Zbytek et al., 2013; Kukiełka et al., 2016). Moreover, computer simulations which enable to verify the adopted constructional solutions of agricultural machines are performed (Szczepaniak and Pawłowski 2005; Zbytek et al., 2009; Pawłowski et al., 2012; Wojciechowski 2013). Verification of obtained parameters takes place in real conditions, during the operation of the machine. Various kinds of test runs are considered in the regard. The results obtained are verified with results obtained in the simulation test.

GOAL, OBJECT AND METHODS OF THE STUDY

The analysis of the connection of two tools of a modular device for soil application of digestate, in the scope of identification of forces occurring in that connection, under conditions of variable operational load, was the one of the main objectives of the conducted research. Managing a digestate as per the R10 recovery process, it should be spread evenly at the field surface, covered and mixed with soil. In order to meet that condition, a modular device for soil application of digestate, which was the subject of tests, was designed (Fig. 1). The device construction computational model was performed with the use of the Ideas NX 6.3 system.

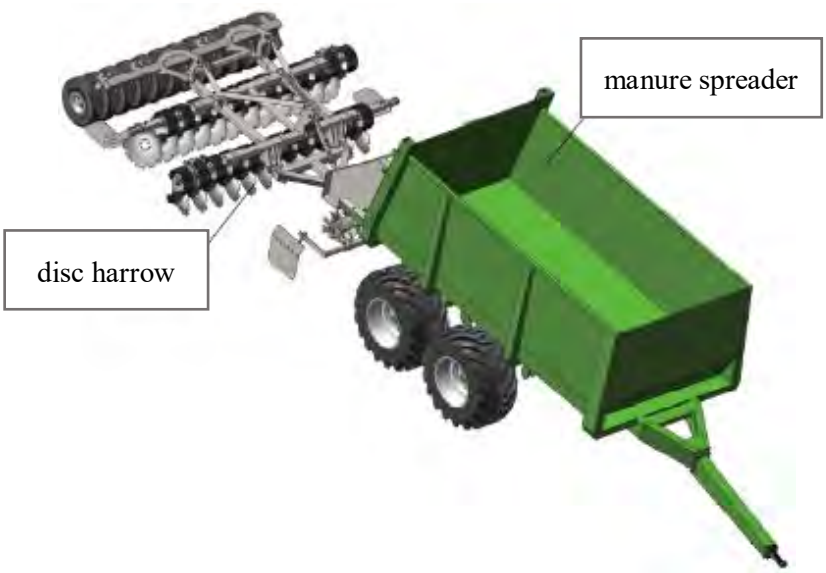

Fig. 1. Modular device for soil application of digestate

FEM mesh was built using standard finite elements located in the programme library. The computational model was discretizationed with quadrilateral and triangular shell and plate elements and beam elements. A computer analysis was carried out for the purpose of determination of the value of forces at the point of tools connection. Carrying out experimental tests under operational conditions, values of forces occurring in the place of connection of both machines were determined (Fig. 2). Strain gauge sensors stuck to a beam with the drawbar eye of the disc harrow were used to determine forces. Strain gauges were stuck in places located with the use of a strength analysis performed in the static scope. In order to determine forces loading the machine in the point of connection, a method discussed by Spadło (2014) was applied. With the method, a classical manner of determination of force values, by means of performance of normal stress equation calculations was resigned from. Geometric parameters and cross-section characteristics are replaced with constants which were then determined experimentally. Constants binding the stresses recorded in the drawbar with forces occurring in the hitch were identified on the basis of an experiment consisting in loading the drawbar in a location of occurrence of forces with significant value and readout corresponding to the stress. The direction of the load operation was selected so as to eliminate the remaining components.

RESULTS

Registration of time course of force values in the disc harrow hitch was performed during the transport pass at a field road and two working pass. An exemplary course of forces occurring in the harrow's hitch during a transport pass at the field road is presented at Figure 3. Five measurement sections are designated at the force distribution: 1 – lifting of the disc harrow to the transport position 2 – ride down from the elevation, 3 – ride with a field road, 4 – ride up the elevation, 5 – stopping the tractor unit.

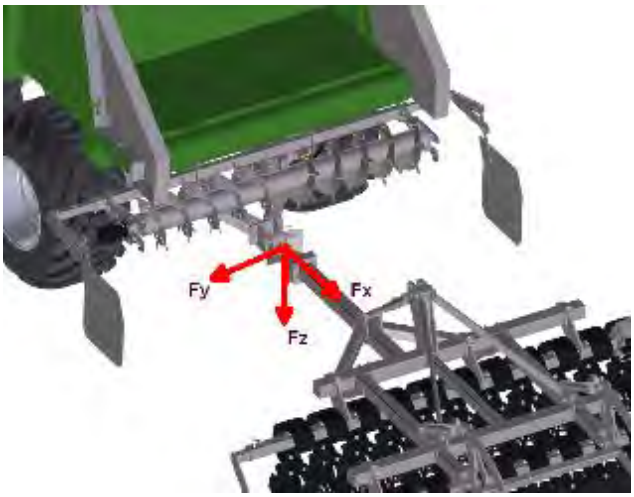

Fig. 2. Designation of forces occurring in the disc harrow hitch

Recorded values of forces during measurements are set in table 1. Negative values of forces mean another reversal of forces operation with respect to the one adopted at Fig. 2. Longitudinal force F_x, occurring at the point of connection, is the force of working resistance of the disc harrow during working pass. It was determined when spreading digestate with modular device, going at a working speed of 5 $km \cdot h^{-1}$ and mixing it with soil at a depth of 10 cm.

Table 1. Values of forces occurring in the hitch during various runs.

Item	Tests	Forces	Values of forces [daN]		
			min.	max.	average
1	Transport pass	longitudinal Fx	-267	780	79
		lateral Fy	-201	65	-2
		vertical Fz	0	807	606
2	First working pass	longitudinal Fx	1023	2082	1456
		lateral Fy	-402	-144	-263
		vertical Fz	115	394	242
3	Second working pass	longitudinal Fx	1285	2298	1820
		lateral Fy	-488	-181	-323
		vertical Fz	93	367	249

The connection of two tools meets the requirements in the scope of the transfer of vertical force (PN-82/R-36107). The hitch transfer loads applied along its longitudinal axis max. 1820 daN, which is the force of working resistance of the disc harrow. The average value of working resistance 1638 daN obtained, recorded during experimental tests, corresponds to the value of the force which was applied to the eye of the disc

harrow's hitch during computer analyses at the 3D computational model. Working resistance adopted or the analysis at the computational model amounted to 1700 daN. Upon consideration in the computational model of the dynamic force coming from the tools' weight and their working resistance (dynamic surplus ratio k_d =1.6 was applied in the calculations), the value of reaction in the drawbar eye increased to the level of 2140 daN. Maximum value of the working resistance recorded during experimental tests, which amounts to 2190 daN, confirms the correctness of assumptions made and the method of carrying out computer analyses.

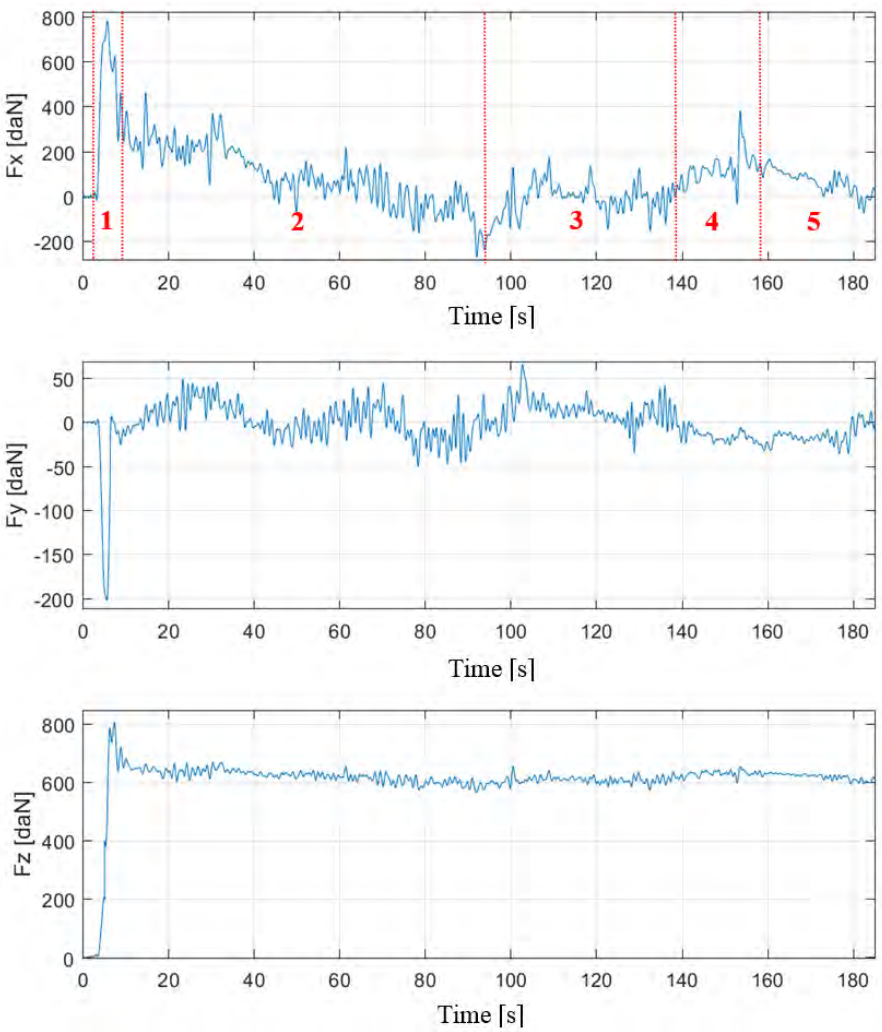

Fig. 3. Exemplary course of forces occurring in the hitch during the transport pass

CONCLUSION

The strain gauge method of values forces determination occurring in the point of connection of two collaborating agricultural machines was presented. The analysis was carried out at the example of a modular device for soil application of digestate. The device consisting of the manure spreader and trailed disc harrow, in one working pass, evenly spreads digestate at the soil area and mixes it and covers it with soil. The construction of the aggregate enables the reduction of energy expenditure as a result of the combination of two treatments in one pass which is in accordance with the

principles of work organization in sustainable agriculture. FEM numerical methods have been used for the build of a 3D model of the modular device and determination of the level of forces at the point of the tools connection. The precision of numerical analyses carried out was verified experimentally with the use of strain gauge techniques. Experimental tests carried out in real conditions of operation allowed for determination of the value of forces occurring in connection during various runs. The course of force obtained allowed to determine average values. The hitch used for the connection of two tools meets the requirements in the scope of the transfer of vertical force. The validation of 3D model of the connection of collaborating tools proved the correctness of the assumptions made.

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SELECTED MECHANICAL PROPERTIES OF POLYPROPYLENE/TPS COMPOSITES AS A MATERIAL FOR FLOWERPOTS AND HORTICULTURE CONTAINERS

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Keywords: polypropylene, starch, flowerpots, mechanical properties, waste management

ABSTRACT
Thermoplastic starch (TPS) was prepared from native potato starch:glycerol:keratin (70:20:10 wt.%) blends and processed using a modified single screw extruder at L/D=16. Recycled polypropylene was mixed with TPS at the ratio of 90:10 and 60:40 and re-granulated at various screw speeds in the extrusion-cooking process. The obtained composites were shaped into big flowerpots using an injection-molding machine. The samples collected from the external pot surface were tested with puncture tests to evaluate the mechanical properties of the material. The addition of 10% of starch-based biopolymer to the recycled PP enhanced the mechanical properties of the tested flowerpots. Selecting the proper composition and processing conditions may help to manage production of pots more sustainable. The results also confirmed the possibility to increase the TPS content up to 40% in horticultural containers and the option of processing such composites with injection-molding as more environmentally friendly than using conventional polymers.

INTRODUCTION

Polymeric composites made from renewable resources, such as starch, flax, hemp or annual plant straw, are potentially the most environmentally friendly materials (Ammala et al. 2011). The demand for new biomaterials is due to, among others, ecological awareness of consumers – who are more likely to choose products from environmentally friendly materials – better and better properties of bioplastics as well as the growing availability of goods made of natural materials or with their addition (Mendes et al. 2016, Vieira et al. 2011). An enormous interest in environmentally friendly materials has inspired the search for new solutions and technologies for the production of such types of biomaterials. The increasing application of plant raw materials for industrial purposes represents an economic opportunity for agriculture (Janssen and Mościcki 2009). It contributes to the functioning of sustainable agriculture and gives the opportunity to utilize surplus starch and straw of annual plants. It also brings a number of benefits (e.g. legal) to manufacturers and users of composite products with added natural resources (Oliveira et al. 2017). In recent years, starch has become one of the basic natural resources used in the production of biodegradable materials (Yu et al. 2013). Biopolymers can be obtained by mixing starch with some plasticizers (often glycerol) in order to let the material melt at a temperature lower than the starch degradation temperature (Da Róz et al. 2011; Morán et al. 2013; Mościcki et al. 2013). This form of starch is known as thermoplastic starch (TPS). Although thermoplastic starch is a cheap

polymer, it has no satisfactory processing capability (Ning et al. 2007). Products based on starch are highly water sensitive. So far, the main challenge has been to replace traditional polymers with biodegradable materials offering the desired stability over the life of the product and having a positive impact on the environment after degradation. The use of different blends of biopolymers with traditional cheaper plastics is thus seen as a compromise to maintain the balance between the properties, costs and biodegradability of materials (Martins and Campomanes Santana 2016; Roy et al. 2011). Biodegradable biocomposites produced from thermoplastic starch enriched with various functional additives in order to accelerate the decomposition of polymer-starch composites can be used to produce environmentally friendly containers by means of the high-pressure injection-molding technique (Oniszczuk et al. 2016). The aim of the study was to obtain some new composite containers for gardening applications using thermoplastic starch as an additive to improve material degradation. Moreover, some mechanical properties of this new flowerpot-shaped polypropylene/TPS composite were evaluated.

MATERIALS AND METHODS

Potato starch (PEPEES S.A., Łomża, Poland), glycerol (POCH S.A. Lublin, Poland) and keratin hydrolyzate (Proteins, Łódź, Poland) were used as thermoplastic starch (TPS) components (Rejak et al. 2012). Thermoplastic starch (TPS) was prepared from native potato starch:glycerol:keratin (70:20:10 wt.%). The raw materials for thermoplastic starch were mixed and TPS granulates were processed using the modified single screw extruder TS-45 (Metalchem, Gliwice, Poland) at L/D=16 (Juśko et al. 2009). The operating parameters were as follows: the screw speed during processing: 80 rpm, the temperature range: 80–110°C, the forming die of 2 mm in diameter. Small pellets (granulates) were collected by a cutting knife and cooled down at room temperature. Recycled polypropylene PP granulate ($MFR_{(190,\ 5kg)}$ 16 g/10 min) purchased from AKPOL (Kraśnik, Poland) was used as the basic polymer material. Polypropylene was mixed with TPS at two composition ratios: PP/TPS 90:10 and 60:40. The obtained mixtures were processed into composites using the above-mentioned single screw extruder at two screw speeds: 50 and 100 rpm. The obtained composites were shaped into 20 L flowerpots by means of the injection-molding technique. The injection-molding machine S+550-3550 (STORK IMM, Hengelo, the Netherlands) was filled with PP/TPS composites, and the formation process was performed at 210°C for 12 sec of process time. Finished flowerpots were collected for further tests. The mechanical properties were tested with the universal testing machine ZWICK Z020/TN25 (Ulm, Germany) with 20 kN load cell. The samples of composite flowerpots of 100x100 mm were cut out from the central part of the outer surface of the pots. Penetration tests were performed using an oval penetrator with 5 mm in diameter with the test speed of 10 $mm \cdot min^{-1}$. The sample was put on the machine's working table and punctured to complete destruction. Some selected mechanical properties were evaluated, such as the maximum force, Young modulus, elongation at maximum force, elongation at break, work at maximum force, and work at break. The Young modulus was evaluated by a secant with the speed of 10 $mm \cdot min^{-1}$. Force–displacement curves were recorded and analyzed with the testXpertII v3.3 software. The mechanical properties were assessed in triple for each composite used the flowerpot component.

RESULTS AND DISCUSSION

The PP/TPS composites were used as the input material for flowerpots due to the TPS property of accelerating the decomposition of polymer-starch products in soil. Besides the environmental advantages, the mechanical properties and resistance to break are extremely important for horticultural purposes. Pots processed with the injection-molding technique based on recycled polypropylene with the addition of TPS need to display sufficient mechanical properties required for the proper protection and cultivation of plants. An advantage of this solution is the re-use of polypropylene due to its recyclability and the application of TPS as a natural component which may improve the decomposition of containers after use. Tests performed to evaluate the mechanical properties showed a significant effect of both the composition of the mixture and the screw speed applied during the processing of PP/TPS composite granulates. Some typical curves from puncture tests are presented in Fig. 1. For PP/TPS composites, they depend on the level of addition of thermoplastic starch and the screw speed applied during the processing of composites. There are significant differences in the behavior of samples in puncture test. The samples of PP/TPS with 10% of thermoplastic starch (Fig. 1a and 1b) were stiffer and much harder than with the addition of 40% of biopolymer (Fig. 1c and 1d).

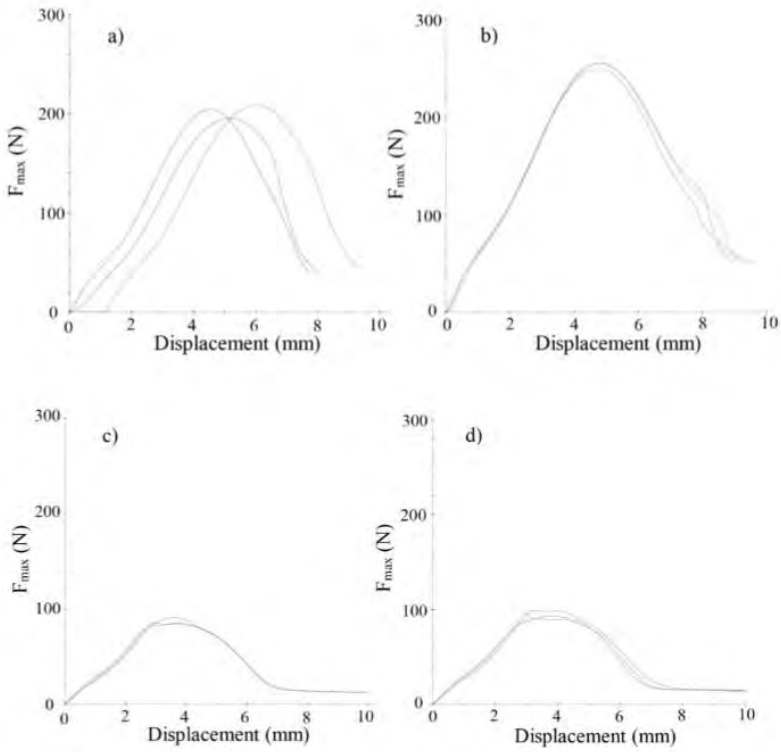

Fig. 1. Typical curves from the puncture tests of PP/TPS composites processed at various screw speeds: a) 90:10 - 50 rpm, b) 90:10 - 100 rpm, c) 50 rpm 60:40, d) 100 rpm 60:40.

One of the most important parameters of horticultural containers is hardness expressed as a maximum force required to break the sample. The results shown in Fig. 1 prove that the addition of 40% of thermoplastic starch to composite blends decreased hardness of the tested materials significantly. Moreover, PP/TPS 60:40 samples did not differ much (around 10 N) across the screw speeds applied during the processing of composites compared with PP/TPS 90:10 where the difference was about 50 N. Similar observations were made for the Young modulus values. This feature also showed values that were

twice as high for the samples prepared on the basis of PP/TPS 90:10 composites (Fig. 2). Higher hardness and Young modulus were recorded during the test of pots made from granulates processed at 100 rpm. A higher screw speed is likely to improve the intensity of treatment inside the extruder barrel, so these composites could be more consolidated offering greater hardness and resistance to stress.

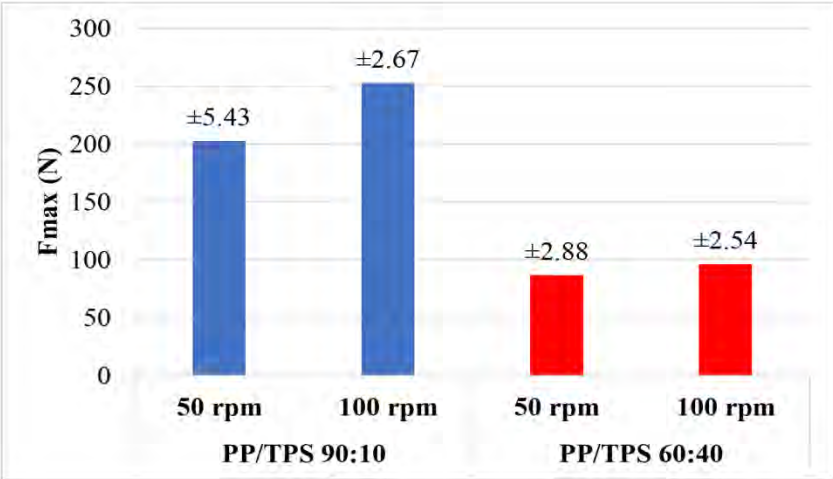

Fig. 2. F_{max} values of PP/TPS composite during puncture test depend on the composition and screw speed applied during processing (mean±standard deviation).

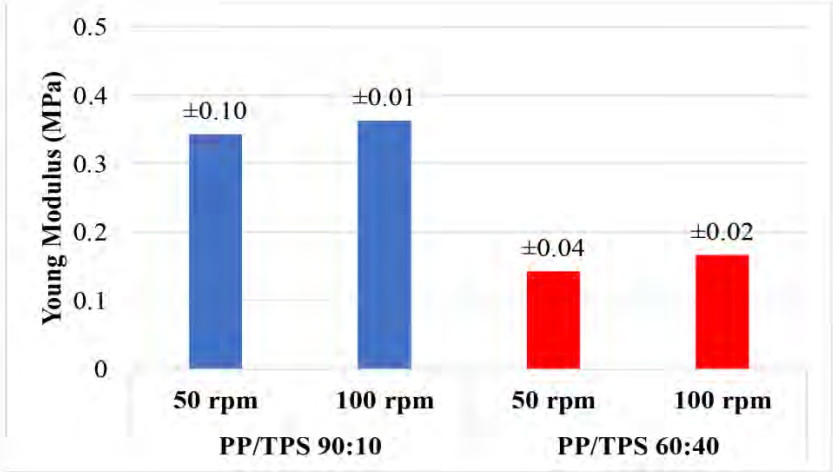

Fig. 3. Young modulus of PP/TPS composite during puncture test depend on the composition and screw speed applied during processing (mean±standard deviation).

The test results for elongation, as presented in Fig. 4, indicate a more intensive elongation of samples made with PP/TPS 90:10 composites, similarly to the results for hardness. Pots processed with composites made from recycled polypropylene and thermoplastic starch are not brittle but elastic, so the elongation varied from 188 to 281% vs. initial thickness. A higher elasticity of samples was reported for those made from composites extruded at lower rpm irrespectively of the recipe applied. More intensive thermomechanical treatment increased hardness and lowered the elasticity of the tested materials. If the samples were harder and less elastic, the work required to break them was greater, as shown in Fig. 5.

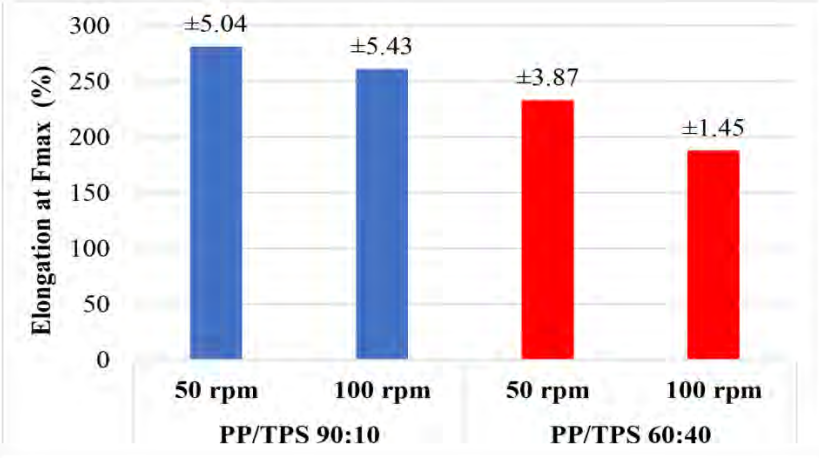

Fig. 4. Elongation at F_{max} of PP/TPS composite during puncture test depends on the composition and screw speed applied during processing (mean±standard deviation).

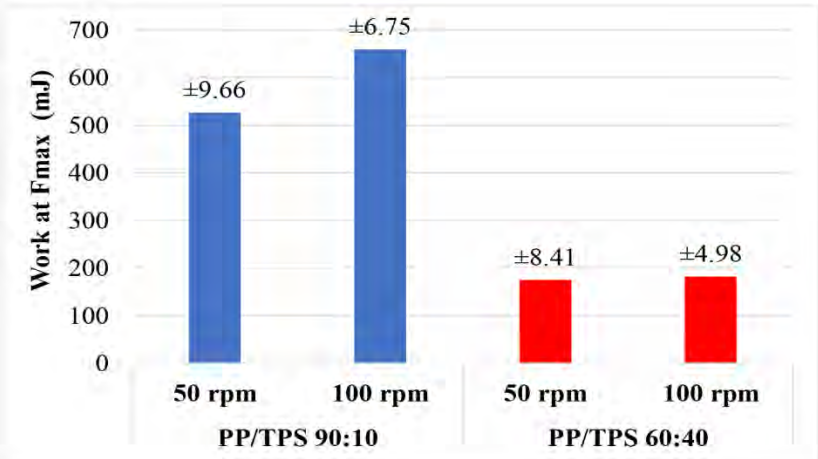

Fig. 5. Work at F_{max} of PP/TPS composite during puncture test depends on the composition and screw speed applied during processing (mean±standard deviation).

The lower values (almost three times) of puncture work were recorded in breaking pots made from the composites of PP/TPS 60:40 as correlated with their lower durability and elasticity. These composites made the material weaker as in the case of a relatively high number of starchy components in blends. For mixed polymer/starch composites, starch is usually added up to 10% (Martins and Campomanes Santana 2016; Ning et al. 2007), and the presented results confirmed this level as better for the quality of containers.

CONCLUSIONS

The discussed results showed the options of use of recycled PP/TPS composites for the production of containers by means of the injection-molding technique. The variable conditions of extrusion-cooking applied to prepare the granulate of PP/TPS composites had an impact on hardness, durability, and elasticity of achieved materials. The application of TPS as an additive to recycled polypropylene could be an effective solution in improving the sustainability of plastic waste management. TPS is biodegradable, so its addition to composites with polymers could accelerate the decomposition of this material in soil. An addition of 10% of starch-based biopolymer to recycled PP produces better mechanical properties, such as greater hardness, Young modulus and elasticity of the tested flowerpots, than 40% of the additive. Nevertheless, the results confirmed the possibility of effective materials and processing management during producing

flowerpots and horticultural containers with the TPS content of up to 40%. Such composites are also processable with injection-molding. Based on these findings, a new range of environmentally friendly composites has a potential to be applied in garden containers.

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ASH COMPOSITION AND DEPOSITION TENDENCIES OF SELECTED BIOMASS TYPES

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Keywords: Sustainable development, Biomass, Ash, Slagging, Fouling

ABSTRACT
Replacement of fossil fuel with renewables including biomass is one of the ways to ensure sustainable development. Biomass incineration is most frequently used energy conversion technology. Notwithstanding that ash arising from the biomass incineration process may cause problems with boiler furnace ash slagging and fouling. This paper presents the resulting figures for computation of indicators that may be used for anticipating ash reaction in respect of selected biomass type. The analysis of those indicators has proven that the Sunflower husks is characteristic of the highest risk of ash slagging and fouling, and Miscanthus Giganteus and wheat straw are characteristic of the lowest risk of ash slagging and fouling.

INTRODUCTION

The idea of the sustainable development is the major drive force in paving the way towards the sustainable economic growth alongside the long-lasting access to natural resources and preservation of natural environment as a value (Wasiak, 2017). Replacement of fossil fuel with renewables, mainly agriculture-derived renewables, is commonly considered to be one of the ways to ensure sustainable development. Nowadays biofuel has not only aroused theoretical and scientific interest but has also developed to occupy a considerable fuel market share to represent the strategically significant sustainable energy source (Wasiak, 2017).

Out of all the types of biofuel that are commonly used, biomass is currently taking on significance as it follows charcoal and crude oil as far as the largest source of primary energy is concerned in the world. Biomass incineration is the most developed technology of conversion of biomass into energy, and biomass incineration in small power boilers is one of the ways to use it for energy purposes (Mirowski, 2016). Biomass may be incinerated as it is or in the processed form of briquettes or pellets but compact fuel gains more and more popularity due to its advantageous usability (Obidziński, 2014; Szyszlak-Barglowicz and Zajac, 2015; Szyszlak-Barglowicz et al., 2015). Notwithstanding the benefits that arise from biomass incineration, organisation of that process is still a huge challenge (Zajac et al., 2017). There are numerous reasons for that and among them the significant issue arises from creation of ash that is the product of incineration when the incineration is still a continuing process and when it is completed (Niu et al., 2016). Reaction of ash derived from the biomass incineration affects operations of the boiler. Although the ash content in biomass is much lower than in charcoal, its source of origin and chemical composition affect the boiler inter alia causing slag and ash to deposit on the boiler furnace to a greater extent, faster wear-and-tear of metal boiler pieces in effect of corrosion. Those problems may cause operating expenses to rise and equipment efficiency and accessibility to diminish (Vamvuka and Zografos, 2004).

Ash deposition-related problems depend on both the boiler construction design and operational conditions, as well as fuel composition (Ma et al., 2007). Biomass source of

origin has a considerable impact upon ash properties. Ash reaction in the boiler furnace may be assessed by means of parameters defined in literature (Bryers, 1996; Vamvuka and Zografos, 2004; Pronobis, 2005; Viana et al., 2012; Garcia-Maraver et al., 2017).

The aim of the study has been to define chemical composition of ash derived from varied types of biomass and on that basis to assess ash slagging and fouling of the boiler furnaces, making use of indicators available in related scientific literature.

MATERIAL AND METHODS

For the purpose of the study 9 most popular biomass sources used for energy purposes in Poland have been analysed. This has been biomass derived from wood industry waste in the form of pine wood chips, lignocellulosic biomass in the form of oak timber, energy crops: willow coppice, poplar, Sida Hermaphrodita, Miscanthus Giganteus, agricultural waste: wheat straw and rape straw and food production waste in the form of sunflower husk.

The study objects had been prepared in compliance with PN-EN 14778 standard. Primary biomass composition was defined by means of CHNS analyser made by LECO. Ash content was defined in compliance with PN-EN ISO 18122 standard. Measurements were made by means of LECO TGA 701 instrument, according to the thermogravimetric method. Incineration heat was defined by means of working probes. It was performed in conformity with PN-ISO 1928 standard, and LECO AC600 calorimeter was used for measuring purposes. Ash content was analysed by means of Thermo iCAP 6500 Duo ICP plasma spectrometer using ASCRM -010 as the reference substance. In the case of ash the following was defined: silica as SiO_2, iron as Fe_2O_3, aluminium as Al_2O_3, calcium as CaO, magnesium as MgO, phosphorus as P_2O_5, sodium as Na_2O, potassium as K_2O.
Based on the ash chemical composition expressed as major oxides, the ultimate and proximate analysis was conducted, and the ash slagging and pollution indices were computed according to the correlations referred to in related papers (Bryers, 1996; Vamvuka and Zografos, 2004; Pronobis, 2005; Viana et al., 2012; Garcia-Maraver et al., 2017):

Base to Acid index (B/A)

The ratio of basic to acidic compounds is considered to be an index for predicting ash deposit inclination. The Base to Acid index was calculated according to the following equation formula:

– ——————— (1)

The lower the B/A value was, the higher the ash melting and flowing temperature was, and thus the risk of ash slagging was lower.

If the B/A<0,15 the danger of slagging decreases, if B/A temperature exceeds 1600°C. Since: it is plausible to anticipate that slagging tendency if the B/A <0.75 (Pronobis, 2005).

Slagging (Babcock) index (Rs)

The Rs index is based on the B/A ratio, but it considers the sulphur content [16] because of previous observations referring to sulphur-containing biomasses with the formation

of deposits enriched in alkali sulphates, which are unstable at typical combustion temperatures. The Rs Index was computed according to the following equation formula:

$$R_s = \left(\frac{B}{A}\right) S^d \quad (2)$$

where:

S^d – is the percentage of S in dry fuel

If Rs < 0.6, low slagging inclination; if 0.6 < Rs < 2, medium trend; if 2.0 < Rs < 2.6, high trend; if Rs > 2.6, very high trend (Pronobis, 2005).

Alkali Index (AI)

The Alkali Index expresses the quantity of alkali oxides in the fuel per unit of fuel energy. AI was calculated according to the following equation formula:

$$= \frac{(\qquad)}{} \quad (3)$$

where:

A – ash concentration obtained in temperature of 550°C

HHV – is the Higher Heating value ($MJ \cdot kg^{-1}$)

When AI > 0.17 kg/MJ fouling or slagging is probable, if AI < 0.34 fouling or slagging is virtually certain to occur.

Sintering index (SI)

The Sintering index (SI) [18] was calculated according to the following equation formula:

$$= \frac{\qquad}{} \quad (4)$$

If SI> 2 no slagging should be expected, If SI <2 the slagging risk should be high.

Iron to calcium ratio

The IC indicator, being the ratio of iron oxide to calcium oxide, was computed according to the following equation formula:

$$= \frac{\quad}{} \quad (5)$$

If IC < 0.3 or IC > 3.0, pollution susceptibility is low and if 0.3 < IC < 3.0, it is high.

Slag viscosity index (Sr)

This index calculates the percentage of silica in the basic compounds of the ash, excluding the alkali compounds. The Sr was calculated according to the following equation:

$$= \frac{\qquad \cdot \qquad}{} \quad (6)$$

High Sr values correspond to high viscosity, and hence to low slagging tendency. If SR> 72, it indicates low slagging inclination, if 72>SR> 65 medium, SR< 65 high.

RESULTS AND DISCUSSION

After having analysed the resulting figures of the study of biomass and chemical composition of ash obtained in the temperature of 550°C, it was concluded that the prevalent feature of lignocellulosic ash was high calcium content. Straw ash mainly contained silica and potassium. Out of the energy crops under consideration, Sida Hermaphrodita ash contained substantial quantity of calcium and potassium alongside small content of silica whereas Miscanthus Giganteus ash contained most of potassium and silica. The Sunflower husks ash contained most of potassium – the highest content amongst the biomass under consideration. All the types of biomass were characteristic of low sulphur content. Ash content in fuel such as biomass is a fairly complex issue. Ash quantity is pre-conditioned by the content of organic matter, inorganic matter, and possible biomass pollution. Besides, incineration temperature also has the impact upon the quantity of obtained ash. It also bears noting that the very information on the quantity of ash is not complete if it is not interpreted in relation to the origin of biomass composition. Ash content in the biomass under consideration ranged from 0,31 to 9.98%. Lower values were obtained for the lignocellulosic biomass and the highest - for straw and sun flower shell.

The indices computed according to the equation formulae 1-6 have been presented in the Table 1. In relation to the values corresponding to the ash slagging and fouling, the resulting figures were marked as extremely high (E), high (H), medium (M) and low (L), in conformity with the study methodology.

Table 1. Ash content in biomass for boiler furnace.

	B/A		Rs		AI		SI		IC		Sr	
	value	risk	value	risk	value	risk	value	risk	value	risk	value	risk
Pine (wood chips)	6.24	E	0.06	L	0.42	M	4.29	L	0.05	L	13.68	H
Oak	3.67	E	0.04	L	0.25	M	2.86	L	0.03	L	21.12	H
Poplar	4.19	E	0.21	L	1.04	M	2.64	L	0.01	L	23.71	H
Willow Coppice	2.51	E	0.05	L	1.56	M	2.63	L	0.01	L	34.82	H
Sida Hermaphrodita	6.48	E	0.37	L	4.68	L	1.29	H	0.02	L	18.72	H
Miscanthus Giganteus	0.80	M	0.01	L	5.86	L	0.50	E	0.10	L	77.98	L
Wheat Straw	0.60	M	0.02	L	8.11	L	0.49	E	0.13	L	82.30	L
Rape Straw	1.41	H	0.11	L	14.33	L	0.43	E	0.13	L	66.86	M
Sunflower husks	15.53	E	2.58	H	25.12	L	0.41	E	0.23	L	16.46	H

Taking into consideration exclusively the B/A indicator, it is plausible to state that nearly every type of the biomass under consideration has been characteristic of high or

very high ash slagging inclination, except for Miscanthus Giganteus and wheat straw. However, due to the low Sulphur content in the biomass under consideration, Rs index is indicative of low ash fouling. The remaining indicators actually are derivatives of various values of respective components of biomass ash. Lignocellulosic biomass has had higher values of AI and Sr indicators whereas energy crops and straw biomass has had higher values of SI indicator and lower values of AI and Sr indicators. This may be explained by the lower value of alkali content (K and Na) in the lignocellulosic ash.

Given the analysis of the resulting indicators, it has been concluded that the Sunflower husks biomass is characteristic of the highest risk of ash slagging and fouling, and wheat straw and Miscanthus Giganteus biomass is characteristic of the lowest risk of ash slagging and fouling.

However, it bears noting that the designated indicators do not provide fully credible information on the growth rate of deposited formation in the boilers because they exclusively depend on the biomass chemical composition. Furthermore, even in relation to the specific biomass, soil conditions, harvesting periods and various biomass parts may have an impact upon diversified quantity and ash chemical composition (Niu et al., 2016).

CONCLUSIONS

Chemical composition of ash is one of the major problems connected with the use of biomass for energy purposes. Main problematic issues are represented by ash components, namely alkali metals (K, Na), alkaline earth metals (Ca, Mg) and Silicon, Chlorine and Sulphur. The resulting ash pollution indicators for boiler furnaces in the case of the types of biomass under consideration do not clearly indicate ash slagging or fouling tendencies but suggest the risk of technical problems during boiler operations. The Sunflower husk is the exception because its indicators clearly indicate that its incineration may cause considerable problems. With regard to the above, further research is needed in the context of varied incineration technologies and boiler operational conditions, taking into consideration variables of various types of the biomass.

Taking also into consideration that the ash chemical composition also results from the fertilisation manner, cultivation procedures or harvesting period, research must be conducted to avoid accumulation of hazardous elements during cultivation.

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THE ASSESSMENT OF WEAR METAL CONCENTRATION IN ENGINE OILS ORIGINATING FROM AGRICULTURAL TRACTORS IN THE ASPECT OF THEIR OPERATIONAL PROPERTIES

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Keywords: engine oil, farm machinery management, agricultural tractors, wear metal concentration, oil-change interval

ABSTRACT
One of the paths leading to the development of sustainable agriculture is to reduce the amount of energy lost during agricultural production. This can be accomplished through proper farm machinery management. The engine oil obtained at the end of the oil-change interval may be a valuable source of information on the processes and causes of wear of the tribological systems of the engine. This paper presents the results of studies on the wear metal concentration (Pb, Cr, Ni, Fe) in engine oils, taken from selected agricultural tractors, which were subject to replacement within the timeframe specified in the maintenance schedule. The statistical analysis of the test results has not revealed any statistically significant differences in the concentrations of the investigated elements in the used engine oils, depending on the mileage. Nevertheless, the calculated coefficients of correlation indicate a positive, weak correlation between the analysed elements and the engine oil consumption processes under operating conditions.

INTRODUCTION

One of the paths leading to the development of sustainable agriculture is to reduce the energy expenditure. Therefore, tractors and farm machines should be as much efficient as possible, both in terms of their power units and their power trains (Bietresato et al., 2015). Tractors and farm machines are characterized by a great variety of types and constructions, extended life span, and a high variability of working conditions compared to other vehicles. Such complex operating conditions are strongly influenced by the unique nature of agricultural production: tractors are used in variable weather conditions, they are operated with varying intensity during the year, they are associated with seasonal work and are driven mainly off-road.

Non-operational factors, such as technical preparation of tractor operators as well as the quality of maintenance and repair facilities are also important (Tomczyk, 2009, 2012). All of these factors affect the specific (depending on the tractor type) wear processes including engine oil consumption.

One of the basic tasks that must be undertaken to protect tractors from adverse operating conditions is to carry out, on a regular basis, the replacement of parts and consumables (Buchwald and Staszak, 2013; Rybacki and Buchwald, 2013). Lubricating oil, without which the engine would not be able to function properly, can operate in the engine as long as it performs its tasks properly (Wolak and Zając, 2017). Delays in servicing or replacing the consumables with improper substitutes can result in undesirable machine failures (Osuch et al., 2016).

According to research (Jósko and Kołodziejski, 2008), one of the fundamental mistakes made by users of agricultural tractors is the failure to keep oil change periods. Another problem is the poor quality of technical services provided by local garages, including

the use of improper oil. The engine oil obtained at the end of the oil-change interval may be a valuable source of diagnostic information. The presence of impurities in the oil depends mainly on the intensity of the wear process, and - to a small extent - it might result from a direct contact with the fuel or the cooling fluid. The analysis of the metal content of the used engine oil can provide information on the wear range of the metal parts of the engine. This paper presents the results of studies on engine oils (collected from selected agricultural tractors), which were subject to replacement within the timeframe specified in the maintenance schedule. The major parameter of the evaluation of oils was the concentration of selected heavy metals (Pb, Cr, Ni, Fe). Within the scope of research tasks, the analyzed engine oil samples were classified based on the empirical data obtained. The analysis was partly conducted with the use of selected tools for exploring and grouping data: agglomeration method (with a single bond algorithm) and the Euclidean distance formula.

MATERIAL AND METHODS

The test material consisted of engine oil samples obtained at the end of the oil-change interval. The samples were collected from various agricultural tractors (of different manufacturers and power classes). The oil samples were qualified based on the oil-change dates recommended by the tractor manufacturers. They were obtained from service companies dealing with the repair of agricultural tractors and individual farmers from the area of the Lublin Voivodeship.

Due to the fact that the structure of the inspection plan and the replacement of oil in agricultural tractors is different in terms of frequency for each type of tractor, it was decided to put the collected oil samples into 4 groups, according to the tractors' operating history.

A1-3 oils were collected from tractors of up to 100 mth, B1-7 oils were from tractors with a mileage of 100-400 mth, C1-7 oils were collected from tractors with a mileage of 400-1000 mth, and D1-4 were collected from the tractors with a mileage of over 1000 mth.

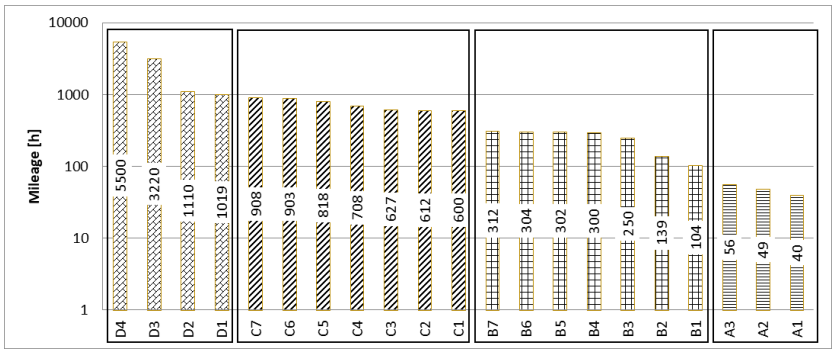

Fig. 1. The number of hours operated by each agricultural tractor

The study was conducted using the XOS HDMaxine analyzer. This is a multi-element tool for determining trace elements in liquid samples on a hydrocarbon matrix, based on high resolution X-ray fluorescence (High Definition X-ray Fluorescence- HDXRF). The contents of the wear elements, i.e. Pb, Cr, Ni and Fe, were determined using the XDMaxine apparatus. All of the analyzes were performed in triplicate for each sample.

The results obtained were statistically analyzed using the STATISTICA software program. To investigate the dependence of the tractors' operating history (including heavy metals), scatter plots with regression line and correlation coefficient were applied

in the analysis of the used engine oils. The research task was to first classify the examined samples so as to extract relatively uniform groups, representing samples with similar concentrations of wear metals.

Of the many methods available for cluster analysis, the agglomeration method was selected (hierarchical classification), in which algorithms are used to group objects in increasing clusters using the selected distance measure (Euclidean). In the basic version, the agglomeration method consists of the following steps: a definition of grouping objects (or cases) and their characteristics, a definition of distance metrics between objects, a selection of the algorithm to calculate distances between clusters.

The last of the necessary steps to allow the analysis of clustering by agglomeration method is to choose an algorithm with which the distance between object classes can be measured. The commonly applied single bond method, also known as the nearest neighbor method, was used in the study. In this method, the distance between the two clusters is determined by the distance between the two nearest neighbors belonging to different clusters.

RESULTS AND DISCUSSION

The results of the determinations of heavy metals in the used engine oils are shown in Figure 2. The obtained data indicate that the concentrations of metals were quite different depending on the type of machine, type of oil, and mileage.

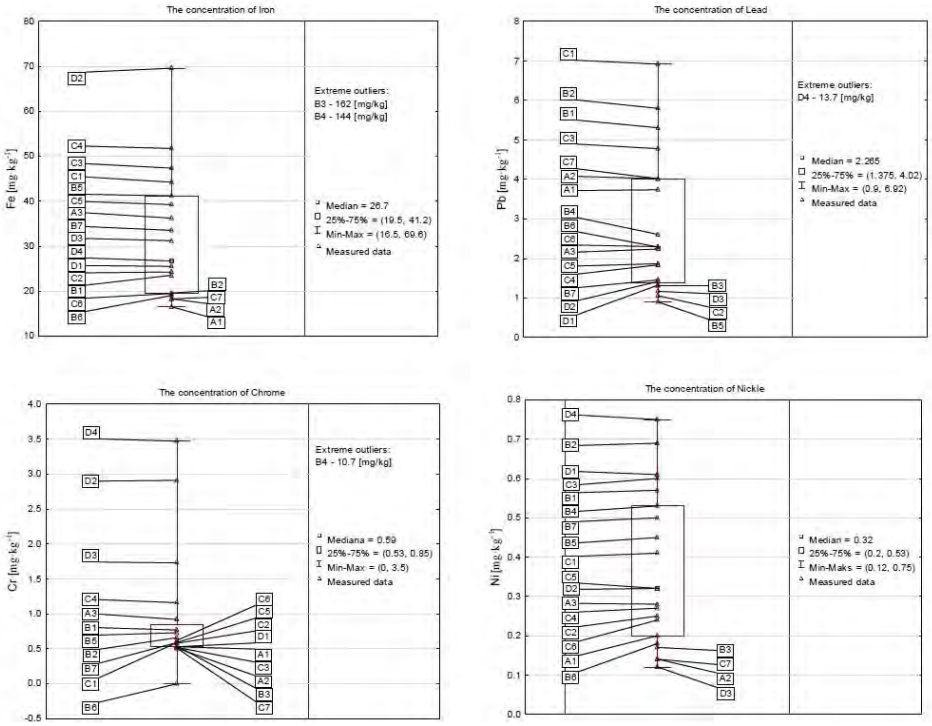

Fig 2. The concentrations of metals

The average lead concentration in the samples was 3.34 mg·kg^{-1}. The lowest value was recorded for sample B5 (0.9 mg·kg^{-1}), and the highest for sample D4 (13.71 mg·kg^{-1}). Such high Pb concentration in sample D4 resulted in a very high coefficient of variation, which amounted to 88%. The concentration of nickel in the samples tested was on the level from 0.12 to 0.75 mg·kg^{-1} (on average: 0.37 mg·kg^{-1}). The variability of concentration was characterized by a high coefficient of variation of almost 53%. The

chromium concentration in the samples tested fluctuated from 0 for sample B6 up to 10.7 mg·kg^{-1} for sample B4. The average concentration was on the level of 1.39 mg·kg^{-1}. As a result of a very high concentration of this element in one of the samples, the coefficient of variation was as high as 164%. In the samples tested, the lowest iron concentration was found in sample A1 (16.5 mg·kg^{-1}) and the highest in sample B3 (162 mg·kg^{-1}). Due to a very high Fe concentration in two samples (exceeding 100 mg·kg^{-1}), the coefficient of variation was at 90%.

The second part of the empirical analysis focuses on identifying the similarities and differences between the analyzed oils from the perspective of the selected criteria (wear metals). The results presented in the form of dendrograms (hierarchical method) are shown in Figure 3.

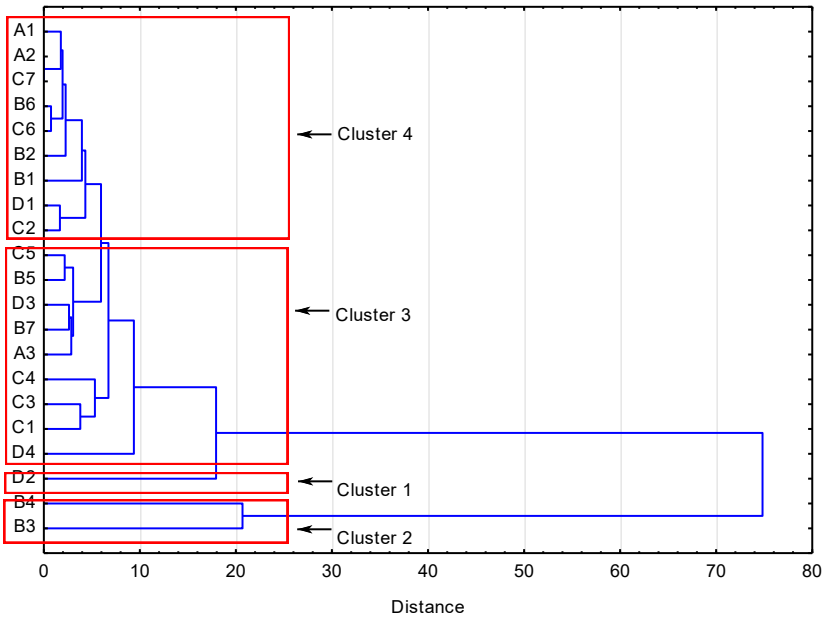

Fig 3. Dendrogram (Euclidean distance)

As a result of the conducted classification, 4 groups of engine oils were identified. The groups were called: cluster 1, 2, 3 and 4. The first group contains only one oil (D2), the second one – two (B3 and B4), the third group – 9 oils (A1, A2, C7, B6, C6, B2, B1, D1, C2), and the fourth one – another 9 oils (C5, B5, D3, B7, A3, C4, C3, C1, D4). Cluster analysis is used to identify groups in which oils are most similar to each other in terms of the analyzed wear metals. These are: A2 and C7, B6 and C6, plus D1 and C2, respectively. The most alienated oils are the ones belonging to clusters 1 and 2.

Comparing the received clusters with the groups formed on the basis of mth, it can be concluded that the mileage does not affect the concentrations of Fe, Pb, Cr and Ni. To further verify whether there is a statistical relationship between the mileage and the concentrations of wear metals, scatter plots with regression line and correlation coefficient were used. The analyzed oils, from the perspective of the mileage (expressed in mth), are strongly asymmetrical; that is why, the logarithms of mileage were applied to make scatter plots and to check correlation.

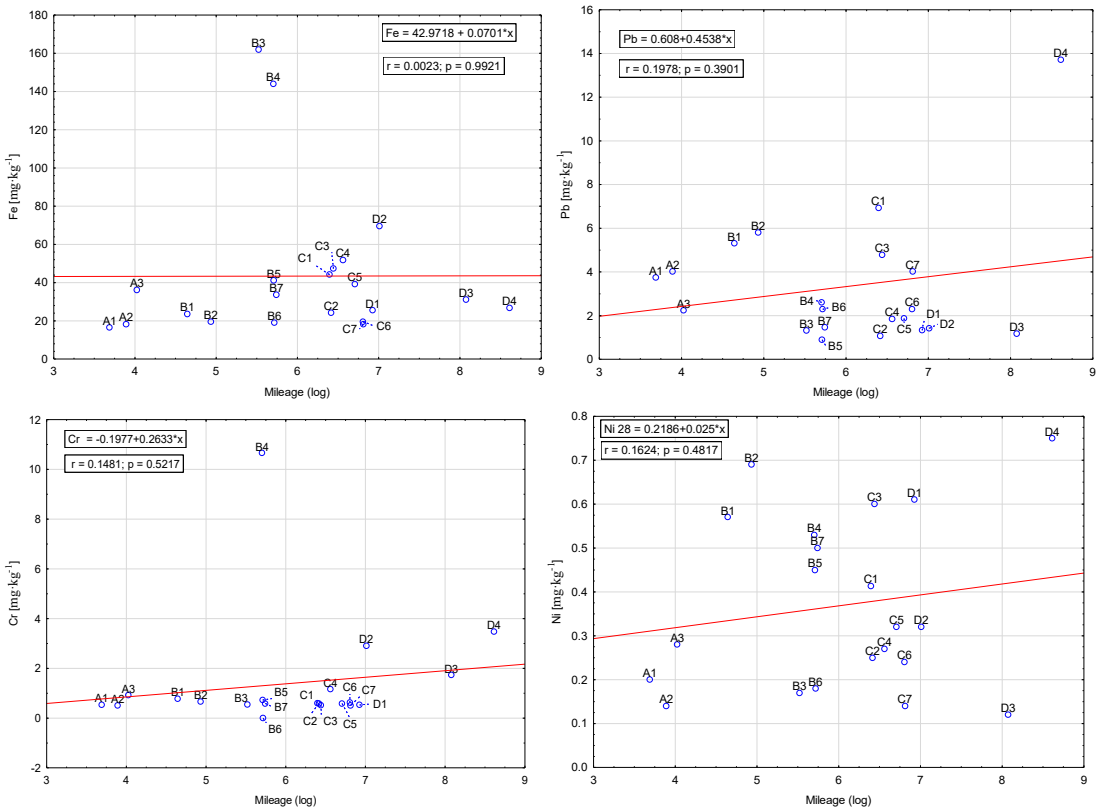

Fig 4. Scatter plots with regression line and correlation coefficient

When analyzing the received significance levels (0.9921; 0.3901; 0.5217 and 0.4817), it was found that all of them are above the limit value (0.05) and therefore they should be deemed statistically insignificant. It may be then concluded that there are no statistically significant differences between the tractor mileage (log Mth) and the concentration levels of wear metals. The correlation coefficients indicate that in all four cases a positive correlation was obtained, confirming that an increase in the analyzed chemical elements is related to the process of wear and tear during operation. The highest correlation coefficient was obtained for Pb (r=0.2). According to J. Guilford's terminology, this is indeed a weak correlation. Very slight (positive) correlation was obtained for Fe (r=0.002). Moreover, scatter plots with regression lines and correlation coefficients indicate strong outliers. These are the following engine oil samples: B3 and B4 (Fe), B4 (Cr), and D4 (Pb).

CONCLUSIONS

Mistakes in technical operation of agricultural machinery, especially the ones affecting combustion engines, may lead to accelerated wear of their components, which in turn oftentimes translates into higher costs of necessary repairs (Osuch et al., 2016). One of the most essential tasks that must be undertaken to protect tractors from adverse operating conditions is to carry out the replacement of consumables at regular intervals. The engine oil obtained at the end of the oil-change interval may be a valuable source of information on the processes and causes of wear of the tribological systems of the engine. The applied XRF method, unlike other methods, makes it easy to determine the concentrations of elements in a very wide measuring range (Pouzar et al., 2001; Zając et al., 2015).

Based on the research findings and the discussion, the following conclusions have been made:

1. The obtained correlation coefficients confirm a weak, positive correlation between the concentrations of the analyzed wear metals and the tractors' mileage (expressed in mth). Consequently, the complex operating conditions of agricultural tractor engines may lead to unpredictable changes in lubricating oils.
2. The wear metals examined (Fe, Pb, Cr, Ni) show a large variety of concentrations. The highest coefficient of variation was calculated for Cr (164%), then for Fe (90%), and Pb (88%). The lowest coefficient of variation was determined for Ni (53%). Therefore, it is difficult to accurately predict the concentrations of the analyzed wear metals in engine oils.
3. Statistical analysis of the study results did not show any statistically significant differences in the concentrations of the analyzed wear metals found in the used engine oils, depending on the mileage. Hence, when evaluating the concentrations of wear metals in engine oil, each element should be assessed individually and full attention should be paid to any noticeable increases in the concentrations.
4. As a result of the use of the agglomeration method (cluster analysis), 4 groups were identified in which engine oils are most similar to each other in terms of the concentrations of the analyzed wear metals. These are: A2 and C7, B6 and C6, plus D1 and C2, respectively.

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THE INFLUENCE OF BIOMASS CULTIVATION TECHNOLOGY (SELECTED TYPES) ON THE SELECTION OF MACHINES FOR ITS HARVEST

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Keywords: sustainable agriculture, biomass, harvesting technology, machines selection, harvest

ABSTRACT
The selection of machines and their mode of operation in a given biomass technology depends on the plant species. The date and multiplicity of harvest also depend on the species of the plant and its destination. Under national conditions, energy crops are harvested in late autumn and winter when the plants are in a state of rest and have a resting vegetation. The aim of the study was to analyze the selection of biomass harvesting machines depending on the technology of growing plants belonging to solid biomass. Basic criteria were identified, which included the selection of machines for harvesting certain types of solid biomass. The selection of machines for different technologies of solid biomass harvest is made taking into account their division into groups gathering similar plants. Within the framework of the work, a flowchart of the selection of technical means for the applied technology of solid biomass collection was prepared taking into account the above division and the principles of sustainable agriculture.

INTRODUCTION

Machine selection and the way they are exploited in certain technology of energetic plants harvesting depend on plant species. The term and multiplicity of harvest also depend on plant species and on its purpose. It is one of the rules of sustainable agriculture. Under national conditions, plants designed for energetic purposes are harvested in late autumn and winter period, when the plants are in state of rest and their vegetation is stopped. In the period of the year appears bad weather conditions, the soil has a high moisture content, sometimes there is snow cover. For these reasons it would be advisable, that machines used in certain harvesting technologies were equipped with caterpillar track systems or wide tires.

Selection of machines for different technologies of plants harvesting was made according to divide into three groups:

- trees and bushes, including tree branches,
- grass
- perennials.

BASIC RULES OF HARVESTING MACHINES COMPLETATION

With consistent with the principles of sustainable agriculture choice of machine for biomass harvesting for energetic purpose, it is very important to consider a biomass production volume and owned tractor. Choice of machines and tractors should provide to accomplish the harvest of plants for energetic purpose in the most gainful term and short time. Then the number of tractors and the groups machines efficiency shouldn't be to large due to over-investment farm over the facility of it accumulation (Muzalewski 2008). In case of using tractor it's recommended to consider the tractor maximal power, which will be cooperate with biomass harvesting machines. Machines should be assort

in the way which allow to used 70% to 85% nominal power of engine and about 80% of engine load during the work of tractor. The parameters allow achieved the lowest fuel consumption by tractor. Purchase the machine should to contribute to improve production organization, keeping agro technological harvest terms and work safety regulations.

Assorting machines for solid biomass for energy purposes, the worker should consider (Muzalewski, 2015; Zbytek and Adamczyk, 2017):

- acreage,
- farm level of advancement and economic potential,
- way of mechanization of harvesting,
- environment factor,
- topographical factor,
- economic factor.

The basic parameter which define need of machine application is exploitation efficiency – ability to accomplish define work during the day in farm condition. Exploitation efficiency W_{07} is equal to (1):

$$W_{07} = \frac{k \cdot A \cdot T}{T_h} (ha \cdot hour^{-1}) \tag{1}$$

where:

A – area of cultivation for harvest (ha·year)
T – recommended time of machine exploitation (20 – 25 years)
T_h – machine exploitation potential in define time (hours)
k – correction factor (0,5 – 0,75).

In many cases, solid biomass harvesting is making with machines from other plants harvesting technologies. Often there is basic equipment in farms. However sometimes, biomass harvesting is making by using specified machines, which are destined to harvesting only one group of plants. These are machines which are used not so often during the year, functional and construction differentiation is typical for them. In the case these are the most expensive machines, so decision of using them should be preceded by rigorous analysis about efficiency in work on farm, provision of services and collective machine exploitation.

The criterion of minimal exploitation W_R^N, which is using for rating purchase and exploitation is equal to (2):

$$W_R^N = \frac{k \cdot T_H}{T} (hour \cdot year^{-1}) \tag{2}$$

Where the symbols have the same meaning as in the equation (1)

It is alleged that purchase of the machine is worthwhile, when W_R exploitation is 20% lower than minimal machine exploitation per year in accordance with $W_R = 0{,}8 W_R^N$.

In many cases planter has to harvest solid biomass for energetic purpose in short agrotechnological term. It is the rough term, which is dependent to weather in a year, soil conditions and vegetation period of cultivated plants. Which means that worker should assess the number of machines for defined biomass harvest area $\mathbf{i_m}$. It can be calculated by (3):

$$i_m = \frac{S}{W_{07} \cdot T_{07} \cdot T_a} \tag{3}$$

Where:

S – cultivation area (ha)
T_{07} – shift time (hour)
T_a – days of agrotechnological term (hour)

To assure continuous work of major machine, worker should select appropriate number of transport devices. Time of machine stop which is an effect of incorrect number of transporting devices in result extend the work time. So, the cost is increasing too. For example, depending on machine constructions and work technology we can divide it for some variants of cooperated work of transport group, harvester or chaff-cutter:

- transport group is moving alongside major machine, material is transported constantly,
- transport device is mounted to major machine,
- machine has its own tank, where material is collected. The trans-shipment take place periodically without stopping machine for loading,
- machine left behind on the ground compacted a briquetted material in shape of poll or filled containers for example sack in big-bag type, which are lading on the transporting vehicles by hay-loader or self-propelled loader.

Many times, user is selecting transporting device for harvesting solid biomass basing on experience or he is using the index method, which is based on adapting criterion (Muzalewski 2015):

- number of transport devices to number of tractors used on farm,
- load of transport devices to drag force of tractors,
- load of transport devices to farm area.

Depending of future cultivation technology, a user selects technical resources.

Coverage which is pertained to select technical resources is showed below:

Type of harvested biomass (plant) → estimate of biomass yield → owned tractor → area of plantation → harvest → selection of major machine for harvesting → loading → transport (select of transport resources)

Block diagram which showed selection of technical resources to solid biomass harvesting technology is presented on Figure 1.

HARVEST OF BUSHES INCLUDING TREE BRANCHES

Short rotation trees and bushes like salix viminalis, populous, robinia pseudoacacia, rosa multifolra are energetic plants. The harvesting takes place when the vegetation period

ended and plants are in rest state. Salix viminalis is harvested every two, three or four years and populous every five, six or seven years (Towpik 2011). Taking in mind higher and thicker populous sprouts than salix sprouts, for harvesting populous, are used machines which are exploited for timber deciduous and coniferous trees in forestry.

Care of the apple trees orchard is integral with works such as: winter pruning, summer pruning and new seedlings which are generate much waste as cutted of branches. Averagely from 1 ha of apple trees orchard 3,5 Mg waste (branches) is created per year from winter pruning. There must be added about 1,5 $Mg \cdot ha^{-1}$ wastes from new seedlings (Hetsh 2008; Podlaski, 2010; CIRECE Report, 2013; Dyjakon et al., 2016). Now, that branches are usually raked (manually or with tractor which cooperate with loaders and hay rakes), collected from interrows, gather in prism shape, burn or crumbed by many types of branch grinders or mulchers and throwed around the trees (the action often creates risk of trees illness which has negative influence on future fruit quality). In last years a problem of developing these wastes lays in minds of orchardists and scientists. Nowadays methods of gathering branches, lefts in orchards after pruning, are such as chipping machines mounted to tractors or in limited part pressed by round baler and square baler (Dyjakon et all. 2016).

From the groups plants are collected by single or two-phase method. Characteristically for the single-phase harvest is cutting and crumbing plants at the same time. In this way woodchips are created and transported for transport devices. Two-phase harvest is divided into two independent phases which take place during the work of different machines. During the first phase plants are cutted and left behind as interrows. During second phase, dry plants are crumbed on the field or on the farm.

GRASS HARVEST

Machines which are used in harvesting green plants are the same as machines in solid biomass harvesting. Harvest of grass for energetic purpose should take place in early spring, when moisture of the harvested plants is the lowest. Fall harvest is possible, but then is necessary to use mowers with conditioner. Mowed material can be gathered by chaff-cutter or square baler, round baler or large size press.

PERENNIALS HARVEST

Sida hermaphrodita, helianthus tuberosus, reynoutria sachalinensis can be added to the group of plants for energetic purpose. Sida hermaphrodita is cultivated for fodder and biomass purpose, which include bio-gas production. Machines which are used in harvesting perennials and in harvesting green plants and potatoes are the same.

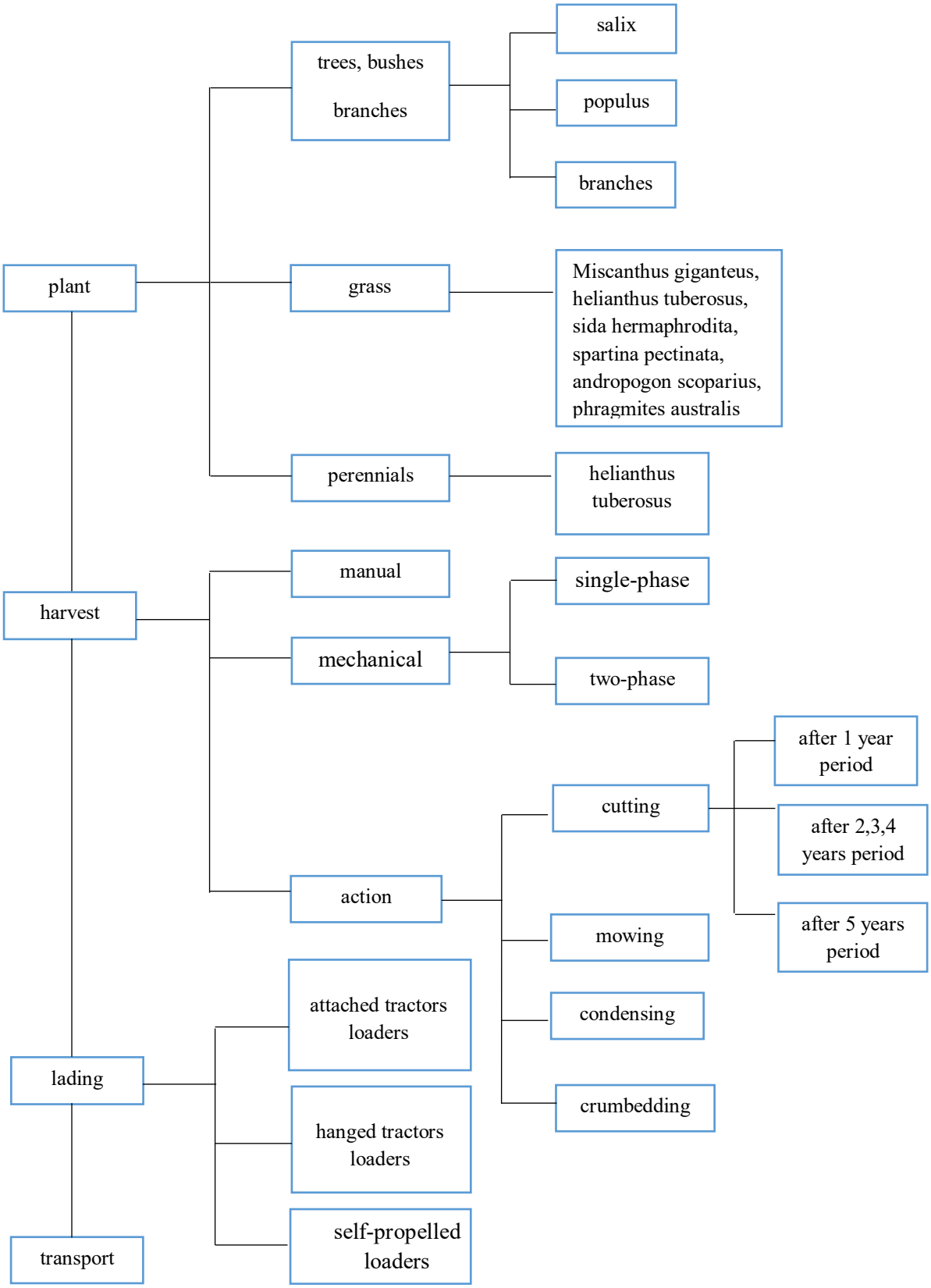

Fig. 1 Block diagram presenting selection of technical resources towards biomass harvest technology (source: own work)

CONCLUSIONS

The solid biomass for energy purposes for technical resources selection guidelines were created. Attributes which should be predicted during plantation founding and which are important for technical resources selection were set down. Then, the regulations consistent with the rules of sustainable agriculture of organization of work and transport resources selection were pointed, to provide constant work of major machine. Using division of energetic plants into groups like: trees and bushes, including trees branches, grasses and perennials was create a different type of harvest selection. All these actions are part of the principle of sustainable agriculture and a proper organization of work.

It's been presented an example of how to select the technical means for the collection of solid biomass depending on the crop to be harvested, the technology used, the specificity of the operation as well as the use of the machinery, and the particular technical details to be considered consistent with the rules of sustainable agriculture. A block diagram of the selection of technical means for the applied solid biomass for energy purposes of harvesting technology has been developed, considering the above-mentioned division of plants constituting solid biomass.

ACKNOWLEDGMENT

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IMPACT OF NATURAL BINDER ON PELLET QUALITY

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Keywords: straw waste management, biomass fuel, rape straw, mechanical performance

ABSTRACT
Production of energy pellets from waste straw is a good way to manage the straw surplus and to increase profitability of the agricultural enterprises. The present paper covers the results of the tests of the hardness of pellet made from a mixture of rape straw with an addition of wheat flour as a natural binder. The samples of raw material for the production of pellet included 0.0%, 4.1% and 7.8 % of wheat flour, which was determined according to dry matter. The average relative humidity of the raw material samples was: 11.6 %, 22.3% and 30.7%. The measurement of the pellet hardness was performed with the aid of the Kahl method. The influence was found of wheat flour contents and the relative humidity of the mixture on the increased hardness of pellet.

INTRODUCTION

The management of straw resources is an important problem for farms. In the sustainable agriculture, the part of the straw can be plowed after harvesting, thereby enriching the humus layer of the soil. The remaining part can be converted into fuel pellets for boilers. Instead of purchase fuel, for example coal, farmers can produce own fuel, improving this way farms economic performance and at the same time producing source of "green energy". In the recent years, the production and use of pellet from biomass as a fuel has considerably increased. Those boilers with maintenance-free mechanical fuel supply and automatic ignition which are used for its combustion, and which offer the possibility of continuous heating work, require good quality fuel granulate. These requirements are related not only to its thermochemical properties but also to mechanical properties. Fuel granulate needs to be durable and it should not suffer from damage during transport, handling and storing. The problem of the quality of fuel pellet is particularly important when it is used in boilers in individual heating of flats because large heating plants have considerably more advanced systems of fuel supply and process control. To improve the mechanical properties of pellet, apart from the selection of technical parameters for the pelletisation process, binding agents are used that increase pellet hardness (e.g., Obernberger & Thek, 2004; Razuan et al., 2011; Emadi et al., 2017). Pellet additions can also be used to improve its combustible properties (e.g., Chyc, 2012, Tarasov et al., 2013). Many types of materials which can be used to bind biomass together in energy pellet are commonly used in feed industry as the elements of granulate for livestocks. They perform there nutritional functions, but they also act as binders and enhance the structure of pellet (e.g., Gehring et al., 2009; Obidziński & Hejft, 2012).
An excess of straw from agricultural production is a favorable factor for its use as a raw material in the production of pellet biofuel. For this reason, research is conducted to invent formulae for good quality energy pellet from this raw material (e.g., Döring, 2013; Lu et al., 2014).
The purpose of the research was the strength assessment of pellet from rape straw that is made solely from straw with an addition of wheat flour, with different humidity degrees of the of raw material and with various contents of flour.

MATERIAL AND METHODS

Rape straw from rapeseed cakes was used to make the raw material for pellet. After grinding the straw with the dry oven test, its relative humidity and the relative humidity of wheat flour were determined, which were 11.8% for rape straw and 6.75% for flour.
Apart from rape straw, a mixture of rape straw and wheat flour was prepared for the production of pellet. Each sample included 700 g of straw. Water in the quantity of 100 ml and 200 ml and wheat flour in the quantity of 28 g and 56 g were added to part of the samples. This corresponded to 4 and 8% of the share of rape straw. During the preparation of the samples, the humidity of straw and flour was omitted. The percentage shares of straw and flour were converted into the shares of dry matter of those elements which, after conversions, were as follows: 0%; 4.1%; 7.8%. The resulting relative humidity of each of the samples and the average relative humidity were also calculated depending on the capacity of water added. The composition of the samples prepared and their humidity is presented in Table 1.

Table 1. Parameters of the mixture of chopped rape straw and wheat flour

Content				Additional water	Moisture content	Average moisture content
rape straw	flour	rape straw (dry matter)	flour (dry matter)			
g	g	%	%	ml	%	%
700	0	100.0	0.0	0	11.8	11.6
700	28	95.9	4.1	0	11.6	
700	56	92.2	7.8	0	11.4	
700	0	100.0	0.0	100	22.8	22.3
700	28	95.9	4.1	100	22.3	
700	56	92.2	7.8	100	21.8	
700	0	100.0	0.0	200	31.4	30.7
700	28	95.9	4.1	200	30.7	
700	56	92.2	7.8	200	30.0	

After 72 hours (the time that was considered to be required for water to penetrate into the structure of the mixture), the pellet was made from the mixtures with the use of a disc pelletizer with the diameter of 6 mm pelletising holes. The pellet obtained was dried off to zero relative humidity and then its specific density and bulk density were determined. The results are presented in Table 2. The methodology included in papers (Lam et al., 2008; Roman, 2016) was used in the measurement of the volumetric mass density of the pellet.
The hardness of pellet was measured with the use of the Kahl hardness tester by determining its destructive force in Newtons. Methodology was described by Obidziński (2014). The measurement was repeated 25 times for each kind of granulate obtained from nine samples of the raw material.

Table 2. Average density of the granulate obtained (measurement performed on dry matter)

Pellet	
Bulk density	Volumetric mass density
$kg \cdot m^{-3}$	$kg \cdot m^{-3}$
396.8	840

RESULTS AND DISCUSSION

The results obtained of the measurements of the pellet strength according to Kahl were subject to a statistical analysis to determine the significance of the impact of the addition of wheat flour and the relative humidity of the material on the pellet hardness. With the use of the variance analysis, the significance (with statistical significance $p < 0.05$) was determined of the impact of wheat flour and the relative humidity of the material on the hardness of pellet. The calculated least significant difference (LSD) was calculated in the hardness of the granulate both for the first factor, i.e. the percentage content of wheat in the material and for the second factor: the relative humidity of the material was LSD =19.581. The test results for the impact of the content of the binder addition (wheat flour) on the hardness of the granulate are presented in Fig. 1. The significant change in the pellet hardness occurred between the content of flour according to dry matter of zero and 4.1%. An increase of the content of flour in the raw material up to 7.8% increased the pellet hardness, yet the difference in the hardness value between the contents: 4.15 and 7.8% did not exceed the LSD value.

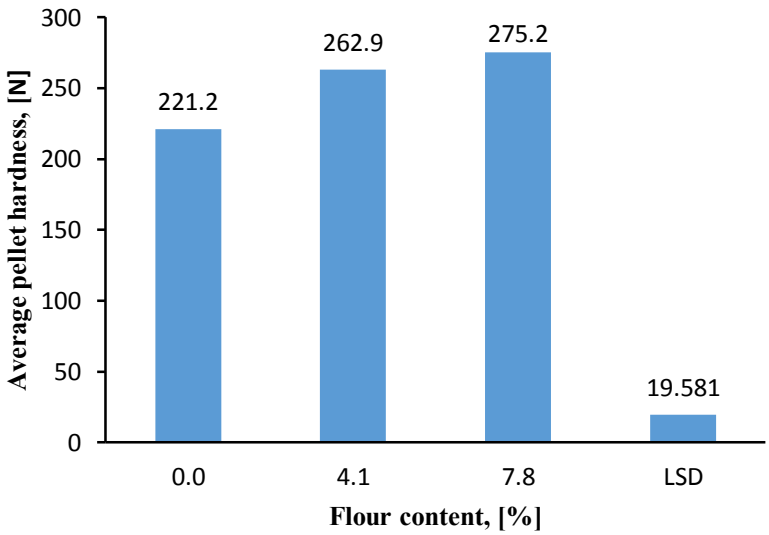

Fig. 1. Impact of wheat flour content in the raw material on the average pellet

In the case of an addition of water to the raw material, it may be stated that the hardness of pellet significantly grew with an increase of the relative humidity of the material (Fig. 2). This was most probably because the addition of water to the mixture had a positive influence on the binding properties of the flour.

When analyzing the diagram of the impact both of the flour content and the raw material humidity, which is presented in Fig. 3, it may be generally stated that the impact of such factors such as the raw material humidity and the flour content in the raw material on the hardness of pellet is interrelated. It can also be observed that with the relative humidity of the raw material of 22.3%, the content of the binder, i.e. wheat flour, had the smallest impact on the hardness of pellet, where straw from rapeseed cake was the main raw material. The diagrams in Fig. 3 furthermore demonstrate that an increase of the raw material humidity from 11.6% to 22.3 would always result in a significant increase of the granulate hardness.

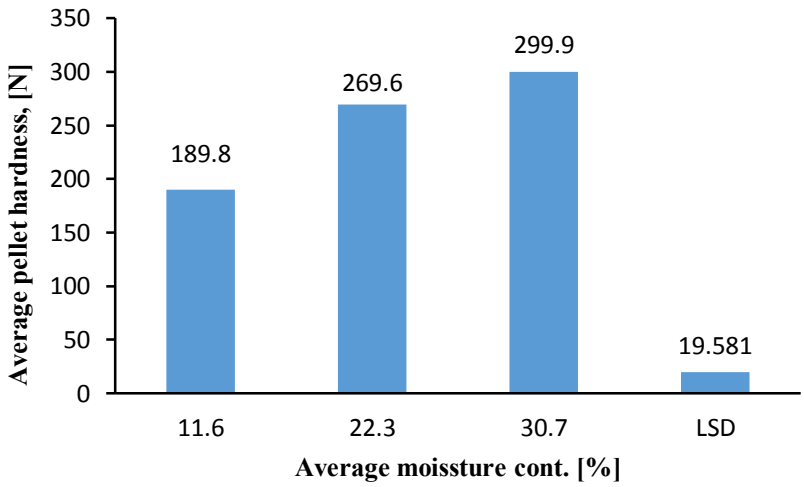

Fig. 2. Impact of average relative humidity of raw material on the average hardness of pellet produced

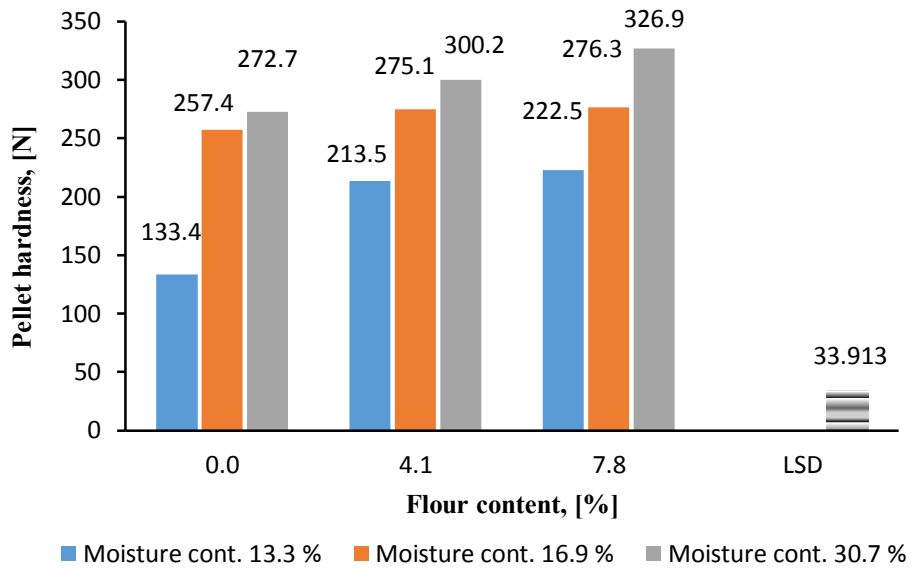

Fig. 3. Impact of wheat flour content in raw material and relative humidity on pellet hardness

Increasing the relative humidity of the raw material more than 22.3% significantly influenced the growth of the pellets hardness, but only at the content of flour 7.85 % degrees of the of raw material and with various contents of flour.

CONCLUSIONS

A significant impact was established of wheat flour content and the raw material humidity on the hardness of the granulate produced from rape straw with an addition of wheat flour. The pellet hardness increased significantly with greater contents of the wheat flour addition and with greater humidity of the raw material. Even a small amount of flour addition (about 4% of dry mass) can significantly increase the hardness of the granulate. Adding wheat flour as a binder above 4.1% does not guarantee a significant increase the pellet hardness.

Addition of water to the raw material influenced on the binding properties of the flour but raises the humidity of the pellet. The addition of water to rape straw and to mixture of straw and flour (to the relative humidity of 22.3%) always significantly increased the hardness of the pellet. Higher relative humidity (between 22.3 - 30.7 %) of the raw material with wheat flour 7.8 % raised the hardness of pellet. This indicates that the significant impact on the hardness of the granulate, made from mixture of wheat flour and rape straw, was as a result from appropriately added quantity of water depending on the flour content degree inside of the raw material.

Research has shown that it is possible to manage the waste of rape straw as a source of "green energy". Research has shown also that there is possibility producing pellet with good mechanical parameters from the waste using natural binders.

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VALUATION OF THE CONTENT OF SELECTED ELEMENTS IN HERBS CULTIVATED IN ORGANIC FARMS IN THE LUBLIN REGION

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Keywords: herbs, heavy metals, organic farming, agriculture

ABSTRACT
Herbal raw materials are widely used in the food, pharmaceutical and cosmetic industries. In the presented studies the content of selected elements in the herbs originating from organic farming in the Lublin region was determined. The research was done for three different herbs: common thyme, pink rock-rose, and nettle by means of an ICP OES SpectroBlue spectrometer. It was shown that the content of heavy metals in the tested samples does not exceed generally accepted norms. The amount of trace in the tested herbs is too low for human health to be the main source to meet the demand. However, they may be a supplement of a daily diet.

INTRODUCTION

According to the latest research interest in herbal medicine has continued to grow. It is a result of a rapid development of diseases such as cancer, neuroses and allergies, which until recently were considered as incurable. Properly selected herbs bring relief during these diseases and lead to their inhibition or even extinction. The use of herbal blends helps to regenerate the human body, regulate the intestinal flora, purify the blood and all endocrine glands, strengthen the nervous and digestive system. The therapeutic value of herbs is in place due to the presence of specific biologically active substances in them, which are characterized by different chemical compositions and they are located in varying amounts in different parts of plants. Sometimes, herbal plants may exhibit toxic properties, and the difference between therapeutic dose might be very similar to the toxic one. For this reason, the use of herbs requires both expertise and caution (Kozak et. al. 2016). Herbal raw materials are widely used in the food, pharmaceutical and cosmetic industries. Herbs can be used in the form of dried, whole or ground/shredded plant parts, their blends, essential oils, herbal extracts, or microcapsules. Because of their aromatic and preservative properties, they are used as natural agents for extending the shelf life of food and as spices. By the term spice plants one refers to plants and parts thereof such as: root, rhizome, bulb, bark, flower, fruit, seed, which due to the specific taste and aroma are used as additives to foods in order to enrich its taste and for medicinal benefits. They are used fresh, dried, or after mechanical treatment, as spices. The intense flavour of some spices is only sensed by sensitive cells located in the mouth, while the lower part of the digestive tract, for example the stomach, has vegetative nervous system, which reacts differently, e.g. pepper is not sensed there at all, but it stimulates secretory function. Considering the important role that selected elements play in human body, as well as their toxicity, the World Health Organization (WHO) has developed daily norms of their consumption. For a human being weighing 70 kg their amounts are equal to: CU-1.5 to 4 mg, Ni-25 to 35 g, Fe-10 to 15 mg, Zn-15 mg, Mn 2.5-6 mg. (Bielecka et al. 2009). Herbal spices cause secretion of digestive

juices that stimulate digestion and intensify secretion of bile from the liver. Choleretic action is necessary in the process of digestion of fats, which are frequently present in the diet in excessive quantities. Herbs are used for medicinal and supporting purposes, but principles of proper nutrition are essential as well. Meals flavoured with spices are easier to digest for the body, and in the further part of the digestive system they are not causing bloating, pain, digestive gases, constipation and diarrhoea. Several herbs combined together in appropriate quantities have medical effects in case of many diseases, and regenerate the whole body. In addition, they provide the body with vital substances of medical and nourishing nature. They also possess detoxifying properties, and strengthen the nervous and digestive systems (Górnicka 2011).

Heavy metals are defined as elements with atomic number greater than 20 and having metallic properties (Neri M., et. al. 2003). Within this group there are macro-and micro-elements, necessary for the proper functioning of living organisms e.g. copper, zinc, chromium, iron, as well as those which are unnecessary for the body, for instance, cadmium, lead, and mercury. However, it should be noted that beyond a certain limit they become toxicand are very dangerous for people, animals, and plants (Cicmanec 1996). Toxicity of heavy metals depends primarily on the degree of contamination, but also on the species and the age of the given organism, the way they have been introduced into the body, their chemical form, the type of interaction with other metals, and the physiological state of the body (Maciejewska 2003). Digestive and respiratory systems are the main ways of penetration of metals into the body. Bioaccumulation of metals in a living organism takes place through transfer by blood, and then retaining and accumulation in cell components, mainly nucleus, mitochondria and cell membrane. Therefore, systematic exposure to heavy metals has a negative effect on the morphological parameters of blood, enzyme activity, protein transport activity, and the structure and function of cells, tissues, and organs (Damek-Poprawa et.al. 2000).

OBJECTIVES

The purpose of this work was to evaluate the content of selected heavy metals in three popular herbs originating from organic farming in the Lublin region (Poland). Studied material was used as a addiction to the organic herbal and fruit teas.

MATERIAL AND METHODS

The test material consisted of three herbs originating from organic farming in the Lublin region (Poland): common thyme (Latin *Thymus vulgaris*), pink rock-rose (*Cistus L.*), and common nettle (*Urtica dioica l.)*

Content of the following elements was determined: Cu [ppb], Fe [ppm], Mn [ppm], Zn [ppb], Co [ppb], Cd [ppb], Pb [ppb], Ni [ppb], and Cr [ppb].
Samples of herbs were mineralised by acid digestion in concentrated nitric acid and hydrochloric acid using a microwave furnace from Anton Paar company. Microwave power of 800W was used at the max. temperature of 200°C. Mineralization procedure according to Multiwave PRO Classsified list of applications, Anton Paar.

The solution obtained was analysed by means of SpectroBlue ICP OES spectrometer. Applied standard: VHGSM68-1-500Element Multi Standard 1 in 5% HNO_3.

RESULTS

Table 1. Contents of selected heavy metals in the three herbs from organic farming

	Cu [ppb]	Fe [ppm]	Mn [ppm]	Zn [ppb]	Co [ppb]	Cd [ppb]	Pb [ppb]	Ni [ppb]	Cr [ppb]
common nettle	0.114	0.012	136.9	1.408	0.378	0.08	9.195	0.942	7.514
common thyme	0.114	686.6	259.8	1.408	0.378	0.08	9.195	0.942	7.514
pink rock-rose	0.114	192.3	183.7	1.408	0.378	0.08	9.195	0.942	7.514

The content of heavy metals (Cu, Zn, Co, Cd, Pb, Ni, Cr) was determined in ppb (parts per bilion) but Fe and Mn in ppm (parts per milion). Cu content was determined at the same level of 0.114 ppb in all tested herbs. A similar relationship was obtained at the Zn - 1.408 ppb. The content of Co was 0.378 ppb and the Ni content was 0.942 ppb in the tested herbs. Pb content and Cr content were determined at the level of respectively 9.195 ppb and 7.514 ppb independently of the species of herb tested. The Cd content was evaluated at the level of 0.08 ppb for all tested herbs. The content of Fe and Mn metals differed in particular herbs was determined. In the case of iron they fluctuated from 0.012 ppm (Fe) determined in the case of common nettle to 686.6 ppm determined in common thyme, as well as 192.3 ppm determined in the case of pink rock-rose. While, in the case of manganese these values were 136.9 in the case of common nettle, 259.8 ppm in the case of common thyme, and 183.7 ppm in the case of pink rock-rose.

DISCUSSION

At the present state of the development of inorganic biochemistry heavy metals are considered to be unnecessary or even toxic. Introduced into the body in small individual doses over a longer period of time they may cause acute or chronic poisoning. However, a number of heavy metals is a permanent and indispensable component of any living organism (iron, zinc, copper, manganese, cobalt). Others, such as mercury, lead, cadmium, thallium, and barium are harmful for the body (Maciejewska A. 2003). The results obtained exceed neither the acceptable standards specified in the Ordinance of the Minister of Health of 13 Jan, 2003 (Ordinance of the Minister of Health of 13 Jan, 2003], nor the reference values provided by the WHO (WHO 2007; Commission Regulation (EC) No 1881/2006, 2006), and they were comparable to the results obtained previously by other researchers (Gajewska R., et.al. 2000; Florczak J., et. al. 1996; Łozak A., et.al. 2002).

CONCLUSION

It has been attested that the content of heavy metals in the tested samples did not exceed the generally accepted standards. In the tested herbs, the amount of trace elements necessary for proper functioning of the body is too low to be the main source to satisfy the demand. However, these herbs can supplement daily diet. There are many researches to develop a suitable method for treating herbal raw materials in the world to eliminate valuable bioactive compounds to protect the consumer from potential biological or chemical toxins are conducted. Unfortunately, these methods are still not satisfactory. It is able to prevent the formation of harmful microbes and parasites as well as heavy metals and other elements toxic for human by using of a suitable controlled cultivation method.

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The proceedings contain 82 reviewed research papers on the main themes of the Symposium:

- Farm machinery and processes in sustainable agriculture standards,
- Energy applications in sustainable agriculture standards.
- Precision Agriculture in sustainable agriculture standards.

The authors originate from 19 countries, and 3 continents, and present a mixture of academics and practitioners. The results of their work presented in the publication contribute to both theoretical aspects and practical issues of the development of sustainable agriculture.

The diversity of authors and presenters made it certain that the main objective of the Symposium to exchange ideas and experiences of applications of the principles of sustainable agriculture was achieved.

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