Volume 7 • 2015

ISSN 2210-7843

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Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Editors:
Bruno Huyghebaert, Edmund Lorencowicz and Jacek Uziak

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Introduction

The 7th edition of the International Symposium on Farm machinery and Processes Management in Sustainable Agriculture takes place in Gembloux, Belgium. This Symposium is organized every two years and is the result of a fruitful collaboration between the Lublin University of Life Sciences of Lublin (UP-Lublin) and the Walloon Agricultural Research Centre (CRA-W). Moreover, EurAgEng kindly supports and sponsors the event.

Sustainable Agriculture is more than never a topical subject. The European Agriculture has to be developed in a more and more restricting framework from the point of view of economic, environmental and societal levels. Each year brings its new constraints as European Directives, Global Market, rules… But these constraints must be seen as opportunities that allow developing Agriculture more durable, more balanced and meeting the needs of all stakeholders without compromising future generation.

This Symposium has two main objectives. First is to bring a stone to the building of a more sustainable Agriculture. Researchers present their latest results on their on-going research in various fields such as novel technologies, management, processes for all compartments and aspects of the Agriculture.

Secondly, from the early beginning this Symposium tries to build a bridge between Eastern and Western countries of Europe. This year we get contributions from 12 countries (Belarus, Belgium; Bulgaria, Czech Republic; Estonia; France; Greece, Iraq; Poland; Portugal, Slovakia; Ukraine) showing this link. These exchanges allowed developing common projects and researches since several year.

Sustainability is not an empty word. It is a driving force for development a new Agriculture that has for now to answer so many challenging issues. This Symposium will be once again the platform for an international synergy and cooperation between researchers from different countries, working all on specific areas related to sustainable agriculture.

The Organizing Committee

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.001

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Data used as an indicator of mechanical olive harvest season

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Abstract

When and how harvest olives are among the most important issues to improve quality and quantity to ensure the best net return to growers. Trunk shakers are commonly used in mechanical harvesting to detach olives. Field trials showed that with this equipment less than 100% of the production is detached, usually 70% to 90% (Michelakis, 2002).It is important to increase the percentage of fruits harvested, to reduce losses. To achieve this goal factors affecting mechanical olive harvesting must be known, to be used in the definition of harvest season. Some of these factors are the result of the orchard management, like tree shape, canopy density, pruning methods. Others depend on the cultivar, such as fruit removal force (FRF), fruit weight (P) and the ratio between them. FRF and P are considered decisive in the detachment process. Results of field trials carried out in the Northeast of Portugal with "Cobrançosa Transmontana" cultivar show the FRF, P and their ratio evolution in the ripening period. They have potential to become indicators of the mechanical olive harvest season.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: Olive harvesting season; efficiency; trunk shaker.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.006

1. Introduction

Olive production faces problems, some of them related to the low product price and high production costs.To face these difficulties it is important to reduce costs and improve fruit quality. Low mechanization level penalizes the sector due to the high cost of hand harvesting.

Olive harvesting mechanization systems allow reducing costs (less manpower needs) and increasing quality (better work rates make possible to harvest in the most convenient period) (Amirante et al, 2012).

Focusing on olive production for oil, the definition of harvesting season depends on some factors. The oil content in the fruits is one of the most important, such as the mechanical harvesting efficiency, considered as the percentage of fruits removed from the total crop of the tree (Ferguson, 2006), to reduce fruit losses.

Factors affecting mechanical olive harvesting are tree shape, canopy density, pruning, orchard density and the cultivar (Ferguson et al, 2010).

Tree shape and canopy density can affect mechanical harvesting efficiency jeopardizing the shaker performance to detach fruits. The impediment is the less ability to transmit the force to the fruits bearing surface (Martin, 1994).

Canopy density can affect mechanical harvesting (Tombesi et al, 2002) slowing the operator, jeopardizing trunk shaker performance, or limiting head´s access to convenient trunk.

Adequate pruning must provide trunk or branch clearance to allow convenient access to trunk shaker and vibration transmission to fruits.

Orchard density suitable for trunk shakers can have 150 trees per hectare to 400 trees per hectare. High density orchards limit tree size, due to between tree competition, facilitating fruit detachment and fruit collection with mechanical harvesters (Ferguson et al, 2010).

Among the factors linked to the cultivar, fruit removal force (FRF), fruit weight (P) and the ratio between them are important for harvest efficiency (Tombesi 1990; Ferguson 2006, Farinelli et al 2012).

These factors affect the efficiency of mechanical harvest and can be used as indicator of when to begin and finish harvest season (Ferguson, 2006).

Another harvesting indicator used is maturity indices based on fruits colour development.

Preliminary results of ratio fruit removal force (FRF) / fruit weight (P) are presented. Field trials took place for two years – 2013 and 2014.

2. Material and Methods

Field trials took place in Portuguese Trás-os-Montes region for two years in an irrigated olive orchard with “Cobrançosa Transmontana” cultivar. Olive orchard has 300 trees spaced at 7 m x 7 m (see Fig. 1).

Fig. 1. Experimental olive orchard.

Fig. 2. Mechanical harvesting equipment.

The mechanical harvesting system is based on a trunk shaker to detach olives and an inverted umbrella to collect them (see Fig. 2). The inverted umbrella can store temporarily 200/250 kg of olives. Under the inverted umbrella a gate may be hydraulically open to allow discharge of the olives.

To evaluate fruit removal force (FRF) and fruit weight (P) five repetitions were considered. The olive orchard was divided in 30 plots with 10 trees each. Five of the plots were selected by randomization. Measurements were made in 10 olives around each tree crown of the five selected plots, each plot as a repetition.

Harvest took place the first week of December 2013 and in the last week of November 2014.

Measurements of the force required to remove olives were made with a dynamometer Chatillon Model DPP – 2.5 kg. Measurements of fruit weight were made with an analytical balance Mettler Pc 2000.

3. Results and Discussions

The ratio FRF/P is a more useful data than FRF or P by themselves. Fig. 3 and Fig. 4 show the evolution of FRF/P ratio during the ripening period on 2013 and 2014.

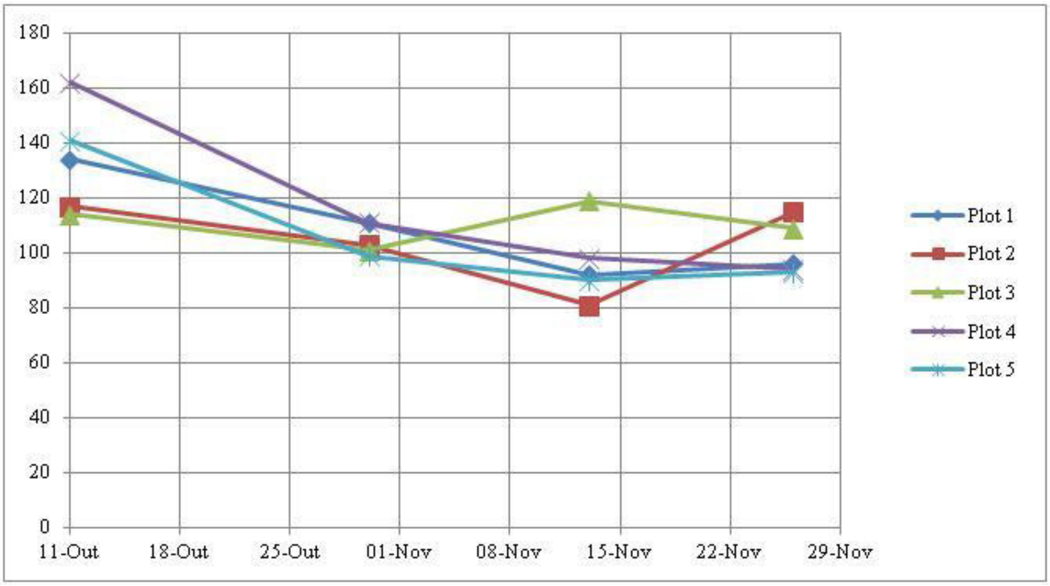

Fig. 3. Evolution of FRF/P ratio during 2013 ripening period.

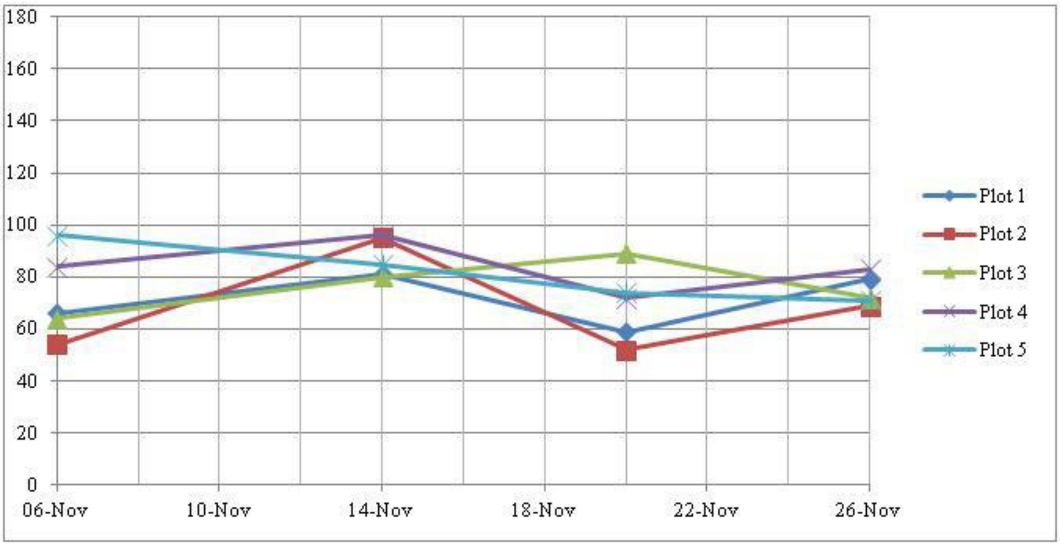

Fig.4. Evolution of FRF/P ratio during 2014 ripening period.

In both years the ratio has predominantly descendant values during the ripening period; in 2013 from 162 to 81, and in 2014 from 96 to 52, as a result of a FRF downward variation and an upward variation of P. In both years the ratio values stabilize the decline in the second half of November, just before harvesting, registering in some plots, in this period, a slight increase in consequence of a FRF increase higher than P increase (contrary to the tendency of previous weeks).

Two main reasons can justify the lower ratio values in 2014, compared with the values of 2013: (1) 2014 summer 2014 had a lower temperature than summer 2013; (2) in 2014 the olive orchard sanitary conditions were worse than in 2013 because *bactrocera oleae* attack.

4. Conclusions

FRF/P ratio can be used to improve harvest efficiency. Harvesting yields equal to or higher than 85% are considered the breakeven point for mechanical harvesting of olives with trunk shakers (Farinelli, 2012).

The establishment of a FRF/P ratio value related to the referred breakeven point, allow using FRF/P as an important indicator of the most appropriate period of time for harvesting with trunk shakers. This study must be done on various cultivars and in different regions.

In the future more field trials are needed to better understand the FRF/P ratio evolution.

Acknowledgements

The authors want to thank to the Program PRODER Medida 4.1 nº 44663 for the financial support, to the farmer of Quinta do Carrascal – Viaz and personnel involved in the field trials.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Sum of effective temperatures in Colorado beetle control

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Abstract

The Colorado beetle (*Leptinotarsa decemlineata*), is a major pest of potato crops in Poland. Both the striped beetle and the black-spotted, red larva feed on potato leaves. Their damage can greatly reduce yield and even kill plants. The paper shows the results of the studies aimed at capabilities of developing model to be used in pest control. The research was conducted in the years 2013-2014 at the Plant Protection Institute – National Research Institute in Poznań, Poland. The obtained results will be helpful in the further stages of developing a model and a computer application supporting the decision to protect the potato by applying chemical treatment against the Colorado beetle.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: Colorado beetle conrol; sum of effective temperatures.

1. Introduction

Colorado beetle (*Leptinotarsa decimlineata*), a harmful potato pest, is a 10-mm long beetle of a yellow or orange coloring. The damages to the potato are done by both beetles and larvae. They eat first and foremost the leaf blade of the plant, with young larvae biting out small holes in the leaf and older larvae and beetles also gnawing at the edges of the leaves. When there are no leaves, the larvae and beetles of the Colorado beetle gnaw at the offshoots and stems. The biggest damages are done by winter beetles shortly after they leave the hibernaculum and before they lay eggs, larvae in the L_3 and L_4 stages, as well as young beetles of the summer generation. Chemical control of Colorado beetle

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.020

is a prerequisite for reducing the damages done by this pest.

2. Objective, data and methodology

The objective of the research was an attempt to develop a mathematical model to be used to support making a decision regarding the application of a chemical treatment against Colorado beetle, *Leptinotarsa decemlineata*, using the sum of effective temperatures (SET). The sum of effective temperatures method is used for forecasting at the time of appearance of certain developmental stages of the pest that need to be controlled. The method is based on assumptions that a full development cycle for a generation of any pest requires a certain amount of heat which has been called a sum of effective temperatures. The sum may be calculated using the following formula:

$$C = (T_1 - t^o) + (T_2 - t^o) + (Tn - t^o)$$

where:
C – sum of effective temperatures
$T_{1....}T_n$ – mean daily temperature
t^o – physiological threshold (zero) – it is a threshold temperature above which a given organism is able to develop

The SET value for a given species is constant and independent of the area in which the pest develops.

The research was conducted in the years 2013-2014 at the Plant Protection Institute – National Research Institute in Poznań (PPI – NRI). In growing seasons in spring time systematic observations of flight of Colorado beetle were conducted on PPI – NRI's experimental field in Winna Góra. They were conducted on the Vineta potato variety, twice a week, 100 plants every time. A part of the caught spring beetles was then bred in laboratory conditions in a phytotron at the Plant Protection Institute – National Research Institute in Poznań.

Determining and verifying the sum of effective temperatures (SET) necessary for the development of given stages of Colorado beetle was conducted in four (2013) and five (2014) phytotron chambers of different humidity.

Each year after the first eggs were reared, 30 larvae were left in the isolator, out of which 25 were taken into account for observation. The observation lasted from the moment the eggs were laid until the pest reached the L3 stage.

3. Results

Decision support systems in plant protection have already been in use in some countries on the Internet for many years. Advisers or producers have access to information regarding meteorological data, the sum of effective temperatures, direct phenological, observations, constant or periodic signaling of the occurrence of subsequent developmental stages of the pest, or recommended pesticides.

Tables 1-2 show mean values for temperature, humidity, the number of days and SET required by the Colorado beetle to develop in controlled conditions. The obtained results allowed for a determination of the relation between the SET values and the number of days between the time the eggs are laid and the time the pest reaches the L2 stage (Fig. 1) and the L3 stage (Fig. 3). The developed curvilinear regression equations are as follows:

$$Number\ Of\ Days(L2) = 0.0036 \cdot SET^2 - 1.1023 \cdot SET + 101.93$$

and

$$Number\ Of\ Days(L3) = 0.0061 \cdot SET^2 - 2.304 \cdot SET + 236.67$$

The coefficients of determination for the above equations are: R^2=0.6401 and R^2=0.7838, respectively, which means that the variability in the number of days between the laying of the eggs and reaching the L2 and L3 stages is explained, respectively in 64% and 78%, by the variability of the SET. Both models resulted to be statistically

significant at the assumed significance level of 0.05.
The obtained results will be helpful in the further stages of developing a model and a computer application supporting the decision to protect the potato by applying chemical treatment against the Colorado beetle.

Table 1. Data regarding the Colorado beetle from the moment the eggs are laid to the moment the L2 stage is reached.

Year	Chamber no.	L2			
		Mean temperature	Mean humidity	Mean number of days	SET in °C
2013	1	14.5	50	30.4	91.3
	2	15.9	70.2	22.7	143.9
	3	19.8	57.2	18.4	152.3
	4	21.4	57.6	15.7	155.0
2014	1	14.5	76.5	29.0	109.3
	2	19.1	60.0	15.0	122.1
	3	19.4	59.3	16.0	126.4
	4	21.4	57.7	15.7	155.0
	5	21.8	70.3	16.0	168.1

Table 2. Data regarding the Colorado beetle from the moment the eggs are laid to the moment the L3 stage is reached.

Year	Chamber no.	L3			
		Mean temperature	Mean humidity	Mean number of days	SET in °C
2013	1	14.5	50.0	43.8	131.4
	2	15.9	67.4	24.5	194.3
	3	19.8	56.9	23.5	194.4
	4	21.4	60.0	21.4	207.3
2014	1	14.5	76.5	36.3	134.3
	2	19.4	58.0	22.0	174.1
	3	19.7	64.8	19.0	155.2
	4	22.2	72.2	19.7	174.3
	5	23.6	69.1	19.7	214.4

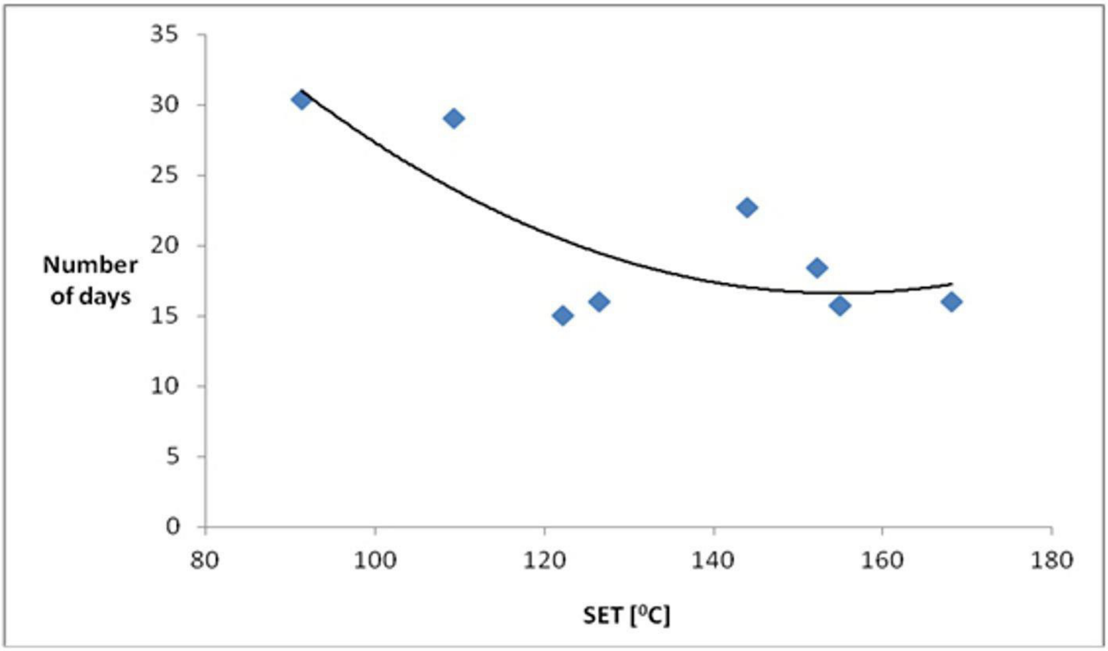

Fig.1. The relation between the SET value and the number of days from the laying of the eggs until the L2 stage.

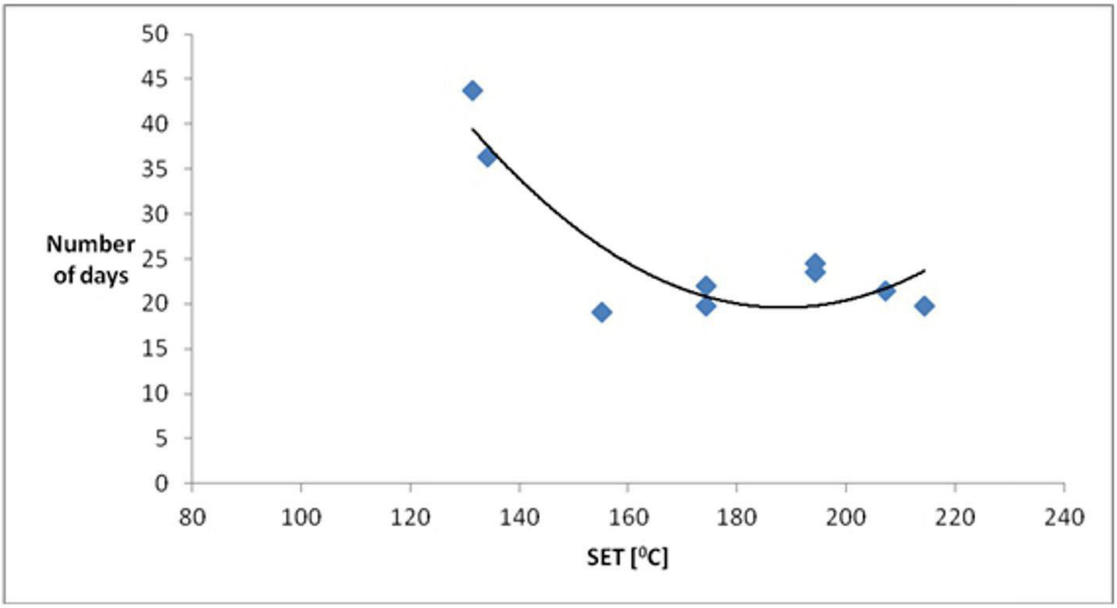

Fig.2. The relation between the SET value and the number of days from the laying of the eggs until the L3 stage.

In Poland, similar studies were carried out with the leaf beetles (*Oulema* spp.), one of the most important pests of winter wheat in Poland besides aphids, and locally the saddle gall midge. Every year beetles and larvae of *Oulema* spp. do significant damage to leaf tissues of winter wheat leaves (Walczak 2005b), which causes high losses in yields. The objective of that research (Walczak 2005a) was to evaluate the impact of temperature and air humidity on the length of egg incubation and larvae development of *Oulema* spp. Extended duration of egg laying and larval development are the main factors making a determination of optimum timing for leaf beetles chemical control very difficult.

To determine the exact time for leaf beetles control, five years of experiments in a growth chamber and three years under field conditions were performed. Two species of *Oulema* spp. were reared in order to evaluate the impact of temperature and air humidity on the length of egg incubation. On the basis of obtained results and statistical analysis a mathematical model in the form of a multiple regression equation was created. The model supports determining the optimum time for chemical control against cereal leaf beetles (Walczak 2008).

Moreover, similar research regarding cutworms in sugar beets was conducted as well. In the 2013-2014 growing seasons a previously developed system was verified in terms of information technology in natural conditions, mainly in the region of Wielkopolska. Systematic observations were conducted in different locations on plantations of sugar beet where light traps were installed. For the purpose of short-term forecasting, during the four-year controlled conditions and field studies, the values of heat sums, 501.1° C, and the sum of effective temperatures, 230.0° C were determined for the development stage of the cutworm (Jakubowska 2009). The calculated values were used in the creation of applications. The effective temperatures were calculated from the date on which there was a mass caught of moths. They were determined by subtracting 10.9° C (i.e. the physiological threshold) from the mean daily air temperature. Over the following days, the effective temperatures were added up. When the sum of these temperatures reaches 230.0° C, you must perform the procedure of spraying the plant protection product – the caterpillars observed at that time are in the L_2 stage.

The observed plantations were located in the provinces of Wielkopolska and Dolny Śląsk. In the years of the study (2009-2014) insecticidal treatments against cutworm, according to the signaling, were to be applied between the 29th and 41st day from the date indicating the beginning of a mass flight of moths. Phenological treatments were determined with the sum of heat in the range of 497.8 to 661.9° C and the sum of effective temperatures between 130.6 and 255.8°C.

The results of the regression analysis indicate statistically significant ($p < 0.001$) effects of both the sum of heat and the sum of effective temperatures on the count of cutworms (coefficient of determination R^2 for the model was 0.73). In regression, the R^2 coefficient of determination is a statistical measure of how well the regression line approximates the actual data points. The results of the field experiments correspond to the previous studies carried out on the monitoring of cutworm in plantations of sugar beet (Jakubowska and Ławiński 2011; Jakubowska et al. 2012a; Jakubowska et al. 2012b; Jakubowska and Bocianowski 2013). Literature data indicate that cutworm is harmful primarily due to its population size, which is heavily influenced by the weather conditions and the extended time of incubation and development of voracious caterpillars. Cold winters, warm and dry springs and summers, and then dry autumns are particularly favorable for cutworm.

4. Summary and conclusion

1. Sums of effective temperatures are helpful when creating models supporting decisions regarding chemical plant protection.
2. The studies determined the relation between the SET and the number of days from the laying of the eggs until a given developmental stage, as well as developed the curvlinear regression equations.
3. The obtained results will be helpful in developing a model and a computer application supporting the decision to protect the potato by applying chemical treatment against the Colorado beetle.

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Formation mechanism of logistics cluster in Belarus

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Abstract

A relatively small number of large industrial enterprises and major exporting companies has a dominant position in the market and determines the corresponding demand for transport services. Logistics activity in the country is one of the growth points of the economic system. One of the ways for increasing the efficiency of logistics activities in agriculture and food transport management sectors in Belarus is the creation of logistics clusters. The article proposes a methodological approach to the formation of logistics cluster in the region. The approach is based on three phases of work: identification of a cluster, evaluation logistics rents and logistic potential of the region, where the cluster is located. This allows assessing the expedience of cluster formation and its subsequent development. This process is connected with agriculture and food processing activity.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: logistic; cluster; rents; potential.

1. Introduction

Processes of globalization, increasing of competition, slowing down market conditions and declining of business activity during the recession create macroeconomic risks for the Belarusian enterprises. It determines the need of improving competitiveness of industrial production, the formation of a strategic reserve of economic growth.

Currently, the tendency of clustering the industries can be observed. This tendency also applies to logistics, which is now associated with the operation of enterprises based on integrated cross-flows (Szołtysek, 2010).

Transport and logistics clusters (TLC) – industry clusters, the end products of which are transport and logistics services in the cargo sector, the passenger sector, or both. Interest in the formation of these structures is caused mainly by two reasons:

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.022

1. TLC – clusters of services, whereas the traditional literature on industrial clusters focused on clusters of commodity production.

2. Transport and logistics industry as well as transport and logistics systems occupy a special position in the country's economy, along with cities and metropolitan areas, important elements of regional economies and their sustainable development.

Because of these reasons the level of transport and logistics system development in the country to some extent determines its economic growth. The efficiency of the logistics industry in the country is estimated by its gross domestic product (GDP) share: in the US, Japan, EU logistics costs volume doesn't exceed 10–12%, while in China it is still less than 25% of GDP (Figure 1) (Zhudzhun et al., 2008).

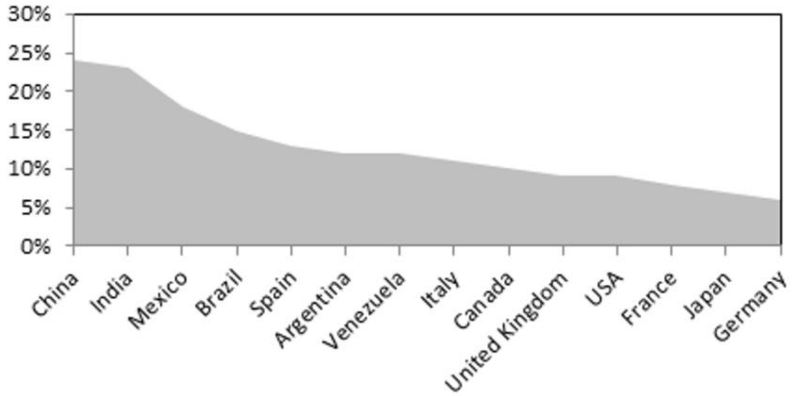

Fig. 1. The share of logistics costs in total GDP Worldwide for 2011

The analysis of Figure 1 shows that the largest logistics costs have those countries in which there are the long routes and logistics supply chain. Also worth noting is that not always the highly developed countries may have a perfect logistics network. For example, despite the fact that logistics in China is recognized as one of the most perspective sectors, the logistics market of China lags behind world standards and technologies. Construction of logistic networks, the introduction of modern logistics technology and the system of distribution and inventory management in China show low efficiency. The average period of raw materials storage for manufacturing enterprises in China is 20 days, finished goods – 51, trading stock of companies – 34 days. Percentage of goods damaged during storage and distribution exceed 2% (Buglak and Zverev, 2006). In Belarus, the situation in the field of logistics is improving in many aspects. Belarus is ahead of the Commonwealth of Independent States (CIS) in three areas of logistics, namely in the effectiveness of customs clearance procedures, the development of transport infrastructure and tracking the passage of goods. Nevertheless, Belarus lags in the availability of services for the organization of international traffic, as well as in competence of the national logistics industry. In Belarus, the transport and logistics sector plays an important role in the economy. The Republic is a net exporter of almost all kinds of transport services. Transit transport corridors between the countries of the European Union (EU) and, potentially, between the EU and Asia pass through the country. This is due to the fact that Belarus has a strategic geographical position on the routes of two European transport corridors, in the development of which the EU and the Russian Federation is interested. Along with a high level of geographical concentration of international trade, the structure of trade by commodity groups in Belarus is also characterized by a high degree of concentration. A relatively small number of large industrial enterprises and major exporting companies has a dominant position in the market and determines the corresponding demand for transport services. Logistics activity in the country is one of the growth points of the economic system. One of the ways for increasing the efficiency of logistics activities in Belarus is the creation of logistics clusters.

2. Logistics cluster: concept and characteristics

Before moving on to the concept of logistics cluster is necessary to define the category of "cluster". Summarizing the work of Rosenfeld (2005), we can conclude that the economic cluster is a group of companies belonging to the same sector (region) and operating in close proximity to each other (Rosenfeld, 2005).

In the economic literature, logistics cluster is defined as an integral part – usually infrastructure – of economic cluster or its subsystem, interpreting it as a cluster formed at the intersection of the main material flows and consolidates profile logistics facilities (Evtodieva, 2011ab;), as well as a type of economic cluster (Kibalov et al., 2007). From this point of view, the range of tasks for such logistics structure are to ensure the through stroke flow of the processes between producer and end-user with the inclusion in integrated supply chain linked products which based on known and similar types of economic activity. In other words in scientific researches logistics cluster is seen as appendix to a particular type of economic activity (Leenders and Fearon, 2006; Sheffi, 2012), highlighting the fact that the logistics cluster provides logistics services to the end user and in fact acts as a cluster of services.

Also logistics cluster is treated as geographically concentrated set of activities cconnected with logistics or as geographical agglomeration of logistics activity. It is characterized by, among other factors, low transportation costs and high level of transport service when moving goods in and out of the cluster. Logistics clusters are examples of public-private partnership, and the strength of this partnership usually determines the success of cluster development (Sheffi, 2012). From our point of view, the logistics cluster is especially organized an integrated logistics system consisting of a group of related organizations (companies, corporations, universities, banks and so on.) concentrated on some territory, complementary to each other and reinforcing the competitive advantages of individual companies and the group as a whole, aimed at the organizational and structural, organizational and analytical improvement (optimization) of flow processes and streaming functions of any content (logistics activity) in the reproductive cycle.

Experts have criticized the restriction of "logistics cluster" concept to the transport and logistics cluster, offering the argumentation and developing appropriate classification of logistics clusters (Houérou et al., 2006; Evtodieva, 2011a; Vladimirov and Tretiak, 2008). If to consider the integrated logistics chain itself as a network, in such logistics networks are presented elements of different quality by nature, several control units and a complex system which combine the interests of the communication subjects is used. In this case, the logistics cluster can be viewed from the position of the object and process decomposition of the logistics network based on the principle of "triple helix" (the interaction of business, government and science). In this case, the logistics cluster in addition to the structural units of the logistics system (network, channel chain) and key business processes (logistics process, function, operation) is complemented by features and characteristics of economic clusters. In this case the cluster approach is reflected to the construction of logistics systems. Along with it also synergistic, tectological and cybernetic approaches are distinguished to the construction of logistics systems and its combinations. In the economic logistics using cluster approach allows you to raise modeling logistics processes and operations to a higher level of organization. In view of this, according to some foreign and domestic researchers in logistics is a change of scientific paradigm – integrated logistics paradigm is maintained (Aphanasenko, 2013). Logistics clusters exhibit the same properties that industrial clusters: increasing productivity through shared resources and suppliers; improvement of social networks, including the transfer of knowledge; the presence of tacit knowledge; high levels of trust and social capital; availability of highly specialized workforce, research centers, technology transfer centers, academic and university research, consulting firms and analytical platforms and innovation centers. However, logistics clusters have some characteristics that make them unique in terms of the formation of clusters and their contribution to economic growth. Logistics cluster benefits can be considered in two limits of two categories: operational benefits associated with transportation, and benefits associated with collaborative resources and assets of the cluster formation participants (Sheffi, 2013; Bookbinder, 2013). Both benefits are increased significantly due to the mutual gain feedback mechanism, generating and forming a kind of logistics rent. The majority of logistics clusters are developed due to certain driving factor of development. The main factor is the government. In younger logistics clusters public-private partnerships and quasi-government structures play a key role. The main factors of development are the characteristics of the natural environment, mainly geographical position. Generally logistics clusters are similar to the economic clusters, combining the features of logistics systems and economic clusters, obeying to the general principles of functioning and development of complex organizational systems. Because of this, the logistics cluster is a specially organized logistics system – the concentration of logistics activities that shown by a group of companies and organizations aimed at organizational and structural, organizational and analytical improvement (optimization) of flow processes and flow functions of any content in the reproductive cycle.

3. Mechanism for the creation of regional logistics clusters

During determining what is meant by the logistics cluster, the question naturally arises as to the appropriateness, necessity and the purpose of its formation or development within a certain area or region. For making a decision on the establishment of a logistics cluster in the region is necessary to evaluate the possibility of building such cluster. Within the first direction clusters in the regions should be searched or identified. Identification is carried out according to the procedure (Androsik, 2013 and 2014) on the basis of calculating the coefficients of localization and agglomeration – two signs of the existence of the cluster – based on economic (logistic) activities in the region, which are reduced to the integral index of clustered region. In the proper sense of the word it's not the clustering. Cluster receives natural impulse for its emergence and development. The essence of controlling actions is to correct and control the trajectory of cluster development. *Clustering regions level* can usefully be measured in the context of localization and agglomeration effects (Record, 201). Typically, they are considered as separate concentration types.

Calculation of the localization coefficients is used to identify clusters by the characteristics of the region (area). For such characteristics are used indicators of employment, income, revenue, investment, number of enterprises, and others (Golovachyov and Khotko, 2013):

$$C_{ij} = \frac{x_{ij}}{\sum_i x_{ij}} \times \frac{\sum_j x_{ij}}{\sum_{ij} x_{ij}} \quad (1)$$

C_{ij} – localization coefficient under characteristics, x_{ij}– characteristics of the i-th industry in the j-th region.

The coefficient reflects the ratio of the share of this industry in the structure of the region to the specific gravity of the same industry in the country. If the index is greater than one, conclude that the production is localized in this region. Next we calculate the agglomeration coefficient. There are arguments for and against the positive impact of agglomeration on the development of the regions and regional clustered growth, however, in view of the high role of agglomeration effects, the structure of urbanization and the size of urban settlements, population density and its qualification structure are paramount. Analyzing the agglomeration effect used the idea of expanding the production function due to urbanization level, its structure and agglomeration potential indicator of the territory and urban settlements. As the level of agglomeration adopted indicator of the share of the urban population, and for characterization of the capacity to generate agglomeration effects used indicator of a medium-sized city. In view of the fact that regions differ in size and economic activity, to eliminate the correlation scale and economic activity, for evaluation are used the indicators of the gross regional product and fixed production per capita.

To calculate the agglomeration coefficient the formula is used:

$$U_{ij} = \frac{G_{ij} \cdot GRP_{ij}}{\sum_j GRP_{ij}} \quad (2)$$

U_{ij}– agglomeration level indicator of the j-th region (area) i-th settlement (district), G_{ij} – urban population share of the i-th profile district (city) in the j-th region, GRP_{ij} – gross regional product of the i-th settlement the j-th region.

If indicator strives to one it shows the growth of the level of agglomeration process and agglomeration potential development. This formula may be supplemented by the agglomeration regions criteria, such as the concentration of the population, the concentration of economic and social infrastructure and management, concentration of scientific and technological activities and education, improving the quality of life. In order to clarify the level of agglomeration effect of the region and its determining as a clear sign of the existence of a cluster in the region, it is advisable to monitor the dynamics of the level of gross regional product per capita (GRP growth rate). The positive dynamics of this coefficient indicates the presence of a cluster. Negative dynamics of the coefficient in the particulars years contrary to the nature of cluster formation, because the cluster, by definition, may not be effective and, therefore, is the point of attraction of resources (attractor). Based on the localization and agglomeration coefficients integral clustered index of region is calculated by the formula:

$$KI_{ij} = C_{Iij} \cdot U_{ij} \tag{3}$$

KI_{ij}– integral clustered index of the j-th region (area) i-th industry, C_{Iij}– potential clustered index of the i-th profile city (district) j-th region, U_{ij}– agglomeration level indicator of the j-th region (area) i-th settlement (district).

The results of calculation of the the index of potential clustered region in the period from 2006 to 2010 are shown in Table 1.

Table 1. The index of potential clustered region.

Region	2006	2007	2008	2009	2010
Brest	2.7291	2.5744	2.1337	1.6779	1.7382
Vitebsk	0.0006	0.0001	0.0002	0.0004	0.0004
Gomel	0.0465	0.0499	0.0488	0.0650	0.0636
Grodno	0.2375	0.2446	0.2906	0.2253	0.2403
Minsk	0.1286	0.1547	0.2033	0.2675	0.2559
Mogilev	0.0312	0.0246	0.0281	0.0378	0.0367

The findings suggest that the regional characteristics of areas influence on the development and effectiveness of logistics operators, which directly determine the possibility of the clusters formation. As a result of the analysis the greatest potential for clustering has Brest region. Calculations show this area the most perspective for development of the potential logistics cluster. Considering the spatial arrangement of areas can be also assumed that the close location of Minsk and Grodno regions will allow include them in a potential cluster. It is necessary to emphasize the fact that almost all plants are located on the main highways of the country that directly related to the infrastructure of roads and railways. The high density of industrial production in Brest and Grodno regions is provided by large enterprises, while small businesses are not widely represented. The high density of industrial production in the Minsk region is provided in both large and small enterprises. This fact shows two fundamentally different clustering models. One (in Brest and Grodno regions) is built on a "Hub-and-Spoke" model when there is an integration of large local firms with small local business and the presence of a clear hierarchy can be seen. The second (in the Minsk region) is constructed on a "Marshallian cluster" model, when there is an integration of small businesses due to their precise specialization, strong local competition in the presence of co-operation, a relationships based on trust. Conducted above calculations were carried out according with block A (based on the localization effect) presented methodology. The next step is to calculate the agglomeration effect (Block B). Analyzing statistics for the urban population can be seen that its numbers vary slightly from year to year as a percentage of the base (previous year). This indirectly indicates the absence of active agglomeration processes in the regions. Dynamics of the share of urban population is smooth, with no major changes, but shows an upward trend. This means that agglomeration processes are slowly enough and the proportion of the urban population is gradually increased. According to the statistics on areas, GRP has an almost permanent structure, the contribution of the regions in the total GRP almost does not change, the change in shares occurs smoothly, indicating the established structure of industrial production and continuing current trends. Next, calculate the agglomeration coefficient according to the methods of clusters identification. The results of these calculations are presented in Table 2.

Table 2. Agglomeration coefficients by regions.

Region	2008	2009	2010	2011
Gomel	0.1016	0.1030	0.0992	0.0963
Grodno	0.0656	0.0697	0.0671	0.0636
Minsk	0.0966	0.0861	0.0922	0.0985
Mogilev	0.0705	0.0696	0.0720	0.0641

According to the method aspiration of the coefficient to one shows the growth of the development level of agglomeration processes and agglomeration potential of economic space. The calculated values are quite low. This testifies to the low intensity of agglomeration processes. In order to clarify the level of agglomeration effect of the region and its definition as a clear sign of the existence of a cluster in the region, it is advisable to monitor the dynamics of the level of gross regional product per capita (chain GRP growth rate). The calculated values are shown in the Table 3. It is also worth noting that the indicator of GRP began to be calculated in 2008. The positive dynamics of indicator shows the presence of a cluster. Negative dynamics contrary to the nature of cluster formation, since the cluster by definition cannot work effectively.

Table 3. Dynamics of the level of gross regional product per capita.

Region	2008	2009	2010	2011
Gomel	0.0053	-0.0434	-0.0235	0.0558
Grodno	0.0526	-0.0463	-0.0491	0.0529
Minsk	-0.1101	0.0723	0.0813	-0.0106
Mogilev	-0.0141	0.0352	-0.0987	0.0671

The presence of negative values shows a decrease of GRP share in total regional product, although only increasing should be observed. Agglomeration coefficients on the regional level because of the nature of agglomeration processes are low. The second direction is based on the identification of assumptions and possibilities for cluster formation in the economy. In this case, the cluster does not exist, but there are conditions for its formation and development. Then clustering management involves implementation of the opportunity to create a cluster structures, and further their maintaining and support. In this case, assessment of the region prospects is carried out in terms of opportunities and conditions for the formation and using of logistics rents and logistics potential in the region. Calculation of the existing logistics rents (rents received from the organization of the movement of material flows) is presented below:

$$R_{lr} = k_1 \cdot AV + k_2 \cdot T, \tag{4}$$

AV – added value, which remains in the region, rubl., T – transit material flow through the region, rubl., k_1, k_2 – the rate of return obtained from the organization of the logistic function of material flow circulating in the region.

Calculation of the potential logistics rents is presented below:

$$R_{pl} = \frac{T_p}{T_c} R_{сл}, \tag{5}$$

T_p – assessment of logistic potential in the region, T_c – the current assessment of the region in terms of logistics.

To rank the regions according to their attractiveness is advisable to use a criterion calculated by the following formula:

$$E_f = \sum_{t=1}^{N} \frac{(R_{ct} - R_{lr} - \grave{O}_{\pi t})}{(1+r)^t} - \sum_{t=1}^{N} \frac{I_t}{(1+r)^t} - \sum_{t=1}^{N} R_t, \tag{6}$$

R_{ct} – logistics rents in period t, R_{lr} – actual logistics rent (basic), $T_{\pi t}$ – the growth rate of inflation to the base period, %, I_t – required investments in period t, R_t – risks in period t, *r* – interest rate.

In the case of a positive assessment decides to support cluster initiatives and projects, ensure the clustering process and the implementation of cluster programs and strategies of logistics clusters formation. Thus in the cluster projects are defined purpose, authority, responsibility of cluster subjects, strategic management, financing, costs, risks, participating in using results. The most appropriate is a partnership agreement, the terms of which are: a form of partnership, the type and order of project implementation, the transfer of ownership on the created object, the allocation of profit, legal and financial guarantees to participants and other features of the agreement (Golovachyov and Khotko, 2013). Institute of public-private partnership supports a set of critical mass of the cluster and ensure its further development. Next formed or determined core of logistics cluster, created and built up logistics infrastructure, the boundaries of the cluster are expanded, which includes logistics operators, trading and manufacturing companies, educational and research institutions. The result of the logistics cluster functioning of the first level is the growth of logistics potential of the region and logistics rent (let's call it the logistics rent I). In this case, at this stage unique logistical assets are created and allow you to be integrated into the international supply chain. As a result, companies receive logistics rent I. During interacting of the logistics cluster with companies from other regions (countries) are generated logistics rent II, which is based on the evolution of inter-firm linkages, both within the logistics cluster and beyond. This allows you to manage their logistics assets more effectively and leads to synergistic effects that can be divided into additive and non-additive. Despite the availability of a variety of theoretical and practical research on the issue of cluster interaction in the literature hardly developed evaluation questions of synergistic efficiency. Thus, Kulagin and Kulagin noted: "there is no clear, uniform methodology for evaluating the effectiveness of integrated units" (Denisov, 2012). The most complete picture of the structure of synergetic effect as a multifaceted concept is revealed in the model of R. Matthews, in which the mechanisms of Subadditivity (S_{sub}) and Superadditivity (S_{sup}) are recognized as the main components of the total synergetic effect (S_k):

$$S_k = S_{sub} + S_{sup} \tag{7}$$

Subadditivity as a characteristic of logistics cluster connectedness leads to reducing of the total costs of the merging companies which attracts capital eliminates duplication of staff functions, etc., while saving the existing volumes of cargo handling. Subadditivity described by the formula:

$$F(x_1 + x_2 + \ldots + x_n) \le F(x_1) + F(x_2) + \ldots + F(x_n) \tag{8}$$

Inequality means that the value of F function from the sum of the variables x_i is less than or equal to the sum of the values of the functions of each of the variables.

Synergetic effect from subadditivity measured by the value:

$$S_{sub} = F(x_1 + x_2 + \ldots + x_n) - (F(x_1) + F(x_2) + \ldots + F(x_n)) \le 0, \tag{9}$$

Superadditivity determines profit growth due to the growth of cargo handling (as a result of strengthening the logistics position of the combined company, the implementation of new investment projects which could not be implemented separately, etc.). Superadditivity described by the inequality:

$$G(x_1 + x_2 + \ldots + x_n) \ge G(x_1) + G(x_2) + \ldots + G(x_n) \tag{10}$$

This means that the value of the G function from the amount of variables x_i greater than or equal to the sum of the functions of each of the variables.

Synergies from Superadditivity measured by the value:

$$S_{super} = G(x_1 + x_2 + \ldots + x_n) - (G(x_1) + G(x_2) + \ldots + G(x_n)) \ge 0, \tag{11}$$

In this way, depending on the S_{super} and S_{sub} ratio the total S_k synergistic effect may be positive or negative. At the same time, the more positive synergies S_k, the deeper and more stable integration process and the more stable logistics cluster becomes; and in the case of $S_k \le 0$, when the synergistic effect is absent or is negative, the cluster disintegrates sufficiently quickly. The problem of evaluating the synergistic effect is one of the most undeveloped in the analysis of effectiveness of integrated structures development in the form of associations of economic entities in the cluster structures. Integration system should be abolished in the case of approximation of losses to the value of synergetic effect.

Effect from the interaction of economic agents (cluster-forming activities) S should exceed the total effects of their autonomous activity ($\sum_{i=1}^{m} S_i$) (outside the cluster):

$$S > \sum_{i=1}^{m} S_i = S_1 + S_2 + ... + S_m, \tag{12}$$

A synergistic effect (S_k) is expressed by the difference:

$$S_k = S - \sum_{i=1}^{m} S_i, \tag{13}$$

There are 3 options:

1) $S_k > 0$ (positive synergetic effect; the larger the S_k value, the more productive the functioning of the cluster is and the better the interaction of participants).

2) $S_k = 0$ (synergistic effect is zero, interaction loses its meaning).

3) $S_k < 0$ (negative synergistic effect, the interaction is not possible).

These effects lead to the formation of the level II logistics cluster or the so-called streaming cluster, under which we understand sustainable interaction geographically independent market actors, whose efforts are focused on maintaining a full cycle of basic and accompanying flows and optimization of resources from the original suppliers to the end users. This type of integration is transforming the relationship between its members on organizational and planning rather than on spontaneous market bases and formed to manage the material, financial, information and human flows from raw material suppliers and manufacturing companies to consumers, interacting with each other within a single chain of the value creation and improving the logistics potential of cluster members.

4. Conclusion

In this case, the construction of the logistics clusters, in relate to servicing of agriculture as well as food processing products, in the region is conducted through three key stages: the identification of cluster, identification and assessment of the value of the rent and logistics potential in the region. Within the calculated evaluations the prospects of development of the region is defined in terms of logistics. In the case of positive ratings, logistics cluster of the first level is formed and created. Its successful operation leads to increasing efficiency of logistics companies, agriculture enterprise, and the emergence of logistics cluster of the second level. It is diagnosed on the growth of the cluster potential and the logistics rent due to the generation of synergy effects.

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Agriculture and Agricultural Science Procedia 7 (2015) 21 – 26

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Theory of movement of the combined seeding unit

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Abstract

Modern energy-saving technologies, that are widely implemented currently in agriculture include the use of combined units that can not only reduce the agronomic timing of field work, but also reduce water loss by reducing the inter-operational periods of time, to reduce the impact of sealing machine units on the ground, to save fuel − materials and so on.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: energy-saving; combined units; combined seed drill; power scheme; trailer combined sowing unit.

1. Background and means for solving the problem

We have developed and successfully tested in the field work of combined machine. It consists of a tractor and a combined seed drill, to which applicator fertilizer and seeder are connected. Operation of such dynamic systems requires high quality rectilinear motion during the manufacturing process and, consequently, the stability of its movement.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.024

The study of complex combined agricultural machine units is possible on the basis of the constructed mathematical models for this, including mathematical models of plane-parallel motion. Methods for constructing such machine units are well represented in the works from Vasilenko (1954), Vasilenko (1952), Vasilenko (1996), and Vasilenko (1965). In this case, the main type of movement of agricultural machine (trailed, mounted and self-propelled) is their plane-parallel motion, because this type of motion is determined by the quality of performing the specified processes. Study of combined agricultural machine units and work aggregates are determined by many already published scientific papers and some still in press from Vasilenko (1965), Bulgakov (2007), Guskov (1988), Timofeev (1965) and Adamchuk (2015). Numerous studies have found that the agronomic, operational and technical performance of the combined tractor units depends largely on the nature of their plane-parallel motion. Therefore, the study of plane-parallel motion of various agricultural machine units is necessary when evaluating existing and the design of innovative combinations of such units Vasilenko (1996).

2. The solution of the problem

In order to study the complex plane-parallel motion of combined machine units it is necessary to build their mathematical models, create differential equations of plane-parallel motion that will eventually allow to find a rational design and kinematic parameters of the sustainability of movement of machine, and, consequently, the quality of the process. Therefore, we first develop a power scheme of trailer combined sowing unit, which consists of aggregated tractor 1, to which is attached the fertilizer distributing drill 2, which produces a stripe of mineral fertilizers, behind which, with the help of the hitch 3 a grain seeder 4 is attached (see Fig. 1).

$$\left.\begin{aligned}
& m_1\ddot{x}_1 + \sum_{i=2}^{4} m_i\ddot{x}_i = \sum_{i=1}^{4} F_{xi}, \\
& m_1\ddot{y}_1 + \sum_{i=2}^{4} m_i\ddot{y}_i = \sum_{i=1}^{4} F_{yi}, \\
& I_1\ddot{\beta}_1 + \left(l_1 - a_1\right)\sum_{i=2}^{4} m_i\left(\ddot{x}_i \sin\beta_1 - \ddot{y}_i \cos\beta_1\right) = \\
& = M_{C_1} - M_{rf1} + \left(l_1 - a_1\right)\times \\
& \times\left[\sin\beta_1 \sum_{i=2}^{4} F_{xi} - \cos\beta_1 \sum_{i=2}^{4} F_{yi}\right], \\
& I_i\ddot{\beta}_i + m_i a_i\left(\ddot{x}_i \sin\beta_i - \ddot{y}_i \cos\beta_i\right) + \\
& + l_i \sum_{j=i+1}^{4} m_j\left(\ddot{x}_j \sin\beta_i - \ddot{y}_j \cos\beta_i\right) = \\
& = M_{O_i} - M_{rfi} + l_i\left(\sin\beta_i \sum_{j=i+1}^{4} F_{xj} - \right. \\
& \qquad \left. - \cos\beta_i \sum_{j=i+1}^{4} F_{yj}\right), \qquad \left(i = \overline{2,4}\right).
\end{aligned}\right\} \tag{1}$$

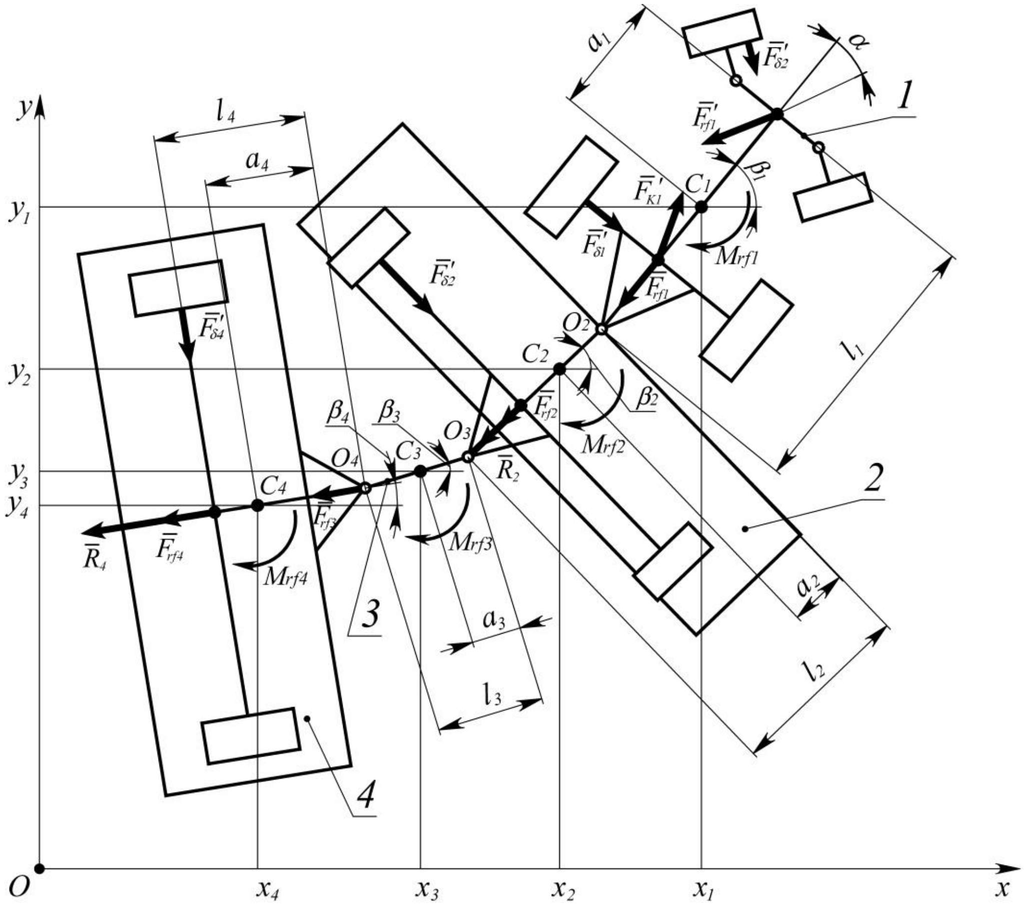

Fig. 1. Power scheme trailer combined unit: 1 – tractor, 2 – fertilizer distributing seeder, 3 – hitch, 4 – grain seeder

In this case, the first three equations in (1) describe the linear motion of the center of mass of the tractor the first three equations, along the axis ***Ox*** and ***Oy*** – $x_1$and y_1 and angular motion ρ_1 around its center of mass. The fourth equation of system (1), written in general terms, describes the combined unit turns around the property of their centers of mass. Thus, the index *i* varies from 2 to 4 and define the actual twists: Mineral spreaders – ρ_2, hitch – ρ_3 and grain drill – ρ_4.

For practical use of the system of differential equations (1) it is necessary to determine force factors that it contains.

Define further:

$$F_{rf\,i} = F^{l}_{rf\,i} + F^{r}_{rf\,i} = \\ = \frac{I_{ki}\left\{2\left[\ddot{x}_i \cos\beta_i + \ddot{y}_i \sin\beta_i + \dot{\beta}_i^2 (l_i - a_i)\right] + \ddot{\beta}_i (d_{ri} - d_{li})\right\}}{r_{ki}^2}. \quad (2)$$

We compute M_{rfi} – moment of resistance of rotation of i-level unit i-th as the sum of the moments of resistance forces: the resistance of the left and right wheels relative to the center of mass of the i-th link:

$$M_{rf\,i} = M_k(\bar{F}^l_{rf\,i}) + M_k(\bar{F}^r_{rf\,i}) = -F^l_{rf\,i}\,d_{li} + F^r_{rf\,i}\,d_{ri} = \\ = \frac{I_{ki}\left\{\left[\ddot{x}_i\cos\beta_i + \ddot{y}_i\sin\beta_i + \dot{\beta}_i^2(l_i - a_i)\right](d_{ri} - d_{li}) + \ddot{\beta}_i(d_{li}^2 + d_{ri}^2)\right\}}{r_{ki}^2}. \tag{3}$$

Rear drive wheels of the tractor depending (2) and (3), with the proviso that $d_{ri}=d_{li}=d_1$ will look like this:

$$F_{rf1} = \frac{2I_{k1}\left[\ddot{x}_1\cos\beta_1 + \ddot{y}_1\sin\beta_1 + \dot{\beta}_1^2(l_1 - a_1)\right]}{r_{k1}^2} - \frac{2M'_e}{r_{k1}}, \tag{4}$$

$$M''_{rf1} = 2I_{k1}\,\ddot{\beta}_1\left(\frac{d_1}{r_{k1}}\right)^2, \tag{5}$$

Where: $M'_e = \frac{M_e\eta}{2}$; M_e – torque that develops engine tractor; η – factor which takes into account the type of tractor transmission.

Define $\bar{F}'_{rf1}$ and M'_{rf1} for the front steering wheels of the tractor.

From equation $F^l_{rf\,i} = \frac{I_{ki}\ddot{x}'_{li}}{r_{ki}^2}$ to have left wheel:

$$F'^l_{rf1} = \frac{I'_{k1}}{r'^2_{k1}}\cdot\ddot{x}''_1 = \frac{I'_{k1}\left\{\ddot{x}_1\cos(\beta_1-\alpha) + \ddot{y}_1\sin(\beta_1-\alpha) - \right.}{1}\times \\ \times\frac{-\ddot{\beta}_1\left[(d_1 + d_0\cos\alpha)\cos\alpha + (a_1 + d_0\sin\alpha)\sin\alpha\right] -}{1}\times \\ \times\frac{\left.-\dot{\beta}_1^2\left[(a_1 + d_0\sin\alpha)\cos\alpha - (d_1 + d_0\cos\alpha)\sin\alpha\right]\right\}}{(r'_{k1})^2}, \tag{6}$$

Where r'_{k1} – the radius of the front wheels of the tractor; I'_{k1} – moment of inertia of the front wheels of the tractor relative to soybean rotation.

For the right wheel:

$$F'^r_{rf1} = \frac{I'_{k1}\left\{\ddot{x}_1\cos(\beta_1-\alpha) + \ddot{y}_1\sin(\beta_1-\alpha) + \right.}{1}\times \\ \times\frac{+\ddot{\beta}_1\left[\left(d_1 + d_0\cos\alpha\right)\cos\alpha + \left(a_1 - d_0\sin\alpha\right)\sin\alpha\right] -}{1}\times \\ \times\frac{\left.-\dot{\beta}_1^2\left[\left(a_1 - d_0\sin\alpha\right)\cos\alpha - \left(d_1 + d_0\cos\alpha\right)\sin\alpha\right]\right\}}{(r'_{k1})^2}. \tag{7}$$

Taking into account (6) and (7) we obtain:

$$F'_{rf1} = F'^r_{rf1} + F'^l_{rf1} = \\ = \frac{2I'_{k1}\left\{\ddot{x}_1\cos\left(\beta_1-\alpha\right) + \ddot{y}_1\sin(\beta_1-\alpha) - \frac{1}{2}\ddot{\beta}_1 d_0 - \dot{\beta}_1^2\left[a_1\cos\alpha - \left(d_1 + d_0\cos\alpha\right)\sin\alpha\right]\right\}}{(r'_{k1})^2}, \tag{8}$$

$$M'_{rf1} = M_k(\bar{F}''^{l}_{rf1}) + M_k(\bar{F}''^{r}_{rf1}) =$$

$$= \frac{2I'_{k1}\left(d_0 + d_1\cos\alpha\right)\left\{\ddot{\beta}_1\left[\left(d_1 + d_0\cos\alpha\right)\cos\alpha + a_1\sin\alpha\right] + \dfrac{\dot{\beta}_1^2 d_0\sin\alpha\cos\alpha}{\left(r'_{k1}\right)^2}\right\}}{1}, \quad (9)$$

Where M'_{rf1} – drag torque of the front steering wheels of the tractor, which is the sum of resistance to rotation torques of the left and right wheels relative to the centre of mass.

Taking into account (5) and (9) we obtain:

$$M_{rf1} = M'_{rf1} + M''_{rf1} = 2I_{k1}\ddot{\beta}_1\left(\frac{d_1}{r_{k1}}\right)^2 + \frac{2I'_{k1}(d_0 + d_1\cos\alpha)\times}{1}\times$$

$$\times\frac{\times\left\{\ddot{\beta}_1\left[\left(d_1 + d_0\cos\alpha\right)\cos\alpha + a_1\sin\alpha\right] + \dot{\beta}_1^2 d_0\sin\alpha\cos\alpha\right\}}{\left(r'_{k1}\right)^2}, \quad (10)$$

Where M_{rf1} – moment of resistance of rotation of the wheels of the tractor.

The force $F'_{k1} = 0$, because it is included in the determination of force F_{rf1}. Numerical analysis of this task should be carried out using a PC.

3. Results and discussion

Thus, we find all analytical expressions for the force factors that compose the system of differential equations (1), which describes the motion of a plane-parallel combined sowing unit consisting of aggregated tractor and hooked up behind him fertilizer distributing drills that band-pass method makes fertilizers and suspended on her grain drill.

In this case, the obtained analytical dependence expressed in terms of generalized coordinates, and, consequently, the system of differential equations of motion (1) after substituting the expressions obtained it will be closed, which gives every reason for its numerical solution on the computer.

The results of the numerical solutions have the possibility to build a combined motion path points of the sowing unit depending on its design and the kinematic parameters, and thus to determine their values, which provide a large rectilinear trajectories sowing unit etc.

4. Conclusion

Compiled earlier system of differential equations of plane-parallel motion combined sowing unit is fully prepared. It can be used for numerical modelling that will enable to analytically determine the rational design and kinematic parameters that ensure its sustainable movement, and thus the quality of the implementation process.

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Agriculture and Agricultural Science Procedia 7 (2015) 27 – 34

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Trajectory planning with obstacles on the example of tomato harvest

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Abstract

The paper presents the PR-APT method (Planning Rectilinear-Arc Polynomial Trajectory) for planning a trajectory of the manipulator end-effector. In the described method, a path consists of two rectilinear segments of intersecting directions combined with the blending arc of a set radius. The arc can make a fragment of an avoidable obstacle. he algorithm and the implemented method on the example of tomato harvest in the greenhouse was presented. The developed algorithm facilitates the trajectory planning in only few steps and therefore, it is supremely effective. Notably, the proposed algorithm ensures the continuity of displacement, velocity and tangential acceleration for the planned motion of the end-effector. The numerical example includes the computational results and the courses of displacement, speed and acceleration for the planned trajectory.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: greenhouses; harvest; obstacle avoidance; tomatoes; trajectory planning.

1. Introduction

Trajectory planning is the first and crucial stage of designing operational processes of robot manipulators. This problem has been addressed in a number of research papers available in literature. Gasparetto and Zanotto (2007) developed a novel method for smooth trajectory planning of robot manipulators. They formulated an objective

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.026

function containing a term proportional to the total execution time and a term proportional to the integral of the squared jerk and finally, obtained smooth trajectory. With respect to optimization techniques, they assumed minimum move time, minimum energy and minimum jerk. Dyllong and Visioli (2003) utilized various spline techniques to plan and modify a trajectory for robot manipulators. The authors analyzed and compared in detail algebraic and trigonometric splines, their combined use and the use of B-spline techniques. Erkorkmaz et al. (2006) presented a trajectory planning strategy for maintaining the tool positioning accuracy in high speed cornering applications. Two spline fitting strategies were developed for smoothening sharp corners. The over-corner test results indicated the possibility of improving the contouring accuracy at sharp corners. Red (2000) investigated a dynamic and adaptive trajectory generator using S-curves. Between the constant acceleration and deceleration periods, there were used constant jerk transitions. Optimization was defined to be the minimum time to transition from the current speed to the set speed for the move segment when jerk and acceleration are limited. The S-curve equations were adapted to instantaneous changes in speed setting and path length. An integrated motion planner determined allowable speeds and transitional profiles based on the remaining move distance. Boryga and Graboś (2009) used polynomials of higher degree to plan a trajectory of robot manipulator. The linear acceleration profiles of end-effector were planned as the polynomials of 9, 7 and 5 degrees. They presented time courses of displacements, velocities, accelerations and jerk for the rectilinear path of end-effector for a three degree of freedom manipulator. A characteristic of the proposed polynomials is a zero jerk value at the motion start and end that has positive effect on drive unit load, motion control and positioning accuracy. Valero et al. (2006), presented an algorithm capable of obtaining a sequence of feasible robot configurations between the initial and final point for the trajectory with obstacles. They divided the algorithm into two stages obtaining a discrete configuration space followed by obtaining an optimal and feasible trajectory. In the second stage, configurations are to be found that allow a minimum weighted free-collision path. For this sequence of configurations, trajectories in the joint space are generated that minimize the total required time and are dynamically compatible with the robot features. Tian and Collins (2004) proposed a novel trajectory planning method for a robot manipulator whose workspace includes several obstacles. They developed a genetic algorithm (GA) to search for valid and optimal solutions to the trajectory in task space. To approximate the time histories of the trajectory, they used a polynomial based on Hermite cubic interpolation. The authors demonstrated the effectiveness and capability of the proposed approach through simulation studies. Graboś and Boryga (2013) presented an algorithm PCM (Polynomial Cross Method) for planning motion of a manipulator end-effector, whose path was composed of two rectilinear segments. Boryga (2014) presented an algorithm for rectilinear-arc trajectory planning whose path is composed of two rectilinear segments connected with a loop-shaped arc. The algorithm can be used in solutions with high speed cornering applications.

Some research centers have conducted the testing of manipulators for agricultural product harvesting, spraying and carrying. In Wageningen, the field tests are performed on a cucumber harvesting manipulator use in a greenhouse. Van Henten et al. (2002, 2003, 2009) developed a manipulator design for fully autonomous cucumber picking robot including the autonomous vehicle, the manipulator, the end-effector, vision system and control system. Besides, Van Henten et al. (2006) discussed the preliminary results of field tests with a robot for removing leaves from a cucumber plant. The field trials have confirmed the robot suitability for automatic cucumber harvesting and removing leaves from a cucumber plant.

Among the research papers addressing the generation of trajectory motion, the one by Van Henten et al. (2003) deserves attention as it presents the algorithms used to calculate collision-free end-effector motions. Although the developed algorithm generated good solutions, it was found to be too slow for on-line operation. Van Willigenburg et al. (2004) searching for a novel faster algorithm used the trajectory of the bang-bang type and assumed it time-optimal control for fruit harvesting. The literature review allowed to state that the further studies should focus especially on development of new fast algorithms for trajectory motion generation (shortening of working cycle time), consider avoidance of obstacles and accuracy of end-effector towards a picked fruit.

This work presents an innovative algorithm for planning the rectilinear-arc trajectories with 7-degree polynomial application. The developed algorithm allows for the trajectory planning in only a few steps and therefore, it is very effective. Additionally, the algorithm ensures the continuity of displacement, velocity and tangential acceleration for the planned end-effector move. Besides, the present paper proposes the concept of the tomato harvest system using the novel algorithm for the generation of end-effector trajectory ensuring high accuracy of positioning, especially at the initial and final trajectory point.

2. Trajectory planning with blending arc

2.1. PR-APT method

The PR-APT method (Planning Rectilinear-Arc Polynomial Trajectory) is applicable for planning an end-effector move trajectory, whose path consists of two rectilinear segments of intersecting directions linked by the arc. On the rectilinear distances, acceleration profile was described by polynomial of 7-degree. It is the lowest-degree polynomial, for which the jerk at the initial and final moment of the motion and at the change of the run-up phase into the brake one is equal zero (Boryga and Graboś, 2009). It was assumed that acceleration on rectilinear segments B-T1 and T2-E does not exceed the preset maximal value $\ddot{s}_{max}$ and further, that at transition from the rectilinear segment to the arc, the resultant speed value of the end-effector does not change. The motion over the blending arc proceeds at a constant speed. During the transition from the arc to the other rectilinear segment, the resultant speed value does not change either. Appropriate determination of acceleration profile for the rectilinear segments necessitates the construction of ancillary segments. The ancillary segments are the axis symmetry of the rectilinear move distances in relation to the points tangent to the arc (Fig.1).

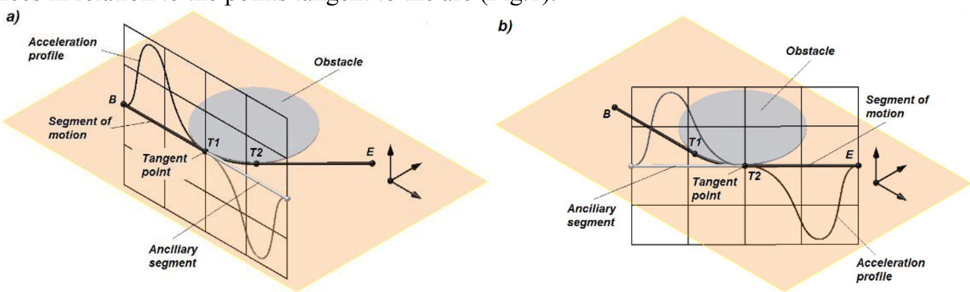

Fig. 1. Acceleration profile on a) B-T1 segment and its ancillary one b) T2-E segment and its ancillary one

To describe acceleration of total segments (move segment and ancillary one), a 7-degree polynomial was applied

$$\ddot{s}(t) = -p \cdot t^2 \cdot (t - 0.5t_e)^3 \cdot (t - t_e)^2 \qquad (1)$$

where: p - polynomial coefficient, t_e - time of motion.

For this polynomial form, tangency point is achieved in the half move time on the total segment. At the same time, acceleration is equal to zero in the point of tangency. At the time of motion over the blending arc, a value of determined speed does not change, hence tangent acceleration is equal to zero. However, normal acceleration appears as the effect of motion over the curvilinear trajectory.

2.2. Algorithm of PR-APT method

Calculation of motion path geometry

Step 1. Assumption:

- coordinates of the initial point $B(x_1^B, x_2^B, x_3^B)$, and final point $E(x_1^E, x_2^E, x_3^E)$,
- coordinates of the arc center $O(x_1^O, x_2^O, x_3^O)$ and arc radius R being a fragment of avoidable obstacle design.

Step 2. Determination:

- coordinates of the tangency point $T1(x_1^{T1}, x_2^{T1}, x_3^{T1})$ of straight line running through point B and tangent to the arc,

- coordinates of the tangency point T2($x_1^{T2}, x_2^{T2}, x_3^{T2}$) of straight line running through point E and tangent to the arc,
- angle β subtended by the arc of radius R (Fig.2).

Step 3. Determination of path increments on rectilinear segments B-T1 and T2-E

$$\Delta s^{BT1} = \sqrt{\sum_{i=1}^{3}(x_i^{T1} - x_i^{B})^2} \;,\; \Delta s^{T2E} = \sqrt{\sum_{i=1}^{3}(x_i^{E} - x_i^{T2})^2} \tag{2}$$

Step 4. Assumption of acceleration limit $\ddot{s}_{max}$ on the rectilinear segments.

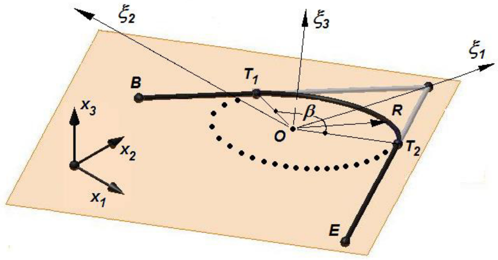

Fig. 2. Motion path with introduced coordinate systems

Step 5. Introduction of the local right-handed coordinate system $\xi_1\xi_2\xi_3$ with the starting point O, axis versor ξ_1 directed towards the point of intersection of lines tangent to the arc and orientation of axis versor ξ_2 intersecting the line B-T1.

Step 6. Determination of matrix transformation $\boldsymbol{A}$ between the local system of coordinates $\xi_1\xi_2\xi_3$ connected with the trajectory and the base coordinate system $x_1x_2x_3$

$$\boldsymbol{A} = \begin{bmatrix} cos(\xi_1, x_1) & cos(\xi_2, x_1) & cos(\xi_3, x_1) & x_1^O \\ cos(\xi_1, x_2) & cos(\xi_2, x_2) & cos(\xi_3, x_2) & x_2^O \\ cos(\xi_1, x_3) & cos(\xi_2, x_3) & cos(\xi_3, x_3) & x_3^O \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

Computations for the Rectilinear Segments (superscript BT1 and T2E)

Step 1. Pre-establishing motion time for segment B-T1 and T2-E

$$t = \frac{6\sqrt{105}(\ddot{s}_{max}\sqrt{21}\cdot(2\Delta s))^{0.5}}{2\cdot(49\cdot\ddot{s}_{max})} \tag{4}$$

For segment B-T1: $\Delta s = \Delta s^{BT1}, t = t^{BT1}$. For segment T2-E: $\Delta s = \Delta s^{T2E}$, $t = t^{T2E}$.

Step 2. Determination of velocity value in the points of tangency T1 and T2

$$\dot{s} = \frac{105}{64}\frac{\Delta s}{t} \tag{5}$$

For segment B-T1: $\Delta s = \Delta s^{BT1}, t = t^{BT1}$ and $\dot{s} = \dot{s}_{T1}^{BT1}$. For segment T2-E: $\Delta s = \Delta s^{T2E}$, $t = t^{T2E}$ and $\dot{s} = \dot{s}_{T2}^{T2E}$.

Step 3. Determination of motion time on B-T1 and T2-E segment.

If $\dot{s}_{T1}^{BT1} \geq \dot{s}_{T2}^{T2E}$, then velocity in the points of tangency and over the arc should be assumed to be $\dot{s}^{A} = \dot{s}_{T2}^{T2E}$, and the motion time on B-T1 segment is derived from the dependency $t^{BT1} = \frac{105}{64}\frac{\Delta s^{BT1}}{\dot{s}_{T2}^{T2E}}$. In the case when $\dot{s}_{T1}^{BT1} < \dot{s}_{T2}^{T2E}$, the velocity at the tangential points and on the arc should be posited as $\dot{s}^{A} = \dot{s}_{T1}^{BT1}$ while the motion time on T2-E established from the dependency $t^{T2E} = \frac{105}{64}\frac{\Delta s^{T2E}}{\dot{s}_{T1}^{BT1}}$.

Step 4. Establishing polynomial coefficient: acceleration, speed and position for segment B-T1 and T2-E

$$p = \frac{315 \cdot \Delta s}{8 \cdot t^{9}} \tag{6}$$

For segment B-T1: $\Delta s = \Delta s^{BT1}, t = t^{BT1}$ and $p = p^{BT1}$. For segment T2-E: $\Delta s = \Delta s^{T2E}$, $t = t^{T2E}$ and $p = p^{T2E}$

Computations for Arc (superscript A)

Step 1. Establishing time of motion over the arc

$$t^{A} = \frac{\beta \cdot R}{\dot{s}^{A}} \tag{7}$$

Step 2. Determination of dependence of angular displacement

$$\beta(t) = \frac{\beta}{2} - \frac{\dot{s}^{A}}{R}(t - t^{BT1}) \text{ for } t^{BT1} \leq t \leq t^{BT1} + t^{A} \tag{8}$$

Step 3. Determination of coordinates of the position vectors $\boldsymbol{X}^{A}$, speed $\dot{\boldsymbol{X}}^{A}$ and acceleration $\ddot{\boldsymbol{X}}^{A}$ of the motion over the arc at base coordinate system $x_1x_2x_3$

$$\boldsymbol{X}^{A} = \boldsymbol{A} \cdot \boldsymbol{\Xi}^{A}, \ \dot{\boldsymbol{X}}^{A} = \boldsymbol{A} \cdot \dot{\boldsymbol{\Xi}}^{A}, \ \ddot{\boldsymbol{X}}^{A} = \boldsymbol{A} \cdot \ddot{\boldsymbol{\Xi}}^{A} \tag{9}$$

where: $\boldsymbol{X}^{A} = \left[x_1^{A}(t), \quad x_2^{A}(t), \quad x_3^{A}(t), \quad 1\right]^{T}$, $\boldsymbol{\Xi}^{A} = \left[R\cos\beta(t), \quad R\sin\beta(t), \quad 0, \quad 1\right]^{T}$

Final Computations

Step 1. Determination of translation in the time on the T2-E segment

$$t_b = t^{BT1} - t^{T2E} + t^{A} \tag{10}$$

Step 2. Performing translation in the time of polynomial depicting acceleration profile for T2-E segment by t_b value

$$\ddot{s}^{BT1}(t) = -p^{BT1} \cdot (t)^2 \cdot (t - t^{BT1})^3 \cdot (t - 2t^{BT1})^2 \tag{11}$$

$$\ddot{s}^{T2E}(t) = p^{T2E} \cdot (t - t_b)^2 \cdot (t - t^{T2E} - t_b)^3 \cdot (t - 2t^{T2E} - t_b)^2 \tag{12}$$

Step 3. Determination of total motion time over the planned trajectory B-T1-T2-E

$$t_e = t^{BT1} + t^{A} + t^{T2E} \quad (13)$$

3. Application of PR-APT Method in Tomato Harvest in Greenhouse

The proposed PR-APT method was utilized for planning trajectory of end-effector during tomato picking operation in a greenhouse. Designing the motion path based on this method was preceded with measurements performed in the Experimental Farm, University of Life Sciences, Lublin where the Admiro F1 tomato cultivation is carried out.

To robotize the harvest tasks, the following assumptions were formulated (Fig.3):

- Staggered arrangement rows of tomato plants, plant spacing in row is h=0.5m. Spacing of I and III row as well as II and IV is h.
- Spacing of I and II row with manipulator locomotion between them is $2h$.
- Tomato plant space was denoted as three zones:

  Z1 – minimum damage risk $r \in (k_1R, R\rangle$ (yellow ring in Fig.3),

  Z2 – increased damage risk $r \in (k_2R, k_1R\rangle$ (orange ring in Fig.3),

  Z3 – harvest zone $r \in (0, k_2R\rangle$, (red circle in Fig.3).

  where: k_1 and k_2 - coefficients of the harvest zone size associated with a tomato variety. The minimum damage risk zones Z1 in the plants from I and II row facilitate safe end-effector motion to approach the plants in III and IV row.
- Consecutive stop positions Pn of manipulator will be located in the axis of each plant from a selected side. A Pn position of manipulator enables picking tomatoes in eight quarters of the Z3 denoted with red.
- The harvested tomatoes will be transported to one site of the pallet – point E that will need a special solution of palletizing system. The assumed coordinate x_2 of point E was L=0.325m.
- During the harvest operation of tomatoes from I and II plant row and one plant from III row, end-effector motion will proceed over the rectilinear trajectories.

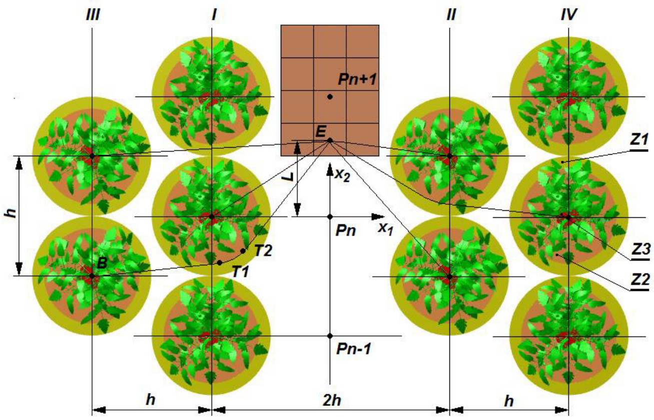

Fig. 3. Tomato cultivation system with end-effector paths.

- During the harvest operation of tomatoes from III and IV plant rows, end-effector motion will proceed over the trajectories with arc. The arc segment planned at the boundary of Z1 and Z2 zone facilitates avoidance of obstacle, i.e. the plant from I or II row (minimization of plant damage).
- The planned trajectories will be located in the horizontal plane x_3=0.5 resulting from the location of ready to harvest tomatoes at nearly the same picking position – 0.5m above the ground. In response to potential differences in the height, the end-effector will perform local movements.

4. Simulation Test Results

The presented method PR-APT will be used for trajectory planning over the path B-T1-T2-E, it includes an arc segment and is the longest trajectory among those realized in the Pn position of manipulator. The base coordinate system $x_1x_2x_3$ is associated with the Pn position of manipulator (Fig.3). The assumed radius was R=0.25m, while h=2R=0.5m. The zone size coefficient for Admiro F1 variety tomato assumed was k_1=0.8. The coordinates of B and E points are B(-1, -0.25, 0.5), E(0, 0.325, 0.5). The arc center has the coordinates O(-0.5, 0, 0.5). The calculated coordinates of the tangency points are $\mathrm{T1}\,(-0.480, -0.199, 0.5)$, $\mathrm{T2}\,(-0.341, -0.121, 0.5)$. Maximal acceleration assumed was $\ddot{s}_{max}$=2 m/s^2. The distance increments on the segments B-T1 and T2-E are equal $\Delta s^{BT1} = 0.522$ m and $\Delta s^{T2E} = 0.561$ m. The motion times resulting from the preset acceleration $\ddot{s}_{max}$ and established distance increments are $t^{BT1} = 0.969$ s and $t^{T2E} = 1.004$ s. The velocities at the tangency points reach $\dot{s}_{T1}^{BT1} = 0.885$ m/s and $\dot{s}_{T2}^{T2E} = 0.917$ m/s. According to the algorithm, the velocity at the tangency points was assumed to be lower from the established $\dot{s}_{T1}^{BT1} = \dot{s}_{T2}^{T2E} = \dot{s}^{A} = 0.885$ m/s. The motion time over the T2-E segment for the decreased velocity is $t^{T2E} = 1.041$ s. The polynomial coefficients on the segment B-T1 and T2-E are equal $p^{BT1} = 27.418$ m/s^9, $p^{T2E} = 15.430$ m/s^9, respectively. Total angular displacement along the arc T1-T2 is $\beta = 0.821$, while motion time over the arc is $t_e^A = 0.232$ s. Translation in the time of motion start on the T2-E segment is $t_b = 0.159$ s, whereas total motion time over the planned trajectory is $t_e = 2.242$ s.

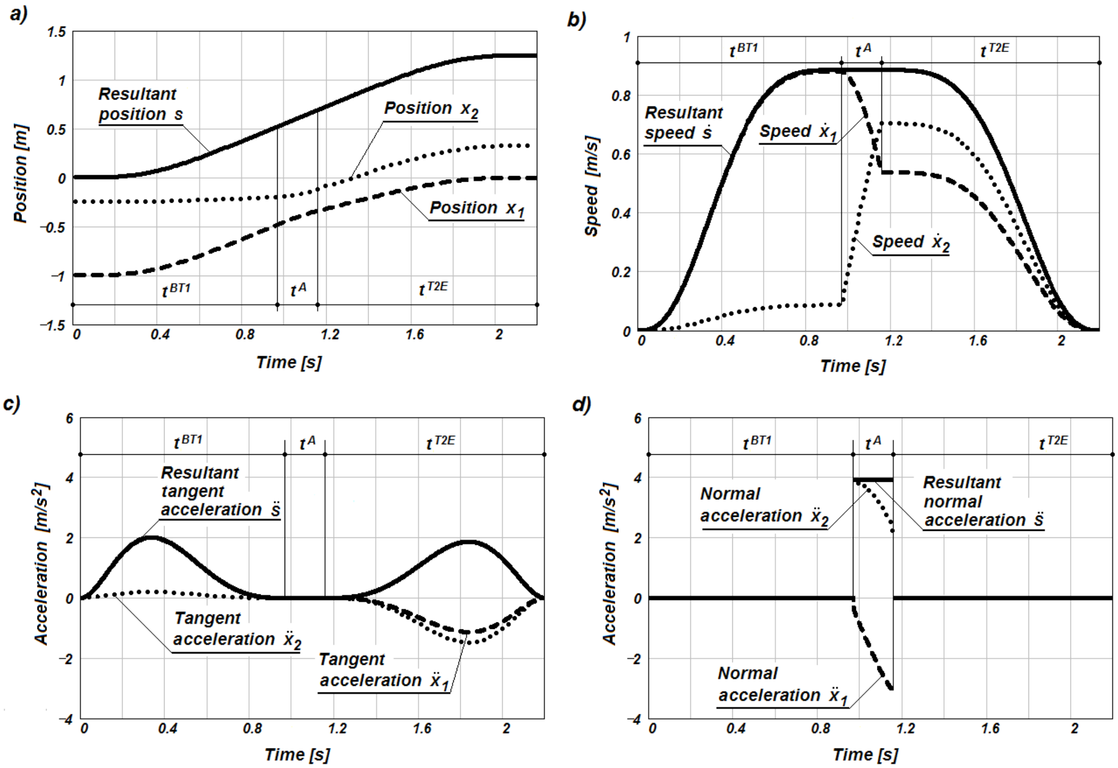

Fig. 4. End-effector profiles: a) position, b) speed, c) tangent acceleration, d) normal acceleration

The simulation tests provided the courses of displacements, velocities and accelerations of robot manipulator end-effector presented in Fig.4. Fig.4a presents the end-effector displacements on the coordinates x_1 and x_2, whose course is in accordance with the predefined trajectory and the total displacement of the end-effector from point B to

E is 1.288 m. Fig.4b presents the course of end-effector speed on x_1, x_2 directions and resultant speed. During the motion over the arc, speed components change in consistence with the trigonometric functions cosine and sine. Resultant speed during the motion over the arc does not change and is $\dot{s}_{T1}^{BT1} = \dot{s}_{T2}^{T2E} = \dot{s}^{A} = 0.885$ m/s. The course of end-effector resultant speed is a continuous function. Fig.4c shows the course of tangential acceleration of the end-effector on directions x_1, x_2 and resultant tangent acceleration. Fig.4d shows the course of normal acceleration of end-effector on directions x_1, x_2 and resultant normal acceleration. In points B, T1, T2 and E, the course of tangential component of acceleration is tangent to the time axis and hence, jerk value in these points is equal to zero. During the motion over the arc, tangential component of acceleration is equal zero, though, normal component appears which is unavoidable during the motion over a curvilinear trajectory.

5. Conclusion

The proposed PR-APT method facilitates planning a trajectory of manipulator end-effector whose path comprises two rectilinear segments of intersecting directions connected with the arc. The method is applicable for trajectory planning with obstacles which are avoided over the arc of the set radius. This method efficiency, as compared to the classical approach of polynomial trajectory planning, results from a necessity of determining only one coefficient of polynomial depicting acceleration profile. The PR-APT method was employed to generate end-effector trajectory at tomato harvest in the greenhouse. The simulation tests showed that displacement, resultant speed and tangential acceleration are continuous functions. The course of acceleration profile is tangent to the time axis in the initial and end point of trajectory which should reduce vibrations and increase accuracy of positioning in relation to a picked fruit and pallet cell. The proposed PR-APT algorithm allows for the trajectory planning in only a few steps and therefore, it is very effective

The analysis of harvest and maintenance measures, as well as the stage of trajectory planning, will serve as the basis for structural synthesis of manipulator.

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Agriculture and Agricultural Science Procedia 7 (2015) 35 – 39

Agriculture and Agricultural Science
Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Mathematical modelling of the process of renewal of the fleet of combine harvesters

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Abstract

The new optimization task within the integrated model of the renewal of the fleet of harvesters has been considered in this paper. The aim of the study is generation of the mathematical model for the renewal of the combine harvester fleet on the basis of integral equations with an unknown lower limit of integration. The integro-functional equations for main trajectories have been obtained, and the qualitative behaviour of main trajectories depending on the rates of scientific and technological advancement has been studied.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: agricultural machinery; combine harvester; fleet; model; optimization

1. Introduction

In order to solve the problem at hand, we have used the integrated model theory of the systems with controlled memory, which have a number of advantages in comparison to other models that are widely used at present. Integral dynamic models are flexible enough to be applied, and after being modified accordingly, they can be used for a wide range of purposes and practical tasks. Depending on the tasks that have been set, a number of model ratios, which

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.027

are insignificant in this particular case, might not be used or, on the contrary, the new correlations, which describe any given peculiarities of the course of technological processes, can be included into the equation system. If we take into account the increasing deficit in labour and fuel resources, the need to use models like the one described above for managing the processes of the replacement and renewal of technical equipment becomes obvious. A good overview can be found in Bochtis et al., (2007 and 2014), Edwards and Boehlje (1980), Gao et al., (1985), Gunnarson et al., (2009), Miu et al., (1997) and Trollope (1982).

2. Materials and Methods

The main task is to define the composition of a fleet of combine harvesters in order to ensure the performance of all tasks arising from the structure of cultivated areas, aimed at harvesting grain crops within the specified agrotechnical time periods with minimum material costs and existing labour resources.

At first, we are going to set the input parameters that are essential for modelling: Thereby, I is the initial set of the types of grain crops and grain legume crops that have to be harvested with combine harvester; i is the crop type, $i \in I$, $|I| = n$; J is the set of combine harvester makes; j is the number of a combine harvester makes, $j \in J$, $|J| = m$; τ is the year of purchase (manufacture) of a combine harvester, $\tau \in [\tau_0, t_0]$; $[t_0, T]$ is the scheduled calculation interval in years; $[\tau_0, t_0]$ is the interval of development of the fleet of combine harvesters; $\beta_{ij}(\tau,t)$ is the output capacity of harvesters of j make, manufactured or purchased in τ, which harvest i crop in t year; $P_{ij}(\tau)$ is the amount of staff that provides maintenance to the j make, which was manufactured or purchased in τ, which harvests i crop; $x_{ij}(\tau)$ is the number of combine harvesters of the j make, manufactured or purchased in τ, which harvest i grain crop, $\tau \in [\tau_0, t_0]$; $a_j(t)$ is time limit for writing off the combine harvesters of the j make: if a harvester was manufactured or purchased in τ, the combine harvester is amortized at $\tau < a_j(t)$, at $\tau \geq a_j(t)$ it is used in an operating cycle at $t \in [t_0, T]$; $S_i(t)$ is the rated area of i grain crop or grain legume crop in t, $t \in [t_0, T]$; $P(t)$ is the availability of machine operators in year t.

The demand for combine harvester should be determined proceeding from the need to harvest all kinds of grain crops and grain legume crops per year t, $t \in [t_0, T]$:

$$S_i(t) = \sum_{j=1}^{m_i} \int_{a_{j(t)}}^{t} \beta_{ij}(\tau,t) x_{ij}(\tau) d\tau, \qquad (1)$$

$$i = \overline{1,n}$$

where m_i is the number of the makes of harvester-threshers used for harvesting i crops.

The demand for labour force required for performing the specific types of work and operations is determined on the basis of the following equation:

$$P(t) = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \int_{a_{j(t)}}^{t} P_{ij}(\tau) x_{ij}(\tau) d\tau\ . \qquad (2)$$

The system of integral equations (1) – (2) is an integral dynamic model with controlled memory. It describes the processes of replacing and renewing the fleet of combine harvesters taking into account scientific and technological progress, since the output capacity of a combine harvester $\beta(\tau,t)$ depends on the year of its manufacture τ, while this function $\beta(\tau,t)$ is non-decreasing, but in the majority of cases it decreases by τ. The functions $S_i(t)$, $P(t)$, $\beta_{ij}(\tau,t)$, $P_{ij}(\tau)$ will always be regarded as pre-set, $t \in [t_0,T]$, $\tau \in [\tau_0,t_0]$.

The functions $x_{ij}(t)$, $x_{ij} \geq = 0$, $i = \overline{1,n}$, $j = \overline{1,m_i}$ are always sought-for, while the functions $a_j(t) < t$, $j = \overline{1,m_i}$ can be pre-set and sought-for, depending on the problem definition.

Equations (1)–(2) depend on the background $[\tau_0,t_0]$, which is why it is required that the functions $x_{ij}(\tau) \equiv x_{ij}^0(\tau)$, $\tau \in [\tau_0,t_0]$ and the values $a_j(t_0) = a_j^0 < t_0$, $i = \overline{1,n}$, $j = \overline{1,m}$ are pre-set.

The functions $x_{ij}^0(\tau)$ can be found on the basis of the solution of the existing task concerning the distribution of the existing fleet of combine harvesters by the types of works in each background year $[\tau_0,t_0]$, or at least for the year t_0, which is the start of the scheduled period. The values $a_j(t_0) = a_j^0$ can be found on the basis of the real dynamics of the write-off of the outdated combine harvesters during the previous development history $[\tau_0,t_0]$.

Depending on the correlation of unknown factors and the equations in the models (1) – (2), two kinds of tasks can be resolved with the given model.

If the number of equations coincides with the number of unknown factors, and the task is completely determined, we get the task of a multi-path forecast for the development of the fleet of combine harvesters within a specific scheduled time period $[\tau_0,T]$. If the number of unknowns is higher than the number of equations, we get the task of optimal control within the scheduled interval $[\tau_0,T]$.

In the event of $m_i > 1$ in the models (1)–(2) the number of unknown factors is higher than the number of equations, which is why the solution is not the only one, and for closing the task, it is required to add a certain optimisation criterion. It allows to solve the problem using the models (1) – (2) as the task of the optimal control over the demand and the renewal of the fleet of combine harvesters within the scheduled interval $[t_0,T]$.

Taking into account the increasing deficit of labour resources in agriculture, we will consider the demand for labour force required for the performance of pre-set tasks within the scheduled interval $[t_0,T]$ as one of the main components of the optimisation criteria. In other words, we will be using the function $P(t)$, represented by the formula (2), as a component included in the optimisation criterion, omitting the limitation (2) in the models (1) – (2). We are also going to use the operating expenses for the performance of the specific volume of works and operations and the expenses for the acquisition of harvester-threshers as the components included in the optimisation criterion.

Thus, we are arrive at the definition of the general problem regarding the optimal control over the demand and the renewal of the fleet of combine harvesters – it involves the tasks of minimising labour costs, operating expenses, and the expenses for the acquisition of the new grain harvesting machines and equipment.

To determine the unknown functions $x_{ij}(t)$, $a_j(t)$, $i = \overline{1,n}$, $j = \overline{1,m_i}$, $t \in [t_0, T]$, which provide the minimum of the function:

$$I = \sum_{i=1}^{n}\sum_{j=1}^{m_i}\int_{t_0}^{T}\left\{\int_{a_j(t)}^{t}\left[P_{ij}(\tau) + r_{ij}(\tau,t)\right]x_{ij}(\tau)d\tau + B_j(t)x_j(t)\right\}dt \to \min, \tag{3}$$

with equality constraints:

$$S_i(t) = \sum_{j=1}^{m_i}\int_{a_{j(t)}}^{t}\beta_{ij}(\tau,t)x_{ij}(\tau)d\tau, \tag{4}$$

$$i = \overline{1,n}$$

with inequality constraints:

$$x_{ij} \geq = 0, \qquad a_j(t) < t, \qquad i = \overline{1,n} \qquad j = \overline{1,m_i} \tag{5}$$

under the initial conditions:

$$a_j(t_0) = a_j^0 \geq 0, \qquad x_{ij}(\tau) \equiv x_{ij}^0(\tau),$$

$$i = \overline{1,n}, \quad j = \overline{1,m_i}, \qquad \tau \in [\tau_0, t_0], \tag{6}$$

where $r_{ij}(\tau,t)$ are operating costs per unit (labour expenses, fuel costs, allocations for in-line repair works and technical maintenance, etc.) for harvesting the i crop in t per one harvester of the j make, purchased in τ; $B_j(t)$ is the cost of the combine harvester of the j make which will be purchased in t, $\boldsymbol{j = \overline{1,m_i}}$, $\tau \in [t_0, T]$.

3. Results and Discussion

In this task, the functions $S_i(t)$, $\beta_{ij}(\tau,t)$, $P_{ij}(\tau)$, $r_{ij}(\tau,t)$, $B_j(t)$ are always known. after determining $x_{ij}(t)$ the required number of harvester-threshers of the j make can be obtained:

$$x_j(t) = \sum_{i=1}^{n} x_{ij}(t),$$
$$j = \overline{1, m}.$$

After determining the functions $a_j(t)$, $j = \overline{1, m}$ all of the combine harvesters of the j make which were purchased in τ can be written off in t, provided that $\tau < a_j(t)$. Besides, the service life of combine harvesters $d_j(t)$ can be determined with the functions $d_j(t) = t - a_j(t)$, $j = \overline{1, m}$.

In the optimal control task (3)–(6) at $m_i > 1$ the number of unknowns $x_{ij}(t)$, $a_j(t)$, $i = \overline{1, n}$, $j = \overline{1, m_i}$, is higher than the number of equations. Thus, it is quite complicated to resolve this task in general. This is why we are making the assumption that $m_i = 1$, i.e., that every i^{th} crop is harvested by harvester-threshers of the same type. Since we have assumed that there is a small number of different makes of harvesters in the same country, such an assumption is quite acceptable from a practical standpoint.

When $m_i = 1$, the task (3) – (6) is in the following form.

To determine the unknown functions $x_i(t)$, $a_i(t)$, $i = \overline{1, n}$, $t \in [t_0, T]$, providing

$$I = \sum_{i=1}^{n} \int_{t_0}^{T} \left\{ \int_{a_j(t)}^{t} [P_i(\tau) + r_i(\tau, t)]\, x_i(\tau) d\tau + B_i(t) x_i(t) \right\} dt \to \min, \tag{7}$$

with equality constraints:

$$S_i(t) = \int_{a_{j(t)}}^{t} \beta_i(\tau, t) x_i(\tau) d\tau, \tag{8}$$
$$i = \overline{1, n},$$

with inequality constraints:

$$0 \le x_i(t) \le M_i, \qquad a_i'(t) \ge 0, \qquad 0 \le a_i(t) \le t, \qquad i = \overline{1, n}, \tag{9}$$

under the initial conditions:

$$a_i(t_0) = a_i^0 \ge 0, \qquad x_i(\tau) \equiv x_i^0(\tau), \quad \tau \in [\tau_0, t_0], \qquad i = \overline{1, n}, \tag{10}$$

while the functions $a_i(t)$ are regarded as different from each other. We will assume that the pre-set functions are the following:

$$\beta_i(\tau, t), \quad r_i(\tau, t) \in C_{[\tau_o, T] \otimes [t_o, T]}, \quad B_i(t) \in C_{[t_o, T]}, \quad S_i(t) \in C^1_{[t_o, T]},$$
$$x_i^o(\tau) \in C_{[\tau_o, t_o]}, \quad P_i(\tau) \in C_{[t_o, T]},$$

all of the functions are positive, and the initial values (10) comply with the equation system (8) at $t = t_0$.

It turns out that this task can be regarded as the group n of optimisation tasks for single-product models of the following type.

To determine the unknown functions, $x_i(t)$, $a_i(t)$, $t \in [t_0, T]$,
where i is fixed, providing

$$I = \int_{t_0}^{T} \left\{ \int_{a_i(t)}^{t} [P_i(\tau) + r_i(\tau, t)]\, x_i(\tau) d\tau + B_i(t) x_i(t) \right\} dt \to \min, \tag{11}$$

with limitations (8)–(10) for the relevant i.

It is obvious that $I = \sum_{i=1}^{n} I_i$, while $I \to \min$, if $I_i \to \min$, $i = \overline{1, n}$.

4. Conclusions

The qualitative analysis of the optimisation task provided in the present paper allows to determine the optimum service life of combine harvesters on the basis of the main properties of the solutions, which require much less information in comparison with the direct solution of an optimisation task. The modes that are obtained in the result of resolving integro-functional equations show the main regularities of the dynamics of renewal and development of the fleet of combine harvesters. The lack or unreliability of the source data, which is quite usual in agriculture, justifies the application of the mainstream approach to studying issues connected with the replacement and renewal of combine harvesters.

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Agriculture and Agricultural Science Procedia 7 (2015) 40 – 44

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Structure development and results of testing a novel modular power unit

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Abstract

The authors of this paper have developed and tested a novel modular power unit with the variable drawbar pull category 1.4-3 (1.4-3 tf) (drawbar pull based classification approach is used in Ukraine and some other countries) under the mark MPU-80. In this paper the proposed results of experimental, field and laboratory research of the ploughing unit based on this power unit are listed.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: Tractors (agricultural); modular power unit; technological module; experiment; drawbar pull.

1. Introduction

One of the most efficient ways of solving a problem that is connected with the nomenclature of tractor power engineering is the implementation of modular power units (MPU), the high versatility and technological adaptability of which is guaranteed through the variability of their drawbar pull category.

This fundamentally new trend of tractor development is relevant for almost all of the world's countries today, referred to the works of e.g. Kutzbach (2000), Steindorff et al. (2010) and Simikič et al. (2014). Yet, it is of

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2210-7843
Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.028

particular interest for countries, for example Ukraine, that are reforming agricultural production and have a deficit of tractors with the drawbar pull categories 2 and 5 (especially the latter).

At first glance, the seemingly easiest way for solving this problem, i.e., purchasing the missing expensive power units from abroad or making them on one's own, is actually quite difficult to accomplish because of the numerous economic problems that would arise along the way. It has already been proven by many years of using and testing the relevant equipment that purchasing tractors from abroad, in addition to resolving some financial issues, also requires developing measures for their adaptation both to the existing machine and equipment fleet as well as zonal edaphic-climatic conditions. Experience has shown that in some cases it can only be done through making considerable changes in the structure of a power unit.

In opinion of authors, one of the ways of solving this problem is making modular power units: universal row-crop machines with the variable drawbar pull category 1.4–3 on the basis of wheel-type tractors with the drawbar pull category 1.4, and modular power units of general purpose with the variable drawbar pull category 3–5 on the basis of tractors with the drawbar category 3.

The engineering feasibility and economic viability of modular power units with a variable drawbar pull category is proven by many years of researching and production testing the general-purpose breadboard model prepared on the basis of a tractor with the category 2.

2. Materials and Methods

The power unit MPU-80 (Fig 1) consists of a wheel-type tractor with the category 1.4 and a technological module (TM). The latter is an additional axle with wheel drive activated from the ground-speed power take-off shaft of the tractor. In its front part the TM has a hook-up mechanism through which it is attached to the linkage-mounted mechanism at the rear. For implement coupling with agricultural equipment, the technological module is equipped with an independent hydraulic linkage system, its own power take-off shaft, fifth-wheel assembly, and braking system.

The rotational movement of the TM in relation to the tractor while moving on headland and copying the field profile in the transverse-vertical plane is guaranteed through the use of vertical and horizontal joints. The coordination of the peripheral speed of the wheels of the TM and the rear wheels of the tractor is achieved through the use of a special reduction gear on the frame of the technological module MPU-80.

Fig. 1. Ploughing unit on the basis of MPU-80.

Table 1. Technical Specifications of MPU -80.

Technical Specifications of MPU-80	
Operating weight (kg): of the wheel-type tractor with the category 1.4	3,640
TM	2,560
MPU-80	6,200
Engine capacity, kW	62.0
Power/weight ratio MPU-80, kW in tonnes	10.0
Distance between the rear wheels of the tractor and the wheels of TM, mm	2,400
MPU-80 basis, mm	4,770
Wheel track, mm	1,450

Tire size of the technological module	16.9R38

Experimental research, operational and verification testing of the ploughing machine-tractor aggregate prepared on the basis of MPU-80 was organised in accordance with a method that is used in studying and testing tractors with the drawbar pull category 3.

During the operating cycle, MPU-80 moved with its right-hand wheels outside of the furrow. The distance between its wall and the right-hand wheels did not exceeded 15 cm.

3. Results and Discussion

The labour intensity of the connection between the technological module and tractor is 0.2 man hours. Experiments proved that two machine operators spend no more than 6 minutes on this activity.

Ploughing was done in the field after harvesting winter wheat. The soil moisture level in the layer of 0–14 cm was 18.8%, while its density was 1,210 kg m^{-3}.

The average quadratic deviation of the depth of tilling with the experimental unit prepared on the basis of MPU-80 was ±2.2 cm, while the effective operating width was ±3.8 cm.

The analysis of the operational and technological data revealed that the output of the new unit per shift is 1.9 times higher compared to the similar performance indicator of a basic ploughing unit in an assembly with a wheel-type tractor with the category 1.4 and the plough ПЛН-3-35 (table 1). It is mainly achieved through a larger (by 68.5%) effective operating width of the new machine prepared on the basis of MPU-80.

The specific fuel flow rate in the new machine is 27.5% smaller, owing to the reduction in the skidding resistance of the power unit. The true value of this indicator for the MPU-80 equipped with the plough ПЛН-5-35 under the testing conditions did not exceeded 10%, which is indicative of its relatively good prospective towing and gripping properties.

The lag hinge of the TM in the MPU-80 breadboard model is located halfway between its thrusters and the rear wheels of the tractor. As a result, as the tests have shown, the wheels of the technological module practically fall within the track of a category 1.4 tractor's rear thrusters. Besides, the sufficient mutual angular mobility in the horizontal plane of the tractor and the process module do not in any way affect the agility of MPU-80: the difference between the minimum turning radii of a category 1.4 tractor and the technological module is 3 cm. Thus, it has contributed to the sufficient agility of the ploughing unit, which is proved by the relatively high value of the operating stroke coefficient – 0.82 (table 2).

Table 2. Operational and technological properties of ploughing units.

Indicator	Indicator value	
Unit structure: tractor plough	Power unit MPU-80 ПЛН-5-35	Tractor with category 1.4 ПЛН-3-35
Operating conditions:		
effective operating width, m	1.77	1.05
tilling depth, cm	22.8	20…22
speed, km h^{-1}	8.35	
Output capacity, ha h^{-1}		
main	1.47	
variable	1.25	0.65
Expenses:		
labour, man ·h ha^{-1}	0.80	1.53
fuel, kg ha^{-1}	12.9	17.8
Utilization factor:		
shift time	0.85	
reliability of the technological process	0.99	
operating stroke	0.82	

It should be noted that using the technological module within MPU leads to an increase in the minimum width of the headland of the unit (by 9–12%) as well as an increase in manoeuvring time (by 2–5%). At the same time, as the results of long-term studies have shown, the total overhead time consumption has been negligible.

In the process of the operational and technological testing of the new ploughing unit, the compacting effect of the thrusters of MPU-80 on soil was assessed. The tests were performed on the stubble of winter wheat with two levels of soil moisture. In one of the fields (area 1) the soil moisture of the agricultural background in the layer of 0–15 was 12.8%, while in the other field (area 2) it was 20.8%.

The density of the soil after the wheels of each axle of the MPU-80 had passed was registered in the layer of 0–15 cm with the help of the radiation unit РПП-2.

The analysis of the experimental data revealed that when not only the tractor, but the technological module moves along the stubble, it does not have an additional compacting effect on the soil (table 2).

After the rear wheels of the tractor had passed, the average value of the soil density was 1.40 g cm^{-3}. The passing of the wheels of the technological module increased the density up to 1.41 g cm^{-3}. The difference - 0.01 g cm^{-3}- is minor, since, in terms of statistical significance, the minimal significant difference (LSD05) is 0.03 g cm^{-3} (table 3).

Hence, it can be claimed with a 95% confidence coefficient that the null hypothesis about the equality of the comparable average density values is not to be rejected. In other words, the statistical performance of the soil density after the passing of the rear wheels of the tractor and the wheels of the process module MPU-80 is the same in general.

When moving along a more moist agricultural background (area 2), the thrusters of the MPU-80 have a slightly different effect on the soil. While the wheels of the front axle of the tractor virtually do not change the soil density, its rear wheels have a statistically non-random further compacting effect, even though it is insignificant. Where the LSD_{05} = 0.024 g cm^{-3}, the actual difference between the average values of compaction after the passing of the front and rear wheels of the tractor was 0.060 g cm^{-3}. As for the wheels of the technological module, even on a more moist background their effect on soil density (its increase) is insignificant. An increase in this value after the passing of the wheels of TM was only 0.01 g cm^{-3}. In terms of statistics, values below 0.05 are insignificant.

Table 3. Soil compaction with the wheels of MPU-80.

Indicator	Indicator value in wheat stubble	
The original density		
	Area 1	Area 2
average value, g cm^{-3}	1.44±0.01	1.21±0.02
average quadratic deviation, ± g cm^{-3}	0.06	0.03
variation coefficient, %	4.17	2.47
Soil density after the passing of the wheels of MPU-80		
1. Front axle of the tractor:		
average value, g cm^{-3}	1.37±0.02	1.22±0.02
average quadratic deviation, ± g cm^{-3}	0.04	0.03
variation coefficient, %	2.92	2.46
2. Rear axle of the tractor:		
average value, g cm^{-3}	1.40±0.01	1.28±0.01
average quadratic deviation, ± g cm^{-3}	0.04	0.06
variation coefficient, %	2.85	4.68
3. Axle of the process module:		
average value, g cm^{-3}	1.41±0.01	1.29±0.02
standard, ± g cm^{-3}	0.04	0.03
variation coefficient, %	2.84	2.32

4. Conclusions

1. The experimental research and performance tests on the ploughing unit prepared on the basis of MPU-80 have shown that the power unit can be modularized with a wide range of other agricultural machines which have been used (and are still used) with tractors of a higher drawbar pull category, e.g., 3.
2. When using the wheel-type tractor with the category 1.4 together with the technological module, one can do without the tractor with the drawbar pull category 3, which is economically very feasible.
3. The use of the process module (as an additional drive axle) in the modular power unit does not lead to a significant increase in soil density (soil compaction).
4. The use of the technological module leads to an increase in the annual load of the multi-purpose ploughing tractor with the category 1.4. The TM might not be used for a certain period during the year, in which case the amount of losses would be ca 5–7 times less than in case of a tractor being idle according to calculations.

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Agriculture and Agricultural Science Procedia 7 (2015) 45 – 49

Agriculture and Agricultural Science
Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Mathematical model of service working body of clenaer on head beet roots

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Abstract

Sugar beet appears to be a strategic food and bio-energy culture, whereas sugar, pulp and green compound leaves are important food and raw materials used in the manufacture of bioethanol. Cleaning is the most difficult issue in the production of sugar beet. Particular attention should be paid to the operation of cutting the top of the roots' head. For example, a small amount of residual leaves on the head of sugar beet is a deteriorating quality indicator, which generally can reduce the quality by 10-15%. Therefore, separation of leaves from the head of sugar beet is a relevant scientific and technical problem.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: sugar beet; working body; head of sugar beet roots; normal reaction; force removal tops.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.029

1. Introduction

The objective of the research was the analytical determination of the forces generated at the point of contact between working body during separation of the top of the head of the sugar beet roots in the soil.

2. Object and methodology

Issues of the theoretical and experimental research related to separation of leaves from the top of the sugar beet head (final purification mainly from residues letters) and the collection are included in the scientific works of Vasilenko (1984), Bulgakov (2005), Pogorely (2004) etc. We have developed a new design of a final purification head of sugar beet roots from residues vertices Vasilenko (1984), Bulgakov (2005), Pogorely (2004).

To determine the forces that arise from the interaction of the working body with the head of sugar beet, there was built equivalent scheme of active interaction diagram (Fig. 1), on which the working body in rotational motion and also while gradually moving the total final purification is in contact with the head of sugar beet.

At the point of contact to work with the authority to head roots will affect these forces:***Q*** – force removal tops Bulgakov (2005), which is directed tangential to the root crops in the direction of the vector of absolute velocity M working bodies; ***N*** – Normal reaction from the head of root crops, directed along upright ***n*** to the head root crops, passing through the point of contact location; $\boldsymbol{F_t}$ – the force of friction, that occurs when the movements of working body on the head root crops and heading in the direction opposite to the absolute velocity vector of ***M*** working body, coincides with point of contact ***K*** and is represented in the form of projections on the x and y axes; ***G*** – power balance working body.

Differential equations of motion of the contact point to the head of root crops in vector form will take the following form Bulgakov (2005), Filchakov (1974):

$$m\bar{a} = \overline{Q} + \overline{N} + \overline{F_t} + \overline{G} \tag{1}$$

where: ***a*** – the absolute acceleration of the contact point ***K*** to the head of root sugar beet; ***m*** – weight of the working body, brought to the point of contact ***K***.

Substituting in (1) the required quantities and other necessary transformation obtained by system of non-linear differential equations of second order, with regard to the unknown function ***x*** (***t***), **y** (*t*) and (*t*) and the unknown normal reaction ***N***:

The system of differential equations (2) can be solved only by numerical methods using computer programs for the known initial conditions. Due to the fact, that the system of differential equations (2) contains unknown power factors – the normal reaction of N, than to define there was carried out monitoring working body with the head of the root. Consequently, the dependence on the angle φ diversion working body and its angular acceleration ***φ*** of time:

$$\left.\begin{aligned}
m\ddot{x} &= \overline{Q}\frac{\dot{x}}{V} + \overline{N}\frac{\dot{x}}{R} - f\frac{\dot{x}}{V}N + mg,\\
m\ddot{y} &= Q\frac{\dot{y}}{V} + N\frac{y}{R} + f\frac{\dot{y}}{V}N,\\
m\ddot{z} &= Q\frac{\dot{z}}{V} + N\frac{z}{R} - f\frac{\dot{z}}{V}N,\\
x^2 &+ y^2 + z^2 - R^2 = 0.
\end{aligned}\right\} \tag{2}$$

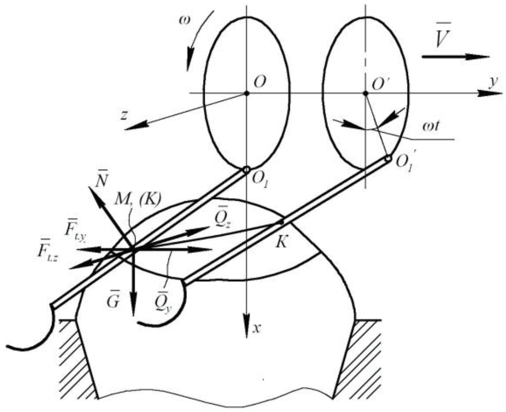

Fig. 1. Equivalent scheme of interaction working member separated leaves from head of sugar beet roots

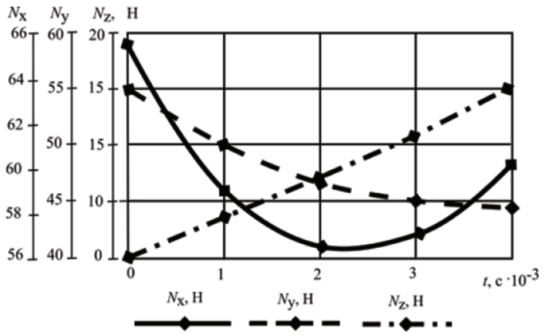

Fig. 2. Dependence of the components of the normal reaction N from the time

Provided that the head of the sugar beet has a completely solid body and the working body in contact with the un-separated eyeball, there have been composited differential equations of motion of the rotating working body around its own axis of the suspension at the time of its interaction with the head of sugar beet from Filchakov (1974):

$$J\ddot{\varphi} + \sum_{R=1}^{n} M_R = 0 \tag{3}$$

Where: $\boldsymbol{R}$ =1 – the sum of the moments of inertia centrifugal forces acting on the body work as it moves along a spherical head of root crops.

3. Results of the study

From equation (3), after algebraic transformations from Targ (1986) Bat (1973), in the end determine the normal reaction $\boldsymbol{N}$ on the roots of sugar beet, when is exposed to system it comprises from two working bodies:

$$N = \frac{J\ddot{\varphi} + M_R - \dfrac{J\ddot{\varphi}_2 + M_{R2}\sqrt{\sin^2\varphi_2\cos^2\alpha + \cos^2\varphi_2}\; m_{21}}{\sqrt{\left[\left(r_0 + l_{nn}\cos\varphi_2\right)\cos\alpha - \dfrac{b}{2}\sin\alpha\right]^2 + \left[\left(r_0 + l_{pp}\cos\varphi_2\right)\sin\alpha - \dfrac{b}{2}\cos\alpha\right]^2}}}{\sqrt{\left[\rho\sin(\alpha_0 + \omega t)\right]^2 + \left[-tg\varphi_0\left(\sqrt{\delta^2 + (d-h)^2 - \left(\dfrac{b}{2}\right)^2} - r_0\right) - Vt\right]^2}}, \tag{4}$$

where: $\boldsymbol{\delta}$ – diverting the rotor axis from the imaginary central axis line; $\boldsymbol{b}$ – width of the working body; $\boldsymbol{M_R}$ and $\boldsymbol{M_{R2}}$ – moments of inertia centrifugal forces preceding and subsequent working bodies around its hingeaxis; $\boldsymbol{m_{21}}$ – arm normal reaction following working authorities prior to its axis with respect to the suspension; $\boldsymbol{\varphi_2}$ – the angle of deflection of the next working body of the plane of rotation; $\boldsymbol{\alpha}$ – angle of rotation of the rotor shaft, $\boldsymbol{\rho}$ – distance from the axis of the rotor head to the top of the root; $\boldsymbol{d}$ – distance from the rotor axis along the surface of the soil; $\boldsymbol{r_0}$ – radius hanging axis working body; lpp – the length of the working body contouring.

The movement of the head of root crops, working body can work on it in the longitudinal, transverse and vertical line. This is due to the presence of power factors, which represents the general axial projection in that direction. In particular, it is a compilation of normal reaction N_z and N_y induced by root crops in the longitudinal and transverse directions. Vertical assembly N_x normal reaction provides the necessary strength at the point of contact, "the head of the root. – working body". The expression for this reaction is:

$$N_x = \left[\frac{\gamma s l \omega^2 \left(\frac{1}{2} r_0 \sin\varphi + \frac{l^2}{6} \sin 2\varphi \right)}{OK} + \frac{\ddot{\varphi}}{OK} \right] \cos\omega t \times$$
$$\times \sin\left[\varphi_0 + arcctg \left(\frac{-tg\varphi_0 \left(\sqrt{\delta^2 + (d-h)^2 - \left(\frac{b}{2}\right)^2} - r_0 \right) - Vt}{\sqrt{\delta^2 + (d-h)^2} \sin\left[\omega t - \arccos\left(\frac{b}{2\sqrt{\delta^2 + (d-h)^2}} \right) \right] - r_0} \right) \right]. \tag{5}$$

$$N_Y = \left[\frac{\gamma s l \omega^2 \left(\frac{1}{2} r_0 \, sin\,\varphi + \frac{l^2}{6} sin\, 2\varphi \right)}{OK} + \frac{\ddot{\varphi}}{OK} \right] cos \left[\varphi_0 + \right.$$
$$\left. + arcctg \left(\frac{-tg\varphi_0 \left(\sqrt{\delta^2 + (d-h)^2 - \left(\frac{b}{2}\right)^2} - r_0 \right) - Vt}{\sqrt{\delta^2 + (d-h)^2} \, sin\left[\omega t - arccos\left(\frac{b}{2\sqrt{\delta^2 + (d-h)^2}} \right) \right] - r_0} \right) \right], \tag{6}$$

$$N_Z = \left[\frac{\gamma s l \omega^2 \left(\frac{1}{2} r_0 \, sin\,\varphi + \frac{l^2}{6} sin\, 2\varphi \right)}{OK} + \frac{\ddot{\varphi}}{OK} \right] sin \left[\varphi_0 + \right.$$
$$\left. + arcctg \left(\frac{-tg\varphi_0 \left(\sqrt{\delta^2 + (d-h)^2 - \left(\frac{b}{2}\right)^2} - r_0 \right) - Vt}{\sqrt{\delta^2 + (d-h)^2} \, sin\left[\omega t - arccos\left(\frac{b}{2\sqrt{\delta^2 + (d-h)^2}} \right) \right] - r_0} \right) \right]. \tag{7}$$

According to the results of numerical simulation on the PC were built the plot (Fig. 2) of the foregoing forces of time. As we can see from the graph of the maximum values of these components normal reaction N, the following: N_{xmax} = 65.0 N, N_{ymax} = 55.0 N, N_{zmax} = 15.0 N.

Each of the components of the normal reaction would have on sugar beet following steps. Thus, the vertical component of the normal reaction N_x will try to deform the head of beet root and make it into the soil; the horizontal component of this normal reaction N_y – will contribute to the slope of the beet root crop in the direction of Haulm machines; the horizontal component of the normal reaction N_z – will attempt to dislodge soil from a root crop in the direction perpendicular to the rotor axis. The most important consideration for further study is the magnitude of the horizontal component N_z, as sugar beet in this direction has the lowest resistance.

These values were further used for modeling forces of the working body of the cleaning head root crops Patent №101760, Ukraine Patent №103046, Ukraine.

4. Conclusion

1. Compiled mathematical model is a system of second order differential equations describing the motion of a working body contact point with the head of sugar beet.

2. Analytical expressions for determination of the area of the head cut beet roots one working body and the forces that are transmitted from the working body to root of sugar beet have been obtained as the solutions from the system of differential equations.

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Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Gainers and losers of the implementation of the new Common Agricultural Policy in Wallonia

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Abstract

The new Common Agricultural Policy (CAP) defined in 2013 is implemented since 2015. It offers several options to the Member States/Regions. This paper describes the choices which have been made in Wallonia and their consequences on direct payments. It appears that 42% of the farmers will lose between 2014 and 2019, while 44% will gain and a quasi-status quo is observed for the remaining 14%. Finally, the new situation is politically acceptable and gives more support to small farms, young farmers and cattle breeders, though the global envelope for direct payments will decline in Wallonia.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: CAP; Wallonia; direct payments; farmers' income

1. Introduction

In 2013, a new Common Agricultural Policy was defined after several years of negotiations between the EU Commission, the Member States, the EU Parliament and the Council of Ministers. The EU Regulation No. 1307/2013 deals with the structure of the direct payments, giving the Member States and their regions several choices according to their own priorities. The Walloon Region (Belgium) finally defined its own policy which is described below. This policy is supposed to have as less and as slow consequences as possible. However, it will have impacts on the value of direct payments and on farmers' income. These impacts were calculated based on the available data before making the final choice of the new rules to be implemented in the Walloon Region, and are

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.030

presented below.

2. New structure of the direct payments in the Walloon Region

The new structure of direct payments in Wallonia is presented in Figure 1.

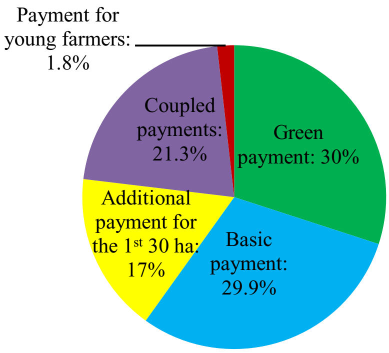

Fig. 1. New architecture of direct payments in Wallonia (%) (2015-2020).

As it is compulsory for each Member State/Region, the “green payment” represents 30% of the total envelope for direct payments. The specific payment for young farmers has been decided to reach 1.8% of the total amount of direct payments, according to the expected number of young settlers.

A characteristic of the Walloon Region is its high level of payments which are still coupled: 21.3% of direct payments, including 18.8% for suckling cows, 1.2% for dairy cows, 1.1% for double-end cows and 0.2% for ewes.

The Walloon Region also decided to devote 17% of the available amount for direct payments to grant an additional payment for the first 30 ha of each farm. So doing the remaining share of the so- called “basic payment” reaches only 29.9%.

3. Evolution of the total envelope for direct payments

As Belgium in one of the Member States where the payment per hectare was among the highest, it has to contribute to the principle of the convergence among the EU Member States. So, the total amount for direct payments will decline for Belgium and for its regions between 2013 and 2020 (Table 1).

Table 1. Budget of the 1st pillar of the CAP for Belgium and Wallonia from 2013 to 2020.

		2013	2014	2015	2016	2017	2018	2019	2020
Belgium	Budget (000 €)	568,980	544,047	536,076	528,124	520,170	512,718	505,266	505,266
	Annual variation (%)	-	-4.4 %	-1.5 %	-1.5 %	-1.5 %	-1.4 %	-1.5 %	-
Wallonia	Budget (000 €)	306,680	291,990	287,712	283,444	279,175	275,176	271,176	271,176
	Annual variation (%)	-	-4.8 %	-1.5 %	-1.5 %	-1.5 %	-1.4 %	-1.5 %	-

Not taking into account the possible inflation rate, the decline for the Walloon Region will reach 11.6%. If the number of farms remains the same (static model), the mean financial support per farm would decline from 21,900 € in 2014 to 19,283 € in 2019.

4. Impact of the new Common Agricultural Policy on the direct payments received by farmers

According to the available data and if the agricultural area and the number of farms remain equal through the period 2014-2019, it appears that 42% of the framers will be significant losers while 44% will be significant gainers. This result is also a consequence of the principle of convergence within each Member State/region. For 14% of the farmers, the change, positive of negative, will be smaller than 5% compared to 2014, and so it can be considered as a status quo (Table 2). Losses are significant (more than 20%) for around 18% of Walloon farmers, while gains are significant for 31% of farmers.

Looking into more details, it appears that the regions where cereals and sugar beets are produced will lose the most, while the regions suitable for cattle breeding will gain. For the specialties "general crops", "crops and dairy cattle", and "crops and non-dairy cattle", the negative impact on the farmers' income will be the highest, contrary to the specialties "dairy cattle", "meat cattle" and "double-end cattle". Concerning the size of the farms, the new CAP will be more profitable for the farms from 30 to 50 ha and will mainly impact negatively the largest farms.

Table 2. Losers and gainers between 2014 and 2019.

	% of Walloon farmers
LOSSES	
50 % and more	0
From 30 to 50 %	6
From 20 to 30 %	12
From 10 to 20 %	16
From 5 to 10 %	8
TOTAL	42
STATU QUO (from - 5 % to 5 %)	14
GAINS	
From 5 to 10 %	5
From 10 to 20 %	8
From 20 to 30 %	5
From 30 to 50 %	6
50 % and more	20
TOTAL	44

5. Distribution of financial support

Though the situation is improved compared to the previous one, it is still clear that the financial support to farmers is still linked to the size of the farm (Figure 2). Globally, the larger is the farm, the bigger is the financial support. Nevertheless, it appears that in 2019 (in red), the dispersion of the points is less important than in 2014 (in blue), showing less disparity among farmers. Effectively, in 2019, 50% of the direct payments will be granted to

20% of the farmers, against 18% in 2014. The Gini index (http://data.worldbank.org/indicator/SI.POV.GINI), as a measure of inequality, varies between 0, which reflects complete equality and 1, which indicates complete inequality (if one farmer gets all the direct payments, all others have none, the index is equal to 1, if each farmer receives the same support, the index is equal to 0) will decline from 0.55 to 0.49.

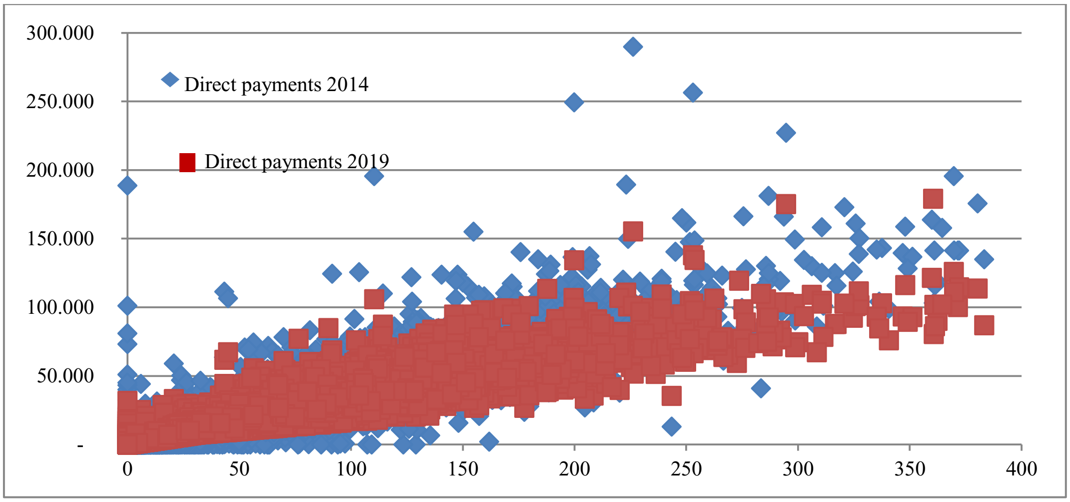

Fig. 2. Financial support from the first pillar of the CAP according to the area of the farms in Wallonia.

6. Conclusions

The implementation of the new Common Agricultural Policy (CAP) is a complex process. In the Walloon Region, it was sought since the beginning to get the smoothest evolution as possible, mainly avoiding too big and brutal losses for some farmers. Though the Walloon Region will get less financial support from the CAP budget, it seems that the results of the new CAP are finally politically acceptable. Smaller and younger farmers will get more support while the losses for largest farmers will be limited.

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Agriculture and Agricultural Science Procedia 7 (2015) 54 – 58

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Aerial method of plant protection with the use of an autogyro for sustainable agriculture

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Abstract

Despite the limitations in the use of aerial applications resulting from Directive 2009/128/EC of the European Parliament and of the Council and the Plant Protection Agents Act (OJ L item 455. 2013), scientific progress in engineering enables the development of new, environmentally safe technologies to expand the use of agroaviation. This paper proposes an innovative method of biological protection of corn against *Ostrinia nubilalis* with the use of an autogyro and presents the results of these operations. An autogyro adaptation for forest applications is proposed, and the preliminary results of a spray uniformity assessment are presented. Based on a two-year study (542.5 ha), the introduction of the Tricholet preparation against *Ostrinia nubilalis* was found to be highly effective (73.55%), which is a positive indication for the innovative autogyro method for introducing *Trichogramma evanescens*. Similarly, positive results were obtained for a liquid agent application using an autogyro-mounted installation: an even coverage of the area was achieved across the entire spray path width while maintaining the required dosing of the plant protection agent.

Keywords: autogyro; biological; chemical protection; forests; maize.

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doi:10.1016/j.aaspro.2015.12.031

1. Introduction

The EU strategy for a sustainable economy in terms of agriculture, forestry and food production requires the use, among other things, of plant protection techniques and technologies that enable both safety and high efficiency levels to be maintained (EU Directive 2009/128/EC). This requires accurate application of the smallest possible amounts of chemical agents in a short period of time, due to their toxic nature. It is also necessary to diversify the dosage depending on the locally variable severity of agrophage occurrence while at the same time minimizing any possible crop losses. The problem of pest protection includes forests as well as agriculturally productive areas, both in Poland and elsewhere in Europe.

The following requirements are crucial for protection to be effective: appropriate time of application, accuracy of dosing, doses meeting the requirements, and short application time, all of which must be met simultaneously. The current technologies and ground-based equipment that are commonly used include tractors with sprayer attachments and self-propelled sprayers, although they do not provide the optimum combination of quality, efficiency and safety. The more accurate and safer the sprayer is, the lower its efficiency is. One advantage of aerial applications over ground-based spraying is the elimination of mechanical damage to crops, rapid execution of the operation and a significant reduction in the required amount of working liquid with its added adjuvants (Mierzejewski et al., 2007). However, aerial applications performed by airplane or helicopter are also very expensive (Głowacka 2009, Majewski 2012).

Despite the limitations in the use of aerial applications resulting from Directive 2009/128/EC of the European Parliament and of the Council and the Plant Protection Agents Act (OJ L item 455. 2013), scientific progress in engineering enables the development of new, environmentally safe technologies to expand the use of agroaviation. A solution meeting the requirements of safe and effective (cost, efficiency, and manoeuvrability) protection of crops and forests is the use of an ultra-light aircraft: the autogyro (World Directory of Light Aviation 2014/2015; Rotorcraft Flying Handbook. 2015). The autogyro is an aircraft of the rotorcraft family, equipped with a rotor and a pusher propeller. The autogyro has fewer requirements in terms of landing site or flight technique than airplanes or helicopters, while operations can be accurately performed even on small areas, and at a significantly lower cost.

2. Objectives, data and methodology

The goal of this study was the assessment of autogyro operations for the biological protection of corn and for forest protection. Tests were performed using the Aviation Artur Trendak & Son ZEN-1 autogyro. This autogyro was modified for the individual tests by installing only the equipment required for each task.

Biological protection of corn against the corn borer (*Ostrinia nubilalis*) was executed using a loose Tricholet formulation (*Trichogramma evanescens*). The preparation was placed in dispensers installed on pylons mounted on the autogyro fuselage (Fig. 1) (Bzowska-Bakalarz et al. 2013). The GPS system installed in the autogyro enabled the aircraft to be guided onto successive flight paths and operational reports to be prepared (Fig. 1), including preparation consumption. Two dispensers provided a Trichogramma dose sufficient for 80 ha.

The territorial range of *Ostrinia nubilalis* occurrence continues to grow, not only around the world but also in Poland, particularly in the south-west of the country. This can lead to damage to all the plants, and therefore biological treatments that reduce the population of *Ostrinia nubilalis* are of a considerable economic significance (Bereś, 2012; Bereś & Konefał, 2010, Sudha Nagarkatti, H. Nagaraja, 1977).

Operations related to Tricholet introduction were performed in 2013 and 2014 on plantations located in the Lower Silesian voivodeship, twice, at a seven-day interval, in accordance with the assessment of corn borer infestation severity. The total area protected was 247.4 ha in 2013 and 295 ha in 2014. The operations were performed at an airspeed of 100 km/h (80 ha/h efficiency) (Bzowska-Bakalarz et al., 2013). Operational effectiveness was determined by comparing the number of plant damage on the protected field and on the control field (without protection agents) as per Abott's formula (1925). The tests were performed on 100 plants in 4 repetitions on each control field and protected field.

The positive results of the biological treatments encouraged the authors to analyse protection options that involve the use of liquid preparations. For this purpose, an autogyro was prepared for oak forest protection concerning the winter moth *Operophtera sp*. This involved setting the spray width and performing preliminary verification of liquid distribution uniformity during liquid spraying. Four AU 7000 atomisers were installed on the autogyro beam, enabling fine-droplet ULV (ultra-low volume) spraying (Fig. 2). At a liquid use rate of 2.2 l/ha (as per the recommendation on the label of the chemical agent against *Operophtera sp*) and a 90 km/h flight speed, tests were performed under the following conditions: no wind (V < 1.5 m/s) and with side wind at the angle of 342° and V = 2.5 m/s). Sheets of Syngenta water-sensitive paper (WSP) were arranged 1m apart, in lines spaced every 20 m, to determine droplet distribution uniformity over the spraying area.

Fig. 1. ZEN1 autogyro with dispensers for biological protection of corn.

Fig. 2. ZEN1 autogyro for ULV spraying.

3. Results

Figure 3 presents the number of corn damage caused by the corn borer in 2013 and 2014. In both years, the average number of damage in the control fields was similar (approx. 1.4 damage per plant), which indicates a similar infestation severity for this pest. Introduction of the Tricholet preparation resulted in a reduction in the number of damage to 0.4 damage per plant.

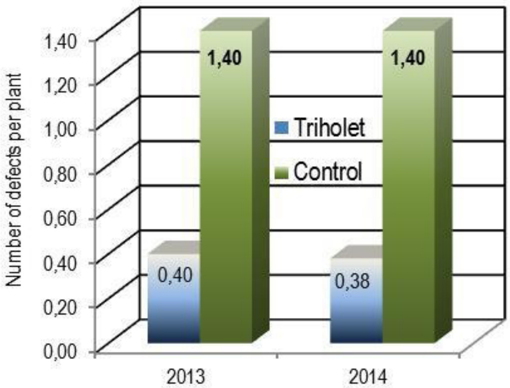

Fig. 3 Number of damage per plant of maize protected with Tricholet and maize without protection.

In all six locations in the Lower Silesian voivodeship, in both years of the study, the mean efficiency of introduction of the biological preparation with *Trichogramma evanescens* was 73.55%. The lowest efficiency (62%) was observed in 2013 in Godziszewo, which may have been caused by the proximity of a forest and long-term corn monoculture. However, the obtained results significantly reduced the risk posed by *Ostrinia nubilalis*.

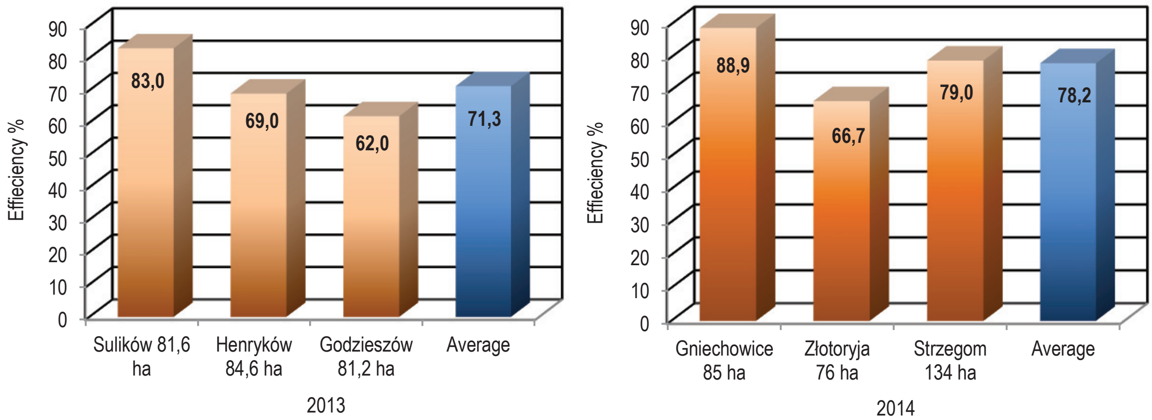

Fig. 4. Efficiency of biological plant protection for six locations in two years.

The spray uniformity tests performed to prepare the autogyro for operations using the Sherpa chemical agent (Fig. 5) demonstrated that the protective operation could be performed in accordance with the requirements of the Plant Protection Agents Act, although this requires appropriate preparation of the spray apparatus. Under still air conditions (Fig. 5), surface coverage uniformity was satisfactory and ensured that the required liquid expense ratio was maintained. However, some variability in coverage ratio was noticed, particularly on the right-hand side of the flight line. This was caused by the autogyro's propulsion system, where the pusher propeller caused an axially torsional, clockwise air flow, and consequently a shifting of some of the dispensed working liquid from the right side to the left. In the event of a slight side wind, an additional shift of the spray stream in the direction of the wind was observed, although this could be rectified easily by the pilot through an appropriate correction of the flight path (using the GPS). However, this requires further research.

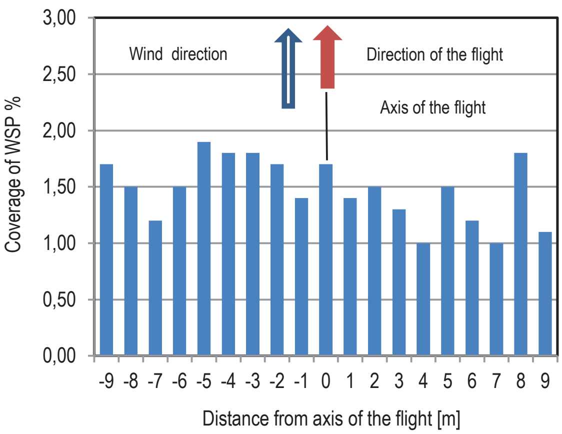

Fig. 5. WSP coverage for still air conditions.

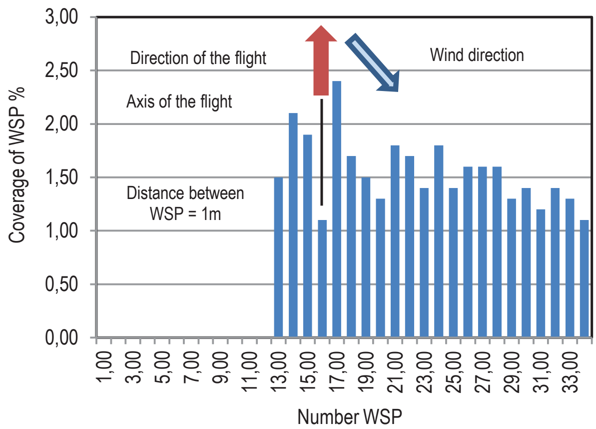

Fig. 6. WSP coverage for angled wind.

4. Summary and conclusion

The autogyro completely eliminated the losses that incur while crossing fields and enabled a rapid response in the event of pest appearance due to the short time required to perform the task for a given area. It meets the requirements of the Directive and is equipped with a GPS device to ensure flight accuracy during operations.

The autogyro provides high efficiency (80 ha per flight) and a high speed of deploying the Tricholet preparation

(*Trichogramma evanescens*). This is particularly important due to the short duration of corn borer infestation and the need for rapid intervention when it occurs.

Employing autogyros for forest protection using liquid agents is also possible and should lead to achieving similar levels of effectiveness as in the case of corn protection. However, this requires further studies related to both optimising the arrangement used for the spraying element on the autogyro and flight control during the operation. The autogyro provided uniformity of protected area coverage and maintenance of the required liquid dispensation rate.

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Agriculture and Agricultural Science Procedia 7 (2015) 59 – 63

Agriculture and Agricultural Science
Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Image based techniques for determining spread patterns of centrifugal fertilizer spreaders

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Abstract

Precision fertilization requires new techniques for determining the spread pattern of fertilizer spreaders. Because of the accuracy and non-intrusive nature, techniques based on digital image processing are most promising. Using image processing, dynamics of particles leaving the spreader can be determined. Combined with a ballistic flight model, this allows predicting the landing position of individual fertilizer particles. In a first approach, a two-dimensional imaging technique was used with small field of view (0.33 m on 0.25 m). In the second approach, a larger field of view (1 m on 1 m) was used. To improve the accuracy of previous technique, binocular stereovision was used to determine three-dimensional information.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

*Keywords:*Spread pattern; image techniques; cross correlation; ballistic flight; fertilizer.

1. Introduction

Precision fertilization requires the right amount of fertilizer to be placed at the right moment at the right spot. This

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.032

implies amongst others that the spreader used must be precisely controlled and adjusted, depending on the working conditions, the type of fertilizer and the optimal fertilizer distribution. Although the centrifugal fertilizer spreader is most commonly used in practice, its controllability and adjustability are rather limited. Nowadays, spreader adjustment is often neglected because of the labor intensive and time consuming nature of spread pattern determination (Tissot et al., 2002). High speed image processing is becoming more of interest in agricultural applications (Hijazi et al., 2012; Vulkagaris Minov et al., 2015). Using this technique to determine dynamics of fertilizer particles on the flight, combined with ballistic flight models (Cool et al., 2014), has the potential to overcome most of these problems (Cointault and Vangeyte, 2005). Therefore, the Flemish Institute for Agricultural and Fisheries Research (ILVO) and its partners are exploring and developing accurate and time efficient techniques to measure the spread pattern of centrifugal fertilizer spreaders using image processing. The requirements of the system are:

- The system should be mobile so that it can be used at farm level to test several combinations of machine settings and fertilizer types in a short timeframe;
- It should enable the adjustment of the spreader in such a way that the desired spread pattern is obtained;
- The technique has the potential to allow future development of a low cost and onboard system, allowing for a continuous adjustment and control in the field.

2. Previous developments and approaches

Traditionally, the spread pattern is determined by measuring the fertilizer distribution on the ground. In order to be able to respect the above mentioned requirements under all conditions, however, it was opted for to predict the distribution based on individual particle landing positions. Theoretically, this could be done via the combined simulation of the movements of fertilizer particles on the centrifugal disks on the one hand and the flight of these particles in the air after leaving the disk. As the simulation of the particle behaviours on the disk is much more difficult (time consuming and higher uncertainty on the results) than the simulation of the flight in the air (where particles are further apart and thus hardly interacting), a hybrid approach combining measurements and simulations was proposed: particle diameter, initial velocity, horizontal and vertical outlet angles are measured via processing of images taken just after leaving the disk and used as inputs to a ballistic flight model, which predicts the landing position relative to the disk. Combining the landing positions of all particles leaving the spreader results in the overall spread pattern.

3. Two-dimensional technique

As a first step, a two-dimensional imaging technique was used with a small field of view (0.33m x 0.25m) to measure the horizontal outlet angles and the velocity of the particles at different camera positions at the circumference of the disk. The vertical outlet angle and the mass distribution were measured with a cylindrical collector. The grains flying under the measurement unit were imaged using two different techniques: (1) high speed imaging technique and (2) a newly developed multi-exposure (stroboscopic) imaging technique (see Fig. 1). Overall, the stroboscopic technique and the high speed technique were capable of measuring the outlet angle and the outlet velocity satisfactorily (average relative difference was less than 1% for the horizontal outlet angle and 2% for the horizontal velocity). The values obtained using the image processing techniques were subsequently used for simulation of the ballistic flight and the resulting spread pattern. Comparison of this spread pattern with the spread pattern determined with the traditional technique, revealed relative errors of up to 30%. More details can be found in Vangeyte and Sonck (2007) and Hijazi et al. (2014a).

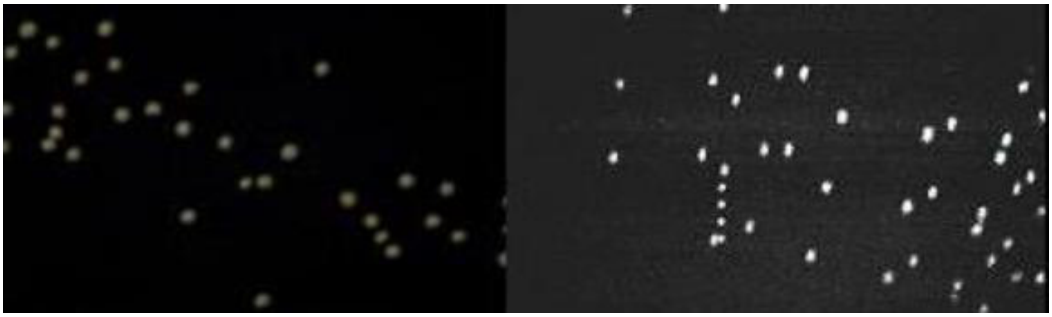

Fig. 1. Particle images for the high speed (left) and stroboscopic (right) imaging technique.

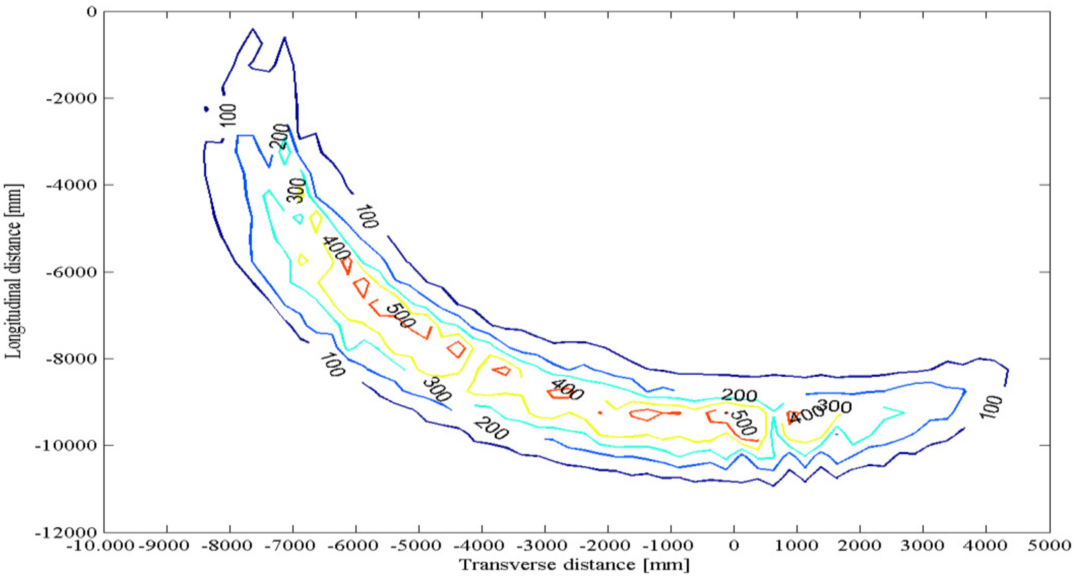

Fig. 2. Spread pattern of a test spreader resulting from measurement with stroboscopic technique.

4. Three-dimensional technique

In the previous approach, no depth information can be obtained due to the fact that only one camera was used, causing inaccuracies in the information extracted from the images. To improve the accuracy of the system, stereovision was introduced to estimate particle movement and position in three dimensions. A binocular stereovision setup of two high speed cameras was used and a large field of view (1 m on 1 m) was applied. For more details on the setup, we refer to Hijazi et al. (2014b). The subsequent steps of the image processing algorithm are illustrated in Fig. 3. In a first step, two subsequent framesets (a frameset is defined as one image from each camera) are acquired. Each frameset is taken on a specific time instance; the time between the acquisitions of both framesets is set by the frame rate of the camera. Secondly, the particles are segmented from the background and noise. In a third step, particles are matched between the left and right image (stereo matching) on each frameset. Based on the camera configuration and difference in position between the particles in these two images, the 3D position of the particles can be determined at two subsequent time instances. In a next step, the particles are matched in time: for each particle in the image of one camera, the corresponding particle in the next image is searched. This step is illustrated in Fig. 4. Finally, based on the difference in 3D position between the two time instances and the frame rate of the camera, the particle 3D velocity is determined. For more details, we refer to Hijazi et al. (2010, 2011, 2014b).

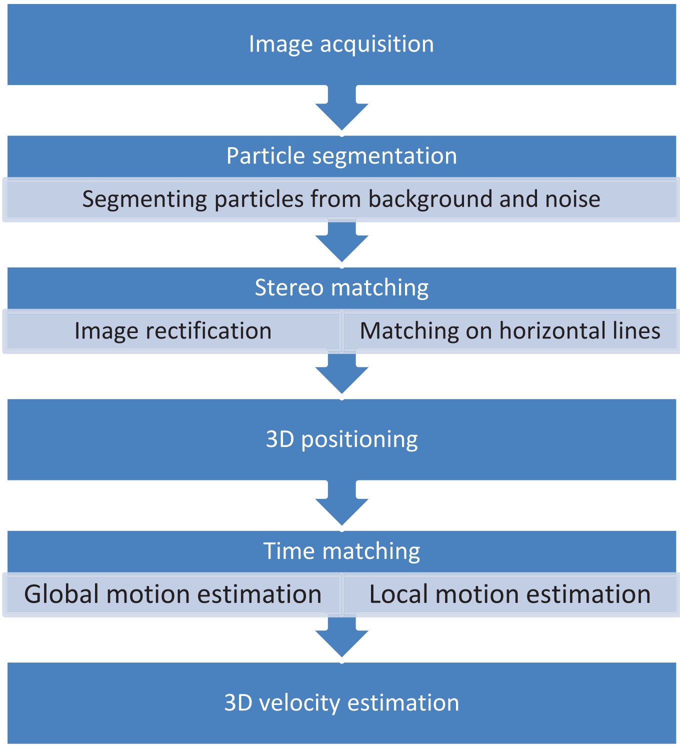

Fig. 3. Flowchart of algorithm for 3D position and velocity estimation of fertilizer particles

Although the results showed to be promising, the particle resolution on the images was too low, introducing matching errors and inaccuracies in the 3D positioning (Cool et al., 2015).

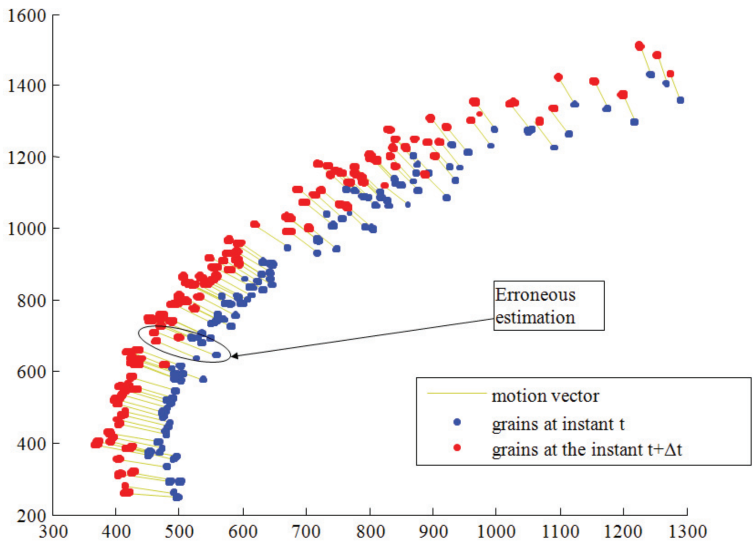

Fig. 4. Results from time matching algorithm for a throw of fertilizer particles (two different time instances)

4. Ongoing research

At the moment, a small field of view (for the sake of increased particle resolution on the images) high speed stereovision system is being developed in combination with adapted motion estimation algorithms and an improved ballistic model. High speed image acquisition is combined with a newly developed high illumination system for multi exposure, which enables the reliable and time efficient estimation of the spread pattern under controlled conditions. The usefulness of the proposed techniques for outdoor application is not yet evaluated.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Optimisation of the machinery park with the use of OTR-7 software in context of sustainable agriculture

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Abstract

The paper presents possibilities for the use of OTR-7 software (Organizer of Agricultural Technology) for optimization of the machinery park equipment in sustainable agriculture. The applied algorithms enable selection of the relevant technical equipment which enables performance of the planned field work. Due to the use of the specialised software, desired economic effects and competitive advantage can be obtained and the risk related to the purchase of expensive equipment can be minimized.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: machinery park; sustainable agriculture; optimisation; agricultural technology; agricultural software.

1. Introduction

A correct selection of the machinery park is vital for correct functioning of a farm. It is particularly significant in sustainable agriculture, where agricultural production must be effective and should enable production of safe, high quality food in a manner that protects the condition of the natural environment, social and economic conditions of farmer's life, employees employed in a farm as well as local societies.

Agricultural machines that have been correctly chosen enable performance of the planned work on time and with

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.034

maintenance of appropriate quality and care for the performed work. Meeting these requirements must be obligatory. However, it may be performed with the use of various sets of machines. Yet, the use of machines with incorrectly selected size and performance may generate too high costs, although it allows performance of fundamental agro-technical treatments. Such costs may considerably exceed those which may be incurred at the optimally selected set of machines. The increase of operating costs of machines may be reported both in case of machines which are too big (and expensive as well) and in case of machines, which are too small (their operation time is too long).

A farm is a complex body with a network of relations between its particular elements. These relations occur between particular branches of production, specific plants (crop rotation) and in the machinery park. When mechanization is designed, selection of suitable field work technologies enforces planning of machines, which perform these works. For example, planning of a no-till technology results in elimination of ploughs from a farm and replacing them with other machines. As a rule, introduction of modern, high-efficient machines enforces at the same time introduction of greater power tractors to a farm. As a consequence, the design of the machinery park must be complex and must cover practically the entire farm (or must reflect the existing one). In particular, field work technologies must be outlined, machines must be adjusted to the predicted amount of work, and tractors to machines which they cooperate with.

Farms are becoming better equipped with computer equipment, they have internet access and software operation skills are higher. As a result, farmers more often use computers to support functioning of their farms (Francik, 2010; Kapela, Borusiewicz, 2012).

2. Selected algorithms for design

Figure 1 presents a simplified algorithm for design with the use of OTR-7 software. Two parts were distinguished there, i.e. a part of the decision-making, where a man decides on the course of the project (introduces data) and a part of computational, where a computer processes data and shows results. In case of non-satisfactory results, users return to a decision-making part, where they change input data and check how it influences the farm balance. From the point of view of selection of the machinery park, the most vital are: production technology changes and replacement of machines and tractors with ones that better suit farmer's needs. Division into two parts (a decision-making and computational) is reflected in the OTR -7 interface, whose main window is divided into two parts: the upper - decision-making, designed for introduction of data and the lower - computational, where computation results are presented.

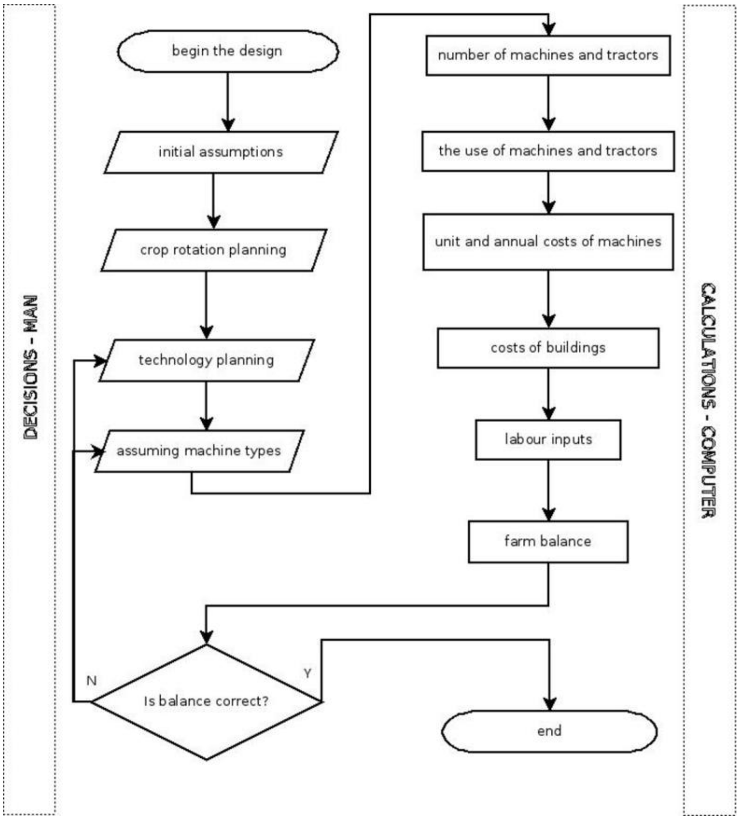

Fig.1. Simplified algorithm for design

Selection of the machinery park consists in planning a relevant type of a machine and then counting a minimum number of machines, which enable performance of the planned works on time. Then, the annual use of a machine and consequently unit (per hour) and annual costs are calculated. This, on the other hand, is a foundation for further calculations and mainly for determination of technology costs and a farm balance. A simplified algorithm for the machine selection has been presented in fig. 2. It shows a procedure optimisation of machine selection for the planned technology. A consequence of choosing a specific machine is assuming appropriate calculation parameters, such as operating efficiency and data indispensable for determination of its operating costs. As a result of assuming a relevant efficiency, a number of required machines of a given type, the annual and unit use as well as annual costs, are calculated. In case the hour costs are too high, a change of the machine type and new calculations are necessary. These actions are undertaken until satisfactory results are obtained (an optimal machine in given conditions).

Too high operating costs may be caused by the fact that the assumed machine is too big and expensive (too high performance) or too small (too low performance). A machine with efficiency that considerably exceeds the needs, due to its high price and low use generates high costs. On the other hand, accepting a machine which is too small, means that a few machines will have to be purchased, its operation time will be long and additionally a few tractors will have to be used for its drive (whose operation time is longer than in case of a suitable machine).

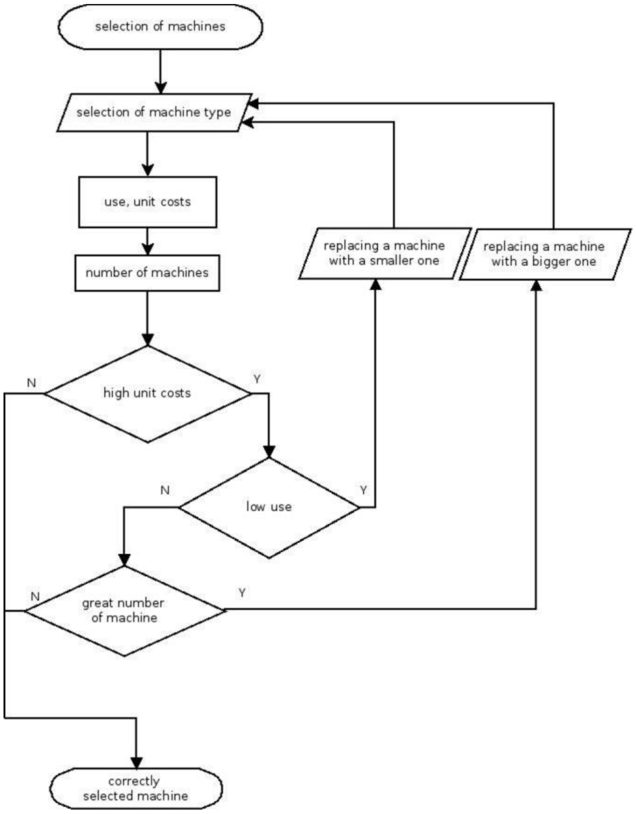

Fig.2. Simplified algorithm for selection of a machine

Machine types are replaced until optimal, in a given situation, rates are achieved. Taking into account the entire farm, where many activities are undertaken, having many machines is necessary. As a result, a designer must analyse many combinations, taking into account that introduction of various machines influences also the costs of use and operation of tractors.

3. Application of OTR-7 software for optimisation of machine selection

The OTR-7 software represents a small group of programs for design in agriculture. Its main function is to support selection of the machinery park for a farm so that technical equipment is relevantly selected on account of quality and quantity. The main criterion of optimisation is minimization of operating costs of machines and assumption of a correct and timely performance of field work. An exemplary screenshot of OTR-7 software has been presented in fig. 3.

The use of the application requires from a user appropriate professional knowledge i.e. knowledge of agrotechnology principles, field work technology, principles of farm machines exploitation etc. When data have been introduced (upper part of the program window), the program calculates data and shows present results (in the lower part of the program window). Further bookmarks in the window, where data are introduced enable design of plant, animal production, additional activity of a farmer and mechanization services both within the scope of their rendering as well as their usage. In the next step, data concerning machines and farm tractors, information on activities undertaken in a farm, farm products, buildings and structures etc. are introduced.

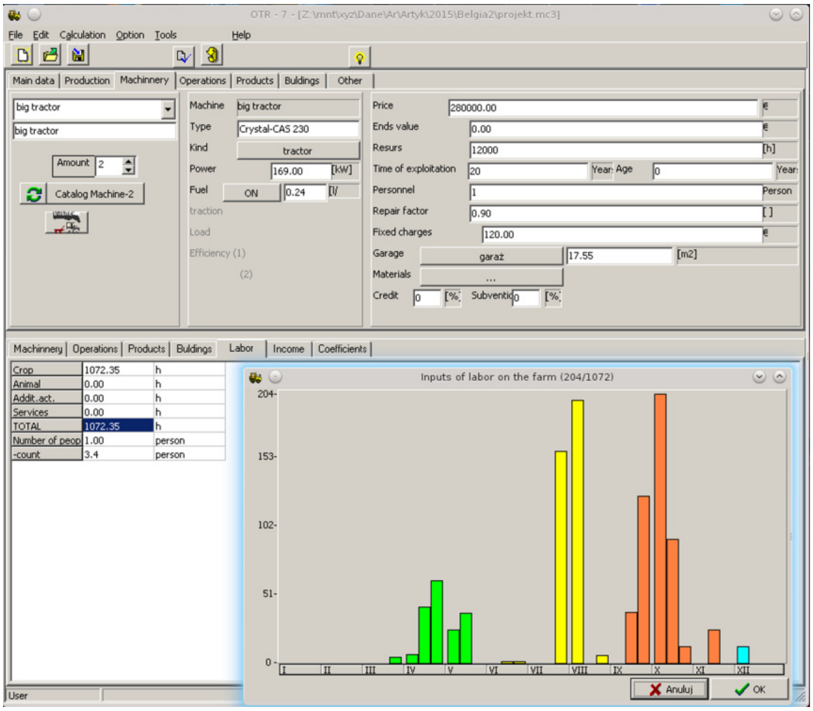

Fig.3. Exemplary screenshot of OTR programme

OTR-7 programme enables calculation of the selected rates for agricultural machines, such as the use and operating costs with division into their particular elements. Detailed analyses concern the farm balance, profitability of particular branches of production, costs and production of particular plants, labour inputs, buildings and calculation of costs of particular agrotechnical treatments. The use of machines and labour inputs in decades may be presented in the form of clear plots, which facilitate analysis and searching for elements of a farm which negatively influence the farm efficiency.

The programme may be used in agricultural didactics and practice enabling design and optimisation of farms with the area from a few hectares to a few thousand hectares. The design process may concern the existing and new-formed farms with a varied production structure. It should be mentioned that optimisation of the existing objects is more difficult. In such case, firstly it is necessary to make a real model of a farm and the best possible reflection of real elements in the program. Further work on optimisation of the model consists in simulation of various changes in the real object and checking their impact on the final financial result. Such simulations must take place with the farm producer's cooperation. It aims at elimination of such suggestions of changes, which theoretically bring beneficial effects, but are unacceptable for a farm owner. It should be mentioned here that e.g. replacement of many machines, although it could be beneficial, as a rule cannot be carried out due to a high value of investment (no funds for its realization).

Sustainable farming, for realization of its fundamental aims, requires a proper selection of the machinery park, which due to a high value, has a vital impact on the financial results, which an agricultural producer obtains. Agricultural machines and tractors are fixed assets, whose lifetime of the machine in the existing farms often exceeds 20 years, so purchase of each machine should be well considered. Farmers, when taking up a decision on the purchase of a machine, take many factors into consideration. However, these are not diligent calculations. It causes that agricultural producers often have an over-invested machinery park, whose work potential considerably exceeds the farmer's needs (Lorencowicz, Cupiał, 2013). Farms, which use software, represented by OTR-7, which enable calculation and simulation of introduction of new machines and cultivation technologies, increase their competitiveness. Moreover, a risk related to incorrect decisions on the modernization of a machinery park is reduced.

4. Summary and conclusion

Contemporary agricultural producers even more frequently reach for computer programmes to back up their activity (Mobli, Rafiee, Madadlou, 2012; Favier, Dodd 2003). The most frequently used software consists of applications which assist current activity, such as financial and reporting programmes, which enable recording of the performed treatments, purchased production means and obtained production. Software for planning and designing the production are less used. It mainly results from the fact that there are more reporting and balance programmes than the planning ones (Cupiał, Szeląg-Sikora, 2014; Jensen, Boll, Thysen, Pathak, 2008). However, the use of applications which belong to the second group may give a farmer a considerable competitive advantage and helps him to avoid mistakes in the process of decision-taking (Recio, Rubio, Criado, 2003). OTR programme, whose basic function is to optimally select the machinery park equipment, gives an opportunity to carry out such simulations and allows checking the results of the decisions, which are undertaken.

Correct planning of the machine set is particularly important in case of the sustainable agriculture. Although, its basic objectives are: compliance with a correct selection and crop rotation, developing a fertilization plan, not using sewage sediments, correct fertilization, livestock density; realization of these objectives and maintaining appropriate production profitability is possible only with suitably selected machines. Taking the above into consideration, it should be assumed that in the near future, significance of programs designed for planning and design in agriculture will increase and farmers even more often will use such type of applications in their farms.

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Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Analysis of mechanical investment in Małopolska province using index of technological modernization ITM

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Abstract

In order to systematize the effects achieved through investment in machinery park of the farm, new indexes were developed: index of information technological modernization (ITM) and index of tractors' replacement (ITR). These indexes allow for the assessment of changes in production technology related to the modernization of machinery park and innovation of farms. Studies have showed that the most innovative farms, for which ITM index was established at three (ITM = 3), are those farms that are characterized by the largest area and simultaneously best equipped with various systems.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: index of technological modernization; investments; machinery park; European funds.

1. Introduction

Selection of machines and their rational exploitation in different groups of agricultural enterprises are the main issues of research of organization and economics of farms in agricultural engineering discipline (Szeptycki and Wojcicki, 2003). Upon accession to the EU, farmers in Poland could benefit from the support for investment activities in the process of modernization of farms and these measures were and are important elements determining the scale and range of modernization of Polish agriculture (Kusz, 2014; Lorencowicz, Cupiał, 2012). The investments

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.035

undertaken were aimed at realization of various objectives determined by a farmer. However, the investment was primarily focused at improving the quality of functioning of the farm while specific objectives were determined in the application. One of the methods which determines the impact of the modernization activities carried out may be a comparison of the values of investments or referring them to the economic effects. However, this method does not allow for comparing technological changes that have occurred as a result of farms' modernization. The development of new indexes was due to the difficult to systematize the results achieved, because of investments in terms of farm mechanization. These indexes universally characterize technological changes occurring as a result from modernization of the machinery park.

2. Objective, data and methodology

a) Index of machines' replacement (IMR)

In order to develop the index of machines' replacement, it was assumed that on the farm, only one out of five cases may occur (Table 1). Machines were first assigned to the appropriate groups. Then, groups of machines constituting new quality (higher level) in the technologies were established. For example, cultivation & seeding remains at higher technological level in relation to the cultivator.

In Table 1, in columns denoted as Owing and New, information on the status of machines on the farm was contained, where "0" denotes no machines, "1" possession or purchase of the machine, while "+1" shows the purchase of a machine that changes technological process toward more modern. IMR index for a machine is determined only for occurrence of a particular type of investment on the farm.

Table 1. Determination of the IMR index depending on the type of investment.

Type	Owing	New	IMR	Description/remark
1	0	0	0*	No machine, no purchase-* index is not determined
2	1	0	0	The farm did not change the owing machine
3	0	1	1	New machine was purchased
4	1	1	2	Replacement of machine into a newer model
5	1	+1	3	Introduction of new technology, purchase of a machine of newer generation

In the studies (due to the selection of the study group), Case 1 denoting the lack of machine of a particular group on the farm and the lack of purchasing a new one, was not present. Because we aimed at the assessment of relationships regarding investments, in this section of calculations, also Case 2 was not considered (i.e. situation in which no new machine was purchased). This Case could only be considered in the analysis of machines owned. Because these assumptions, for the machines purchased, IMR index was established at a rage between 1 and 3. IMR index was determined for an individual investment; it did not concern the farm as a whole. Therefore, it was not included in the analysis of farms; however, it provided the basis for subsequent calculations.

b) Index of information technological modernization (IMT)

Index of information technological modernization was developed based on previously presented index of machines' replacement (IMR). For its determination, farms were classified into four categories (index value corresponds with the number category):

0 – farm does not purchase machines;
1 – farm buys new machines, and previously had no machines of this type;
2 – farm replaces machines into newer models without any technological change;
3 – farm changes production technology through purchasing more technologically-advanced machines.

Farms that have not purchased new machines, possessed ITM equal to "0", and were not subjected for calculations (due to the study group selection, farms that have not benefited from the aids were not considered).

Assignment of a farm into the appropriate group was dependent on the highest value of IMR index. For example, the farm in which it occurred, in relation to at least one group of machines, IMR equal to 3 gained the ITM also equal to 3. IMT calculated for the farm indirectly determines the farmer's openness to innovation.

The study included 286 farms realizing investments using EU funds under the PROW program during 2007–2013. The funds were allocated in the following years, during three calls for proposals. Subjects under study were divided into four equal groups, the division criterion was the area of the farm (area) and an economic size unit (ESU).

3. Results

Figure 1 presents the percentage proportion of farms characterized by a defined ITM within groups. It may be noted that in the following recruitments, percentage proportion of farms with higher ITM increases. It reflects the confidence among farmers to introduce new technological solutions of the production undertaken. Some impact on the change of ITM in terms of time is exerted also by technical progress, which results in the emergence of new techniques and technological productions. Within the areas of groups, one observes an increase in the proportion of farms with higher ITM with increasing area of farms. Also, in terms of ESU groups, farms with the largest production exhibit the highest value of ITM.

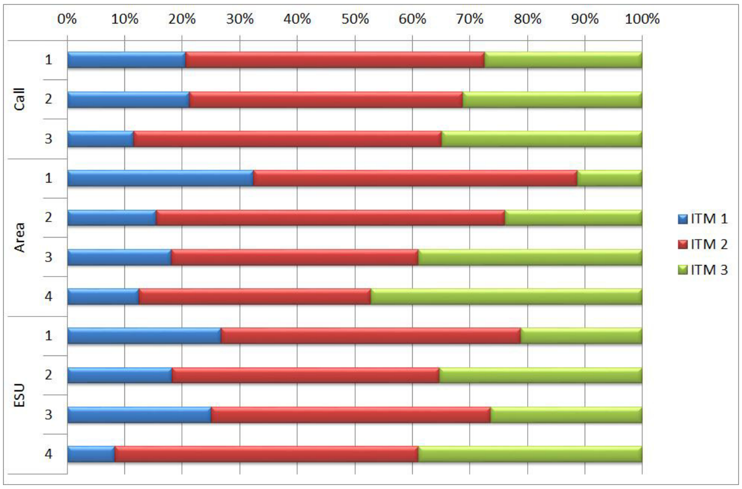

Fig. 1. ITM in groups.

Correspondence analysis is a descriptive and exploratory technique which provides information about the structure of the relationships between columns and rows of contingency table. Analysis of statistics and graphs proposed by this method allows intuitive inference on the relationships occurring between categories of qualitative variables. This analysis allows to find points corresponding to each categorical variables with respect to the new reference, which allows to determine the relationships between variables of different types (Stanisz, 2008). Figure 2 presents coordinates and columns for the variables denoted as surface group and ITM group.

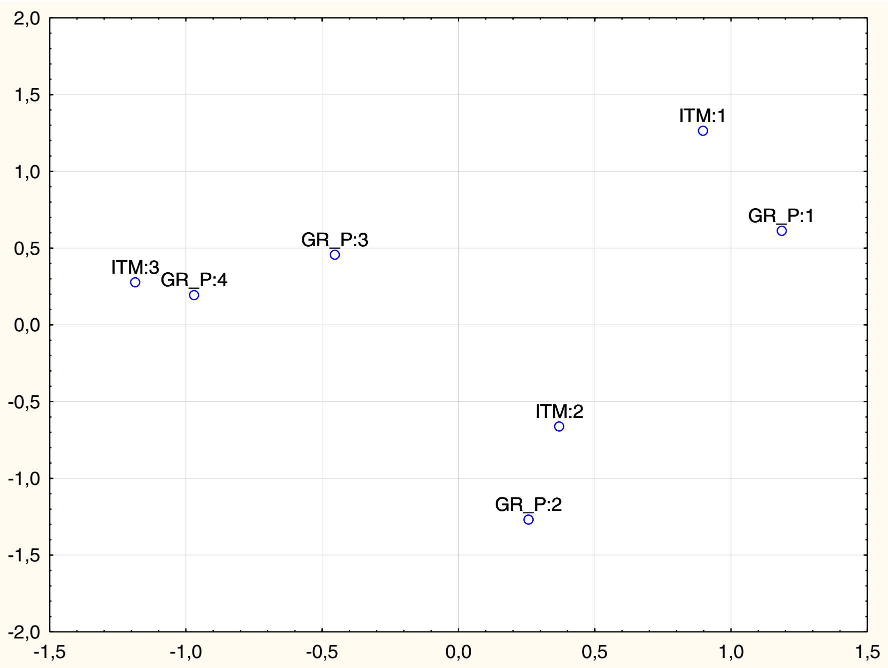

Fig. 2. The graph of coordinates and columns for variables denoted as surface group and ITM group.

It can be observed that ITM = 1 and ITM = 3 are located at a huge distance from the vertical axis. The point indicating the first surface group GR_P = 1 is in proximity to the point of ITM = 1. On the second axis, one observed grouping of ITM = 3 with the fourth surface group GR_P = 4, with simultaneous proximity of third surface group GR_P = 3. ITM = 2 corresponds to the second surface group GR_P = 2.

4. Summary and conclusion

This study confirmed that changes in production technology related to the modernization of machinery park and innovation of farms can be evaluated via the ITM index. Analyses indicate that the most innovative farms, characterized by ITM = 3, are farms with the largest area, and simultaneously best equipped with systems. By investing, they introduce new production technologies along with new machines. Farms with ITM = 1 are the smallest objects and at the same time possessing the least amount of equipment. They buy machines, which they previously did not have, to complete the machinery park. Farms of the second group are units which modernize the existing equipment by buying new machines to replace older models. They do not change the production technology, but only renew the existing equipment.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Molecular identification of fungi isolated from Dracocephalum moldavica L. seeds

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Abstract

Dracocephalum moldavica L. which is known as dragonhead is an annual herbaceous aromatic plant belongs to family *Lamiaceae*. It is native to central Asia and has been naturalized in eastern and central Europe. Extracts and oil from this plant are used widely in the pharmaceutical, cosmetic, food and flavouring industries. Because mycological quality is important for industrial use of seeds of this plant, the goal of the study was to identify the most dominant fungi occurring on *Dracocephalum moldavica* L. seeds using molecular techniques. The method of molecular identification was based on rDNA-extraction and the subsequent amplification of the D2 large subunit. Two fungal strains (G435/14 and G443/14) were isolated from Dracocephalum moldavica L. seeds. The strains were identified as *Fusarium sporotrichioides* (G435/14) and *Alternaria alternata* (G443/14). Most seeds were settling by *A. alternata* and just few by *F. sporotrichioides*.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: Dracocephalum moldavica L; fungi indentification; *Fusarium*, *Alternaria*, MicroSEQ®

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.036

1. Introduction

Dracocephalum moldavica L. which is known as Moldavian balm or Moldavian dragonhead is an annual herbaceous aromatic and honey yielding plant belongs to family *Lamiaceae*. It is native to central Asia and has been naturalized in eastern and central Europe. Moldavian dragonhead has an attractive blue or white flowers and aromatic lemon scented foliage because the main components of the essential oil are citral and geranyl acetate. Its seeds contain high quality oil, protein and mucilage with health-promoting properties. Extracts and oil from this plant are used widely in the pharmaceutical, cosmetic, food and flavouring industries as indicated by Alaei et al. (2013), Maham et al. (2013) and Yousefzadeh et al. (2013). Recently it has been shown that essential oils from *Dracocephalum moldavica* flowering aerial parts to act as efficient and biologically safe insect repellent for storage products (Chu et al., 2011). In cultivation of *D. moldavica* rarely occur diseases and pests that affect the quantity and quality of herb raw materials and seeds. At the beginning of the growing season plants may be occasionally infected by soil borne pathogens. Therefore, because of the possibility of infection by pathogens causing seedling blight it is advisable to seed treatment before sowing, as described by Kwiatkowski et al. (2011). Because mycological quality is important for industrial use of seeds this plant, the goal of this work was to identify the most dominant fungi occurring on *Dracocephalum moldavica* L. seeds using molecular techniques.

2. Materials and methods

The experimental material in the study was seeds of *Dracocephalum moldavica* collected from the field after harvest. 50 infected by fungal pathogens and 50 uninfected seeds were selected to the study. The seeds were placed on Bengal rose medium (Biocorp) to enable fungal growth (Fig. 1). In prior to lining seeds (visibly infected and uninfected) on part of seeds were soaked in methylated spirit for 15 min. The other part was not soaked. After strains isolation they were grown on PDA medium (Biocorp) for 4 days and were preliminary identified basing on micro- and macro-morphological observations by microscope and in microcultures, respectively. Two selected strains were identified using molecular methods.

The method of molecular identification was based on rDNA-extraction and the subsequent amplification of the D2 large subunit. Extraction of the fungal DNA was performed with the PrepMan Ultra reagent (Applied Biosystems). A fast MicroSeq D2 LSU rDNA fungal PCR kit (Applied Biosystems) was used to amplify the D2 LSU rDNA region. The next step after PCR purification (using ExoSAP-IT® PCR Products Purification Kit for ABI) was to prepare the sequencing cycle using MicroSeq D2 Fungal ID Sequencing Kit (ABI). Next, the Performa Purification System (EdgeBio-Performa Gel Filtration Cartridges) was performed. Capillary electrophoresis was run through an ABI 3130×l sequencer (Applied Biosystems) with a 50 cm capillary array and polymer POP6_1. The MicroSEQ® ID software was used to assess the raw sequence files and to perform sequence matching to the MicroSEQ® ID (Applied Biosystems) to validated the reference database according to Frąc et al. (2014).

3. Results and discussion

The studies on pathogens infected Moldavian dragonhead are few and ambiguous. So far, it has been found that in the cultivation of Moldavian dragonhead are pathogens causing seedling blight (Kwiatkowski et al., 2011). Two fungal strains (G435/14 and G443/14) were isolated from *Dracocephalum moldavica* L. seeds and identified using a molecular method. G435/14 was genetically identified as *Fusarium sporotrichioides* (specimen score was 43; top match for this strain was recorded with DSM 62423), while G433/14 as *Alternalia alternata* (specimen score 43; top match was found with DAOM 208486). The length of consensus sequences was 278 and 212 bp for *F. sporotrichioides* and *A. alternata*, respectively.

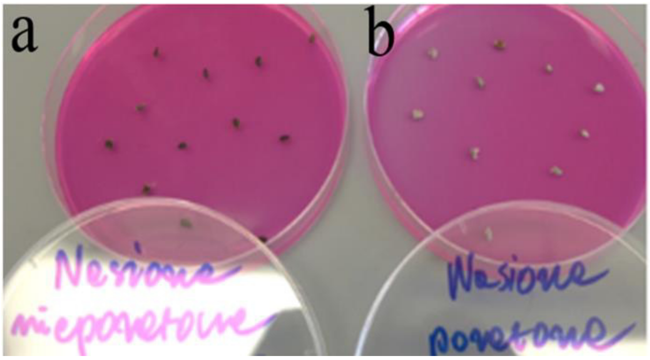

Fig. 1. (a) infected and (b) uninfected seeds.

The study showed, that the surface of *Dracocephalum moldavica* seeds was settled by numerous fungi, but belonging to the same genus – monoculture (Fig. 2). The populations of microbial species detected on the seeds surface depended on the level of infection. *A. alternata* dominated on the surface of studied seeds whereas *F. sporotrichioides* occurred occasionally (Fig. 3).

Fig. 2. Development and growth of fungi on seeds.

Fig. 3. Identification of pathogenic fungi.

Although *Dracocephalum moldavica* is resistant to fungal infection, identified fungi, especially *Alternaria alternata*, naturally occurs on the surface of different seeds (Frąc et al., 2010). Traditionally, morphology-based approach is mainly used for fungal identification. But, such type of identification is long –lasting, needs huge experience and sometimes in very difficult, because some microscopic fungi don't have a sexual state (Ding et al., 2011). Generally, fungi with similar morphology possess a high level of genetic variation that is the way that molecular identification of these organisms is useful tool in their classification.

Figure 4 shows the distance tree based on the D2 large subunit rDNA gene sequence. The species were extracted as species with highly similar sequences to G435_14 and G443_14 by MicorSeq research. The results (Fig. 4) indicated that G435_14 was closely related to the *Fusarium* group composed by *F. verticillioides*, *F. proliferatum*, *F. poae* and *F. sporotrichioides*. However, similarity 100% identity (278 bp) was obtained for *F. sporotrichioides*.

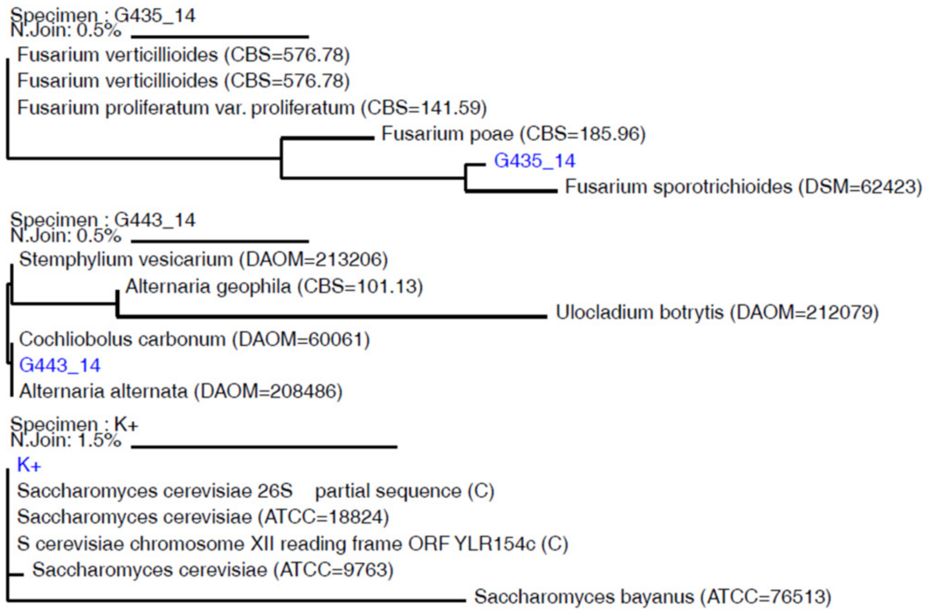

Fig. 4. Neighbor-joining phylogenetic tree based on rDNA-D2 LSU sequences of G435_14 and G443_14 fungal strains.

Based on the distance tree G443_14 strain grouped into the following species: *Cochliobolus carbonum*, *Alternaria alternata*, *Ulocladium botrytis*, *Alternaria geophila* and *Stemophylium vesicarium*. However, low bootstrap values were found with some species, including *Ulocladium botrytis*, *Alternaria geophila* and *Stemophylium vesicarium.* The sequence of G443_14 agrees with that of *Cochliobolus carbonum* and *Alternaria alternata* (100% identity for 212 bp). The sequences analyses, but also micro- and macroscopic observations, allowed to identified the G443_14 as *A. alternata*. These studies show that the phylogenetic relationships established from molecular data can be correlated with morphological data. The electropherogram of sequencing presented at Figures 5 and 6 shows the part of sequences as particular nucleotides.

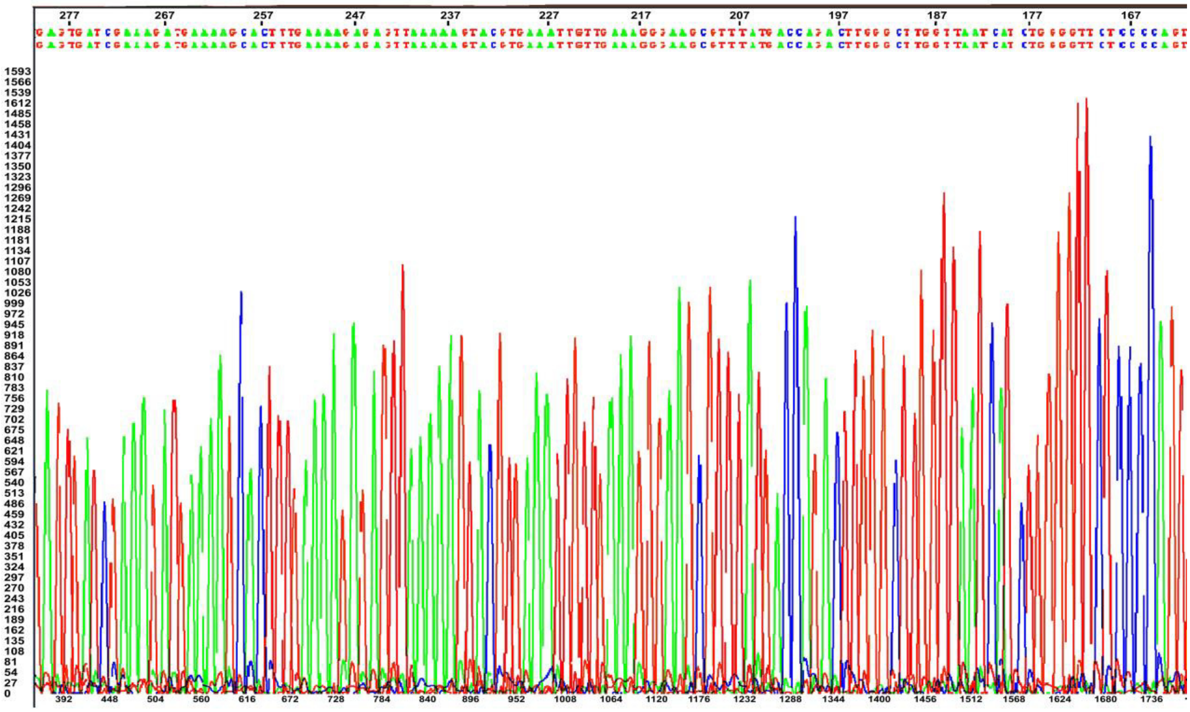

Fig. 5. Elektroforegram of sequencing of G435_14 fungal strain (*F. sporotrichioides*).

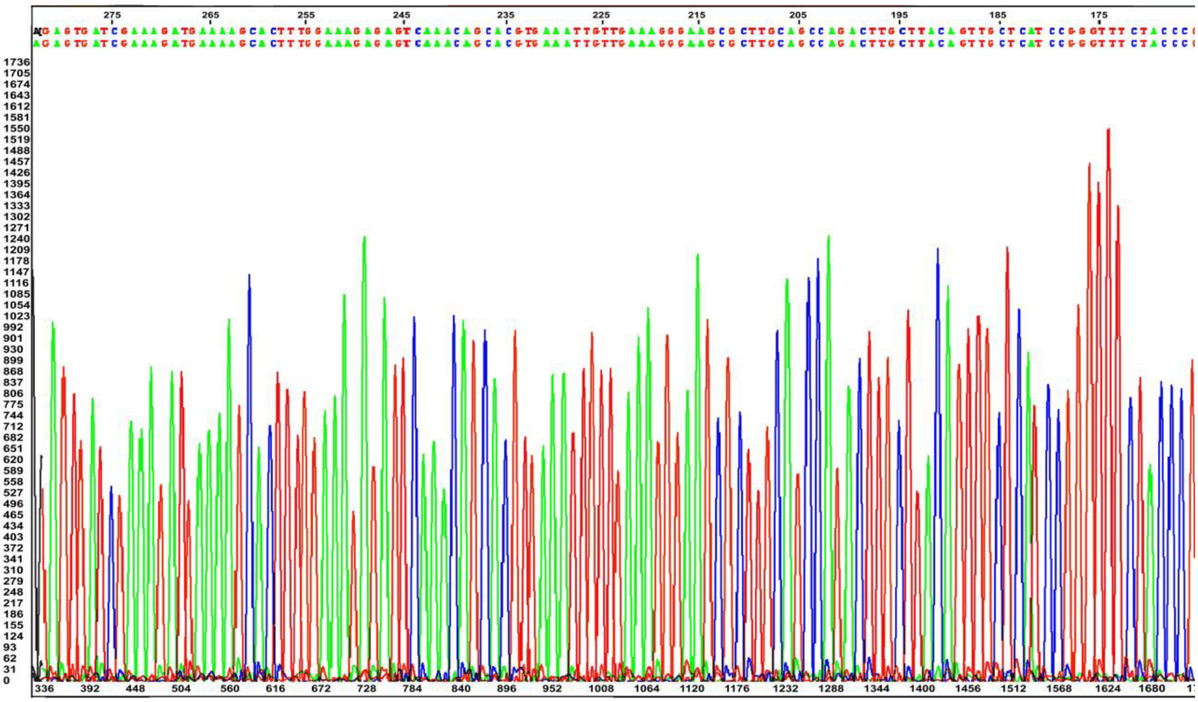

Fig. 6. Elektroforegram of sequencing of G443_14 fungal strain (*A. alternata*).

Summary and Conclusions

In this study the fungal isolates were classified based on sequencing a region with the D2 LSU rDNA gene which was considered to fungi identification. Comparison of sequences of the fungal genotypes to those available in the MicroSeq database revealed that they were closely related to particular species. The strains were identified as *Fusarium sporotrichioides* (G435/14) and *Alternaria alternata* (G443/14).

The study also indicated that most seeds were settling by *A. alternata* and just few by *F. sporotrichioides*.

Acknowledgements

The analyses were performed using equipment bought with European Union funds – The Eastern Poland Development Programme 2007-2013, Regional Laboratory of Renewable Energy, Institute of Agrophysics PAS.

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Agriculture and Agricultural Science Procedia 7 (2015) 80 – 86

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Studies on stress relaxation process in biodegradable starch film

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Abstract

In the paper the effects of keratin and polyvinyl alcohol additives on the stress relaxation course in thermoplastic starch film were presented. The 3-parameter Zener model was used to describe the behavior of film under loading taking into account sample sizes and initial deformation velocity. The effects of air relative humidity, initial deformation velocity and the way of sample cutting on model parameters were also determined. The increase of keratin content resulted in the decrease of E_0 parameter, whereas the increase of polyvinyl alcohol caused its increase.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: stress relaxation; thermoplastic starch; keratin; polyvinyl alcohol; Zener model.

1. Introduction

On account of its properties thermoplastic starch film is a material which can replace synthetic packaging in the future (Hangoard et al., 2001; Nafchi et al., 2013). Modified starch is a plant polymer easily available, obtained from potato, maize and rice. It is characterized by complete biodegradability, easy availability of produce and also low production cost. (Kyrikou and Briassoulis, 2007; Siwek et al., 2010). Unlike petrochemical origin materials, starch does not cause environmental pollution and disease risk growth. These qualities encourage producers to develop environment and health friendly packaging technology (Boryniec et al., 2004; Zhao et al., 2005; Iovino et al., 2008). Unfortunately, there are some drawbacks related to starch properties such as: susceptibility to moisture absorption,

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.038

unsatisfactory mechanical properties and fast aging, which reduce the range of their full applications (Martin et al., 2001; Chen and Lai, 2008; Da Róz et al., 2011). To obtain the specified level of mechanical properties and their stability in time during production, plasticizers (Moore et al., 2006; Jiang et al., 2006) or other supplementary additives (Mao et al., 2000; Majdzadeh-Ardakani and Nazari, 2010) are used. There are also applied different kinds of starch (de Graaf et al., 2003; Janssen and Mościcki, 2009) and various production engineering is tested (Xie et al., 2009; Ashogbon and Akintayo, 2014). Using additives improves mechanical properties determined by such parameters as: modulus of elasticity, critical stress and strain as well as puncture resistance (Petersen et al., 2001; Follain et al., 2005; Gołacki et al., 2014). Apart from elasticity and plasticity the film is characterized by viscoelastic properties, which are connected with the energy dissipation processes (Stropek et al., 2014). Susceptibility to impact loading is another parameter which is not only studied for biological origin materials (Stropek and Gołacki, 2013, 2015, 2016) but also polymers (Kołodziej et al., 2014).

The aim of this paper was determination of the effects of keratin and polyvinyl alcohol additives on the stress relaxation course in thermoplastic starch film. The 3-parameter Zener model was used to describe the behaviour of film under loading taking into account sample sizes and initial deformation velocity. The effects of air relative humidity, initial deformation velocity and the way of sample cutting on model parameters were also determined.

2. Material and method

2.1. Material

Thermoplastic starch was produced with the use of: potato starch, plant glycerol, polyvinyl alcohol with the molecular mass of 72000 g/mol and keratin with 87.5% dry substance. The film was prepared in two stages. In the first stage the mixtures of potato starch, glycerol and keratin or polyvinyl alcohol were made. From those mixtures the starch pellet was obtained in the TS-45 single-thread worm extruder. The labels and compositions of mixtures are presented in Table 1. The second stage consisted in producing a film sleeve from starch pellet by means of the blowing method.

Table 1. Samples composition, % by mass.

Sample label	Potato starch	Glycerol	Polyvinyl alcohol	Keratin
sga 1	78	20	2	
sga 2	75	20	5	
sga 3	70	20	10	
sgk 1	79.5	20		0.5
sgk 2	79	20		1
sgk 3	78.5	20		1.5
sgak 3	76	20	3	1

2.2. Method

The samples were cut on specially designed knife-edge die of 80x150 mm sizes and put into plastic bags allowing the air to be suck off in order to delay the aging process of film. Relaxation stress tests were carried out with the Instron 8872 universal testing machine. The films with different contents of keratin, polyvinyl alcohol and mixture of keratin and polyvinyl alcohol were tested. The samples were put between the specially developed gripping jaws.

The samples were characterized by different moisture contents because they were stored under three various conditions with the air relative humidity 50%, 91% and 99%. The first level of humidity was obtained under the environmental conditions and the other two by placing the film samples in the exsiccators with the water solution of table salt at the specified concentrations. The humidity of 91% corresponded to the solution with 5-mole concentration, and humidity of 99% - 0.3 mole. The samples sealed to obtain the humidity corresponding to the solution concentration were suspended for 24 h from special frames in the exsiccators.

The stress relaxation tests were carried out in three stages. Before each test the sample thickness was measured by means of micrometer caliper with the accuracy of 0.01 mm.

The first stage consisted in testing the two film compositions sga1 and sgk1 at two initial deformation velocities of 6 and 60 mm/min. At first tests for the two additional deformation velocities of 600 and 3000 mm/min were planned to be carried out. However, it was impossible due to samples tearing. The samples were tensed to the force value of 30 N and next permanent deformation was maintained. The force response value changes were recorded for 50 s. 10 repetitions were made for each velocity.

The second stage consisted in checking effects of sample cutting way. The samples were cut parallel and perpendicularly to the film blowing direction. In this case the two film compositions sgk3 and sga3 were tested at the initial deformation velocity of 60 mm/min. The samples were tensed to the force value of 30 N and next the permanent deformation was maintained. The force response value changes were recorded for 50 s. 6 repetitions were made for each direction of sample cutting.

The third stage consisted in carrying out stress relaxation test for the samples with different moisture contents. The five film compositions sgak3, sga2, sga3, sgk2, sgk3 were tested at the environmental humidity amounted to 50%, 91% and 99%. The samples were tensed to the force value of 10 N and at the initial deformation velocity of 60 mm/min. Next the permanent deformation was maintained. The force response value changes were recorded for 50 s. 3 repetitions were made for each humidity.

2.3. The modelling of experimental courses

The 3-parameter Zener model was used to describe the behaviour of film under loading. The sample sizes and deformation velocity were taken into account in the initial stage of the test (Chen and Fridley, 1972; Gołacki and Stropek, 2001).

$$F(t)=\left(\frac{S\cdot v}{l}\int_0^{t_m}(E_0+E_1\cdot e^{-\frac{E_1}{\eta_1}\cdot(t_m-t)})\cdot dt\right)\cdot e^{-\frac{E_1}{\eta_1}\cdot(t-t_m)} \tag{1}$$

where: S is the cross section area, v is the initial deformation velocity, l is the sample length, t_m - is the increasing deformation time and t is the time counted from the beginning of sample deformation.

Formula (1) is applied in the second stage of the test in which the constant deformation was maintained ($t > t_m$). It takes into account also the relaxation stress which already occurred during the increasing deformation. The force response courses obtained as a result of the experiment were approximated by the formula:

$$F(t)=A_0+A_1\cdot e^{-\alpha_1\cdot(t-t_m)} \tag{2}$$

in which A_0, A_1, and α_1 are the parameters.

The nonlinear minimization Quasi-Newton method was applied to determine the values of those parameters. 33 measuring points were used to approximate the experimental course in the following way: the first 10 points every 0.01 s, the next 10 every 0.1 s, the successive 9 every 1 s and the last 4 every 10 s. From the comparison of formulae (1) and (2) there were determined the E_0, E_1 and η_1 model parameters (Chen and Chen, 1986) described with equations (3-5).

$$E_0 = \frac{A_0 \cdot l}{S \cdot v \cdot t_m} \tag{3}$$

$$E_1 = \frac{A_1 \cdot l \cdot \alpha_1}{S \cdot v \cdot \left(1 - e^{-\alpha_1 \cdot t_m}\right)} \tag{4}$$

$$\eta_1 = \frac{A_1 \cdot l}{S \cdot v \cdot \left(1 - e^{-\alpha_1 \cdot t_m}\right)} \tag{5}$$

3. 3. Results

Figures 1 and 2 show the relationship between the E_0 modulus of elasticity as well as t_1 time constant and air relative humidity for different film compositions respectively. The time constant t_1 is the quotient of η_1 and E_1.

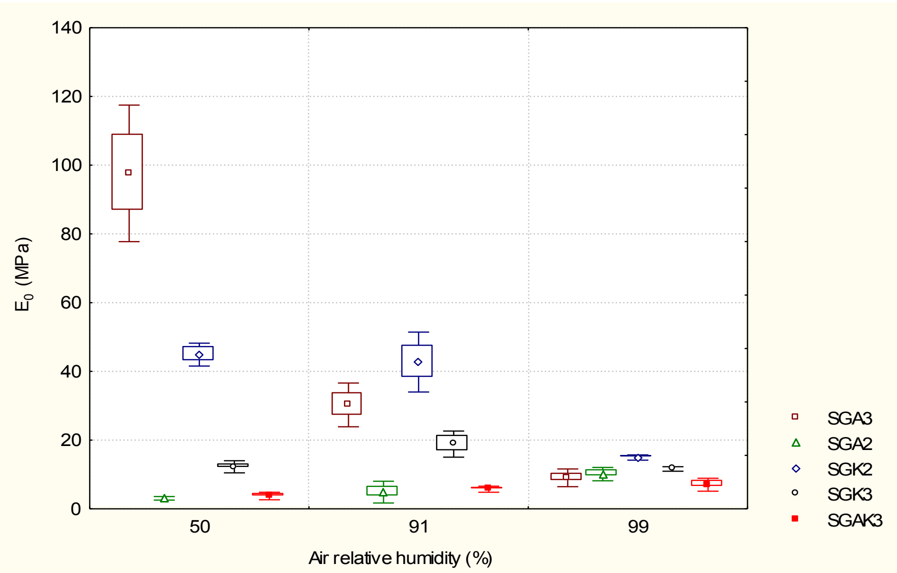

Fig. 1. Relationship between the E_0 parameter of Zener model and the air relative humidity for different film compositions

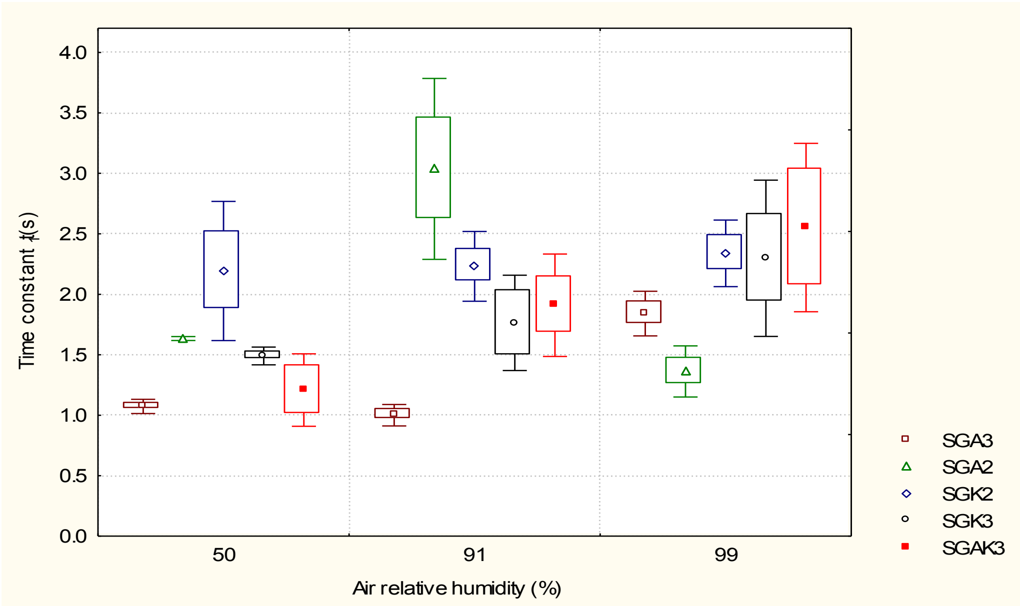

Fig. 2. Relationship between the t_1 parameter of Zener model and the air relative humidity for different film compositions

Fig. 1 shows the effect of polyvinyl alcohol and keratin additives on the value changes of E_0 parameter. The increase of polyvinyl alcohol content up to 10% resulted in higher values of E_0 parameter for air relative humidity of 50% and 91%. At the air humidity of 99% statistically significant differences between the mean values of E_0 parameter for different polyvinyl alcohol content films were not found. The increase of keratin content from 1% to 1.5% caused the decrease of E_0 parameter for the whole air humidity in the films where keratin was the only additive. As follows from Fig. 2 both keratin and polyvinyl alcohol content do not cause changes of time constant for different air relative humidity values.

While determining the effect of the initial deformation velocity on the parameters of Zener model, statistically significant differences between the mean values of E_0 parameter for different film compositions were not found. The initial deformation velocity had the effect only on t_1 time constant as shown in Fig. 3.

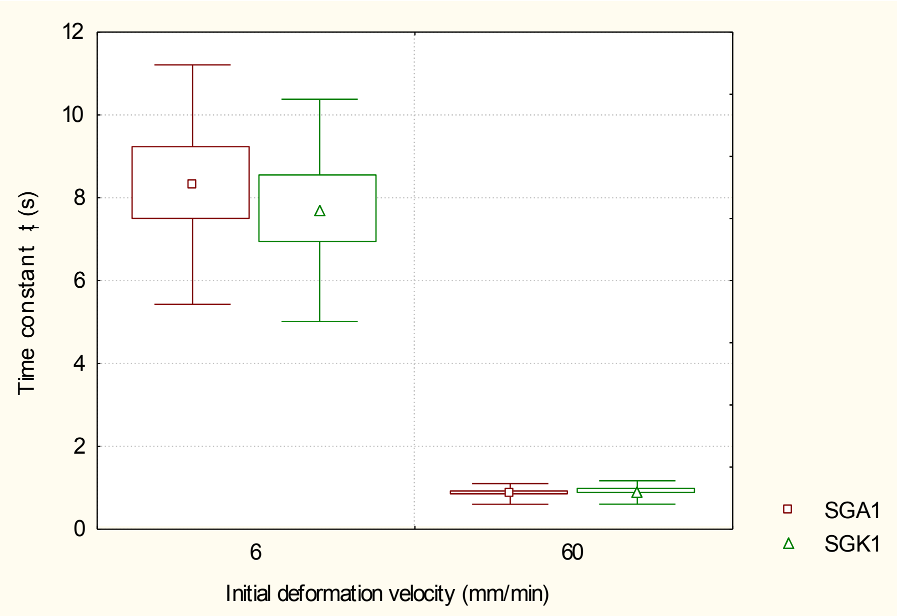

Fig. 3. Relationship between the t_1 time constant and the initial deformation velocity

The t_1 time constant decreased with the increasing initial deformation velocity for both tested film compositions. Time constant is a measure of stress loss in material during the test.

The way of cutting sample had no effect on model parameters. The sample cutting parallel and perpendicularly to the direction of film blowing did not induce statistically significant differences between the mean values of Zener model parameters for both tested film compositions.

The 3-parameter Zener model applied for description of the film behaviour under loading was consistent with the experimental curves. It was composed of free term E_0 equation 1 or A_0 equation 2 presenting stabilized stress level at the end of the test and viscoelastic terms (E_1 and η_1 parameters in equation 1 or A_1 and α_1 in equation 2) describing stress relaxation.

4. Conclusions

The increase of keratin content resulted in the decrease of E_0 parameter, whereas the increase of polyvinyl alcohol caused its increase. The values of E_0 parameter for different contents of keratin and polyvinyl alcohol pointed out to large differences at the air relative humidity amounting to 50%. Those differences disappeared at the air relative humidity of 99%. The initial deformation velocity had the effect only on the t_1 time constant. The time constant decreased with the increasing initial deformation velocity for the tested film compositions. The 3-parameter viscoelastic Zener model described the stress loss processes in the material during the test in a satisfactory way. The research results do not allow explaining their relation to the structure of the film material. There was no statistically significant effect of additives on t_1 time constant.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

System supporting location of service works in agriculture on example of vehicle recycling network

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Abstract

The paper presents a decision support system for the selection of locations of dismantling stations in a vehicle recycling network. The system uses genetic algorithms effectively. Locations were optimized according to the following criterion: minimization of costs connected with transport, storage and dismantling of end-of-life vehicles as well as costs connected with transport of parts and materials. The proposed system is universal and may be used in agriculture to determine locations of a different kind of facilities organized in a network, on any given area.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: decision support system; location problem; genetic algorithms; service works in agriculture.

1. Introduction

The location problem has been known for a long time, and it is discussed in the process of planning and management networks of a certain kind of facilities (objects). When designing a network, we wish to select the locations of the objects that belong to the network so as to optimize the function that characterizes the location of all the objects in a network. Due to huge variety of networks, the solution to the problem is sought for each case individually. The development of IT techniques created new possibilities concerning the optimization of the location of objects in the spatial structure of the system being designed or managed. There are various models and methods of

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.039

optimization, including linear programming and sophisticated heuristics, depending on the complexity of the problem. The paper proposes a simulation method using genetic algorithms for the location of objects of the network, with a limited site selection. Here, location is understood as a spatial organization of objects of the network in the topographical sites to choose from, within the specified industrial/administrative area (country/macroregion).

Recently, there have been a lot of publications concerning the location problem, e.g. location of product distribution centers with respect to selected parameters of the process, most frequently minimization of the distance. There were developed models taking into account a different number of products (multi-product) Nozick and Turnquist (2001) and different methods of distribution Nonås and Jörnsten (2007) and Weiwei Gong et al. (2007). Daskin et al. (2002) and Zuo-Jun et al. (2007) formulated this problem in the form of a nonlinear integer programming model and used Lagrangian relaxations. Different tools were used to solve the model depending on the degree of the model complexity Shu et al. (2005) - Column Generation Method. Ek Peng Chew et al. (2002) used genetic algorithms to solve the problem of location and took into consideration the cost of distribution process and the quantity of stocks. Given random changes of distribution process parameters, the quantity of stocks may be assessed using computer simulation, Miranda and Garrido (2006) and Monte Carlo methods, Kwilosz (2011).

Naturally, increased motorization and mechanization is accompanied by the process of systematic increase in end-of life cars. In Poland, there are still a lot of old vehicles. Unfortunately, the average age of a car registered in Poland increases every year. In 2010, 30% of all registered cars were older than 15 years. This is the reason why there is a problem of end-of-life vehicles recycling, and why it will aggravate. It applies both to vehicles used in rural areas as well as large cities. Scrapped vehicles are a source of recyclable materials or environmental pollution. Solving the problem of recycling is consistent with new regulations concerning waste management in accordance with the Directive 2000/53/EC of the European Parliament and of the Council of 2000. This directive contains detailed regulations concerning recycling. It sets out that, no later than 1 January 2015, for end-of-life vehicles, the recovery of materials shall be increased to a minimum of 95% of their weight.

Therefore, the goal of this work was to design a decision support system that facilitates the selection of optimum locations of objects in a specified area, and the implementation of the system for dismantling stations in vehicle recycling network. Genetic algorithms, due to their advantages as a method of complex tasks optimization in the location problem Li Jin et al. (2010), Rui Song et al. (2002), Taniguchi Jyunichi et al. (2005), were used in the developed system. The developed decision support system, facilitating the selection of location of objects that belong to a network, was tested for its sensitivity to changes of input data.

Each end-of-life machine, device and vehicle is a source of valuable recyclable materials. Recycling is an environment friendly and cost-effective way of end-of-life vehicles utilization.

The concept of recycling may be understood in two ways Oprzędkiewicz and Stolarski (2003):

1. Recycling of a vehicle involves its complete processing by shredding and reuse of materials obtained in this way in other processes. This method is preferred by such countries as France and Belgium.
2. Recycling of vehicles is divided into two stages. First, all components, parts and materials either for direct reuse, recondition or rework are dismantled. The remaining waste materials may be used in other processes. This method is promoted by Germany, Italy, Sweden and Great Britain.

Although the cost of dismantling makes up a significant percentage of the total cost of recycling, it is still technically justified and allows for better compliance with the Directives of the European Union. Dismantling stations organized in a network, supported by information technology, logistics and appropriate marketing are self-sufficient and make profit. An example may be a system organized by FIAT within the external FA.RE. programme (Fiat Auto Recycling). Based on the second approach, the authors assumed 3-level organization of a recycling network (fig.1). The network consists of the following objects: vehicle collection points (CP_N), dismantling stations (DS_J), and processing facilities (PF_K). The cost of recycling depends on the cost of transport of vehicles, parts and materials between the facilities (objects) of the system. Therefore, the location of each object should be correlated with the locations of other objects of the network.

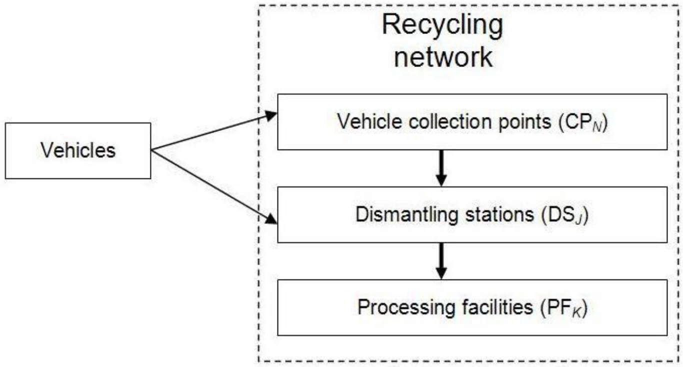

Fig.1. A relational model of a three-level recycling network

2. Formulation of the optimization task

Initial assumptions were formulated as regards the decision support system for the selection of location of dismantling stations in a vehicle recycling network:

1. Location of a dismantling station is sought considering the location of the existing processing facilities, and suggested location of vehicle collection points.
2. The number of vehicle collection points depends on the selected area as well as the assumed territorial and legal conditions.
3. Vehicles collected in collection points are transported to the nearest dismantling station.
4. The concentration of dismantling station depends on demand. However, the distance from the collection points should also be taken into consideration.
5. The network should include at least one processing facility.
6. The vehicle recycling network is designed on a specified, limited area.

The sought solution of the optimization task, with the above assumptions, is the number and location of vehicle dismantling stations. The optimization task, concerning the location of dismantling stations, was formulated relative to minimization of the objective function:

$$F = \sum_{n=1}^{N} \sum_{j=1}^{J} K_{S_{nj}}(Q_n) + \sum_{j=1}^{J} K_{m_j}(q_j) + \quad (1)$$
$$+ \sum_{j=1}^{J} K_{d_j}(q_j) + \sum_{j=1}^{J} \sum_{k=1}^{K} K_{C_{jk}}(S_k) \rightarrow \min$$

with the following constraints:

$$K_{S,}, K_m, K_d, K_C \geq 0 \quad (2)$$
$$1 \leq N \leq N_{\max} \quad (3)$$
$$1 \leq J \leq N \quad (4)$$
$$1 \leq K \quad (5)$$

where:
$F=K_{rec}$ - the objective function denoting total cost of vehicles recycling,
J - number of vehicle dismantling stations,
K - number of processing facilities,
N – number of vehicle collection points,
N_{max} – maximum assumed number of locations of objects,
K_S – cost connected with transport of vehicles from the collection point to the dismantling station,
K_m – cost of storing vehicles in the dismantling station,
K_d – cost of dismantling vehicles in the dismantling station,

K_C – cost of transporting parts and materials from the dismantling station to the processing facilities,
Q_j – daily stream of vehicles received by the j-th dismantling station,
Q_n – daily stream of vehicles received by the n-th collection point,
S_k – daily stream of parts and materials in the k-th processing facility,
j, k, n – summing indexes.

It is at the dismantling stations that the main part of the process takes place, namely: dismantling of vehicles as well as storing both vehicles and dismantled parts to be transported to processing or utilizing facilities.

It was assumed that the cost of storing vehicles at a dismantling station K_m is considered only when the number of cars deposited at the station is greater than the daily throughput of the station.

The cost of dismantling K_d depends on the scope of work and is calculated for each vehicle in each station. The cost includes the following:

- cost of dismantling work that depends on the labour cost, investment costs and depreciation, fixed (operational) cost, and internal transport cost,
- cost of utilization of non-recyclable waste material.

The cost of transport K_S and K_C depends on the distance between potential locations of a given dismantling station and other objects that belong to the recycling network, the weight and type of transported cargo as well as the method of transport. The input data must be the distances between potential locations of the dismantling station and other objects that belong to the recycling network. They are determined based on the road map and presented in the form of a matrix. The remaining dependences may be represented by the identified unit cost of transport.

The solution of the above optimization task requires using the original method as the components of the objective function, namely, the cost of recycling, are non-linear functions of the scrapped vehicle stream. The number of vehicles changes randomly, and the optimum solution is sought in a limited space. Additionally, the cost of recycling depends on many factors that are difficult to express using numbers or it is not possible to present their influence on cost using mathematical formulae. Due to the optimization properties of genetic algorithms, one of the methods of Artificial intelligence (AI), the following research assumptions were made in the paper: "Simulation techniques based on genetic algorithms may be an effective tool to support decision-making concerning the locations of vehicle dismantling stations due to the optimization of cost connected with recycling". As a result, there was proposed a system for the analysis of the cost of recycling to support decision-making as regards spatial location of vehicle dismantling stations using genetic algorithms.

3. Structure of the decision support system

The principle of operation of the system supporting the selection of the location of vehicle dismantling stations is presented in fig. 2.

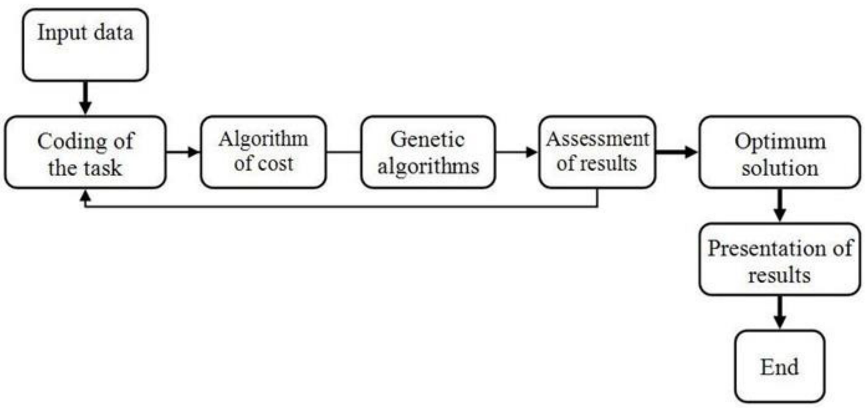

Fig. 2. The principle of operation of the system supporting decision-making concerning the location of vehicle dismantling stations

Input data – is a module where data about the objects of the recycling network (e.g. J, K, N, …), and the matrix of distance between them for a selected area are input, and numbers Q_i of vehicles to be recycled are generated. Coding of the optimization task– each variant of the number and location of the dismantling station being analysed in the system is coded in the form of an ordered binary sequence, called a chromosome. Recycling cost is calculated for each chromosome. Cost determination algorithms are responsible for the calculation of all costs that make up the total recycling cost, and the objective function with constraints.Optimization using genetic algorithms is the most important module of the system that finds the optimum solution - the number of the dismantling stations as well as their topographic location.

3.1. Coding and solving the optimization task

A binary location vector that represents chromosomes in the applied genetic algorithm was used to code potential locations of all dismantling stations (DS) in the recycling network. The number of the vector's coordinates is equal to the number of vehicle collection points; in the analysed case N=37. The coordinate xn of the location vector (n=1, …, N) provides information as to whether there is a dismantling station (DS) in the n-th vehicle collection point (CP). The value equal "1" denotes that a dismantling station is located in the place, and the value equal "0" denotes that there is no such station. Uniqueness of this information results from the initial assignment of the chromosome coordinates to the CP locations, e.g. chromosome (1, 0, 1, 0, 1, 0) denotes that dismantling stations are located in the first, third and fifth location of all six locations being analysed. The shortest distance criterion is used to indicate the CP points from which the vehicles are transported to these three DS stations. Hence, in the distance matrix $[a_{jn}]$, values:

$$x_{1n_1} = \min a_{1n},\quad x_{2n_2} = \min a_{2n},\quad x_{6n_6} = \min a_{6n}$$

are sought for n=1,3,5. Indexes n_1, n_2, …, n_6 indicate the number of the place of location of the station (DS). The example below presents the assignment of vehicle dismantling stations (DS) locations to vehicle collection points (CP). In the example N=6, symbols A,B,…, F denote locations of vehicle collection points (CP).

Table 1. An example of coding and finding solution of the task.

Place of location, matrix $[a_{jn}]$	**A** a_{j1}	**B** a_{j2}	**C** a_{j3}	**D** a_{j4}	**E** a_{j5}	**F** a_{j6}
A, a_{1n}	0	182	196	106	125	84
B, a_{2n}	182	0	191	105	126	96
C, a_{3n}	196	191	0	91	88	142
D, a_{4n}	106	105	91	0	52	56
E, a_{5n}	125	126	88	52	0	75
F, a_{6n}	84	96	142	56	75	0
Chromosome $[x_n]$	**1**	**0**	**1**	**0**	**1**	**0**

Locations of CP	**Locations of DS selected by the chromosome**			$x_{jn_j} = \min_{n=1,3,5} a_{jn}$
	A	**C**	**E**	
A	0	196	125	$n_1=1 \Rightarrow x_{11}$
B	182	191	126	$n_2=3 \Rightarrow x_{23}$
C	196	0	88	$n_3=2 \Rightarrow x_{32}$
D	106	91	52	$n_4=3 \Rightarrow x_{43}$
E	125	88	0	$n_5=3 \Rightarrow x_{53}$
F	84	142	75	$n_6=3 \Rightarrow x_{63}$

As the example shows, six CP points were assigned a DS located in A, C and E. Fig. 3 presents the assignment; namely, to which dismantling station (DS) the vehicles from the vehicle collection points (CP) will be transported. Each chromosome contains information about the number of vehicle dismantling stations and their locations in a given area.

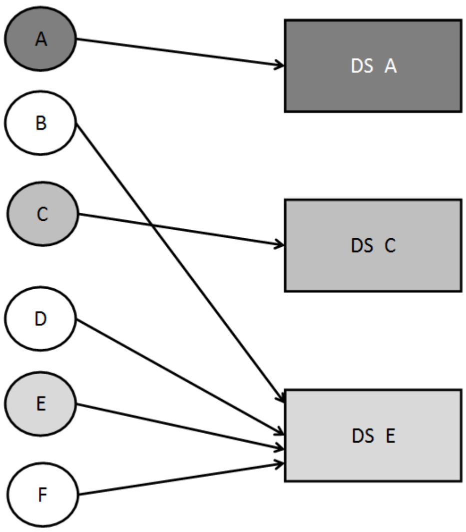

Fig. 3. A diagram presenting optimum assignment of vehicle collection points A,...,F to vehicle dismantling stations A,C and E.

3.2. Optimization using the genetic algorithm

The solution of the optimization task, formulated in the paper, was sought using the developed genetic algorithm (the method of transformation of the population of chromosomes which code the selection of DS considering the minimum cost of recycling). The flowchart of the algorithm is presented in fig. 4.

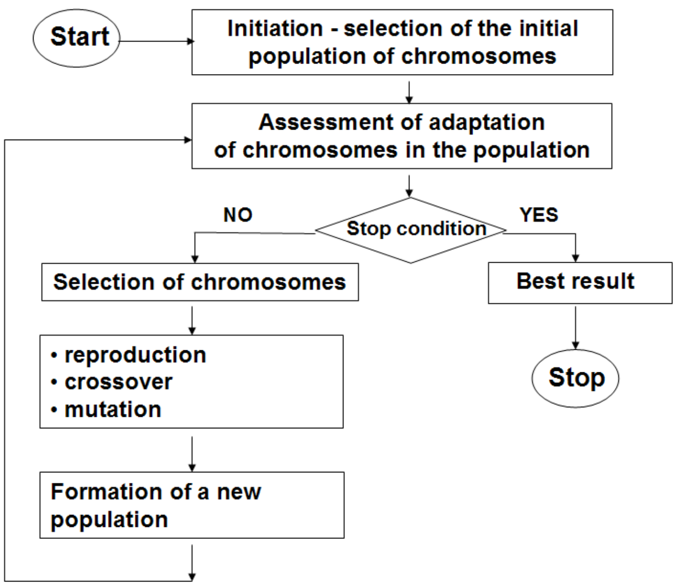

Fig. 4. A flowchart of the genetic algorithm.

The algorithm uses the following genetic operators: mutation, crossover and reproduction:
Gene mutation - the mutation operator was introduced (with probability 1) in the chromosomes which were identical (deterministic selection) in order to introduce diversity in the population, which (at least partially) prevents the premature convergence of the algorithm.
Crossover – the crossover operator was used only in cases of selected individuals (the most promising ones), and the point of crossover is selected at random.
Reproduction - an elite strategy and genetic algorithm with partial exchange of population. The elite strategy involves protection of the best chromosomes in successive iterations. In the genetic algorithm with partial exchange of population, only part of the population which is to forms the next generation, does not undergo any modifications, i.e. crossover and mutation. In this particular case, it applies to the best (fittest) individual from the population.
Selection - the individuals to form the next generation are selected based on the ranking method. Each individual is assigned the number specifying his position on a list - a rank.
Halt condition - no improvement in the adaptation function (minimization of the recycling cost) in ten successive iterations (generations).

The originality of the method used involves automatic formation of new chromosomes (by the developed decision support system) which indicate potentially possible locations for which the cost is calculated. The chromosome, for which it is impossible to significantly improve the calculated objective function (1) of the optimization task, is assumed to meet the optimization criterion.

4. Conclusions

The presented system is universal and may also be used to locate other types of objects on a selected area, e.g. agricultural products collection or distribution centres. The proposed method for optimizing the location of vehicle dismantling facilities using genetic algorithms was developed to include the complexity of the process of recycling. The advantage of the proposed intelligent system that supports decisions concerning the location of dismantling stations is the fact that it allows to obtain solutions for different values of decision variables in a short time, which supports making decisions in changing conditions, while the network is being formed and during its functioning.

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Agriculture and Agricultural Science Procedia 7 (2015) 94 – 98

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Productivity of farms in the aspect of various activity forms

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Abstract

The paper analyses productivity of the selected agricultural resources which is an indicator describing the efficiency of agricultural production processes management. Final gross production was assumed as an indicator describing the obtained effects of agricultural production. The scope of the paper covered farms according to their activity, i.e. operating individually and grouped in producer groups. The grouped farms have better productivity of fixed assets. In these objects, fixed assets productivity index indicates that 2.80 kPLN·ha^{-1}AL of the production value is per 1 unit of fixed assets value which is 1 kPLN·ha^{-1}AL. For comparison in the non-grouped farms "abilities" of the property invested in the machinery park for generating revenues were only 0.97 kPLN·ha^{-1}AL.

Keywords: Productivity; agricultural production; agricultural producers' group; resources.

1. Introduction

Changes in the market surrounding farmers speeded up after 2004 and forced producers to search for methods increasing their effectiveness. Agricultural enterprises of high potential to modernize, which translates into high quality products, their attractive price and makes them desirable at the market, can sustain competition (Kowalski et al., 2012; Sawa, 2007). Real needs of the Polish agriculture induce producers to take up formalized form of cooperation in the vertical integration system. Formation of agricultural producers' groups, next to agricultural

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doi:10.1016/j.aaspro.2015.12.042

groups or cooperatives, is the example of vertical integration. Due to associating in producers' groups, farmers are to obtain advantages in the form of production and transaction costs reduction and to become active participants on the market (Chlebick, 2011; Kołtun, 2014; Szeląg-Sikora and Cupiał, 2003). Willingness to obtain advantages through lowering production costs is not the only premise for starting cooperation in producers' groups. When evaluating the economic efficiency of subjects, besides their ability to reduce production costs, one should also consider the ability to lower transaction costs, very essential from the point of view of implementation of modernization process of technical infrastructure (Bachev, 2004; Helander, Delin, 2005). The idea of appointing a producers' group has been known for ages. However, it has gained a new meaning in the recent few years. It results from the farmers' need to integratewhich is related to the need of the moment influenced by the present market mechanism, when the farmers must take economic decisions including the situation on the market. Undoubtedly, the law of supply and demand and great competition are factors deciding on the position of agricultural farmers on the marketing outlets. However, initiative of common activity for farmers is not only strengthening of its market position. For many of them, it is a chance for strengthening the potential of particular production factors. Disadvantageous agrarian structure of the Polish farms (especially in the Southern Poland) translates not only into their low competitiveness but also determines their efficiency of farming by too slow modernization process of the technical infrastructure and therefore also into low labour efficiency and high production costs (Szeląg-Sikora, 2013; Sikora, 2014). Also, according to Kożuch (2000) relatively low efficiency of the Polish agriculture in a considerable degree isa result of the fragmented agrarian structure, which makes fast increase of the labour efficiency, production efficiency and farmers' abilities to absorb technical and technological progress impossible.

2. Objective, data and methodology

In total 5 producer groups were covered by research. They were varied on account of the production trend and the number of members (farms) of particular groups. According to the accepted assumptions for comparative purposes, a comparative group of individual farms was selected, pursuant to the principle that each producer groups responds to the "group" of individual farms. When selecting facilities for the research from the comparative group, they tried to qualify facilities which had similar management conditions. The same production trend and in a possible scope, also possessing comparable land resources, was accepted as the exit criterion. Selection of farms took place based on three main criteria:
a) the production trend was in compliance with the grouped farms,
b) had an agrarian structure similar to the grouped farms according to particular production trends,
c) the owner of the facility agreed to carry out research.
Additionally, they featured similar environmental and soil conditions and the market surrounding. The research was carried out with the guided survey method by means of the questionnaire. Division of the researched facilities into two groups, i.e., producer groups and individual farms was accepted as the main grouping factor. Producer and comparative groups on account of the production trend were selected. 96 farms in total were covered by the research. 42 farms in total were grouped in the researched 5 producer groups.The thematic scope of questions placed in the questionnaire on account of the accepted area of the research issue included all production processes in the economic year 2011/2012.

Calculated indicators

Efficiency – unit effect (result) due to the factor unit, which caused this result. Productivity of particular resources is a fractional indicator which describes efficiency of agricultural production.

Productivity (PFP) is a ratio of the amount of production in a specific and considered period to the amount of used and consumed input resources. The discussed input resources, are nothing else but various supply of the system and resources of the system used for production of the final product (Kożuch, 2000).

Land productivity (land efficiency) (*Pz*):

$$Pz = PK/F \text{(kPLN·ha}^{-1}\text{AL)} \quad (1)$$

where:
PK – gross final production (kPLN),
F – agricultural area (ha AL).

Gross final production – constitutes a sum of the obtained plant and animal production value.

Plant and animal production value included:
- value of the main product,
- value of the side product (only in case it was the subject of the market exchange),
- domestic use value,
- subsidies to a product or to its cultivation area (these could be subsidies from the state budget of the European Union budget within the Common Agricultural Policy).

Value of production in case of particular activities of plant production was calculated for 1 ha of AL of cultivation or for 1 LU.

The productivity index of the selected technical means (of the machinery park)(*Wppm*):

$$Wppm = PK/WOPM(\text{kPLN}\cdot\text{ha}^{-1}\text{AL}) \quad (2)$$

where:
WOPM – Gross replacement value (kPLN $\cdot$ha^{-1}AL)

Productivity of work inputs (E_{WP}):

$$E_{wp} = PK/NP \ (\text{kPLN}\cdot\text{man-hour}^{-1}) \quad (3)$$

where:
NP –work inputs (man-hour)(Gębska and Filipiak, 2006, Szeląg-Sikora, 2013).

3. Results

The issue of agrarian fragmentation of the Polish country still remains one of the key problems of the Polish agriculture. Supporting the process of agricultural producer groups' formation has become one of the ideas for the improvement of situation in this scope. It is assumed that horizontal integration of farmers will lead to strengthening their bargaining power and consequently to improvement of their incomes. Facilities, accepted for research, were varied on account of the possessed land resources. Within the producer groups, the average area of the investigated farm was 42.5 and was two times higher than the average for a comparative group of individual farms (tab. 1).

The final gross production, which for comparison referred to the entire farm was at the average considerably higher in the grouped farms, was included as the final effect compared to the unit of agricultural land area.

Table 1.Area of arable land and sowing of the researched farms, gross final production and work inputs

Specification	Producer groups	Individual farms
	Average	
	(ha·farm^{-1})	
Arable land	24.96	16.65
including: wheat	13.34	13.31
root	3.27	1.49
industrial	0.81	0.19
vegetables	5.54	1.24
fodder	2.00	0.51
Grasslands	16.19	3.41
Orchards and plantations	1.39	1.49
Agricultural land	42.54	21.55
Gross final production	(kPLN·farm.$^{-1}$)	
	1 118.63	266.77
	(man-hour ·ha^{-1}AL)	
Work inputs	215.24	300.70

Work inputs are one of the most important positions in the balance of the incurred inputs in farm production. At the same time they are an input indicator for determination of work efficiency. Results presented in table 1 prove that the non-grouped farms led more labour-consumptive production, namely at the level of 307.02 man-hour·ha-[1]AL. According to the information obtained during the guided survey in these objects, so high labour inputs resulted from a low mechanization degree of field work, mainly cropping of the cultivated vegetables which was carried out manually. For comparison, in the non-grouped farms the incurred work inputs were lower by 91.6 man-hour·ha-[1]AL.

Each farm should be equipped with basic farming machines. Mechanical tractive force, which decides on the degree of use of majority of the remaining machines and agricultural devices, thereby on the promptness of performing particular agro-technical treatments, is the most important in the structure of the machinery park. Table 2 presents farm equipment with the selected elements of the machinery park. Average number of tractors for all grouped farms was at the level of 1.52 item·farm^{-1}. In case of the non-grouped farms, the minimum average value was slightly higher and amounted to 1.60 item·farm^{-1}. Analysis of the quantity equipment in delivery trucks proved that in individual farms the average was 0.59 item·farm^{-1}. Combine harvesters constituted a part of the machinery park. Detailed equipment of the machinery park with technical means, presented in table 2, proves that the researched farms in majority of cases have indispensable tools and machines for the performed agricultural plant as well as animal production. The producer groups' farms many times owned, at the average, a lower number within particular assortments of machines and tools. For example, the number of ploughs in the grouped farms was lower by 0.08 items·farm^{-1} than the number of these tools in the compared farms. Average number of sowing and planting machines for the grouped farms was lower than the average value of this index for individual farms.

Table 2.Farm equipment with selected elements of the machinery park and gross replacement value.

Specification	Producer groups	Individual farms
	Average	
Farm equipment with selected elements of the machinery park (item·farm^{-1})		
Trucks	0.40	0.52
Tractors	2.14	2.24
Combine harvesters	0.29	0.31
Trailers	1.48	1.67
Ploughs	0.93	1.02
Harrows	0.74	1.28
Cultivators	0.14	0.33
Cultivation aggregates	0.48	0.70
Manure spreaders	0.55	0.61
Fertilizer spreaders	0.60	0.67
Slurry spreaders	0.43	0.24
Manure loaders	0.48	0.46
Grain drills	0.38	0.67
Spacing drills	0.14	0.30
Automatic planters	0.14	0.48
Root plants harvesting combines	0.60	0.65
Sprayers	0.64	1.06
Ridging hillers	0.31	0.28
Mowers	0.76	0.52
Tedders	0.45	0.65
Pick-up balers	0.29	0.31
Self-loading wagons	0.10	0.04
Green forage cutters	0.05	006
Milking machines	0.55	0.44
Coolers and cool storages	0.14	0.46
Gross replacement value (kPLN ·ha^{-1}AL)		
Cars	0.71	1.88
Tractors	2.59	4.27
Combine harvesters	1.77	0.89
Remaining	5.30	10.37
Total	10.37	17.41

In order to calculate the productivity of the machinery park, first, its gross replacement value was calculated. When analysing the structure of the gross replacement value of the machinery park, its particular components also differentiate compared objects. In the grouped objects, the capital invested in farm tractors was lower by 1.70 kPLN·ha^{-1}AL.

Efficiency of production may be reflected by calculation of the land productivity. Comparison of the investigated objects as grouped or non-grouped farms, proved that, at the average, per one grouped farm, the land productivity was by 13.92kPLN·ha^{-1}AL higher than in the grouped one (tab. 3).

Table3. The productivity indexes

Specification	Producer groups	Individual farms
	Average	
Land productivity (kPLN ·ha^{-1}AL)	26.30	12.38
Productivity of work inputs (kPLN·mhr^{-1})	0.12	0.07
The productivity index of the selected technical means (of the machinery park)	2.80	0.90

Work efficiency is an indicator that defines productivity of incurred work inputs. When comparing generally grouped objects with the non-grouped, one man-hour in one of them was compensated at the average with the final gross production value at the level of 0.12 kPLN, whereas in the non-grouped value of this index was only 0.07 kPLN (tab.3).

4. Summary and conclusion

Polish farms, in order to carry out the above mentioned tasks should be equipped with modern technical infrastructure, without which it is impossible to increase the plant or animal production. Therefore, mechanization of agriculture is so essential. It results from the increase of land and work productivity, facilitation and lowering labour costs and thus it gets the Polish agriculture closer to achieve the aims.

Possessing higher land resources allows obtaining higher final production value, relation of which to the technical production means value, in this case accepted as the replacement value of the machinery park, allows determination of the usage degree of the machines and devices potential. Value of the productivity indicator of technical production means prove that the grouped objects are in a more advantageous situation. The grouped farms have better productivity of fixed assets. In these objects, fixed assets productivity index indicates that 2.80 kPLN·ha^{-1}AL of the production value is per 1 unit of fixed assets value which is 1 kPLN·ha^{-1}AL. For comparison in the non-grouped farms "abilities" of the property invested in the machinery park for generating revenues were only 0.97 kPLN·ha^{-1}AL.

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Effect of pasteurization on rheological properties of white carrot juice

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Abstract

The rheological behaviour of untreated and pasteurized white carrot juice was modelled to investigate the influence of temperature on viscosity and its fluid type. The research was conducted using a rotational viscometer at shear rates ranging from 1 to 100 s^{-1} and temperatures between 10 and 60°C. The rheological behaviour of untreated white carrot juice was well described by the Newtonian model while the pasteurized juice showed a pseudoplastic behaviour and was satisfactorily fitted to Ostwald-de Waele model. The Arrhenius equation adequately described the effect of temperature on the viscosity. The activation energies were depended on kind of fluid and were 15.41 and 5.90 kJ/mol for untreated and pasteurized white carrot juice, respectively.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: white carrot juice; thermal treatment; rheological properties.

1. Introduction

Sustainable agriculture is the production of food, plant or animal products by methods that are profitable, environmentally friendly and good for human communities. This definition includes also production of food on the basic of natural ingredients and effective energy-saving management.

Food industry has been looking for suitable, natural raw materials for manufacturing products with designed

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2210-7843
Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.043

colour for a long time. One of the raw materials which can fulfil these requirements is white carrot. It is little known and widespread vegetable but contains almost all nutrients of traditional, orange carrot apart from carotenoids Wronowska and Zadernowski 2012). White colour of the carrot products gives possibility to mix them with other vegetables and fruit juices. Addition of juice from white carrot doesn't change the colour but influences on rheological properties of obtained mixture.

The knowledge of the rheological behaviour is necessary for processing of fruit and vegetable products. The rheological properties of juices have several application in developing food process, equipment, quality evaluation and structural understanding of food and raw material (Manjunatha, Raju 2013). They are required to determine the power requirements for unit operation such as: pumping, sizing of pipes, pasteurization, filling, mixing and evaporation (Barbosa-Canovas et al. 1996, Rao 1999). They are also important in the calculation of heat, mass and momentum transfer phenomena (Telis-Romero et al. 1999). Vegetable and fruit juices were subjected to different temperatures and concentration levels during processing, storage and transportation, where the rheological properties can be changed dramatically (Kobus et al. 2014).

Nomenclature

σ	shear stress (Pa),
γ	shear rate (s^{-1}),
μ	viscosity (Pa·s),
n	flow behaviour index,
K	consistency coefficient ($Pa·s^n$),
K_0	frequency factor ($Pa·s^n$),
E_a	activation energy of flow ($kJ·mol^{-1}$),
R	universal gas constant ($kJ·mol^{-1}·K^{-1}$),
T	absolute temperature (K),

2. Objective, data and methodology

The aim of the paper was to determine the influence of pasteurization on the rheological properties of juice from white carrot variety *White Satin F1*. The juice was obtained with the help of laboratory press. Pasteurization was conducted at 90°C for 20 minutes. Rheological properties were measured using Brookfield viscometer (Brookfield Engineering Laboratories: model LVDV-II + PRO). A sample of 16 ml of carrot juice was used in ULA-baker for all experiments. The concentration of carrot juice was 10°Bx. The temperature of sample was changed from 10 to 60°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. The rheological data obtained for white carrot juice were fitted to Newton model:

$$\sigma = \mu\gamma \tag{1}$$

and Ostwald-de-Waele model:

$$\sigma = K\gamma^n \tag{2}$$

The influence of temperature on consistency coefficient was evaluated from Arrhenius relationship (Quek et al., 2013):

$$K = K_0 e^{\frac{E_0}{RT}} \tag{3}$$

3. Results

The rheograms in Fig 1 show plot of shear stress and viscosity versus shear rate of untreated white carrot juice. Shape of flow and viscosity curves indicates that this juice exhibited Newtonian behaviour.

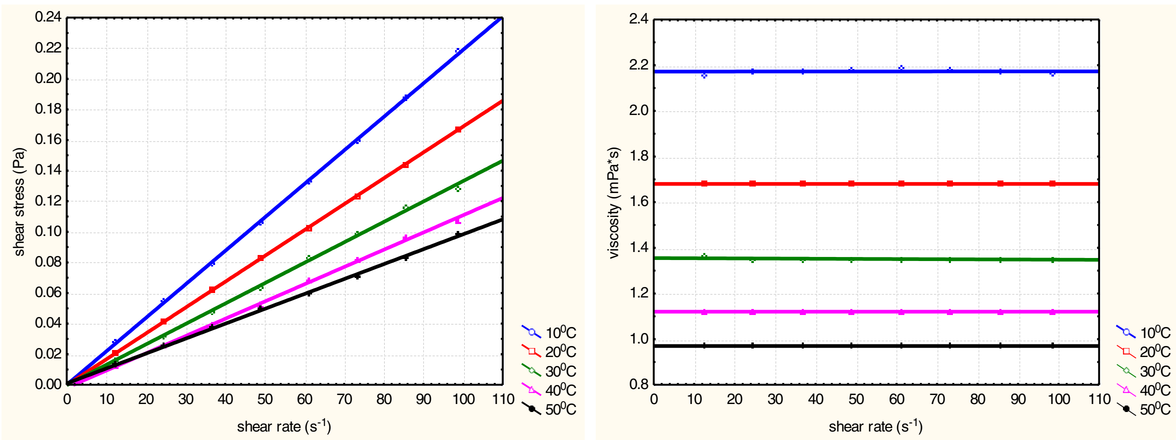

Fig. 1. (a) flow curves of raw carrot juice (10ºBx) at different temperatures; (b) viscosity curves of raw carrot juice (10ºBx) at different temperatures

In Fig 2 were shown flow and viscosity curves of pasteurized carrot juice. In this case rheograms of viscosity versus shear rate show concave curves downward that indicates on non-Newtonian, shear –thinning behaviour.

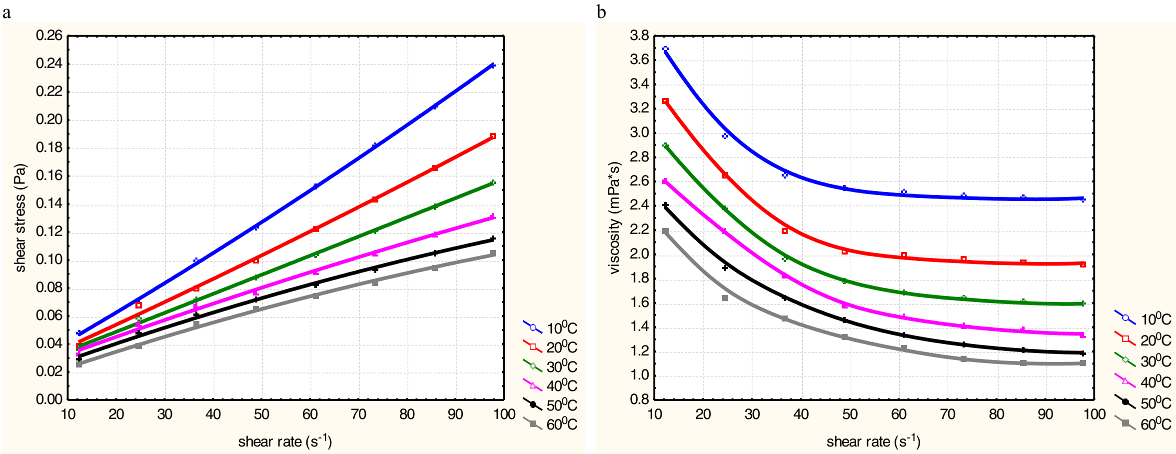

Fig. 2. (a) Flow curves of pasteurized carrot juice (10ºBx) at different temperatures; (b) viscosity curves of pasteurized carrot juice (10ºBx) at different temperatures

Because the pasteurized white carrot juice exhibited non-Newtonian behaviour Ostwald-de-Waele model was applied to calculate its rheological properties. The values of consistency coefficient and flow behaviour index for pasteurized white carrot juice were presented in Table 1. All the values of flow behaviour index are below 1 supporting the pseudoplastic behaviour of pasteurized juice.

Table 1. Rheological properties of Ostwald-de-Waele model for pasteurized white carrot juice

Temperature (^{0}C)	Consistency coefficient (Pa·s^n)	Flow behaviour index (-)
10	0.00624	0.787
20	0.00584	0.743
30	0.00550	0.700
40	0.00520	0.662
50	0.00485	0.657
60	0.00414	0.685

The Arrhenius equation was used to describe the effect of temperature on the consistency coefficient both juice. From this relationship the frequency factor and the activation energy were obtained. The results were shown in Table 2.

Table 2. Rheological parameters for untreated and pasteurized white carrot juice

Kind of juice	Frequency factor (Pa·s^n)	Activation energy (kJ·mol^{-1})
Untreated	$2.91\cdot10^{-6}$	15.41
Pasteurized	$5.21\cdot10^{-4}$	5.90

The activation energy for untreated juice was significant higher that for pasteurized juice. The greater the activation energy for untreated white carrot juice provides that there is higher effect of temperature on viscosity than in the case of pasteurized juice.

4. Summary and conclusion

The rheological behaviour of untreated carrot juice was satisfactorily described by the Newtonian model, while the pasteurized juice showed a pseudoplastic behaviour. To compare different in behaviour fluid the consistency coefficient and the energy activation was calculated. The higher consistency coefficient values were obtained for pasteurised carrot juice while the energy activation was higher for untreated juice. The pasteurization process can change not only the viscosity but also the rheological properties of white carrot juice.

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Agriculture and Agricultural Science Procedia 7 (2015) 103 – 107

Agriculture and Agricultural Science

Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Effect of Asahi SL application on common bean yield

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Abstract

The experiment was carried out in 2010 and 2011 on experimental fields of the Institute of Agricultural Sciences of the State School of Higher Education in Chełm, Poland to study the effect of Asahi SL on bean (*Phaseolus vulgaris* L.) of Aura cultivar yielding. Bean seeds were sown at the depth of 3 - 4 cm, spacing of drills 45 cm, to achieve the density of 30 plants per 1 m^2. During the vegetation period 0.1% and 0.3% concentration of Asahi SL was applied in two application frequencies: single spraying of plants (in the 2 – 3 leaves stage) or double spraying of plants (first in the 2 – 3 leaves stage and second at the beginning of the bean's blooming). Four different variants of spraying with Asahi SL were compared with the control, where biostimulator was not applied. The number and weight of seeds, the number of pods and the weight of thousand seeds according to International Seed Testing Association (ISTA, 2010) method were recorded. It was found that single spraying of plants with Asahi SL advantageously influenced on bean yield increasing the number and the weight of seeds and the number of pods. Control, where biostimulator was not applied was characterized with the lowest yield factor parameters. The highest thousand seeds weight was found for the application of 0.1% Asahi SL solution and in the control.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: bean; nitrophenolates; pod; weight of thousand seeds; yield.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.045

1. Introduction

Sustainable agriculture is the management of conditions and means of agricultural production, which takes into account the needs of present and future generations, both in terms of production efficiency and sustainability of ecosystems with the involvement of scientific, technological and institutional progress (Neher 1992). Production of safe, high quality food in a way that protects the environment supports the use of bio-stimulators especially in condition of stress factors which negatively affects a crop yield. Biostimulators are preparations containing biologically active substances, which modifying metabolism allows obtaining a higher yield of plants. Asahi SL, occurring also under the name of Atonik belongs to the group of such preparations. It includes simple phenolic compounds, which occur naturally in a plant in low amounts (Przybysz et al., 2010). Spraying plants with this preparation is beneficial for their vegetative and generative growth and biomass production. After the application of Asahi SL the increase of the amount and quality of yield in many plants was reported, in particular when during the cultivation, disadvantageous environmental conditions occurred (Basak and Mikos-Bielak, 2008; Kozak et al., 2008a; 2008b; Przybysz et al., 2010; 2014). The use of this biostimulator advantageously influences the effectiveness of photosynthesis and the increase of the organic and mineral compounds content influencing the improvement of yield factor parameters (Przybysz et al., 2010; 2014; Majkowska-Gadomska and Wierzbicka, 2013; Tomczyk and Elkner, 2015).

The aim of the study is to investigate the effect of Asahi SL bio-stimulator on common bean (*Phaseolus vulgaris* L.) of Aura cultivar yielding.

2. Materials and Methods

2.1. Plant materials and growth conditions

The study was carried out in 2010 and 2011 on experimental fields of the Institute of Agricultural Sciences of the State School of Higher Education in Chełm located in Depułtycze Królewskie, Poland (51º07'N; 23º43'E). Soil type was characterized as Brown Rendzina belonging to Rendzinas soil group. It is alkaline (pH in 1M KCl – 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 4.5 m^2 (1,35 x 3,33 m). Bean seeds of cultivar Aura were sown on the 8th of May 2010 and on the 11th of May 2011 at the depth of 3 - 4 cm, spacing of drills 45 cm, to achieve the density of 30 plants per 1 m^2. During the growing season plants treated with Asahi SL which contains: sodium ortho-nitrophenolate ONP (0.2%), sodium para-nitrophenolate PNP (0.3%) and sodium 5-nitroguaiacolate 5NG (0.1%). 0.1% and 0.3% solution of Asahi SL was applied in two application frequencies: single spraying of plants (in the 2 – 3 leaves stage) or double spraying of plants (first in the 2 – 3 leaves stage and second at the beginning of the bean's blooming). It was applied with a battery sprayer GARLAND FUM 12B field sprayer (Lecher LU 120-03) at a pressure of 0.30 MPa, using 300 l of liquid per hectare. The four different variants of spraying with Asahi SL were compared with the control, where bio-stimulator was not applied. Tillage for bean was done using good agricultural practices. Mineral fertilization in kg of nutrient per hectare was as follows: 30 kg $N \cdot ha^{-1}$, 60 kg $P \cdot ha^{-1}$, 120 kg $K \cdot ha^{-1}$. It was not used pesticides (pests do not exceed the thresholds of harmfulness).

2.2. Plant yield determination

Upon harvesting, the number and weight of seeds, the number of pods and the weight of a thousand seeds for each plot (four replications of each combination) according to International Seed Testing Association (ISTA, 2010) method were recorded.

2.3. Statistical analysis

The results were statistically analysed by analysis of variance ANOVA by Statistica. To verify the significance of differences between the treatments means the confidence interval of Tukey's test were used at significance level $P \leq 0.05$. Results marked with the same letter do not differ significantly from each other.

3. Results and Discussions

The study analysed the influence of Asahi SL bio-stimulator on bean yielding. Single plant spraying with 0.3% Asahi SL solution in 2010 significantly increased the number and the weight of bean seeds (enhanced by 53% and 47%, respectively, in comparison with control) (table 1 and 2). In the subsequent year of study the highest yield of seeds was reported in the combination, where single spraying of plants with 0.1% solution was applied (increase the number of seeds by 45% and the weight of seeds by 38% in comparison with control). In 2011 single foliar applications on plants with a higher concentration of Asahi SL (0.3%) resulted in a 27% and 25% increase in the average number and weight of seeds, in comparison with control. Double application of Asahi SL caused decrease in the number and the weight of seeds in comparison to single application of this preparation, except for combination, where 0.1% of bio-stimulator solution in the first year of research was applied.

Table 1. Number of bean seeds depending on concentration and application number of Asahi SL (No*m^{-2}).

Concentration of Asahi SL	0.1%		0.3%		Control	
Year	2010	2011	2010	2011	2010	2011
Application method						
Single spraying	610.3 bc	673.5 a	869.3 a	590.0 ab	568.0 c	465.8 b
Double spraying	729.3 ab	498.5 b	692.8 bc	561.0 ab		

Means in the same column with different letters are significantly different (α=0.05) (relates to the same year).

Table 2. Weight of bean seeds depending on concentration and application number of Asahi SL (g*m^{-2}).

Concentration of Asahi SL	0.1%		0.3%		Control	
Year	2010	2011	2010	2011	2010	2011
Application method						
Single spraying	278.0 bc	297.9 a	382.3 a	269.0 ab	260.9 c	215.2 b
Double spraying	341.8 ab	219.7 b	284.2 bc	253.1 ab		

Means in the same column with different letters are significantly different (α=0.05) (relates to the same year).

So far, no results concerning the impact of application of Asahi SL on been yield. Kocira et al. (2013) found, that Kelpak is one of bio-stimulators positively influencing the yield of beans. Also application of amino acids bio-stimulator (Terra Sorb Complex) increased the yield of bean (Kocira et al., 2015). Numerous authors proved that Asahi SL (Atonik) positively influences yielding of different plants (Harasimowicz-Hermann and Borowska, 2006; Marjańska-Cichoń and Sapieha-Waszkiewicz, 2010; Matysiak et al., 2011). Kozak et al's research (2008a) prove that Asahi SL used in the button phase increased the seeds and soya straw yield. The application of Asahi SL increased the yield of rapeseeds (Malarz et al., 2008; Matysiak et al., 2011), particularly in case of stress conditions (Harasimowicz-Hermann and Borowska, 2006). Michalski et al. (2008a) and Matysiak et al. (2011) proved that the application of this preparation positively influenced grains yielding, increasing seeds of barley, barley mixture with wheat and wheat. Double application of this preparation in maize cultivation seems to be justified, which is confirmed by the results obtained by Michalski et al. (2008b). Moreover, Asahi SL (Atonik) positively influenced on vegetable plants, orchard and agricultural plants yielding increasing the yield of roots in case of chicory and sugar beet, celery, leek and onion bulbs, potato tubers, strawberry fruit, tomato and pepper fruit (Cerny et al., 2008; Cwalina-Ambroziak and Amarowicz, 2012; Djanaguiraman et al., 2005; Dobrzański et al., 2008; Marjańska-Cichoń and Sapieha-Waszkiewicz, 2010; Matysiak et al., 2011).

In study single spraying of plants with 0.3% Asahi SL solution in 2010 and 0.1% solution in 2011 increased the number of pods developed on a plant (enhanced by 41% and 46%, respectively, in comparison with control) (table 3). The increase of the frequency of preparation application to double resulted in the decrease of pods number in the combination with 0.1% of Asahi SL solution in 2011 and in the combination with 0.3% with bio-stimulator solution in both years of study. In the first year, higher number of pods at the double application of lower concentration of bio-stimulator in comparison to its single application was reported.

Table 3. Number of pods depending on concentration and application number of Asahi SL (No*m^{-2}).

Concentration of Asahi SL	0.1%		0.3%		Control	
Year	2010	2011	2010	2011	2010	2011
Application method						
Single spraying	195.5 b	219.0 a	264.0 a	189.3 ab	187.8 b	150.0 b
Double spraying	221.5 ab	169.3 b	225.8 ab	180.8 ab		

Means in the same column with different letters are significantly different (α=0.05) (relates to the same year).

Kozak et al. (2008a) proved that application of Asahi SL in soya cultivation increased the number of pods developed on a plant. Furthermore, plants *Arabidopsis thaliana* L., winter rapeseed and spring rapeseed treated with this bio-stimulator were characterised with a higher number of siliques (Harasimowicz-Hermann and Borowska, 2006; Malarz et al., 2008; Przybysz et al., 2010).

Plants, which in 2010 were sprayed with 0.1% Asahi SL solution, independently from the frequency of applying preparation as well as plants from the control obtained the highest weight of thousand seeds (increase by 14% and 11%, respectively) (table 4). The lowest weight of thousand seeds was reported in the combination with double spraying of plants 0.3% with bio-stimulator solution. In 2011, a tendency to increase the weight of thousand seeds in control, where the preparation was not used, was reported.

Table 4. Weight of thousand seeds of bean seeds depending on concentration and application number of Asahi SL (g).

Concentration of Asahi SL	0.1%		0.3%		Control	
Year	2010	2011	2010	2011	2010	2011
Application method						
Single spraying	457.2 a	442.4 a	440.4 ab	445.6 a	459.2 a	461.9 a
Double spraying	469.4 a	443.2 a	410.1 b	450.8 a		

Means in the same column with different letters are significantly different (α=0.05) (relates to the same year).

The application of Asahi SL in soya cultivation positively influenced the weight of thousand seeds (Kozak et al., 2008b). The study carried out by Malarz et al. (2008) and Matysiak et al. (2011) confirmed that application of this bio-stimulator in rapeseed cultivation, it concerns both the winter form as well as the spring form, slightly increased the weight of thousand seeds. Michalski et al. (2008b) found a positive effect of Asahi SL on the increase of the weight of thousand seeds of maize.

4. Conclusions

Asahi SL bio-stimulator, which is one of the elements of sustainable agriculture, has a positive effect on common bean yield. Single spraying of plants with Asahi SL is increasing the number and the weight of seeds and the number of pods. Control, where bio-stimulator was not applied is characterized with the lowest yield factor parameters. The highest thousand seeds weight is found for the application of 0.1% Asahi SL solution and in the control combination.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Effect of Fylloton application on photosynthetic activity of Moldavian dragonhead (*Dracocephalum moldavica* L.)

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Abstract

The field experiment was carried out in 2014 in Perespa, Poland to examine the impact of biostimulant Fylloton on the photosynthetic activity of Moldavian dragonhead cv 'Alba'. Moldavian dragonhead seeds were sown in April at a depth of 1-1.5 cm, with the spacing 45 x 20 cm. During the growing season, Fylloton was foliar-applied at a dose 2 l/ha (0.7%) and 3 l/ha (1%) by single spraying or double spraying of plants. One week after application of biostimulator, the photosynthetic activity of plants was measured. Use of Fylloton had a positive impact on the efficiency of photosynthetic apparatus and chlorophyll content in the leaves of Moldavian dragonhead plants. Fylloton is environmentally friendly preparation and helps to improve the efficiency of photosynthetic apparatus. It should therefore be recommended for use in sustainable agriculture.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: amino acids; *Dracocephalum moldavica*; *Lamiaceae*; photosynthesis; seaweed; biostimulant.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.002

1. Introduction

Plant cultivation technologies friendly to humans and the environment are intensively searched for in sustainable agriculture. The increasing demand for food and plant products determines the development of crop production and the actions aimed at obtaining high yields of good quality crops. One of the elements which allow to obtain the expected production effects are biostimulants or formulations based on organic or inorganic compounds naturally occurring in the environment, eventually synthetic. Their mechanism of action is based on the induction of plant resistance mechanisms to stress factors like pathogens, pests and adverse weather conditions. Therefore these substances contribute to improve the amount and quality of the crop plants. Natural biostimulators usually contain free amino acids, extracts from seaweed or fruit, effective microorganisms, humic substances or chitosan. Many studies prove that biostimulants positively affect various metabolism processes controlling plant growth, development and productivity (Calvo et al., 2014; Kocira et al., 2013; Kocira et al., 2015; Przybysz et al., 2014).

In biostimulants, components activating metabolic processes in plants may be present alone or in conjunction with micro, macro- or other active ingredients. It seems that the combination of active ingredients is more effective in stimulating the metabolic processes in the plant, and therefore in the presented studies our attention is focused on biostimulator Fylloton. It is based on the compounds naturally occurring in the environment such as extract of seaweed (*Ascophyllum nodosum*) and free amino acids of vegetable origin obtained in the enzymatic hydrolysis. Until now research on the combined use of seaweed extract and amino acids are rare (Norouzpour and Abad, 2013; Pulk, 2015).

Moreover, no reports exist on use of such extracts on medicinal plants. Therefore, it seems appropriate to examine the impact of biostimulator Fylloton on the photosynthetic activity of Moldavian dragonhead cv 'Alba' (*Dracocephalum moldavica* L.).

2. Materials and Methods

2.1. Plant materials and growth conditions

The study was carried out in 2014 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. Moldavian dragonhead seeds were sown in the third 10-day period of April at a depth of 1-1.5 cm, with the spacing 45 x 20 cm. During the growing season, Fylloton was foliar-applied at a dose 2 l/ha (0.7%) and 3 l/ha (1%) by single spraying (at the 10-12 leaf stage – 20th June) and double spraying of plants (at the 10-12 leaf stage - 20th June and at the beginning of plant blooming – 4th July). This was 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. The following experimental variants were carried out: control: where plants were treated with the same volume of water (no biostimulator was applied), 1- or 2-fold spraying with 0.7% Fylloton and 1- or 2 fold spraying with 1% Fylloton. All the results were compared to control. Tillage for plants was done using good agricultural practices. No pesticides were used (pests did not exceed the thresholds of harmfulness).

2.2. Photosynthetic activity of plants

During the growing season, one week after application of biostimulator, the photosynthetic activity of plants was measured. In the case of a single spraying the second measurement was carried out in the second term at the appropriate plant development stage. To estimate the actual photochemical activity of PSII *in situ*, chlorophyll *a* fluorescence in plants was measured using a pulse amplitude-modulated (PAM) fluorimeter (Mini PAM, Walz, GmbH, FRG, Germany) with a light emitting diode at 650 nm and a standard intensity 0.15 μmol $m^{-2}s^{-1}$ PAR (photosynthetically active radiation). A Leaf-Clip holder 2030-B was used during all the measurements. Standard settings optimized for measurements with leaf samples at approx. 12 mm distance between fiberoptics and leaf surface were used for measurements. The parameters listed hereinafter were set. Measuring light: on; Measuring pulse frequency: 0.6 KHz; Actinic illumination time: 30s; Actinic light intensity: 5 (relative intensity 5.5); Actinic light factor: 1.00; LC-WIDTH: 10s; LC INT: 3; Int-Temp: on; Light gain: 1.00; Temp. gain: 1.00; Saturating light pulse width: 0.8; Saturation pulse intensity: 8; Electronic signal damping: 2 (0.2s); Measuring light intensity: 8. The Auto-Zero function was applied in order to suppress any unavoidable background signal. All the measurements were done under field condition with the assumption that a photon flux density is below saturation level. The following fluorescence parameters were measured: F - the present fluorescence yield, M - fluorescence after saturation pulse was applied, *Yield = (M – F)/M,* PAR-photosynthetically active radiation, ETR-electron transfer rate calculated as: *ETR = Yield * PAR * ETR – factor; i.e. ETR = Yield *PAR * 0.5 * 0.84.* The standard factor 0.84 corresponds to the fraction of incident light absorbed by a leaf.

Chlorophylls and a nitrogen status N were estimated by Chlorophyll Meter SPAD-502 Plus (Konica Minolta) (ten plants of each experimental combination).

2.3. Statistical analysis

Data on photosynthetic parameters of four replicates of each combination were subjected to 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 $p < 0.05$. Statistical analysis was performed with Statistica 12 (StatSoft, Inc.).

3. Results and Discussions

Fluorescence measurements carried out in the first term (I measurement) showed that the single use of 0.7 % solution of Fylloton resulted in the 3 - fold increase of photosynthetically active radiation (PAR) used by plants, as compared with 2-fold spraying with biostimulant of a higher concentration (Table 1). This parameter is however difficult to interpret as it corresponds to the amount of energy captured by plant at the exact time of measurement. Although no visible difference in weather condition, the differences can occur on molecular level. One should also consider the condition of the plant itself (energy levels in the photosynthetic apparatus). On the other hand, the increase of this parameter can indirectly inform about the utilization of the solar energy by plant. This parameter is accompanied by a parameter F which corresponds to the maximum fluorescence yield of a sample under natural/field conditions. The increase of F entails the decrease in PAR. Generally, this parameter informs about a fraction of an energy, which in the moment of experiment is not used during photosynthesis. Fm' is a maximum fluorescence yield of illuminated sample. Based on this basic information, various fluorescence parameters have been defined that have proven useful for characterization of photosynthetic performance. Particularly useful expressions were derived for the maximal Photosystem II (PS II) quantum yield of dark-adapted samples, the effective PS II quantum yield of illuminated samples, Y(II) = (Fm'-F)/Fm' = ΔF/Fm' (Genty et al., 1989). Y(II) corresponds to the fraction of energy that is photochemically converted in PS II (used in photosynthesis).

Table 1. Effect of Fylloton on the PS II chlorophyll fluorescence and photosynthetically active radiation of Moldavian dragonhead (*Dracocephalum moldavica* L.) plants.

Experimental variant	F		Fm'		PAR	
	I	II	I	II	I	II
Control	399.63a	364.14bc	1028.50a	1434.43ab	449.25ab	78.57ab
Single spraying with 0.7% Fylloton	376.63a	286.29a	1018.75a	1686.00bc	875.75b	57.00a
Double spraying with 0.7% Fylloton	501.88a	315.43ab	1266.00a	1411.29a	304.63ab	124.86b
Single spraying with 1% Fylloton	371.88a	308.00ab	1039.00a	1764.71c	629.88ab	48.43a
Double spraying with 1% Fylloton	339.50a	384.57c	1061.00a	1752.71c	270.00a	117.43b

I – measurement at the 10-12 leaf stage; II - measurement at the beginning of plant blossoming.

Means in the same column with different letters are significantly different (α=0.05).

An increase of 11 and 12% of the effective photochemical yield of PS II (Y (II)) was obtained after a single application of Fylloton as compared to the control, independent of the concentration (for the 1% and 0.7 % solution of biostimulant) (Table 2). Although no statistical differences, an increase in this parameter was observed for all the experimental variants as compared to control.

The highest electron transport rate (ETR) was obtained during I-st measurement in a single - sprayed plants with a lower concentration of Fylloton. The three-fold increase of this parameter was observed as compared to the double use of the biostimulant formulation at a lower concentration. It is worth of notice that the highest ETR rates were registered for plants at the 10-12 leaf stage which means the period of intensive growth as compared to the period of blooming. Interestingly, double application of Fylloton results in the increase of ETR parameter during blooming as compared to control.

Foliar application of Fylloton resulted in the increase of the content of chlorophyll in the leaves of Moldavian dragonhead (for first and second measurement) as compared to control. A similar result was reported after application of Atonik biostimulator on cotton, *Arabidopsis thaliana,* oilseed rape, and common osier (Djanaguiraman et al., 2009; Przybysz et al., 2014; Wróbel and Woźniak, 2008). Both increase in the yield Y(II) and SPAD parameter indicates no need for applying N-fertilizer.

Leaf chlorophyll content is often well correlated with leaf photosynthetic rates (Percival et al. 2008). Correlations between SPAD values and F-Fm'/Fm' values as measures of photosystem II efficiency are limited. The F-Fm'/Fm' ratio is positively correlated to the PSII quantum yield and an indirect measurement of plant physiologic status for which values of 0.8 ± 0.05 correspond to highly efficient use of the excitation energy in photochemical processes. In our study such a value was observed for the experimental variant where a single spraying with Fylloton was applied (II term). F-Fm'/Fm' ratios of 0.6-0.8 were associated with SPAD values between 49 and 62 in this study.

Numerous authors reported that biostimulant-treated plants increase the intensity of photosynthesis on basil, cotton, rocket, *Arabidopsis thaliana,* oilseed rape and common osier (Borowski and Blamowski, 2009; Djanaguiraman et al., 2009; Janas 2011; Przybysz et al., 2014; Wróbel and Woźniak, 2008).

Table 2. Effect of Fylloton on the photosynthetic and chlorophyll parameters and of Moldavian dragonhead (*Dracocephalum moldavica* L.) plants.

Experimental variant	Y(II)		ETR		SPAD	
	I	II	I	II	I	II
Control	0.597a	0.742a	110.79ab	24.63ab	52.2a	49.8a
Single spraying with 0.7% Fylloton	0.623a	0.830b	222.76b	19.84a	62.6b	54.0ab
Double spraying with 0.7% Fylloton	0.583a	0.771ab	65,10a	39.51b	61.6b	55.9b
Single spraying with 1% Fylloton	0.621a	0.824b	146.69ab	16.64a	59.3b	56.3b
Double spraying with 1% Fylloton	0.665a	0.778ab	73.46a	37.81b	59.2b	57.2b

I – measurement at the 10-12 leaf stage; II - measurement at the beginning of plant blossoming.

Means in the same column with different letters are significantly different (α=0.05).

4. Conclusions

Fylloton affected the photosynthetic activity of Moldavian dragonhead, but the results were dependent on the concentration, frequency of application of biostimulant and on the date of measurement. Photosynthesis is however a very complex process, therefore the improvement of the vitality of plant should be interpreted in terms of increase of both parameters: photosynthetic yield Y (II) and the greenness of plants expressed in SPAD parameter.

Use of Fylloton had a positive impact on the efficiency of photosynthetic apparatus of Moldavian dragonhead plants. A single spraying of plants increased the effective photochemical yield of PS II (Y(II)) (in the second measurement). Use of Fylloton biostimulant affected positively the chlorophyll content in the leaves of Moldavian dragonhead. Fylloton as a product based on sea algae extract and amino acids is environmentally friendly and helps to improve the efficiency of photosynthetic apparatus and should therefore be recommended for use in sustainable agriculture.

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Agriculture and Agricultural Science Procedia 7 (2015) 113 – 118

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Economic size and developmental possibilities of chosen family farms in Poland

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Abstract

The economic size of agricultural farms is defined by means of the standard output (SO). However, economic effects of these farms depend on the way of husbandry. The analysed family farms of the area ranging from 8.58 ha UAA to 150 ha UAA had economic sizes ranging from €9,737 to €24,9379. Such a range made it possible to create 4 groups of farms according to classes of the economic size ES6. Calculated developmental possibilities were from -1167 PLN·ha^{-1} UAA to 3880 PLN·ha^{-1} UAA. It was stated that with an economic increase of the economic size developmental possibilities increase which is indicated by positive average correlation between these variables. In the best situation, regarding developmental possibilities are large farms having 12 times more possibilities than small farms. Significant differences in developmental possibilities between analysed groups of farms were stated. Significant differences were not stated in the amount of direct subsidies. Significant differences were stated in received direct surplus between small and large farms.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: developmental possibilities; economic size; farm size; Gross margin.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.003

1. Introduction

In Polish farming a domineering part is played by family farms. According to a common agricultural census from 2010 in Poland there were 1,480 thousand individual farms which run their agricultural business and had more than one hectare of agricultural lands. The average area of agricultural farms was 7.92 ha UAA (GUS, 2011). For many years analyses concerning the influence of owned agricultural lands on economic effects and developmental possibilities of farms have been carried out (Szuk, 2009a; Wasąg, 2009; Bakucs et al., 2013; Kocira, 2013; Mahmood et al., 2014, Sheng et al., 2015). In practice there are no studies on the influence of the economic size of a farm on its developmental possibilities.

Each farmer as well as entrepreneur is still making their decisions. They are mainly related to a kind of production (what to produce, how to produce, how much to produce and for whom to produce) (FAPA, 2000). Except these decisions a farmer runs also a developmental activity related to production. This activity must be well thought out and planned because except market threats the farmer must pay a special attention to possibilities of occurrence of unfavourable atmospheric conditions. It concerns directly the plant production and indirectly the animal production. The most stable source of financing the developmental activity are owner equities which may completely cover investment expenses or form own contribution when using the borrowed capital. Gołębiewska (2010) states, that in agricultural farms, there is a low level of taking advantages of outside financial sources, mainly due to fears of indebtedness. That is why it is important to analyse the situations of individual farm groups regarding developmental possibilities to direct aid funds which enable the sustainable development of agricultural farms.

2. Materials and Methods

2.1. Technical and economic analysis of farms

Materials used in the study are a part of research realized within the developmental project No 12004396 “Technical and ecological modernisation of chosen family farms” (Kurek and Wójcik, 2011).

In the work results of 44 developmental family farms were used. On the basis of documents and farmer’s entries the description of the activity of each farm in 2010 was done. Descriptions of farm activities included:

- structure of agricultural lands and sowing t
- plant and animal production
- labour expenditures and objectified labour expenditure
- material expenditure
- money revenue and expense
- balance sheet of the business.

The economic size was calculated on the basis of the coefficient of Standard Output (SO). Standard Output is an average value of production from 5 years of a definite production activity (plant or animal) received within 1 year out of 1 ha or from 1 animal in average for a given region in production conditions (EC No 1242/2008).

The developmental possibilities were calculated on the basis of agricultural gross income less salary at par and depreciation of technical measures and livestock buildings.

$$M_r = D_{rb} - W_p - A_{st} - A_{bi} \tag{1}$$

where:

M_r – developmental possibilities (thousand PLN·year^{-1}),
D_{rb} – gross agricultural income (thousand PLN·year^{-1}),
W_p – salary at par (thousand PLN·year^{-1}),
A_{st} – depreciation of technical measures (thousand PLN·year^{-1}),
A_{bi} – depreciation of livestock buildings (thousand PLN·year^{-1}).

Farms were divided into 4 groups defined on the basis of the economic class according to ES6 Economic Size Class (Bocian et al., 2014).

Gross Margin was calculated as a difference between income from the farm production activity plus direct surplus and direct costs for this production. The expenditures on production floating assets are costs for purchase of pesticides, mineral fertilizers, and nutritive fodders.

2.2. Statistical analysis

The statistical analysis was done by means of Statistica software. Normality of variable distribution was checked using the Shapiro-Wilk test. Only the variable "developmental possibilities" had normal distribution and in this case significance of differences was tested using the Tukey's test. In other variables regarding lack of normality of distribution of analysed data the significance of differences between tested variables was checked using the Kruskal-Wallis test where $\alpha = 0.05$. When significant differences occur they were determined using nonparametric statistics applying the Mann-Whitney U test.

3. Results and Discussions

3.1. General characteristic of research objects

In the analysed group of farms the average area of agricultural lands was 44.19 $ha \cdot farm^{-1}$ (Table 1). The smallest farm was 8.58 ha UAA and the biggest one was 150 ha UAA. In some farms there was only field production. Average stock density expressed in livestock unit (LU) was 0.7 $LU \cdot ha^{-1}$ UAA. On one farm the stock density was very high and amounted 3.6 $LU \cdot ha^{-1}$ UAA. The analysed farms were characterized by a large variability regarding the economic size. In tested group there were both small and large farms. The economic size of farms ranged between 9737 € to 249379 €. Replacement value of labour technical measures was very differential and ranged between 7357 $PLN \cdot ha^{-1}$ UAA and 56302 $PLN \cdot ha^{-1}$ UAA.

Table 1. General characteristics of agricultural farms.

Value	Agricultural land *($ha \cdot farm^{-1}$)*	Arable land *($ha \cdot farm^{-1}$)*	Stock density *($LU \cdot ha^{-1}$ UAA)*	Economic size *(€)*	Replacement value of labour technical measures *($PLN \cdot ha^{-1}$ UAA)*
Minimum	8.58	5.00	-	9737	7357
Maximum	150.00	150.00	3.6	249379	56302
Average	44.19	36.31	1.0	67061	25950
Standard deviation	30.39	31.59	0.7	44786	10144

In the structure of crops cereal crops were domineering having 56.7% of share (Fig. 1). In tested group the share of cereal crops was on the similar level as a national average (GUS, 2011). Over 20% share in the structure of meadow and pasture cropping indicates breeding od animals fed with roughages. The reform of sugar and the low profitability of potato crops influence the little share of root crops in the structure of agricultural lands.

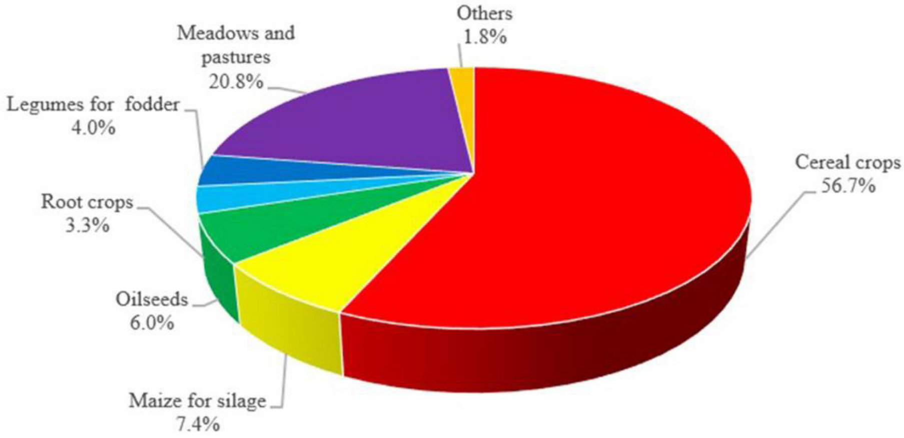

Fig. 1. Structure of agricultural lands.

3.2. Developmental possibilities

Performed calculations showed that in the tested group 5 farms have negative developmental possibilities (Fig. 2). It means that these farms practically are not able to be developed. Such a situation occurring for a longer time may lead to farm bankruptcy. Analysing the influence of the economic size on developmental possibilities in the analysed group of farms a positive average correlation (r = 0.4659) between developmental possibilities and the economic size where significance level was p = 0.0014 was stated.

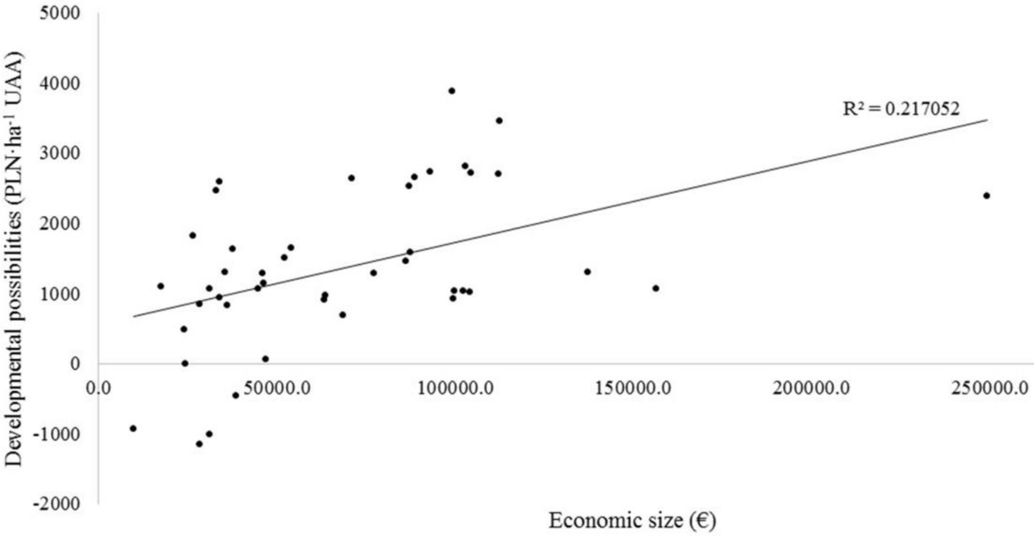

Fig. 2. Developmental possibilities and economic size.

In the tested group of 44 farms 4 farms were singled out regarding the economic size. There were 4 Small farms (8000 ≤ € < 25000). There were 16 Medium-small (25000 ≤ € < 50000), 15 Medium-large (50000 ≤ € < 10000) and 9 Large (100000 ≤ € < 500000) farms (Table 2).

The small farms used on average 18.07 ha UAA. The biggest average area had the large farms – 68.30 ha UAA. The biggest stock density was recorded in large farms and the smallest in small ones. The smallest expenditures on production floating assets of on average 1354 PLN·ha^{-1} UAA were in medium-small farms. The large farms had more than 4 times higher expenditures on these assets.

Table 2. Characteristics of farm groups.

Economic size class	Number of farms	Economic size *(€)*	Agricultural land *(ha·farm^{-1})*	Stock density *(LU·ha^{-1} UAA)*	Expenditures on production floating assets *(PLN·ha^{-1} UAA)*
Small	4	19004.6	18.07	60.09	2274
Medium-small	16	36193.3	25.70	98.80	1354
Medium-large	15	79474.8	59.33	84.27	2299
Large	9	131374.7	68.30	124.21	5484

Developmental possibilities in the individual groups of farms created on the basis of the economic size were differential (Table 3). The increase in developmental possibilities along with the increase in the economic size of farms can be observed. Checking significant differences using the Tukey's test showed that developmental possibilities of the small farms differ significantly from developmental possibilities of the medium-large and large farms. Bułkowska (2009) came to similar conclusions stating in her studies that the medium-large farms regarding higher production and financial results are able to carry out investments. Whereas Szuk (2009b) states that investment possibilities of agricultural farms are connected among others with the scale of business run in them. Basaj (2010), analysing the modernization potential of agricultural farms in Poland in the light of FADN results, paid attention to the fact that farms of the area above 30 ha UAA have investment possibilities which is partially confirmed in this work because the medium-large and large farms have the biggest average area and also the biggest developmental possibilities.

The performed Kruskal-Wallis test where $\alpha = 0.05$ did not show any significant differences in the size of direct subsidies between the groups of farms defined on the basis of the economic size. Analysis of difference significance between the farms grouped according to the economic size using the Kruskal-Wallis test showed that there are significant differences in the size of gross margin. The further analysis using Mann-Whitney test showed that there are significant differences between the small and large farms ($p=0.0372$). On the basis of done analysis of difference significance using a nonparametric test, the lack of significant differences in the replacement value of machine facilities between the groups of farms created on the basis of the economic size was stated. Szuk (2009) states that investment possibilities of agricultural farms are connected among others with the scale of business run in them. Basaj (2010) analysing modernization potential of agricultural farms in Poland in the light of FADN results paid attention to the fact that farms of the area above 30 ha UAA had investment possibilities. Bułkowska (2009) stated in her studies that the medium-large farms regarding their much higher production and financial results are able to carry out investments.

Table 3. Developmental possibilities, direct subsidies, gross margin and replacement value in the farm groups.

Economic size class	Developmental possibilities *(PLN·ha^{-1} UAA)**	Direct subsidies *(PLN·ha^{-1} UAA)*	Gross margin *(PLN·ha^{-1} UAA)*	Replacement value of labour technical measures *(PLN·ha^{-1} UAA)*
Small	155a	910	3533	35444
Medium-small	892ab	923	5838	27700
Medium-large	1768bc	912	4890	22953
Large	2053c	915	6580	22791

* Means in the same column with different letters are significantly different ($p<0.05$).

4. Conclusions

Agricultural farms have to be still developed so that they could compete effectively. Their development is possible only when they have proper financial resources. The basis source of the financing activity both operational and developmental should be own funds coming from operational activity of agricultural farms.

The performed analysis showed that along with the increase in the economic size developmental possibilities increase. It is affirmed by the positive average correlation between these variables. The large farms which have over 12 times bigger possibilities than small farms are in the best situation regarding developmental possibilities. There were significant differences in developmental possibilities between the groups of the Small farms and Medium-large and Large as well as the Medium-large and Large ones. The tested farms gained direct subsidies on the same level as the statistical analysis confirmed in which there were no significant differences between the analysed groups. Farms of the economic size class – Large gained on average by 3047 PLN $\cdot ha^{-1}$ UAA higher gross margin than the Small farms. Significant differences in the received gross margin between Small and Large farms were stated.

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Agriculture and Agricultural Science Procedia 7 (2015) 119 – 124

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Agricultural use of biogas digestate as a replacement fertilizers

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Abstract

Functioning of an agricultural biogas plant is connected with generating large amounts of post-digestion matter. After considering the physicochemical properties, the basic direction of digestate utilization should be its use 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 in the soil was also examined before and after digestate application. Digestate was used in alfalfa cultivation. The analysis showed an increase in macroelements content in alfalfa leaves. It was found that digestate can be used as a fertilizer.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: digestate; fertilizers; alfalfa; heavy metals.

1. Introduction

The current stage of civilization development is beset with new problems associated with the availability of energy sources. At present, energy requirements are mainly fulfilled by fossil fuels. However, their resources are limited and according to numerous scientific forecasts they may soon be exhausted. Moreover, energy obtained from fossil fuels has a detrimental effect on the condition of natural environment, contributing to its degradation (Biernat et al. 2012, Comparetti et al. 2013).

In view of these fears and dangers there emerges a growing interest in new energy carriers which could constitute energy sources alternative to fossil fuels, and would improve the natural environment. Biodegradable organic waste and

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.004

municipal waste can be the desired energy sources (Biernat et al. 2012).

Implementation of modern technological solutions in industry can also have a beneficial effect on environmental protection, mainly due to the reduction of waste, including hazardous substances (Chaaban 2001).

Many countries are striving after the production of energy from renewable sources. These sources also include the production of energy from anaerobic decomposition of agricultural substrates (Comparetti et al. 2013, Govasmark et al. 2011). In Sweden it has been decided that until 2018 40% of all food waste should be recovered in the form of energy (Chiew et al. 2015).

Fermentation processes are a method of organic waste utilization, widely known all over the world. As a result of the process, there are formed biogas and post-digestion matter which can be used as a fertilizer in agriculture. Substrates for methane fermentation include biological waste from agriculture, food industry or urban greenery maintenance, and also sludge from sewage treatment (Biernat et al. 2012).

Functioning of agricultural biogas plants is connected with producing large amounts of post-digestion matter. Its amount is approximately similar to the mass of substrates used in the fermentation process in a biogas plant. In some biogas plants digestate mass can be smaller if a part of technological liquid is reversed as process water to fermentation chambers (Mystkowski 2015).

Post-digestion liquid from a biogas plant can be used either in a liquid or solid form. In the case of larger installations and, consequently, greater amounts of post-digestion matter create the need for storage. As a rule, separation is used to obtain solid fraction, which is used as a fertilizer, and liquid fraction – leachate, which is returned to a biogas plant (Kowalczyk-Juśko et al. 2015). The generation of large amounts of leachate is one of the most important problems in digestate management. Desiccation (separation) is conducted to reduce the negative features of this product (Kaparaju et al. 2008).

Digestate can be defined as liquid from anaerobic decomposition of animal and plant waste (Mystkowski 2015). It contains considerable amounts of mineral elements (nitrogen, phosphorus, potassium). In terms of rapidity of action (absorption of elements by plants) it resembles mineral fertilizers since N, P and K elements are easily available for plants. Post-digestion pulp also contains a part of organic matter, which has a positive effect on physicochemical properties of fertilized soils (Kouřimská et al. 2012, Kowalczyk-Juśko et al. 2015, Odlare et al. 2008, Rehl et al. 2011).

Post-digestion pulp management is an extremely important issue for each biogas plant in Poland. It should be planned at an early stage of preparation for biogas plant construction. According to the law, digestate from agricultural biogas plants is treated as potentially hazardous waste such as sewage sludge, which seriously complicates the possibility of its management (Kowalczyk-Juśko 2014). Govasmark et al. (2011) as well as Heviánková et al. (2013) emphasize the possibility of occurrence of pathogenic bacteria and heavy metals in digestate. This is why it is important that digestate is safe for use as a fertilizer.

The basic direction of digestate management, after considering its physicochemical properties, should be its utilization as a bio-fertilizer (Kowalczyk-Juśko et al. 2015). Eickenscheidt et al. (2014) and Vázquez-Rowe et al. (2015) also highlight the use of digestate as a fertilizer, in place of mineral fertilizers. 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 et al. 2011, Kowalczyk-Juśko et al. 2015, Tao et al. 2014). Digestate used as a fertilizer improves soil fertility, plants quality and their immunity to biotic and abiotic agents (Kouřimská et al. 2012). Kouřimská et al. (2012) in their studies conclude that the use of digestate improves the quality and yield of vegetables. Chiew et al. (2015) say that the use of digestate as a fertilizer increases the content of macro- and microelements in the soil and plants. Odlare et al. (2008) did not find any negative effects that digestate might have had on the soil.

As a waste product, digestate can be subjected to disposal operations, however, generally it is recommended that digestate should undergo recovery operations. The most frequent way of post-digestion pulp management is recovery by means of R 10 method – 'treatment on the soil surface bringing benefits for agriculture or improving the condition of natural environment' (Czekała et al. 2012). For this reason post-digestion substance can be used as an agent improving soil quality (Kowalczyk-Juśko 2014).

It is important to understand that natural and organic fertilizers are not the same according to the law. In common language these two terms have the same meaning, which leads to many misunderstandings. Natural fertilizer is defined as derived from farm animals (manure, liquid manure), whereas organic fertilizer is produced from an organic substance or a mixture of organic substances. A natural fertilizer must be mixed with soil, but an organic one need not. Similarly, there is a prohibition of using natural fertilizers on soils without vegetation cover when a field slope is more than 10% (Kowalczyk-Juśko 2014).

There are numerous techniques of applying digestate on the soil surface. Their choice depends on the methods of digestate processing, type of fertilized crops, time of fertilization. Liquid manure spreaders or sprinkling machines are used to apply digestate on a field surface. Sprinkling machines can be used for post-digestion sludge with low content of dry matter (below 5%). It is recommended to consider more possibilities of using digestate apart from its direct application on fields, for example as a bio-fertilizer, fertilizer nutrient or energetic material, (Garfi et al. 2011). Solid fraction of post-digestion sludge after separation can be further processed. Second drying and pelletization are often used (Kratzeisen 2010, Kowalczyk-Juśko et al. 2015).

The aim of this investigation is to examine the possibility of agricultural utilization of digestate in place of mineral fertilizers, and also comparing the content of macroelements after fertilization with digestate and mineral fertilizers.

2. Method

Digestate was obtained from the biogas plant in Piaski (Lubelskie Province) and was applied on an experimental field for alfalfa cultivation. For the sake of comparison, alfalfa was also sown on another field and was fertilized with mineral fertilizers. The experimental fields were 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. The fields were sown in April, 2015. The first harvest of alfalfa was gathered and examined for the content of macroelements. Digestate was used in the amount of 180 l per 50 m^2 (36000 l/ha). On the field that was fertilized with mineral fertilizers there were used: nitrogen – 20 kg/ha, phosphorus – 60 kg/ha, potassium – 80 kg/ha.

Digestate was also 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.

3. 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). Digestate pH reaction was 8,73 and is similar to the pH reaction of bovine liquid manure (7,90).

The analysis of the results showed that digestate did not contain any heavy metals. Both digestate and bovine liquid manure contain similar amounts of macroelements. Based on the results of this investigation it has been found that digestate can be used as a fertilizer.

In view of many authors' indications that digestate fertilizes 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. The results are presented in Table 2.

The analysis of the tests results revealed an increase in soil pH reaction from 7,56 to 7,63. The small increase in soil pH reaction is of no special importance since this is still a basic reaction, which is favorable to good development of plants. There was also observed increase in the selected macroelements. The content of phosphorus rose by 5,90 mg per 100 g of soil, potassium by 9,20 mg per 100 g of soil and magnesium by 0,4 mg per 100 g of soil.

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.

Table 1. Comparison of selected macroelements and heavy metals in digestate and bovine liquid manure

Examined feature	Digestate	Bovine liquid manure
1	*2*	*3*
Phosphorus [g/l]	0,09	2,30
Potassium [g/l]	5,25	3,70
Calcium [g/l]	0,25	0,21
Magnesium [g/l]	0,04	0,09
Cadmium [mg/l]	<0,43	<0,43
Lead [mg/l]	<0,43	<0,43
Nickel [mg/l]	<0,43	<0,43
Chromium [mg/l]	<0,43	<0,43
Copper [mg/l]	0,43	0,49
Zink [mg/l]	2,01	1,90
Manganese [mg/l]	2,20	1,80
Iron [mg/l]	70,70	19,70

Table 2. Tests for pH reaction and macroelements content in the soil.

Examined feature	Before digestate application	After digestate application	Difference (3-2) in %
1	*2*	*3*	*4*
Reaction [pH]	7,56	7,63	0,93
Phosphorus [mg per 100 g of soil]	31,40	37,30	18,79
Potassium [mg per 100 g of soil]	7,20	16,40	127,78
Magnesium [mg per 100g of soil]	13,40	13,80	2,99

In order to detect changes in the content of macroelements in alfalfa cultivated on the soil fertilized with mineral fertilizers and digestate, the alfalfa leaves from the first harvest were tested for the content of macroelements. The results are presented in Table 3.

Table 3. The content of selected macroelements in alfalfa leaves from the first harvest.

Examined feature	Alfalfa sown on the soil fertilized with mineral fertilizers	Alfalfa sown on the soil fertilized with digestate	Difference (3-2)
1	*2*	*3*	*4*
Nitrogen [%]	3,11	3,66	0,55
Phosphorus[%]	0,28	0,30	0,02
Potassium [%]	1,67	1,96	0,29
Calcium [%]	1,85	1,96	0,11
Magnesium[%]	0,37	0,38	0,01

The analysis of the study results showed a percentage increase of particular macroelements in alfalfa leaves. The highest increase was observed in the content of nitrogen and potassium, which rose by 0,55 p. p. (percentage point) and 0,29 p. p., respectively. The relative percent differences for the examined macroelements were as follows: nitrogen – 17,68%, phosphorus – 7,14%, potassium – 17,37%, calcium – 5,95%, magnesium – 2,70%. The increase in the content of macroelements in alfalfa leaves has positive significance, because it is possible to obtain fodder rich in macro- and microelements. Alfalfa is a fodder which is eaten willingly by animals, for this reason it is most often used to feed dairy cattle. In addition, it also makes a good component of fodder for pigs, poultry, sheep and horses. It is a plant which is extremely rich in protein. Its leaves contain mineral salts, especially calcium, phosphorus, potassium, magnesium and a whole range of microelements. In consequence, it is recommended to replace mineral fertilizers with digestate by reason of a higher content of macroelements in alfalfa cultivated on the soil fertilized with digestate, because of which such fodder is more willingly eaten.

4. Summary

The major factors that determine 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).

Fertilizing fields with digestate brings numerous benefits, e.g. reduction of the demand for plant protection products (destruction of weed seeds during fermentation), reduction of odor nuisance, or destruction of possible pathogens (Kowalczyk-Juśko 2015).

The investigation revealed that post-digestion liquid contains similar amounts of macroelements as bovine liquid manure. No heavy metals were found in digestate. An increase in the content of macroelements was observed in the leaves of the alfalfa fertilized with digestate in comparison with the alfalfa fertilized with mineral fertilizers. Consequently, post-fermentation residues from biogas plants can be used as a fertilizer. The only condition is the rational utilization of such residues. Further studies are necessary to confirm that digestate has an effect on plants' yielding.

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Agriculture and Agricultural Science
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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Influence of cellulose content in plant biomass on selected qualitative traits of pellets

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Abstract

The results from tests for the presence of cellulose in the agricultural biomass waste for selected quality traits of pellets produced were presented. Selected test raw materials revealed the average cellulose content determined by Kürschner-Hanak method in the range from less than 32% (buckwheat straw) to less than 43% (rye straw). There was negative linear relationship between the cellulose content in pellets from waste plant biomass and the bulk density and stability of pellets. It would be justified to carry out research on the content of lignin in plant biomass in the context of its impact on density, durability and the calorific value of the agglomerate.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

*Keywords:*plant biomass; cellulose; properties of pellets.

1. Introduction

Decreasing fossil fuels resources affect the growth of their prices, and their use entails consequences related, among others, to global warming. This was pointed out in “A European Strategy for Sustainable, Competitive, and Secure Energy”. It emphasizes the problem of depletion of fossil fuels and increasing prices for crude oil and natural gas, and the need to ensure the energy security, and to create competitive internal energy markets (Green Paper, 2006,

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.005

Pultowicz, 2009).The fundamental aim of sustainable energy policy is to limit the negative impact of energy industry on the atmosphere and at the same time to ensure the energy security, to meet the social needs and the competitiveness of economy (Lorek, 2007). There is some emphasis on rational use of energy from renewable sources including solid biomass of agricultural origin.

Solid biofuels are among the main sources of renewable energy. Resource base can be mainly provided by field crops, with a focus on the use of waste biomass and surplus from conventional crops, such as cereals and other crops straw as well as grasses from permanent grasslands and wastelands (hay) (Świętochowskiet al., 2011). This biomass, as a fuel, consists of three basic substances (Rybak, 2006): organic (combustible), mineral, and water. The organic substance is composed of cellulose (fiber), lignin, and hemicellulose, in the construction of which such chemical elements as carbon, hydrogen, oxygen can be distinguished. Percentage of these compounds has an impact on the amount of energy contained in the biomass expressed as a heat of combustion (Kowalczyk-Juśko, 2009, Rybak, 2006, Wandrasz and Wandrasz, 2006). Minerals such as potassium, sodium, calcium, carbonic and phosphoric acid salts etc. are important components of solid biofuels. Content of these components makes up an average of approximately 0.2-1.7%. Cellulose, hemicellulose, and lignin are the basic structural material of organic matter. General information about the lignocellulose material is its chemical composition (Paukszta, 2006). Differences in these compounds contents in the plant biomass determine the originality of their characteristics and species diversity. Properties of these substances are also different.

Cellulose is a polymer belonging to the group of polysaccharides composed of glucose residues connected in the form of long, unbranched chains and is the basic material for plant tissue construction. This is a white,fibrous pulp with a density of about 1.25 $g \cdot cm^{-3}$;it is non-fusible and insoluble in chemical solvents. The calorific value of this compound in a dry state amounts to 17.03 $MJ \cdot kg^{-1}$. Hemicellulose belongs to the group of polysaccharides and, in contrast to the structural composition of the cellulose, has branched chains. Calorific value of this compound is 16.67 $MJ \cdot kg^{-1}$dry matter. Lignin is a solid substance built of high-molecular polymer composed of unsaturated alcohols and phenols. In this group of compounds, it is distinguished by the highest calorific value equal to 26.36 $MJ \cdot kg^{-1}$dry matter (Wandrasz and Wandrasz, 2006).

The uniformity of physical and chemical characteristics of different, in terms of species, plant biomass can be provided by the pressure compaction. The mechanism of binding the particles of bulk organic material depends on many factors. Hejft (2002) draws attention to material factors and construction and operating issues of compaction device as well as processing of the obtained product. Among the material factors, in addition to the fineness degree, its homogeneity and physical condition of the plant matter, the presence of substances to facilitate the particles merging, is important as well. The literature highlights the plasticizing of material particles (cellulose recrystallization) with respect to the compaction process temperature (Hejft, 2006). Wandrasz and Wandrasz (2006) report that pure cellulose with the purity of 99.81%, is a substance that can be easily formed into pellets. However, there are no data taking into account the relationships between the cellulose content and selected quality features of pellets, particularly their density and durability.

The aim of the study was to analyze the dependences between the cellulose content in waste agricultural biomass and selected qualitative characteristics of the pellets produced.

2. Material and Methods

Following types of plant raw materials were selected to study: rapeseed straw, winter wheat straw, winter triticale straw, rye straw, buckwheat straw, and hay. These raw materials were harvested in farms located in the Lublin province.

The materials were grounded using a flail shredder equipped with a 10 mm mesh screen. The shredder, for selected raw materials, provided the following fraction percentage:>3.15 mm: rapeseed straw – 50.48%, wheat straw – 54.86%, triticale straw 68.60%, rye straw – 47.24%, buckwheat straw – 25.45% (Kachel-Jakubowska and Szpryngiel, 2014). Such ground straw was subject to compaction process applying the pellet-forming device with a unilateral stationary flat matrix of 25 mm thickness and 8 mm hole diameter. The rotational speed of compaction rollers was 11.67 $rad \cdot s^{-1}$, and rollers drive was transferred from an electric motor with an output of 7.5 kW through a set of gears.

The resulting granules, after a stabilization period of 24 hours, were subjected to further lab testing, in which contents of the following items were determined:

- moisture – gravimetric method according to PN-EN 14774-2:2010;
- ash – gravimetric method according to PN-EN 14775:2010;
- cellulose –Kürschner-Hanak method;
- lignin and hemicellulose as the difference between organic matter and cellulose content;
- calorific value after determination of combustion heat in the analytical state – calorimetric method according to PN-EN 14918:2010.

For these products, the density of 10 granules was also determined by direct measurement of external dimensions using caliper and weighing the portion of pellets by means of laboratory scales with an accuracy of 0.01 g, and then calculating their bulk density. Subsequently, the mechanical stability of pellets was determined using a rotation scanner with two containers of standard size and rotating at a speed of5.22 rad·s^{-1}for 600 s in accordance with requirements of PN-EN 15210-1.

The results were statistically processed including the estimation of means, standard deviations, and the trend lines were made by formulating their equations and coefficients of linear fitting.

3. Results

The average contents of cellulose, hemicellulose and lignin, water, and ash for the test material are shown in Figure 1.

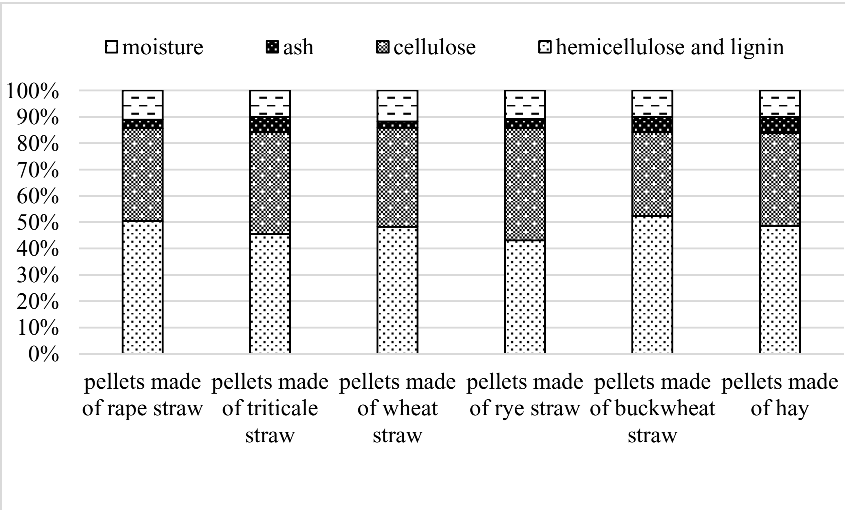

Fig. 1. The average contents of cellulose, hemicellulose and lignin, moisture and ash in pellets made of cereal straw and hay.

The mean percentage of cellulose ranged from 31.8% (buckwheat straw pellets) to 42.64% (rye straw pellets). The share of hemicellulose and lignin ranged from 43.04% (rye straw pellets) to 52.44% (buckwheat straw pellets) (Fig. 1). The water content amounted from 9.96% - pellets made of buckwheat straw and hay pellets, to 11.78% - wheat straw pellets (Fig. 1). Wheat, rapeseed, and rye straw pellets were characterized by the lowest ash content, with respective values of 2.38%, 3.38%, and 3.60%. The highest amount of ash was reported for pellets made of hay - 6.11% (Fig. 1).

Comparing the results of water and ash content with literature data and the quality requirements for pellets in the context of the raw materials used, it can be said that, taking into account the study conditions, these parameters were comparable and met the requirements of PN-EN 14961-6 (Denisiuk, 2009, Kowalczyk-Juśko, 2009, Rybak, 2006, Wandrasz and Wandrasz, 2006). Cellulose content in the waste agriculture biomass tested was slightly lower than the content of this compound in the pulp of coniferous and deciduous trees, for which the respective ranges are 48-56% and 46-48% (Dobrowolska et al., 2010).

Figure 2 presents density of the pellets in a view of the cellulose content. Mean values of density ranged from 1032 kg·m^{-3} (rye straw pellets) to 1185 kg·m^{-3} (buckwheat straw pellets).

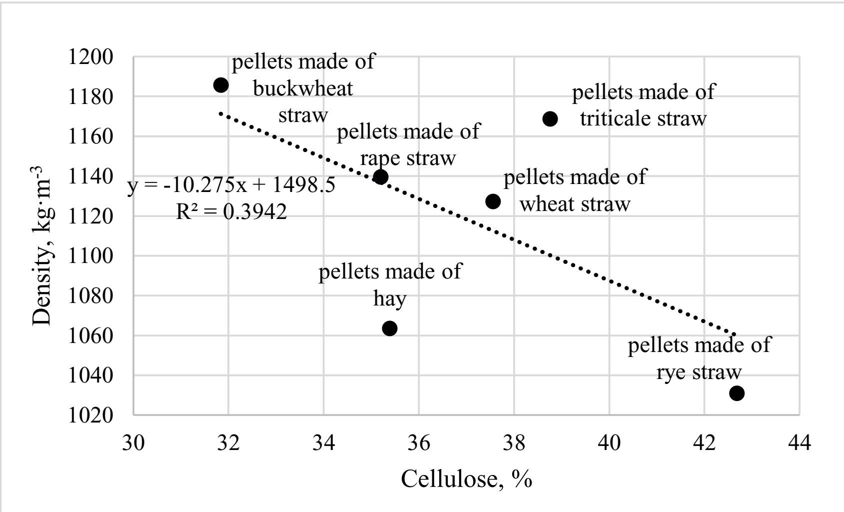

Fig. 2. Density of pellets vs cellulose content.

It has been found that there is a tendency of decreasing the density of pellets depending on the increase in the cellulose content. Probability of straight line fitting is R^2=0.3942 (Fig. 2).

Figure 3 illustrates the mechanical durability of pellets in an aspect of the cellulose content.

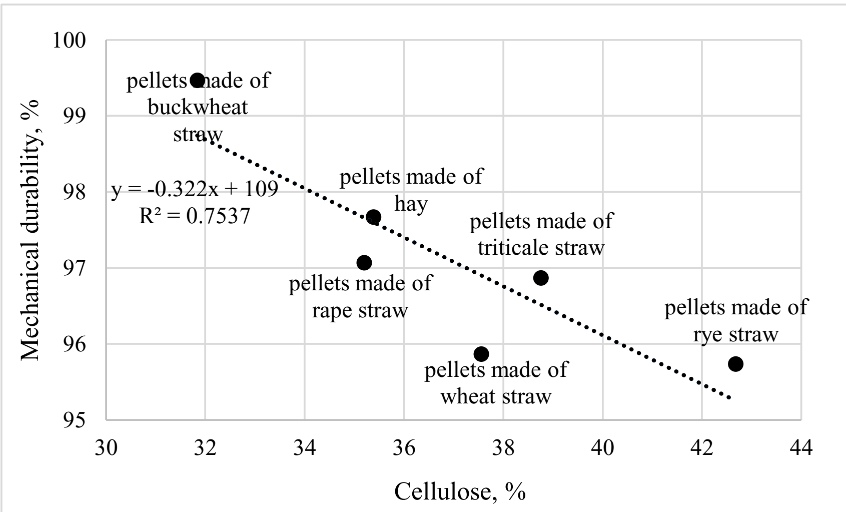

Fig. 3. Mechanical durability of pellets vs cellulose content.

Mean values of mechanical durability under study conditions ranged from 95.7% (rye straw pellets) to 99.5% (buckwheat straw pellet). Mechanical durability of pellets decreases along with the increase in the cellulose content. Probability of line fitting R^2=0.7537 (Fig. 3).

The calorific value of pellets depending on cellulose content was also determined (Figure 4).

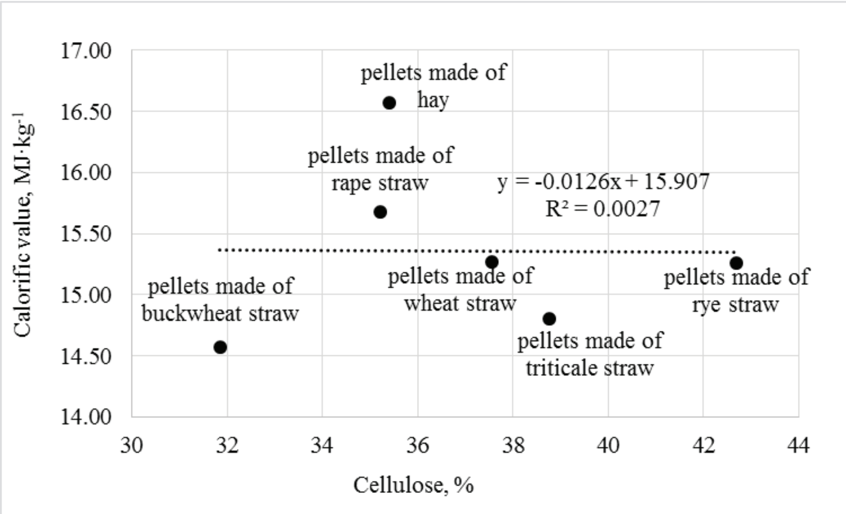

Fig. 4. Combustion heat of tested raw materials in air-dry statevs cellulose content.

The calorific value ranged from 14.57 MJ·kg^{-1} (buckwheat straw pellets) to 16.57 MJ·kg^{-1} (pellets made of hay). No clear dependence was found between cellulose content vs. calorific value (Figure 4). Higher calorific value is probably associated with increased percentage of lignin that is characterized by calorific value at the level of about 26.36 MJ·kg^{-1} (Wandrasz and Wandrasz 2006).

Achieved results are comparable with literature data and pellets meet the requirements of PN-EN 14961-6 (Denisiuk, 2009, Kowalczyk-Juśko, 2009, Rybak, 2006, Wandrasz and Wandrasz 2006).

4. Conclusions

Based on the study, the following statements and conclusions can be drawn:

1. Cellulose content in tested waste agricultural biomass differed among species. Its lowest percentage was found in pellets made of buckwheat straw (31.8%), while the highest in rye straw pellets (42.64%).

2. Study conditions revealed negative linear dependencies between cellulose content in pellets made of waste plant biomass and their density and durability. Corresponding linear fitting coefficients R^2were 0.3942 and 0.7537. For the calorific value of tested pellets, no strong relationships with the cellulose content were recorded (R^2=0.0027).

3. It would be justified to carry out the research on the content of lignin in plant biomass in the context of its impact on density, durability, and calorific value of the agglomerate. It is important in respect to production of formed fuels and energetic use of waste plant raw materials.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Combustion of plant biomass pellets on the grate of a low power boiler

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Abstract

The study deals with the analysis of results on CO, NO, and SO_2 emission recorded when burning pellets of oil cake, rape straw, and birch sawdust in the low-temperature water boiler of the top combustion. The air was supplied to the boiler through a fan under the grate at a speed of 1 $m \cdot s^{-1}$ and 2.5 $m \cdot s^{-1}$. There were significantly different emissions of CO, NO and SO_2 under varying conditions of airflow supply to the boiler. Emissions of NO and SO_2 depended mainly on nitrogen and sulfur contents in the biomass, while CO emissions were mainly dependent on the amount of supplied air. Such heating devices allow for ecological combustion of pellets made of a plant biomass, but air distribution needs to be improved. It is advisable to develop nomograms to facilitate the selection of airflow speed in relation to the biofuel used for a specific boiler type, ensuring its use in accordance with the concept of sustainable development.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: pellets combustion; plant biomass

1. Introduction

The concept of sustainable development, assuming the complex operation, is based on factors determining the process of change, in which the exploitation of resources, investment trends, directions of technological progress,

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.007

and institutional changes, are in harmony and retain the possibility of meeting current and future human needs and aspirations (Baum 2003). According to this idea, agricultural engineering, in addition to production and economic objectives, as well as those related to the use of a biomass for energy purposes, should accomplish the environmental goals, protecting the natural environment against all kinds of contamination and risks associated not only with agricultural production, but also subsequent use of the products of these activities (Baum 2003, Krasowicz 2006).

The energy use of solid biofuels in the processes of direct combustion finds increasing interest of customers. Increasing their supply in the market of renewable fuels leads to a decrease in their prices, thereby increasing the competitiveness with other fossil energy sources, more often replacing them. At the same, individual heat sources using mainly coal and wood (boilers, ceramic and metal furnaces, as well as kitchen stoves and fireplaces) used in free-standing houses, the number of which is estimated for over 17 million units (Kubica 2010), not always provide an efficient and clean combustion of solid biofuels, e.g. in the form of pellets or briquettes. Of course, sophisticated heat devices using solid biofuels and supplied with chopped wood or molded fuels, the efficiency of which reaches up to 90% and that can perfectly replace older grate power boilers dedicated to burn coal, are offered on the market, however, the rate of such installations modernization is lower than the increase in the use of biomass fuels. A large number of low-power boilers intended for domestic use, that are supplied with portions of fuel, was modernized consisting in the use of automated control of the air supply or forcing the water circulation in heating system. However, controlling the heat output in such boilers using air results in a small improvement in the efficiency of the combustion process, as well as the high emissions caused by low flame temperatures. These are essentially uncontrolled emissions of many hazardous products of incomplete combustion, such as carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic compounds (VOC), and tar (Kraszkiewicz and Kachel 2014; Olsson and Kjällstrand 2002).

When combusting solid biofuels, it is important the economy of the air supplied to this process. Restricting the airflow will not stop the process, but only outgassing the volatiles, that in the unburned forms as carbon monoxide and carbon black will be transported to a chimney, will occur. Excessed air will cool the furnace and boiler, which will reduce the combustion efficiency, worsening the heat exchange between the furnace and the heating medium (water) circulation in the boiler. Value of the air excess ratio also depends on the fuel type, the process of combustion mechanism, as well as design of the furnace or burner, as well as conditions of their operation (Lorenz 2005). Hansen et al. reported (2009) that wood combustion occurs best when the air excess ratio ranges between 1.4 and 1.6. Obernberger et al. (2006) concluded that the effective reduction in CO quantities can be achieved in an optimized combustion process, ensuring good mixing of fuel with air. Required retention time is higher than 1.5 s at high temperatures above 850 ºC and with low air excess rate.

Nitrogen oxides can be formed by three different reaction pathways. The first - thermal, is not applicable to the biomass combustion due to relatively low temperature of the process (approximately 800-1200 ºC), thermal formation of NO_x is only temporary and is of minor importance. The second pathway refers to the formation of NO_x from oxidation of fuel (in a series of basic reaction steps) and is the most important mechanism for the generation of nitrogen oxides in the biomass combustion, where about 95% is NO (Nussbaumer 1989; Temmerman et al. 2011). Therefore, NO_x emission intensifies along with the increase in nitrogen content in a fuel (Leckner and Karlsson 1993; Nussbaumer 1995). The third path takes into account such events as reference fuel supply, boiler chamber geometry, and the type of combustion technology. These are the main variables affecting the formation of NO_x (Van Loo and Koppejan 2007). Problems with excessive NO_x emissions appear at the participation of nitrogen beginning from 0.6% by weight. This applies in particular the cake, cereal straw, grasses, and residues of fruits (Nussbaumer 2002). Sulfur contained in the fuel is included in the exhaust gases in the form of aerosols as SO_2 (and in small quantities as SO_3). Therefore, the SO_2 emissions are usually negligible when combusting the biomass due to low sulfur concentration. According to Obernberger (2003), the problems associated with sulfur emissions should be expected at the concentration greater than 0.2% by weight, in fuel. This may be important in the case of rape straw, cake and grasses combustion.

Therefore, the biomass combustion process carries a number of problems related to its physical and chemical characteristics, mainly with the content of volatile substances that enforce the stringent air economy affecting the temperature of the process and structure of the exhaust gases emission.

The aim of the research was to perform the combustion of pellets made of selected biomass types in the low-temperature water boiler of top combustion, while carrying out the analysis of exhaust gas for the presence of CO, NO, and SO_2 with respect to the fuel type and the air supply.

2. Material and Methods

The study involved pellets made of birch sawdust, rapeseed straw and oil cake. For those solid biofuels, their dimensions were determined by making the direct measuring using caliper. Their basic physical characteristics were also determined applying the following methods:

- water – gravimetric method according to PN-EN 14774-1:2010
- net calorific value – according to PN-EN 14918:2010
- ash – according to PN-EN14775:2010
- carbon, hydrogen – by means of IR absorption according to CEN/TS 15104:2006
- nitrogen – applying automatic thermal conductivity detector according to CEN/TS 15104:2006
- sulfur – measurement using automatic IR analyzer according to PN-G-04584:2001

Tests of accumulated research material combustion were carried out using the test stand, the integral part of which was the upper combustion boiler with fixed grate with a nominal power of 10 kW recharged periodically (Figure 1). In addition, it was equipped with a fan airflow and fluid circulation pump. Control upon these devices was carried out by means of the microprocessor ST-28. Water storage capacity of the boiler was 32 dm^3 and that of the heat exchanger 400 dm^3. Loading of fuel and ash removal was done manually. The water flow rate in the boiler was 85 $dm^3 \cdot h^{-1}$.

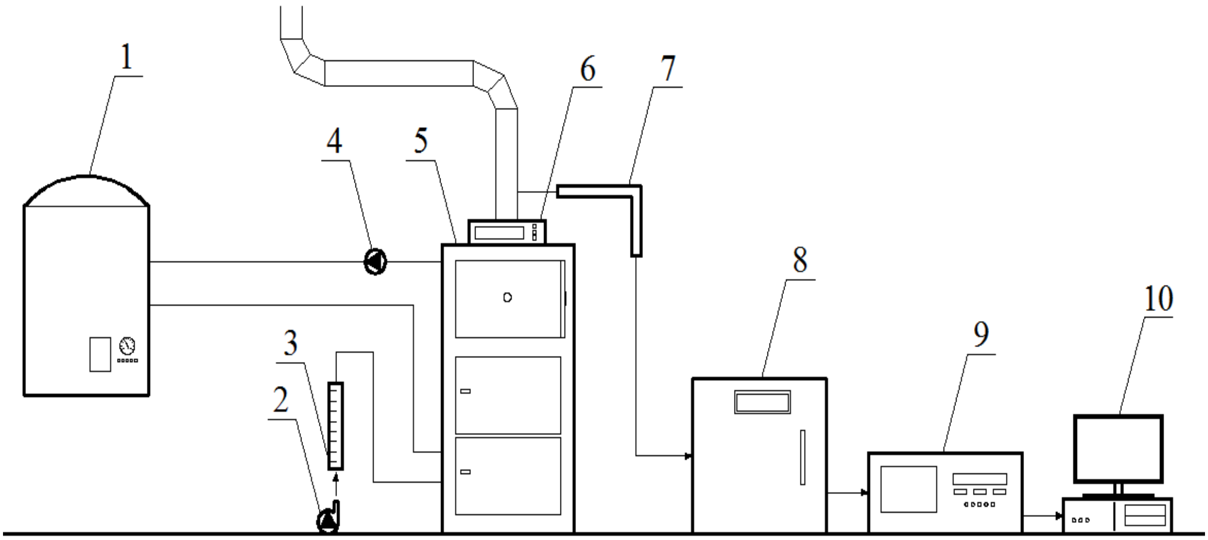

Fig. 1. Diagram of measuring system: 1- heat exchanger, 2-air fan, 3-flow meter, 4- pump operating fluid, 5- boiler, 6- microprocessor-based controller boiler, 7- probe with heated hoses, 8-dryer flue gas, 9-gas analyzer, 10- personal computer.

The boiler was connected to the chimney made of steel tube with a diameter of 0.1 m and a length of 3 m. The exhaust gas consumption was realized from the chimney at a distance of 1 m from the boiler flue. The measuring probe was connected to the dryer of exhaust gases PGD-100 (Madurai Eljack Electronics Co.), from which the exhaust gas was directed to the analyzer. During tests, we used portable gas analyzer Photon (producer as above). It operates based on the infra-red and electrochemical sensors (NDIR), while the measurement made by NDIR sensors refers only to CO, NO, SO_2, whereas electrochemical ones - O_2.

The tests consisted of combusting the portions of above mentioned pellets, providing air under the grate at a speed of 1 m/s and 2.5 m/s. Measurements of the air flow rate were carried out using anemometer LCA 501. The measurement results for the exhaust gas were recorded in the database of the analyzer every 2 seconds. Data from the stable phase of the boiler work were selected, when the excess air coefficient ranged from 1 to 2.

Achieved results of the CO, NO, and SO_2 concentrations in the exhaust gas were related to the dry flue gas stream containing 10% oxygen and standard conditions ($mg \cdot m^{-3}$) at 0 °C and 1013 mbar according to the guidelines contained in PN-EN 303-5:2012. The collected data were statistically analyzed in STATISTICA 10.0 using ANOVA and Tukey's test. All analyzes assumed the level of significance $\alpha = 0.05$.

3. Results

The average values of physical and chemical properties of solid biofuels in question are shown in Table 1. Analytical moisture of the raw materials was uniform and was about 8%. The best energy properties expressed as the net calorific value were revealed by pellets made of birch sawdust of birch and oil cake, while rape straw pellets had net calorific value about 15% lower. The ash content was more varied ranging from 1.5% (birch sawdust pellets) to 5.5% (oil cake pellets) (Table 1).

Table 1. The physical and chemical properties of solid biofuels under consideration.

Fuel parameters in the operating state - averages	Unit	Research material		
		pellets made of rape straw	pellets made of oil cake	pellets made of birch sawdust
Length	mm	3.15-25	3.15-20	3.15-8
Diameter	mm	8	8	8
Moisture	%	8.50	8.25	7.50
Net calorific value	$MJ \cdot kg^{-1}$	15.67	18.20	18.50
Ash content	%	2.70	5.50	1.50
C	%	47.30	48.90	49.10
H	%	5.85	6.45	5.95
N	%	1.00	5.92	0.23
S	%	0.20	0.70	0.01

Indicators of CO emissions from combusting selected species and forms of a biomass are shown in Table 2. The resulting values of CO emission converted to the reference of 10% of O_2 in the exhaust gas varied in both groups of combusted types of biofuels as well as due to variable rates of air supply to the boiler. The highest values of this indicator were recorded during the combustion of sawdust birch pellets at the minimum air flow rate to the boiler. Under these combustion conditions, similar and slightly lower emission values occurred for pellets made of oil cake. Respective mean values amounted to 9562 and 8003 $mg \cdot m^{-3}$ at 10% O_2, whereas the lowest average values (443 $mg \cdot m^{-3}$ at 10% O_2) were recorded for birch pellets, though at the air flow supply of about 2.5 $m \cdot s^{-1}$. The variance analysis of values for CO emission revealed significant differences between mean values within individual groups of raw material; the Tukey's test did not indicate any uniform groups (Table 2).

The indicators of NO emission from combustion of selected types and forms of a biomass are shown in Table 3. Under the test conditions, values of NO emission indicators converted into the reference of 10% O_2 in exhaust gas, varied. The highest values of this ratio were recorded during the combustion of cake pellets at the maximum rate of air flowing to the boiler. Under the same combustion conditions, lower emission values were found for pellets made of rape straw. Accordingly, the average values for these fuels were 871 and 604 $mg \cdot m^{-3}$ at 10% O_2. The lowest values (174 $mg \cdot m^{-3}$ at 10% O_2, on average) were recorded for birch pellets also at the air flow rate at a level of 2.5 $m \cdot s^{-1}$ (Table 3). Based on the variance analysis of values specified for NO emission, significant differences between the mean values in each group of raw materials were observed, and Tukey test indicated a single homogeneous a-a group for the NO emission indicators ($p=0.999729$) (Table 3).

Table 2. Indicators of CO converted to baseline for 10% of O_2 in the flue gas.

Fuel type	The air speed, $m \cdot s^{-1}$	Indicators of CO, $mg \cdot m^{-3}$ at 10% O_2				
		sample size	min	max	mean	standard deviation
pellets made of rape straw	1.0	21	4523	7375	6203	720
	2.5	100	921	1331	1144	96
pellets made of sawdust birch	1.0	46	5661	15323	9562	3110
	2.5	97	237	1136	443	224
pellets made of oil cake	1.0	100	2494	13525	8003	3261
	2.5	82	351	6396	2359	1782

Table 3. Indicators of NO converted to baseline for 10% of O_2 in the flue gas.

Fuel type	The air speed, $m \cdot s^{-1}$	Indicators of NO, $mg \cdot m^{-3}$ at 10% O_2				
		sample size	min	max	mean	standard deviation
pellets made of rape straw	1.0	21	338	459	373	29
	2.5	100	583	623	604	10
pellets made of sawdust birch	1.0	46	219	304	251 a	26
	2.5	97	153	188	174	8
pellets made of oil cake	1.0	100	156	418	234 a	79
	2.5	82	564	1358	871	258

a-a homogeneous group

Indicators of SO_2 emissions from combustion of selected types and forms of a biomass are shown in Table 4. The resulting values of SO_2 emission indicators converted to the reference of 10% O_2 in the exhaust gas were very varied within the group of used biofuel types as well as in terms of the air supply rate.

Table 4. Indicators of SO_2 converted to baseline for 10% of O_2 in the flue gas.

Fuel type	The air speed, $m \cdot s^{-1}$	Indicators of SO_2, $mg \cdot m^{-3}$ at 10% O_2				
		sample size	min	max	mean	standard deviation
pellets made of rape straw	1.0	21	52	107	86 a	16
	2.5	100	4	27	10 a, b	6
pellets made of sawdust birch	1.0	46	56	275	140 a	68
	2.5	97	5	46	13 a, b	10
pellets made of oil cake	1.0	100	127	599	469	117
	2.5	82	51	995	613	351

a-a, b-b homogeneous groups

The highest values of this ratio were recorded during the combustion of oil cake pellets at the maximum flow rate of air supplied to the boiler. Lower values were observed at the air flow of 1 m/s. Accordingly, average values for this fuel amounted to 613 and 469 $mg \cdot m^{-3}$ at 10% O_2. Much lower values were reported during combustion of other types of pellets. At the air flow rate equal to 1 $m \cdot s^{-1}$, the mean SO_2 emission values were about 100 $mg \cdot m^{-3}$ at 10% O_2, while at average rate of 2.5 $m \cdot s^{-1}$ about 10 $mg \cdot m^{-3}$ at 10% O_2 (Table 4). Based on the variance analysis of values determined for SO_2 emissions, significant differences between the mean values within individual groups of raw materials were recorded, and Tukey test performed for SO_2 emission indicators revealed following two homogeneous a-a groups, wherein the rape straw pellets rape (1 $m \cdot s^{-1}$) showed homogeneity with the three combustion tests at respective probabilities: 0.202425, 0.785230, 0.284284, as well as b-b (p=0.999999) – Table 4.

4. Discussion

Completed tests of selected biofuel combustion were assumed to vary due to the use of pellets with different physical and chemical characteristics, as well as due to the two speeds of air supply to the boiler. Hence, the interpretation of achieved results of CO, NO and SO_2 emissions refers to the criteria adopted. At the same time, the comparative analysis of results classified in particular combustion tests is difficult, because the available literature data on emissions of CO, NO, and SO_2 include general values for straw and wood without distinguishing the types and average values for the entire combustion process. They are often emissions from structurally different heating devices and laboratory stands, and therefore these values are varied. According to Kordylewski (2008) after Juszczak (2002), typically 100÷1000 $mg \cdot m^{-3}$ of carbon monoxide is emitted during wood combustion in a furnace, yet under unfavorable combustion conditions, its proportion can reach even more than 35000 $mg \cdot m^{-3}$. Emission of NO_x, in which 95% is made up by NO during the wood combustion, ranges from 170 to 920 $mg \cdot m^{-3}$, and due to negligible sulfur content in wood, there is no SO_2 emission. Jewiarz and Kubica (2012) reported following ranges of CO, NO_x and SO_2 emissions at 10% O_2 content in exhaust gas for rye, wheat, and rape straw: 1281.7-4283.6, 166.6-206.6, and 87.7-109.7 $mg \cdot m^{-3}$. Nevertheless, Temmerman et al. (2011) analyzed combustion of wood, for which indicators of CO, NO, and SO_2 emissions at 13% O_2 content in exhaust gas amounted respectively to 189.98, 144.09, and 14.06 $mg \cdot m^{-3}$.

The own studies revealed that much more emissions of carbon monoxide and sulfur dioxide were recorded during combustion of pellets in question at the lowest (1 $m \cdot s^{-1}$) speed air flow to the boiler were achieved than in tests, when the speed of air flow to the boiler was 2.5 $m \cdot s^{-1}$ (Tables 2 and 4). These values were comparable to data presented by other researchers (Jewiarz and Kubica 2012; Kordylewski 2008). Increasing the speed of air during combustion of rapeseed and oil cake pellets in general led to an increase in nitric oxide in the exhaust gas, as the combustion of wood pellets made from birch sawdust did not produce such relationship. This resulted from a significant nitrogen content in these biofuels, mainly in pellets made of oil cake. This fact depreciates the raw material for use as pure biofuel. Nevertheless, due to the higher net calorific value than other biomass-related fuels, the oil cake can be used in blends with those raw materials. According to Cieślikowski et al. (2006), there is a remarkable risk of excessive nitrogen emission (NO_x) at the percentage of oil cake in blend higher than 15%. Under the test conditions, the smallest emissions and at the same time the best ecologic and energy features characterized the combustion of pellets made from birch sawdust. Combusting the rape straw showed similar emissions of sulfur dioxide as sawdust birch pellets (Table 4).

The technique of the upper combustion, the countercurrent combustion, characteristic for traditional domestic installations (furnaces, boilers) applied in distributed, individual heating systems, is characterized by low energy efficiency and high emission of pollutants (Kubica 2010).

The study revealed significant differentiated emissions of CO, NO, and SO_2 under variable conditions of air flow speed supplied to the boiler. The NO and SO_2 emissions depend mainly on nitrogen and sulfur contents in the biomass (Demirbas 2005, 2007). It is important that energy use of the biomass in the top-combustion boilers is often accompanied by problematic CO emission, in particular at the oxygen deficiency. Therefore, the air distribution should be improved in such devices, and when using the electronic control of the combustion process, it requires development of more accurate algorithms that control the air flow to the boiler. It is important to develop nomograms for a specific type of boiler to facilitate the selection of speed airflow to the boiler in relation to biofuels and to ensure its sustainable use.

5. Conclusions

The present study resulted in the following remarks and conclusions:

1. Physical and chemical properties of the pellets made from the rapeseed and birch biomass allow for their satisfactory and sustainable use in low-temperature grate heating devices assuming the optimal selection of the

amount of air supplied. In contrast, characteristics of the oil cake pellets did not allow for environmentally acceptable combustion associated with significant emissions of CO, NO, and SO_2.

2. Increasing the air speed of 1 $m \cdot s^{-1}$ to 2.5 $m \cdot s^{-1}$, the combustion of solid biofuels under consideration, reduces CO and SO_2 emissions by at least 80%. Therefore, eco-efficient combustion of pellet made from the biomass requires the use of heating equipment with adjustable air supply depending on the requirements of a combusted fuel.
3. It would be justified to extend studies with other types, and most of all forms of plant biomass, as well as their effect on the combustion process in the low-power devices.
4. Manual of a boiler should include detailed data (nomograms, tables) to enable selection of operating parameters of the boiler for combustion of desired biomass type in order to minimize emissions, mainly due to CO.

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Effect of selected parameters on process efficiency and energy consumption during the extrusion-cooking of corn-rice instant grits

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Abstract

More and more people begin to pay attention to how foodstuffs are produced. Due to the changing lifestyle, consumers seek products that do not require long preparation. The extrusion-cooking process responds to this type of applications with an easy management of processing promising product stability and quality. Extrusion-cooking involves the extruding of granular material under high pressure and high temperature. Such a method of treatment of raw materials makes extrudates produced from natural ingredients, i.e. corn or rice, suitable for direct consumption and guarantees their prolonged shelf-life. In our study, mixtures for instant grits were prepared from corn with a rice additive of 25% and 50%. Extrudates were prepared using a single-screw extruder TS-45 (L/D=12:1). The range of the temperatures of the extrusion process was 125/130/135°C. The process was carried out with the variable screw rotation speed of 80, 100 and 120 rpm. This paper presents the results of process efficiency and energy consumption during the extrusion-cooking of instant corn-rice grits. Based on a bidirectional analysis of variance, the process efficiency, regression equation and correlation coefficients were determined for evaluating the impact of the processing conditions on selected properties.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: extrusion-cooking; gluten-free; efficienty; specific mechanical energy

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.008

1. Introduction

Currently, food processing plays an important role in the manufacture of functional foods, supplemented with healthy components and as well as being convenient to use and requiring a short preparation time. Food manufacturers introduce products that contain plant materials and valuable extracts, which ensures that the human body is supplied any essential nutrients. Nowadays, consumers attach more and more attention to healthy food, which is a challenge for manufacturers of products intended for direct consumption. New techniques and technologies employed in food processing, such as extrusion-cooking, micronization, expanding, and combination of plant additives, replace popular snacks with a new generation of healthy products (Guy 2001; Ramirez-Jimenz et al. 2003, Wójtowicz 2007; Wójtowicz et al. 2012).

Extrusion-cooking is a process that involves the treatment of bulk material under high pressure (up to 20 MPa) and high temperature (up to 200°C), which yields significant changes in the physicochemical characteristic of the product and its quality. During processing, mixing, heating and shearing take place in order to give products specific properties corresponding to the pre-set manufacturing parameters (Mościcki et al. 2012; Yeh et al. 1999; Drożdż et al. 2010). The extrusion process is carried out on devices known as extruders. Products undergo starch gelatinization, so the extrudates are already precooked and do not require additional cooking. The extrusion process enables the use of raw materials with a wide range of granulation. Through a combination of process parameters and the use of a variety of recipes, it is possible to obtain an array of products with specific properties (Wójtowicz 2008). Extrusion-cooking technology is used in the food industry for the production of various types of foodstuffs, such as snacks, instant cereals, baby food, breakfast cereals, texturized vegetable protein, crisp bread, etc. (Harper 1981; Mercier et al. 1998; Mitrus et al. 2011, Mościcki et al. 2007; Sing et al. 2007).

Corn/maize grit is one of the most popular materials used in the production of extrusion-cooked food (Jurga 2012; Naz et al. 2005). Rice comes in many varieties characterized by hard, glassy grains and starch granules firmly embedded in a protein matrix (Mościcki et al. 2007). Processing with appropriate conditions allows new type of products to be obtained with a different texture, appearance and quality (Gondek et al. 2013, Wójtowicz et al. 2012; Zarzycki and Rzedzicki 2009). In qualitative terms, better products are derived from harder maize, which is caused by the higher amylose content in composition (Czerwińska 2011). Corn and rice products and dishes are hypoallergenic and gluten-free. Due to the specific protein composition, compared to other cereals, corn and rice products are recommended for people suffering from celiac disease (Oniszczuk et al. 2015; Gondek et al. 2013; Jurga 2012; Mościcki et al. 2007). The aim of the study was to evaluate the impact of selected processing parameters on process efficiency and energy consumption during the extrusion-cooking of corn-rice instant grits.

2. Materials and Methods

As raw materials, corn grit (distributor Aviko, Ciecierzyn, Poland) and rice (from Kobierzyce, Poland) were used. Instant grit composition is presented in Table 1. The moisture content of the raw materials was checked by the dryer (ASAE Standard 269.3 1989) before the extrusion process, and then the mixtures of components were moistened to the degree of 12, 14, 16 and 18% of moisture content, using a specific volume of water (Wójtowicz and Juśko 2012) at 20°C. A ribbon mixer was used along with a dispensing nozzle to ensure that the material is properly moistened and to avoid unequal level of hydration of the raw material. The mixing time was set for 15 minutes to obtain a loose structure. The mixture of raw materials was rested for 1 hour to uniform the moisture. The mixtures prepared in this manner were fed into the extruder's hopper. The extrudates were processed using a single-screw extruder TS-45 (L/D=12:1). The range of the temperatures of the extrusion-cooking process was the following: 125/130/135°C. The process was carried out by modifying the rotational screw speed between 80, 100 and 120 rpm. A forming die with a single hole of 3 mm was used. The extrudates were dried for 24 hours and ground by a laboratory grinder LMN10 (TestChem, Radlin, Poland) to a granulation below 1 mm.

Table 1. Composition of extruded instant grits.

Recipe	Corn grits [%]	Rice flour [%]
I	75	25
II	50	50

2.1. Process efficiency

The efficiency of extrusion-cooking of instant grits was determined by the sampling of corn-rice extrudates at a specific time (Wójtowicz 2001). The efficiency was calculated according to the formula:

$$Q = \frac{m}{t} \quad [kg \cdot h^{-1}] \tag{1}$$

where:
Q – process efficiency, [$kg \cdot h^{-1}$]
m – mass of extrudate obtained in the measurement, [kg]
t – time of measurement, [h]

2.2. Specific Mechanical Energy

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 different initial moisture content of raw materials. The engine load and process efficiency of each test were converted into *SME* according to Ryu and Ng (2001), taking into account the working parameters of the extruder, and calculated according to the formula:

$$SME = \frac{n}{n_m} \cdot \frac{O}{100} \cdot \frac{P}{Q} \quad [kWh \cdot kg^{-1}] \tag{2}$$

where:
SME – specific mechanical energy consumption, [$kWh \cdot kg^{-1}$]
n – screw rotations, [rpm]
n_m – screw rating rotations, [rpm]
O – engine load in comparison to a maximum, [%]
P – rated power, [kW]
Q – process efficiency, [$kg \cdot h^{-1}$]

2.3. Statistical analysis

The results obtained with bidirectional ANOVA analysis of variance with interactions were carried out in the Statistica software (Statistica version 10.0, USA). The first factor was the moisture content (*M.C.*) and the other the screw speed (*S.S.*). The analysis of variance was performed separately for the process efficiency and *SME*.

3. Results and Discussion

The efficiency of the extrusion-cooking process increased along with the increasing screw rotational speed in both compositions of raw materials (25% and 50% of rice). An increased component of rice resulted in a higher efficiency of extrusion-cooking. For products based on the mixture of raw materials, which contains 25% of rice, the efficiency ranged from 18.72 $kg \cdot h^{-1}$ to 32.52 $kg \cdot h^{-1}$ (Fig. 1A), while for a mixture with 50% of rice, it ranged from 18.6 $kg \cdot h^{-1}$ to 38.52 $kg \cdot h^{-1}$ (Fig. 1B). An increased moisturization level resulted in a decreased efficiency of the extrusion-cooking.

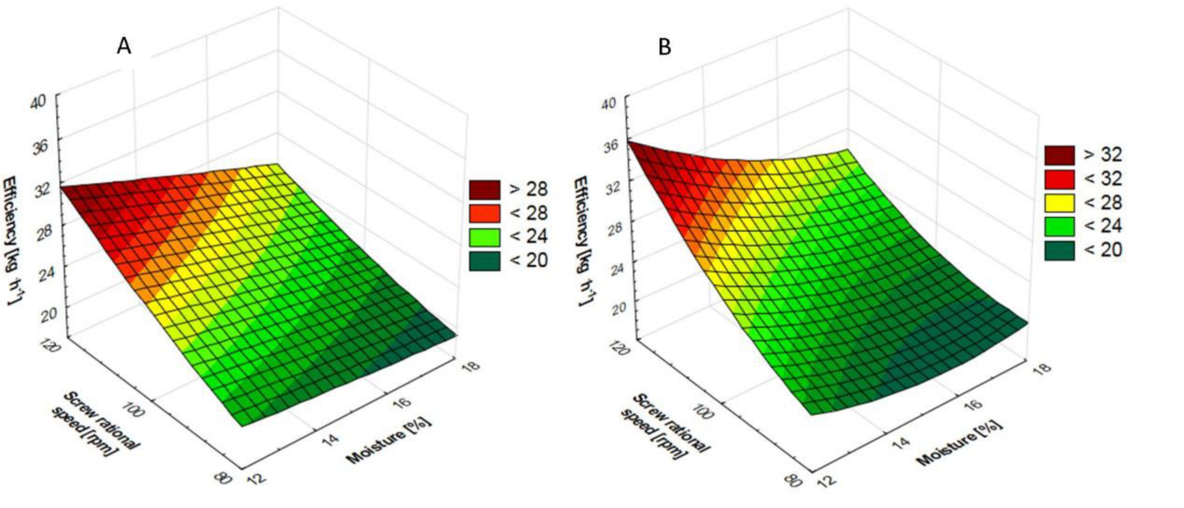

Fig. 1. Extrusion-cooking process efficiency of instant grits from corn and rice at 25% (A) and 50% (B) depends on moisture and screw speed applied.

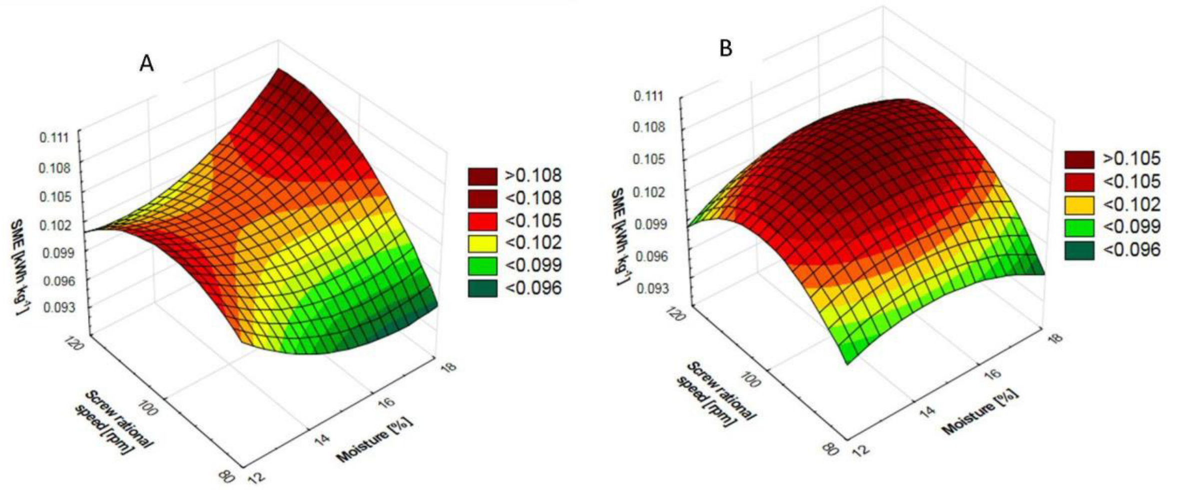

Fig. 2. Specific mechanical energy [*SME*] during the extrusion-cooking process of grits from corn and rice at 25% (A) and 50% (B) depends on moisture and screw speed applied.

Increasing the screw speed up to 100 rpm resulted in higher energy consumption during the instant grits extrusion process while the speed of 120 rpm resulted in a lower value of this parameter (Fig. 2B). At the range of moisture level from 12 to 16%, energy consumption of the extrusion process increased proportionally to the level of moisturization of raw materials. Over 16% of the initial moisture content, there was a decline of the energy consumption parameter. The lowest value of *SME* was observed during the processing of the mixture containing 50-50% of corn-rice at 12% of moisture content and under 120 rpm of screw speed (0.992 $kWh \cdot kg^{-1}$), and the highest was 0.108 kWh/kg for samples with 14% of initial moisture content processed at 100 and 120 rpm of screw speed. Similar values of *SME* were noted for the extrusion process of mixture containing 25% of rice (Fig. 2A).

Table 2. Analysis of variance of extrusion-cooking process efficiency of instant corn grits with rice addition.

Additive level	Source of variation	Degr. of Freedom	*SS*	*MS*	*F*	*p*
25%	Moisture (*M.C.*)	3	95.5440	31.8480	402.1212	<0.0001
	Screw speed (*S.S.*)	2	395.7408	197.8704	2498.3636	<0.0001
	Moisture * Screw speed (*M.C.**S.S.*)	6	35.2224	5.8704	74.1212	<0.0001
	Error	24	1.9008	0.0792		
50%	Moisture (*M.C.*)	3	198.9216	66.3072	1105.1200	<0.0001
	Screw speed (*S.S.*)	2	628.1928	314.0964	5234.9400	<0.0001
	Moisture * Screw speed (*M.C.**S.S.*)	6	126.3096	21.0516	350.8600	<0.0001
	Error	24	1.4400	0.0600		

Source: Authors' calculations

Table 3. Analysis of variance of extrusion-cooking *SME* of instant corn grits with rice addition.

Additive level	Source of variation	Degr. of Freedom	*SS*	*MS*	*F*	*p*
25%	Moisture (*M.C.*)	3	0.0001	0.0000	13.3269	<0.0001
	Screw speed (*S.S.*)	2	0.0003	0.0001	89.1894	<0.0001
	Moisture * Screw speed (*M.C.**S.S.*)	6	0.0006	0.0001	61.9544	<0.0001
	Error	24	0.0000	0.0000		
50%	Moisture (*M.C.*)	3	0.0001	0.0000	29.9343	<0.0001
	Screw speed (*S.S.*)	2	0.0003	0.0001	141.1824	<0.0001
	Moisture * Screw speed (*M.C.**S.S.*)	6	0.0006	0.0001	86.8041	<0.0001
	Error	24	0.0000	0.000		

Source: Authors' calculations

The results of variance analysis depend on moisture content and screw speed. Their interactions are shown in Tables 2-3, and multiple regression equations, determination and correlation coefficients are shown in the Table 4. Based on the presented results, it can be concluded that at the level of $\alpha = 0.05$, significant differences were reported in the process efficiency and energy consumption of the extrusion-cooking process, depending on the moisture level of mixtures and the screw speed applied.

Table 4. Regression summary for dependent variables of studied parameters for mixtures of corn grits and rice depends on the moisture content and screw speed applied.

Additive level	Tested value	Regression equations	*R*	R^2
25%	Efficiency	Q=14.470-0.716·$M.C.$+0.203·$S.S.$	0.96	0.92
	SME	SME=0.089+0.000·$M.C.$+0.0001·$S.S.$	0.41	0.17
50%	Efficiency	Q=14.175-0.980·$M.C.$+0.251·$S.S.$	0.90	0.82
	SME	SME=0.0924+0.0001·$M.C.$+0.0001·$S.S.$	0.24	0.59

Source: Authors' calculations

Using the multiple regression, equations of variability were determined for the tested parameters, depending on the level of rice addition, moisturizing of raw materials blends and the rotational screw speed used (Table 4). The screw speed, as a directional factor in the equations, adopted positive values reflecting the increasing values of the studied parameters with the increasing speed of extruder screw during the processing of corn grits with rice addition.

In the case of initial moisture content, coefficients were negative for process efficiency and positive in the equations of energy consumption during the extrusion-cooking.

High correlation coefficients indicate a good match of equations designated for processing efficiency, depending on the moisture level of mixtures and the screw speed during the extrusion process. In the case of energy consumption, the correlation coefficient for the mixture with rice in an amount of 25% was 0.41, which means that moderate correlations between the moisture and the screw speed applied were observed. In the case of rice at the level of 50%, the correlation coefficient were even smaller and totaled 0.24, which indicates a weak relationship between the parameters.

For the tested corn grits with rice addition, high coefficients of determination (0.82-0.92) were obtained indicating a positive impact of the moisture level of raw materials and of the screw speed on the extrusion-cooking process efficiency. The coefficient of determination, for mixtures with rice in the amount of 25%, was 0.17. In contrast, mixtures with rice in an amount of 50% were characterized by the determination coefficient at the level of 0.59. Both factors indicate no significant impact of raw materials on the initial moisture content and of the screw speed on the tested parameters (Table 4).

4. Conclusions

Presented results demonstrate the possibility of employing extrusion-cooking in the production of extruded instant grits based on corn and rice mixtures. Processing management in the case of the varied moisture content of mixtures and extruder screw speed had a direct impact on the process efficiency and energy consumption. The use of rice as an additive had a significant influence over the process efficiency of extrusion-cooking of instant grits.

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Agriculture and Agricultural Science
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Application of electric fields as a method for plant disease forecasting

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Abstract

The splattering of raindrops is a very important factor in the spread of plant diseases from the Septoria group. The spreading mechanism of this disease via spores is observable particularly during short and violent storms. The methods used currently to forecast Septoria infection are based mainly on the climate condition and the calendar measurements, primarily taking into consideration the disease cycles. These measurements, however, do not take into account the most important factor: the splattering of raindrops as a method of transporting spores onto higher parts of the plants. If this factor is ignored, the forecasting models are flawed and have little correlation with the real development of a disease epidemic. The method presented in this study uses an electric field to measure the range of dispersal and number of splatter particles. This is achieved by means of a measuring system that allows for accurate and reliable measurement of the dispersal range of splashed raindrops. These raindrops scatter the spores and transmit the infection to higher parts of the plants as well as to neighboring plants.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

*Keywords:*plant disease; electric field.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.009

1. Introduction

Raindrop splatter resulting from water drops hitting the ground or a plant constitutes one of the most significant mechanisms causing the spread of infection throughout plantations.

There are numerous plant pathogens producing spores that are able to reach the surface or other parts of uninfected plants by being carried by droplets. Such a mechanism of disease spread has been the subject of many studies intended to determine the impact of the spatial range of droplet distribution on epidemic development. These studies focused primarily on investigating the spread of the following cereal crop diseases: Septorianodorum, Septoriatritici and Rhynchosporiumsecalis, whose spores are transmitted mainly by droplet splatter (Shaw, Royle, 1987), (Shaw, 1990).

Septoria leaf spot diseases are the most widespread diseases of cereal leaves. In Poland Septorianodorum and Septoriatritici are two pathogens of significant importance that can cause significant crop damage (Maliński, 1992), (Pokacka, 1985). Septorianodorum and Septoriatritici are caused by cryptogamic parasites. Septoria leaf spot caused by Septorianodorum develops not only on leaves but also on seed spikes. The symptoms of the disease are also noticeable on the leaf sheath and node. Only plant roots remain unaffected.

There are several common sources of infection, such as unplowed soil with straw, which can remain a source of spores for more than three years. Moreover, the infected remains of cereals are also a favorable habitat for the formation of perithecium containing ascospores.

The development of the disease as well as the epidemic occurs mainly in spring due to pycnidospores, which constitute the main source of infection. These spores are formed in fruiting bodies (pycnidia) located in dead parts of the leaves. They emerge from the fruiting bodies in the form of a jelly-like sticky secretion full of spores. While this coating forms excellent protection from adverse weather conditions, it creates a heavy mass preventing the spores from being spread by the wind.

Therefore, the only mechanism by which spores can be transferred to higher parts of cereal leaves and other healthy plants is by raindrop splatter. The scale of horizontal (onto non-infected plants) and vertical transmission (onto higher parts) depends on the kinetic energy of the raindrops. The kinetic energy of raindrops together with the characteristics of the rain, i.e. duration and dry periods between each rainfall, have a decisive impact on the speed and spread of an epidemic. For example, if the rain has a large kinetic energy, but is of short duration, then the spores will not have enough time to be separated and clumps are transported in the droplets to the upper plant parts as well as to other plants (Caron,1993), (Caron, 1990). Every clump represents an infective unit containing a large number of spores able to cause severe disease spreading out from the point of infection. Such an infection is associated with spreading of the whole clump across the leaf and causing infection of the entire leaf surface. The vegetative cycle starts again on the part of the plant with infected leaves and more pycnidospores are produced. The next rainfall with a sufficiently high kinetic energy will transmit the disease to higher parts of the plant and to neighboring plants. The vegetative cycles will then overlap until the infection reaches the spike.

As indicated above, the strength and range of splatter are the determining factors in the development of a Septoria infection. The methods used currently to forecast Septoria infection are based mainly on climate condition and calendar measurements, primarily taking into consideration the disease cycles. These measurements, however, do not take into account the most important factor: the splattering of raindrops as a method of transporting spores onto higher parts of the plants. If this factor is ignored, the forecasting models are flawed and have little correlation with the real development of a disease epidemic. This, in turn, causes the unnecessary application of preventative fungicide spray, intended to protect crops from damage, since the risk value calculated from inaccurate forecasts is too high. While this method is undoubtedly effective, it results in unnecessary treatments that in consequence increase both the financial costs and the environmental burden of pesticides.

In order to achieve balanced and effective protection of plants against Septoria infections it is necessary to create a reliable model of forecasting epidemic development.

At present, with the help of traditional measuring methods, the creation of such a model is virtually impossible. The method presented below, which is based on the application of electric fields, allows a system to be created for the accurate and reliable measurement of the dispersal range of splashed raindrops. These splashed raindrops contain the spores, hence transmitting the infection to higher parts of the plant as well as to neighboring plants.

2. Application of an electric field to determine the trajectory and range of droplet splatter

If a drop of water lands on an electrode set to a suitable potential, then during the moment of splash the electrode charge will be transferred to the drop, and the products of the splatter will carry this charge away. However, such an assumption contains a number of doubts in terms of the practical feasibility of achieving a measurement. Water is a compound with highly variable physiochemical and electrical properties. Although ideally pure water has a very low electrical conductivity and acts as an insulator, even the smallest amount of added impurity causes a very large increase in conductivity, resulting in the water acting as a conductor. In other words, the water found in raindrops is a liquid of high electrical conductivity.

3. Study methodology

The generated drops strike the ground (the base electrode) with a high electric potential, and are charged by the electric field during the splatter process. This process produces water drop disintegration, forming a whole array of splatter particle sizes. When these splatter products come into contact with the base electrode, they accumulate a charge; later, as charged products, they are captured by the measuring electrode, which intercepts their electrical charge. A substitute circuit diagram and measuring system – a charged droplet being intercepted by an electrode is shown in Fig. 1.

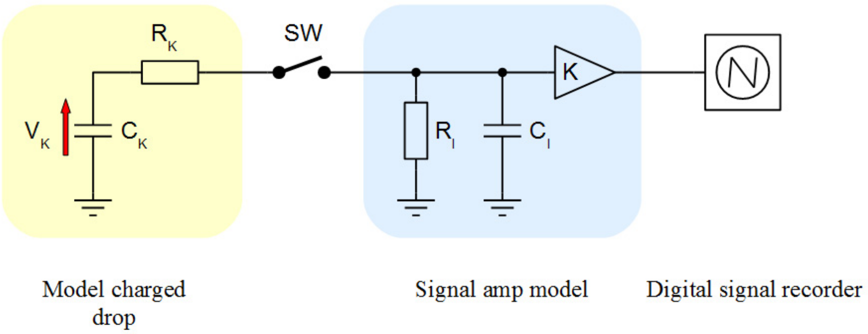

Fig. 1.Equivalent circuitof the measuring system

This diagram shows the course of the electrical processes that occur as a result of raindrops falling and interacting with the measuring system.

The C_k capacitor, with voltage value V_k, and the R_k resistor represent the capacity relative to the ground and the resistance of the charged droplets. Closing of the SW switch reflects the moment of contact between the droplet and the receiving (measuring) electrode, and its discharge by a signal amplifier input circuit. The actual signal amplifier, along with the collecting electrode, on the substitute diagram represents a non-inertial K amplifier with infinite input impedance, with R_i and C_i elements attached to the input, forming the input resistance and capacitance as observed from the collecting electrode. In the above circuit, the instantaneous value of capacitor discharge i(t) is equal to (1) (Krakowski, 1995, Sikora, 1998):

$$i(t) = \frac{u_i(t)}{R_i} + C_i \frac{du_i}{dt} \tag{1}$$

In accordance with the principle of charge conservation, the charge accumulated on the droplets causes a flow of current i(t) which is equal to (2) (Kuna-Broniowski, 1995)

$$Q_i = \int_0^{t_i} i(t)\,dt \tag{2}$$

As a result of the experiments forming part of this study, it was observed that charge variations greatly influence the function of the droplet weight and therefore can be used to measure the mass of the splattered raindrops. The relationship between droplet mass and its charge can contribute to the improved measurement accuracy of plantation biohazard since there is a positive correlation between the amount of Septorianodorum spores transmitted via droplets and their mass (Brennan , 1985), and the same is true for other pathogens (Fatemi&Fitt, 1983).

Because the relationship between the droplet mass and the electrical charge it carries is of fundamental importance for the practical use of this measurement method, a virtual computer instrument was constructed specifically for the purpose. This instrument allows one to measure the electric charge of the individual raindrops that form as a result of dispersal. The method developed enabled the measurement of the diameter of the dispersed drops that reached the measuring electrode. Therefore it was possible to correlate Q = f(m) even for the smallest droplet diameters that are formed as a result of water splash.

Table 1. Measurement results showing droplet diameters and their charges.

Diameter [mm]	Charge [C]
0.15	6.739E-12
0.15	9.288E-12
0.10	1.013E-11
0.15	1.112 E-11
0.25	2.015 E-11
0.20	1.277 E-11
0.273	1.734 E-11
0.50	1.909 E-11
0.25	2.015 E-11
0.35	2.042 E-11
0.35	2.046 E-11
0.60	2.290 E-11
0.65	2.337 E-11
0.60	2.378 E-11

By the means of the above equipment, a series of experiments was conducted to determine the relationship between droplet size resulting from the splatter and the electric charge that is returned. The diameter of the receiving electrode was reduced to a size of about 5 mm and the water in the dispenser was coloured. Each time a charged droplet touched the electrode it was shown on the screen, and the droplet charge was measured and saved in a file. At the same time the droplet diameter was measured optically by a measuring microscope. The measurement results and the calculated statistical relationship between droplet mass and carried electric charge are given below.

Based on the calculated sample characteristics it can be concluded that the correlation between the returned charge and the diameter is very strong (rxy=0.942). Thus, there is a very high charge variability (39.278%), of which approximately 90% is the result (rxy2 = 0.887) of the huge variation in diameter (51.178%). Therefore the hypothesis that large charge variations occur due to random losses when the droplets are splattered can be rejected. Thus, the known relationship between droplet diameter and the charge carried by non-conductive liquid droplets can also be adapted and used in research using droplets to investigate the phenomenon of spore spreading.

Table 2. Regression analysis.

	The regression coefficientb	Free terma
value	3.00E-11	9.083E-12
standard error	1,829E-12	1.339E-12
correlation r^2	0.887	3.468E-12
test F, freedom degrees	203.143	26
SS regression, SS residues	2.443E-21	3.127E-22

The least squares method was used to fit a straight line that described the relationship between droplet diameter and carried electric charge.

$$y = (3.00 \cdot E-11)x + 9.083 \cdot E-12 \quad (3)$$

Then the F-Snedecor test was used to check the confidence level of the model, and the value achieved was F0 = 203.143, which argues in favour of the hypothesis of good fit for this model

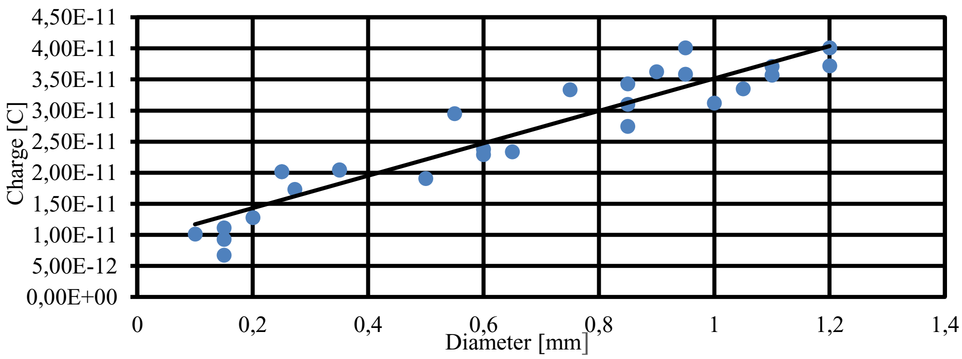

Fig.2. A plot of charge and droplet diameter - a linear relationship.

4. Conclusions

The studies and analysis show that the method using electric fields to determine the droplet size enabled the size to be measured of the splattered droplets that form when raindrops hit the ground. By placing a measuring electrode within a suitable range it is possible to determine the range of raindrop dispersal. It is crucial to build a correct and multivariate model of Septoria epidemic development, especially for cereal infections. By determining the relationship between the size of the droplet and its electrical charge it is also possible to determine the minimum droplet size necessary to transfer infective spores. Raindrops that are too small, and such drops are also produced in large quantities when the droplets reach the ground, are not able to move a spore from the infected area to a healthy site as their size is too small (smaller than the spore dimensions). Droplets which are too small are therefore irrelevant to the forecasting model and can be easily eliminated in the measuring procedure by setting the sensitivity of the apparatus at the required level in order to discriminate measurement signals from droplets that are too small

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Agriculture and Agricultural Science Procedia 7 (2015) 152 – 157

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Repair cost of tractors and agricultural machines in family farms

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Abstract

The mechanization cost in agriculture institute between 20% and 30% of the total production cost. The repair cost of agriculture machines is the second important element of the operation cost of the machines. The paper presents problems related to the calculation of the repair costs and analysis of selected family farms in Poland. The paper argues that there is no precise method for the calculation of the repair costs. The variation of factors influencing the costs, such as exploitation conditions, machines quality or prices relations; causes that the coefficients used in the calculations are not universal and differ between different countries.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: farm machinery costs; family farms.

1. Introduction

Modern agriculture is characterized by high level of mechanization. The number of machines and other equipment increases constantly with the increment of the operation costs. Such costs stand at 20 to 30% of the total production cost (Lips & Burose, 2012). Essentially, the repair and maintenance costs are the second, after fuel, component of operation costs. Despite the high quality of the modern machines, in many cases the actual unit repair cost is much higher than for traditional designs. The knowledge of repair and maintenance costs is essential for

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2210-7843
Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.010

making decisions related, among others, to the replacement of machinery and correct preparation of farm's budget (Morris, 1998).

The tractors and machines costs in Polish agriculture are relatively high. It is mainly due to the high level of land fragmentation with the average farm area of less than 10 ha and with the total number of farms above 1,429 thousands (Statistical yearbook…, 2014). Almost half of the Polish farms have the agricultural area of less than 5 ha, whereas only about 11 thousands farms has the area above 100 ha. There are 1,437,000 tractors with the average age of above 23 years. The other machines used in Polish agriculture have similar data related to the average age and the level of wear. The largest farms have managed to improve their technical equipment thanks to the funds from the European Union. However, in general the majority of machines are overworked and fully exploited. In general, the owners of small farms do not invest in new machines but prolong the utilization life of the existing machines even to 40 years. That increases the frequency and costs of repairs. The majority of farmers try their best to reduce the maintenance costs by performing the repairs themselves and by using cheaper spare parts.

The aim of the investigations is to indicate the difficulty and complexity in the calculation of the maintenance and repair costs in family farms.

2. Calculation of repairs and maintenance costs

The calculation of the repair costs of tractors and agricultural machines is a complex and problematic issue. It is due to random character of those costs and its dependency on several parameters. As a standard the calculation is done with the application of the repair cost coefficient which is the ratio between the accumulated repair costs to the list price of the machine (1).

$$r=Kn/Cm \tag{1}$$

where,
r – repair cost coefficient,
Kn – accumulated repair costs [PLN],
Cm – list price of the machine [PLN]

Hence, an annual cost of the repairs can expressed as:

$$Kn= Cm*r \tag{2}$$

and a unit cost:

$$Kjn= Cm*r/W_T \tag{3}$$

where,
Kjn – repair unit cost [PLN/h]
W_T– estimated life [h]

Another measure used sometimes for the calculations of maintenance and repair costs is the repair cost coefficient calculated for the hour or 100 hrs of machine use:

$$Kjn= Cm*r_{100}/100 \tag{4}$$

where,
r_{100}– repair cost coefficient calculated for 100 hrs of machine use

The repair cost theory developed in 1950s indicates the relationship between the repair costs and the age and use of the machines. That relationship has been confirmed by research done in several countries (Albisser et al., 2009; Hunt, 2001; Landers, 2000; Lips & Burose, 2012; Niari et al., 2012; Wendl, 1989; Witney, 1998). However, there are also reports indicating that the annual repair costs remain at the same level (Liechti, 1994). The above research reports on an investigations performed over a long period of time (monitoring of the machines over a period of 10 years) in farms with small areas (up to 20 ha).

The actual values of the repair cost coefficients are different in different countries (tab.1).

Table 1. Repair cost coefficients r for selected tractors and agricultural machines for various countries

Machine	Repair cost coefficients r as a percentage of list price	
	Annual	Per 100 hrs of use
Polish data [a]		
Tractors below 30 kW of engine power	4.50	0.69
Tractors above 30 kW of engine power	5.00	0.75
Trailer	5.00	1.67
Plough	5.00	5.00
Fertilizer spreader	7.33	11.00
Grain drill	5.00	7.14
Sprayer	4.00	6,00
Combine harvester	4.44	2.67
Baler	4.00	6.15
Potato harvester 1 row	6.25	5.00
Swiss Data [b]		
Tractors 21-29 kW of engine power	8.33	1.00
Tractors30-36 kW of engine power	7.50	0.90
Trailer 5 ton	6.00	1.80
Plough	8.33	8.89
Fertilizer spreader 500 litres	5.00	10.00
Grain drill 3 m	4.00	8.57
Sprayer 500 litres	3.33	8.00
Combine harvester 3.9-4.2 m	4.17	2.35
Baler	5.00	3.00
Potato harvester 1 row	6.67	2.82
UK data [c]		
Tractor	x	1.00
Trailer	x	2.67
Plough	x	7.50
Fertilizer spreader	x	10.0
Grain drill	x	6.67
Sprayer	x	4.67
Combine harvester	x	2.50
Baler	x	4.00
Potato harvester	x	2.80
USA Data [d]		
Tractor	x	0.50
Trailer	x	2.50
Plough	x	5.00
Fertilizer spreader	x	6.67
Grain drill	x	5.00
Sprayer	x	4.67
Combine harvester	x	1.33
Baler	x	4.00
Potato harvester	x	2.80
South African Data [e]		
Tractor	5.90	x
Trailer	1.80	x
Plough	4.90	x
Fertilizer spreader	12.90	x
Grain drill	7.90	x
Sprayer	4.90	x
Combine harvester	2.80	x
Baler	6.00	x
Potato harvester	6.00	x

[a] (Muzalewski, 2008), [b] (Gazzarin, 2014), [c] (Witney, 1988), [d] (Hunt, 2001), [e] (Theunissen, 2002)

The differences in the actual values are due to local conditions such as agriculture characteristics (size of the farms, production conditions) and also price relations (cost of spare parts, labour, power). In many countries there is also a problem with updating of the values of the coefficients. The investigation on the real repair costs and the values of the coefficients requires a lot of effort and is very expensive.

The correction of the repair cost with the application of suitable factors is one of the methods to take into account the age and use of the machines (tab.2). The following correction factor can be applied according to the formula:

$$Kn = Cm*r*x \quad (5)$$

where,
x – repair cost correction factor

Table 2. Repair cost correction factor *(x)* for tractors

Initial Value	Use as % of W_T									
	Final Value									
	10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*	*100*
0	0.31	0.45	0.56	0.64	0.72	0.78	0.85	0.90	0.96	1.01
10		0.58	0.66	0.74	0.80	0.87	0.92	0.98	1.03	1.08
20			0.75	0.82	0.88	0.94	0.99	1.04	1.09	1.14
30				0.89	0.95	1.00	1.05	1.10	1.15	1.19
40					1.01	1.06	1.11	1.16	1.20	1.25
50						1.11	1.16	1.21	1.25	1.29
60							1.21	1.25	1.30	1.34
70								1.30	1.34	1.38
80									1.38	1.42
90										1.46

Source: (Taschenbuch…, 2002)

Table 2 indicates that in case of tractors with use of above 90% of estimated life the increase in the repair costs reaches 46% in comparison to the average values (correction factor 1.46).

3. Materials and Methods

The investigations of mechanization costs, including the repair costs, were done on the group of 200 farms, starting in year 1992. The analysis was done for data collected in 2001 from 103 farms (Lorencowicz, 2005; 2007).

Additional investigations were done by graduate students and covered analysis of selected cases. It included 5 farms with arable area from 17.8 to 65.5 ha (Łuczkowski, 2014; Stankiewicz, 2007).

The costs of the repair in a private workshop were established (Kita, 2009). The study covered repair cases of tractors (13) and combine harvesters (4). The enquiry included repair costs also in the authorized agricultural machine services (Kudeń, 2015). The analysis of repair costs of 49 tractors was also included in the results.

4. Results and Discussions

In the group of investigated 103 farms the average annual use of tractors was on 312 hrs (mostly between 151 and 300 hrs). For trailers the annual average use was 63 hrs (most frequently below 40 h). For other machines, the annual use was typically below 40 hrs/year. The predicted length of the life for tractors was ca 30 years and for the other machines between 20 (sprayers) to 30 years (trailers). The annual costs of the spare parts ranged between PLN 2,000 and PLN 8,000, depending on both, the size of the farm (Fig. 1a) and value of the machine set (Fig. 1b). The average share of the spare part costs in the direct machinery costs (excluding depreciation) was 23%.

The data from the farms under investigations indicate was high proportion of repair costs. The value of the spare parts purchased was from 19% up to even 61% of the direct costs (Łuczkowski, 2014; Stankiewicz, 2007).

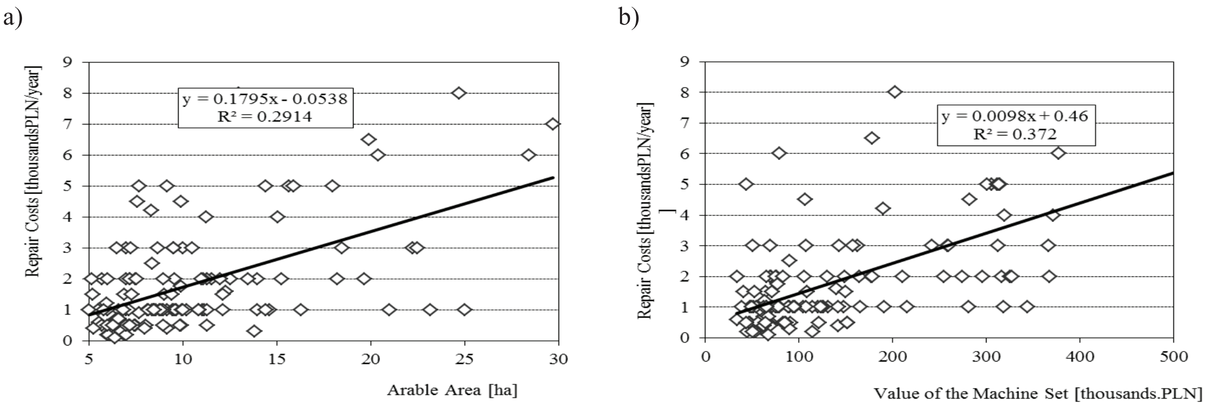

Fig. 1. Direct repair costs vs arable farm area (a) and value of the machine set (b) (Lorencowicz, 2005)

The comparison between the repairs costs done in a small private garage (the job is done by the workshop owner) and in authorised machine workshop (3 companies, each with minimum 3 working positions and 5 employees) indicates vast variation. Such variation can be explained by the fact that the private garage repaired mainly older (even 28 year old), less complex tractors with low engine powers (average ca 40 kW). Whereas, the authorised services worked mainly on younger, few-year old tractors (average 7 years) with average engine power of 105 kW (maximum 221 kW). However, the repair costs were not related to the age of the tractors but with the scale of the repair. It is also apparent that Polish farmers decide to use the external workshop, either small garage or authorised service, only in complex cases, in which they cannot accomplish themselves.

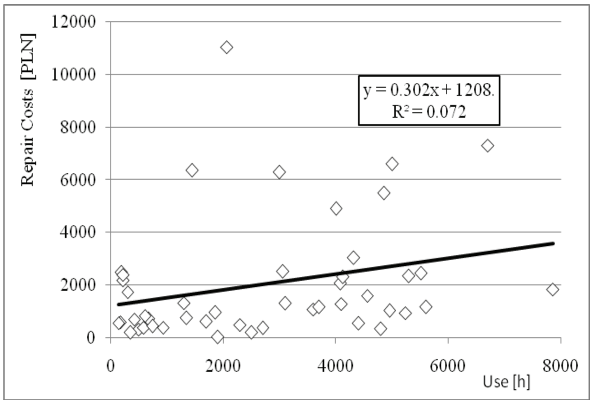

Fig. 2. Repair Costs vs the use of tractors (Kudeń, 2015)

As it can be seen at the figure (Fig. 2), there is no relationship between the cost of the repair and the use of the tractor. Taking into account the average values, the repair cost coefficient for the tractors under investigations can be estimated at 0.26.

5. Conclusions

Based on the research presented and on the analysis of the literature, it can be stated that there is no one, precise method for the calculation of the repair costs. The variation of factors influencing the costs, such as exploitation conditions, machines quality or prices relations; causes that the coefficients used in the calculations are not universal and differ between different countries. It is advisable to estimate coefficients suitable for the conditions of a particular country, with its specific type of agriculture. The specific circumstances of Polish agriculture, with small sizes of the farms and old tractors and agricultural machines, highly affect the repair costs. At the same time, the low annual use of the machines creates the situation that many of those machines do not reach the usage level qualifying for a disposal. Regarding the repairs, it is also apparent that the farmers try to perform repairs themselves, limiting the outsourcing by specialized companies.

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Agriculture and Agricultural Science Procedia 7 (2015) 158 – 164

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Productivity of resources and investments at selected ecological farms

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Abstract

Land and labour resources indicate that Polish agriculture has extensive options of competing on the European market. However, structural realities, particularly the agrarian scattering and excessive labour resources in the agricultural industry, contribute to low productivity of Polish farming. Productivity improvement can be achieved through increasing sizes of agricultural establishments as well as production of organic (eco) products. The paper presents the productivity review of land, capital and labour resources as well as material investments in production of the output volume at 50 ecological farms situated in the territory of the Macro-Region of Southern Poland. The studied farms were engaged both in general and specialised plant and animal production.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: ecology; investments; resources; costs; productivity.

1. Introduction

Scattering of the production potential among small producers affects lower productivity and poorer competitive position of Polish farming compared to the agricultural industry in those countries where concentration of farmland is higher. This is due to poorer management efficiency represented by smaller farms as well as their lower willingness to absorb technology advancements. On the other hand, unreasonable approach to these matters leads to

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.011

rapid overinvestment, resulting in lack of economic sustainability. It should be pointed out that agriculture is by definition less productive than other sectors of the economy. In EU Member States, added value per one person employed in agriculture is fifty per cent lower than in other sectors. In Poland, on the other hand, it is more than four times lower, as a consequence of poor quality of farm land and excessive employment. There are less than 7 hectares of crops per farmer in Poland, compared to the average 14.3 hectares across the European Union. Despite the positive changes that occurred recently in the Polish agricultural industry, this sector still represents very low level of productivity, due to decreasing employment and increasing sizes of farms. Productivity improvement can be achieved through increasing sizes of agricultural establishments as well as production of organic (eco) products, which are more and more frequently chosen by populations in all countries (Malaga-Toboła, 2013). For the above reason, ecological farming is among the most rapidly growing branches of agriculture in the European Union, and the importance of this type of production is increasing worldwide as well (Batte et al., 2007).

It should be emphasized that organic farming is a sustainable, self-sufficient and economically safe system, based on sustainable plant and animal production (Barszczewski et al., 2006; Jankowska-Huflejt et al., 2006; Kuś and Stalenga, 2003). The ecological aspect, on the other hand, has become the basic category of agricultural production process sustainability (Morris and Winter, 1999; Adamowicz, 2000; Mouchet, 1998; Bockstaller et al.; 1997), as the idea of sustainable growth has its theoretical foundations in ecological economy. The main assumption of the above is the ability to develop an economic system within the existing environmental system. The choice of the system depends not only on physical limitations in the area of farm resources (soil quality, climate and financial resources), but also to a continuously greater extent on environmental protection requirements (Magette, 2000). Environmental conditions and economic aspects overlap. Market mechanisms require farms to be competitive in order to survive on the market. The measure of competitiveness is the ability to efficiently utilize the production resources, mainly capital, technologies, and human resources (Kołodziejczak, 2010). Higher productivity translates into higher efficiency, and the latter is a prerequisite of competitiveness and achievement of competitive advantage (Kalińska et al., 2007).

The purpose of the paper was to review the productivity of land, capital and labour resources, as well as direct investments in production of output volume at ecological farms.

2. Materials and Methods

Productivity is the technical interdependence between the production resources investment streams, i.e. land, capital and labour, and product resources, represented by commodities or services. The scope of the study covers 50 organic farms situated in the territory of the Macro-Region of Southern Poland engaged in general and specialised plant and animal production. Average area of arable land across the studied establishments was at 12.92 ha, ranging from 1.56 ha to 46.60 ha. Grassland prevailed within the land utilization structure, with the average area of 6.85 ha. 5.58 ha were covered by crops. The primary crops were cereals and, to a lesser extent, root crops, fodder plants and vegetables. The dominance of grassland was due to the primary orientation of animal production, i.e. breeding of milk cattle. Almost 25% farms were oriented only on milk production. The density of animals at ecological farms is the function of availability of self-sufficient fodder sources and demand of crops for nutrients. Thus, sustainable density of farm animals is among the fundamental principles of ecological production methods. The studied farms were maintaining 8.47 LSU on average, of which as many as 7.82 LSU of cattle. Animal density was at 0.60 $LSU \cdot ha^{-1}$ of farmland. Except for the rare examples, the farms were well equipped in terms of plant and machinery; each of them had at least one agricultural tractor and basis supporting machinery. The sources of study results included documentation kept by organic farms as required by the applicable laws, as well as aided interviews with farm owners in 2012. For the purposes of comparative analysis, the studied farms were divided into four groups by size, i.e.: < 5 ha; 5.01 to 10.00 ha; 10.01 to 20.00 ha; and +20 ha. Populations of the specific groups were as follows: 12; 17, 11, and 10 farms, respectively. Higher number of agricultural establishments that were smaller in terms of size corroborates the claim that the smallest farms are those which are at the same time most willing to switch to ecological production methods, and their number is increasing at the highest rate. Certainly, the undisputed cause of this occurrence is the ability to obtain State funding, which represent a significant component of the financial budgets of such agricultural establishments. Productivity as the proportion of production volume to the quantity of goods used or consumed can be assessed with the use of various criteria, according to the units in which products and investments are expressed. Therefore, productivity measures may vary in form, and they are numerous (Lis, 1999). Immediate production measures are those with production volume in the numerator and the quantity of consumed resources in the denominator, for each type separately or for all types of resources jointly; this proportion is typically expressed as costs.

Total productivity:

$$Pn = \frac{Pk}{N} \tag{1}$$

where:

Pn – total productivity of material investments;
Pk – final production (PLN);
N – investments (PLN)

Productivity of land resources:

$$Ps = \frac{Pk}{S} \tag{2}$$

where:

Ps – productivity of land ($PLN \cdot ha^{-1}$);
S – area of farm land (ha).

Productivity of objectified labour resources:

$$Pm = \frac{Pk}{M} \tag{3}$$

where:

Pm – productivity of the machine park;
M – replacement value of machine park (PLN).

Productivity of labour resources:

$$P.r = \frac{Pk}{R} \tag{4}$$

where:

$P.r$ – productivity of labour resources ($PLN \cdot FTE^{-1}$);
R – number of fully employed persons - full-time equivalent (FTE).

Number of full-time equivalents – means the number of persons working at a farm on a full time basis (2120 hours according to Eurostat methodology) during the year, which is capable of achieving income parity.

3. Results and Discussions

Sustainability and multifunctionality of development of rural areas and agriculture produces advantages both in the area of resources, primarily those originating from the natural environment, and in the field of management effects and consequent population earnings.

Productivity of a production system means a technical interdependence of input and output streams, expressed as the Y/X quotient. In this paper, output (Y) is taken as the value of final production, expressed in monetary units, while input (X) means: the area of arable land; replacement value of machine park; human resources; and the total value of material investments.

Across the studied agricultural establishments, average productivity of material investments was at 2 (Figure 1). The above means that the value of the product for which material investments worth 1 PLN were used amounted to 2 PLN on average.

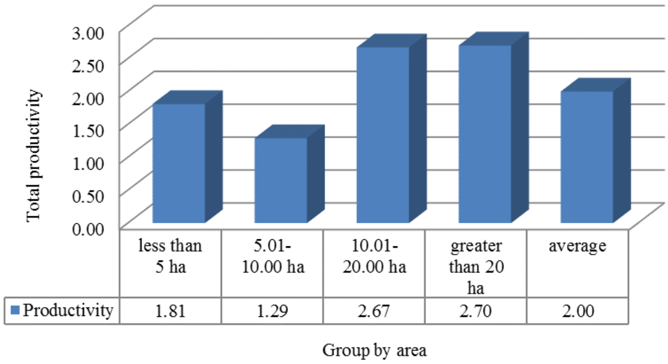


Fig. 1. Total productivity.

Within the selected area groups, this productivity value ranged from 1.29 at smaller farms (sized 5.01 to 10.00 ha) to 2.70 at >20 ha farms. The estimated differences were mainly due to the business orientation. Larger and largest farms in terms of size were specializing mainly in production of milk and the productivity of material investments was highest here. The respective values for these groups were 2.67 and 2.70.

Productivity of land is the quantity or value of end production of the farming industry per 1 ha of arable land. The average value achieved across the studied farms was 8 thousand PLN per 1 ha or arable land (Figure 2).

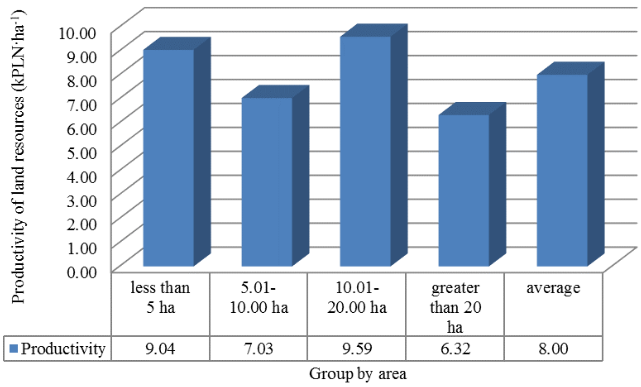


Fig. 2. Productivity of land resources ($kPLN \cdot ha^{-1}$).

In specific size groups, productivity of land at the smallest farms, under 5 ha of arable land, was comparable to that obtained by establishments sized 10.01 to 20.00 ha. The respective values for these groups were 9.04 and 9.59

kPLN·ha^{-1}. Within the remaining size groups, they were definitely smaller, i.e. for the group of 5.01 to 10.00 ha at 7.03 kPLN·ha^{-1}, and for the group over 20 ha: only 6.32 kPLN·ha^{-1}. The results achieved are the consequence of such factors as, inter alia, land use structure, crops structure and yielding. An important factor determining the productivity of organic farming is the quality of land, which translates to types of crops that can be grown on such land and to yields that can be obtained per hectare. Soils in Poland are among the least fertile in Europe; one hectare of Polish arable land corresponds to 0.6 hectare of arable land in the European Union in terms of productive potential (Skłodowski and Bielska, 2009).

Farms with lowest productivity had a high proportion of permanent grassland, while the small areas of arable land were mainly used to grow fodder and grains. As regards the agricultural establishments with highest productivity, arable land prevailed in the land use structure, designed mainly for cereals, root crops and vegetables. Therefore, cereal yields were significantly higher in this case than at the farms with lowest recorded productivity.

Mechanization allows increasing the production scale with limited labour resources. This fosters improvement of production factors efficiency in agriculture. On the other hand, higher efficiency achieved while working with machines generates certain time reserves that can be used for commencing non-agricultural activities, which is consistent with the concept of multifunctional development of agriculture (Belletti et al., 2003).

Productivity of objectified labour resources is defined as the proportion of end production to replacement value of the machine park. On average, 1 PLN invested in engineering means of production would generate production worth 0.23 PLN (Figure 3).

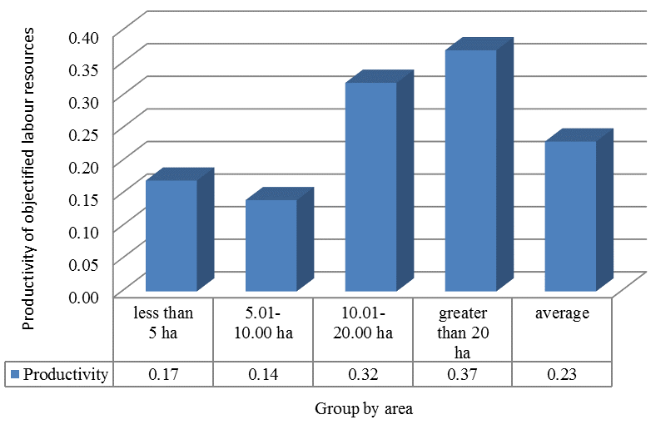
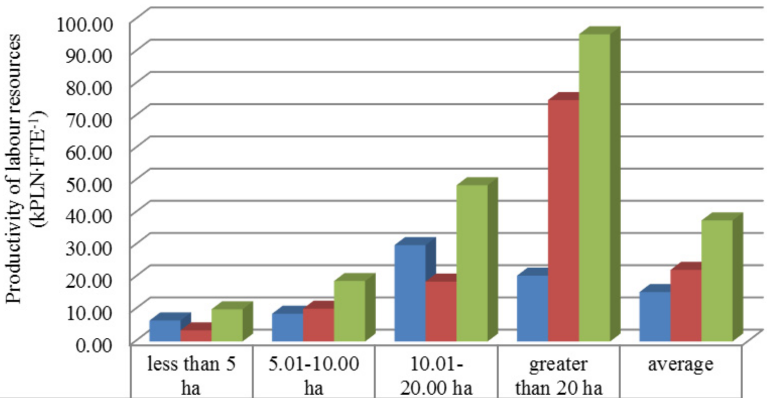


Fig. 3. Productivity of objectified labour resources.

Relatively high availability of technical resources at the smallest and small farms results in low productivity of objectified labour (Tabor and Kmita, 2007). In the <5 ha group, this value was at 0.17, while in the group of farms sized 5.01-10.00 ha it was only 0.14, which may result in lack of economic sustainability and consequently inability to replace the existing machine park. Productivity values are twice as high on average at larger and largest farms. Within the group of farms sized 10.01 to 20.00 ha, productivity of objectified labour was at 0.32, while in the group of +20 ha: as much as 0.37. This clearly indicates the ability of full replacement of objectified labour resources.

Productivity of labour resources, expressed as the quotient of end production and number of full-time equivalents at a farm, is presented on Figure 4. One employed person was generating production worth 37.59 kPLN on average. More than 59% of this productivity was generated by animal production.



	less than 5 ha	5.01-10.00 ha	10.01-20.00 ha	greater than 20 ha	average
Plant production	6.53	8.61	29.91	20.45	15.35
Animal production	3.45	10.18	18.6	74.93	22.24
Total production	9.99	18.78	48.51	95.38	37.59

Fig. 4. Productivity of labour resources (kPLN·FTE^{-1}).

Within the studied groups by area, labour productivity ranged from 9.99 kPLN at the smallest farms to 95.39 kPLN at the largest establishments. There is a demonstrable growing tendency of productivity along with increasing area of arable land. With regard to plant production, highest productivity was recorded at farms sized 10.01 to 20.00 ha, at 29.91 kPLN·FTE^{-1}. This value represented almost 62% of total productivity. Such a high result was affected by good employment structure and crops structure. There were 3 persons employed at farms within this group on average, compared to 4 persons in the remaining area groups. At the same time, these farms were growing vegetables and herbs, among others, which allowed generating high value of production output. On the other hand, the value of animal production per one person fully employed in agriculture was highest at the largest farms, sized over 20 hectares. It was at 74.93 kPLN·FTE^{-1}, which represented almost 79% of total productivity. The result obtained was affected by high level of animal production specialization, oriented towards production of milk, as well as highest density of livestock, at 0.80 LU·ha^{-1}.

Upon the analysis of productivity of a farmer's and his family members' labour, we should conclude that an average farmer in Poland works fewer hours at his farm than he is able to do without the risk of health impairment. It means that the same value of agricultural products could be produced by fewer persons than the current number of workers. Across the studied farms, within the groups of farms sized under 5 ha and from 5.01 to 10.00 ha, employment was not in proportion to the available land resources and objectified labour resources, which resulted in low productivity of labour, the latter significantly limiting the ability to achieve economically sustainable production.

4. Conclusions

The primary measure of competitiveness of farming establishments is their ability to efficiently utilize the production resources, mainly capital, technologies, and human resources. The rate of productivity of agriculture is relatively low in Poland, which is due to the following causes: excessive employment, small areas of arable land, low marketability and low yields of soils. Another factor that strongly reduces productivity is the excessive value of technical equipment, which is practically irreplaceable at smaller farms. This is verified by study results obtained at 50 organic farms.

At the studied farms, average productivity of material investments was at 2, ranging from 1.29 at smaller farms to 2.70 at farms larger than 20 hectares. Thus, the highest productivity value was more than twice as high as the lowest result.

Average productivity of land was 8 thousand PLN per 1 hectare of arable land. Only the subsidies make this productivity higher than the country average (ca. 1.3 $k€·ha^{-1}$), comparable to the productivity achieved at EU-27 where it ranges around 2 $k€·ha^{-1}$ (Eurostat, 2015).

High availability of technical resources at the smallest and small farms results in low productivity of objectified labour, at 0.17 within the group under 5 hectares, and only 0.14 within the 5.01-10.00 ha group. This may lead to lack of economic sustainability and consequently inability to replace the existing machine park. Productivity values are twice as high on average at larger and largest farms, amounting to: 0.32 in the group of farms sized 10.01-20.00 ha, and 0.37 in the group sized over 20 ha. These conditions are adequate for full replacement of objectified labour resources.

Productivity of farmer's and his family's labour is a consequence of the production processes. This value was 37.59 kPLN per one full-time equivalent on average. In this case, productivity is also higher than the country average, which is ca. 8.6 k€ per one person employed in agriculture, yet significantly lower than the EU-27 average where it ranges around 29.5 k€ per one person employed in agriculture (Eurostat, 2015). In addition to low efficiency of land, the causes of low productivity of labour also include excessive employment, particularly prevalent at small farms.

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Agriculture and Agricultural Science Procedia 7 (2015) 165 – 169

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

The use of an active substance depending on the application method of plant protection products: seed dressing versus foliar treatment

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Abstract

The study into the use of an active substance per hectare was performed to examine three matches of seed dressing fungicides in comparison to foliar applications registered in Poland to protect crops against the same diseases. In each analysed case, the application of an active substance was lower in the case of seed dressing. In the highest instance, an over 34-fold difference was noted in the case of the protection of spring barley against barley net blotch with tebuconazole fungicides.
Therefore, in light of integrated pest management requirements concerning the reduction of pesticide use, when the probability of an occurrence of harmful organisms is high and the possibility to replace application methods does exist, the use of seed dressings should be recommended.

Keywords: plant protection product; seed dressing; foliar treatment.

1. Introduction

Use of chemical plant protection products in agriculture gives rise to numerous questions and studies regarding their overall safety Śmiechowska and Florek (2011) and residues Łozowicka (2015), Łozowicka et al (2013), Szpyrka and Walorczyk (2013), Walorczyk et al (2014). Non chemical methods of pest control sometimes achieve

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doi:10.1016/j.aaspro.2015.12.012

relatively good results Hurej et al 2013, Matyjaszczyk (2013), Matyjaszczyk (2015), Tratwal and Bocianowski (2014), Tratwal and Walczak (2010), Wojciechowski et al (2013). However, the chemical pest control is commonly used in agriculture as it ensures a stable yield.

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).

In the literature, the information can be found that application of plant protection products in the form of seed dressings allows for the reduction of the amount of an active substance per hectare Taylor and Harman (2003), Stevens (2002), Paulsrud et al (2001) or application cost Wachowiak and Kierzek (2009). How significant is reduction of the amount of active substance? It is difficult to find examples which support this viewpoint.

The aim of this paper is to answer the following question: How does the use of seed dressings fit into the requirements of integrated pest management in terms of applied doses of plant protection products in comparison to foliar treatment?

2. Material and Methods

Research into the Polish register of plant protection products in June 2015 was carried out. The study was performed using fungicides registered for major crops' protection. Fungicides were selected because there are comparatively few insecticides on the market, and obviously there are no herbicidal seed dressings.

The objective of the research was to find matches of registered seed dressings and products for foliar application containing the same active substances and registered to control the same pests in the same crops.

In spite of only analysing the Polish register, it appears to be the case that the study results are relevant for most EU countries, (as well as other countries that share a similar climatic zone) because the active substances as well as the products, are both registered throughout the EU and also outside of the EU, although the recommended doses for foliar application may differ slightly, and the trade names may differ significantly.

To calculate the amount of an active substance per hectare it was estimated that the foliar products as well as seed dressing were applied according to the maximum recommended dosage. The maximum recommended sowing rate (250 kg of grains/ha) was followed in the case of seed dressings.

3. Results

During the research it was noted that the occurrence of seed dressings and foliar application preparations which contain identical active substances for the protection of the same crop were not uncommon. As the harmfulness of pests depends crucially on the growth stage of the crop its worth stressing that seed dressings and foliar treatments are applied in different growth stages of the crop. In the course of the research it became evident that few matches: foliar product/ seed dressing are registered to control the same pests.

As a result of the research, three matches were identified (the details are presented in Table 1). The active substances of the products in question belong to either groups of triazoles or imidazoles:

- Control of foot rot (harmful organism *Fusarium* Spp.) in winter wheat, with one seed dressing and one product for foliar treatment on the market, containing two active substances: fluquinconazole and prochloraz.
- Control of barley net blotch (harmful organism *Pyrenophora teres*) in spring barley with tebuconazole fungicides. There are two different products for foliar treatment: one in the formulation SC (suspension concentrate) and the second in the formulation EW (emulsion oil in water). There is one seed dressing on the market. The foliar products are registered under a number of trade names listed in Table 1.
- Control of barley net blotch (harmful organism *Pyrenophora teres*) in winter barley with one seed dressing and one product for foliar treatment on the market, containing two active substances: prothioconazole and tebuconazole.

The calculation of maximal recommended doses leads to the conclusion that in each case the consumption of the active substance was significantly higher in the case of foliar treatment, as illustrated in Figures 1, 2 and 3. In the first case of winter wheat protection (Figure 1), the use of fluquinconazole is more than one and a half times higher, whereas the use of prochloraz stands at approximately four times higher than in the case of using seed dressing. In the second case of protection of spring barley against barley net blotch (Figure 2), the difference in the use of tebuconazole is (depending on the foliar product) over 33-34 times higher (!) for foliar treatment. In the third case concerned with the protection of winter barley (Figure 3), the foliar use of tebuconazole is over 12 times higher and the use of prothioconazole is 10 times higher when compared to seed dressing.

Table 1. Comparison of matches of foliar fungicides and seed dressings containing the same active substances, registered in Poland in June 2015.

Fungicide	Target use	Active substance	Application rate/ha	Consumption of a.s./ha
Vista 228 SE	Winter wheat – *Fusarium* spp.	fluquinconazole – 174 g/l prochloraz – 54 g/l	1,8 l/ha	313,2 g/ha fluquinconazole 97,2 g/ha prochloraz
Jockey New 113 FS		fluquinconazole – 100 g/l procloraz – 13,3 g/l	750 ml/100 kg seeds	187,5 g/ha fluquinconazole 24,9 g/ha prochloraz
Bounty 430 SC Speekfree 430 SC	Spring barley – *Pyrenophora teres*	tebuconazole – 430 g/ls	0,6 l/ha	258 g/ha
Darcos 250 EW, Erasmus 250 EW, Helicur 250 EW, Toledo 250 EW, Tebu 250 EW, Troja 250 EW, Syrius 250 EW, Syrius Extra 250 EW, Sparta 250 EW		tebuconazole – 250 g/l	1 l/ha	250 g/ha
Zaprawa Zbożowa Orius 060 FS		tebuconazole - 60 g/l	50 ml/100 kg seeds	7,5 g/ha
Prosaro 250 EC	Winter barley – *Pyrenophora teres*	protioconazole - 125g/l tebuconazole – 125 g/l	0,75 – 1 l/ha	93,75 – 125 g/ha protioconazole 93,75 – 125 g/ha tebuconazole
Lamardor 400 FS		protioconazole – 250 g/l tebuconazole – 150 g/l	20 ml / 100 kg seeds	12,5 g/ha protioconazole 7,5 g/ha tebuconazole

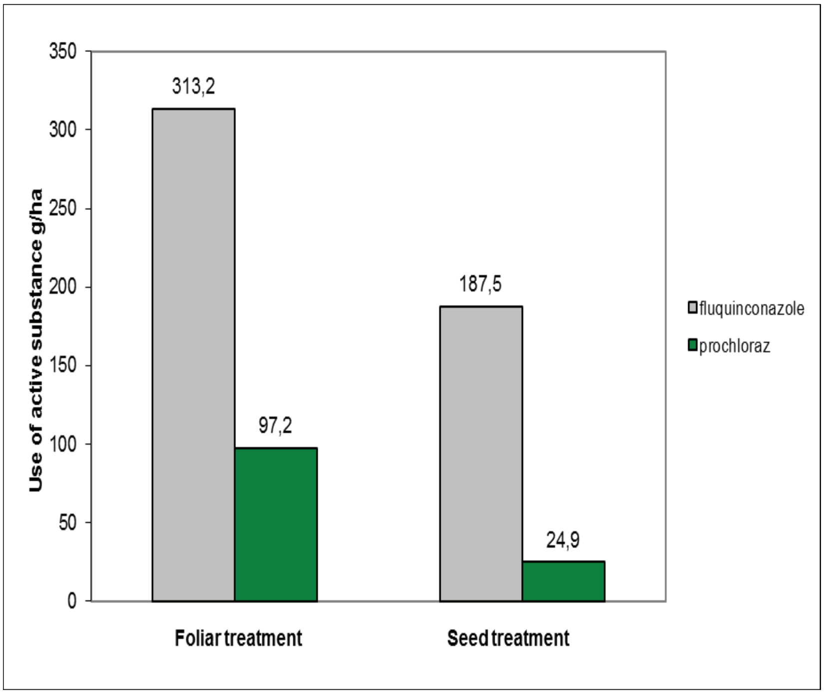

Fig. 1. Influence of application method on the use of active substance in protection of winter wheat against foot rot (harmful organism *Fusarium* Spp.)

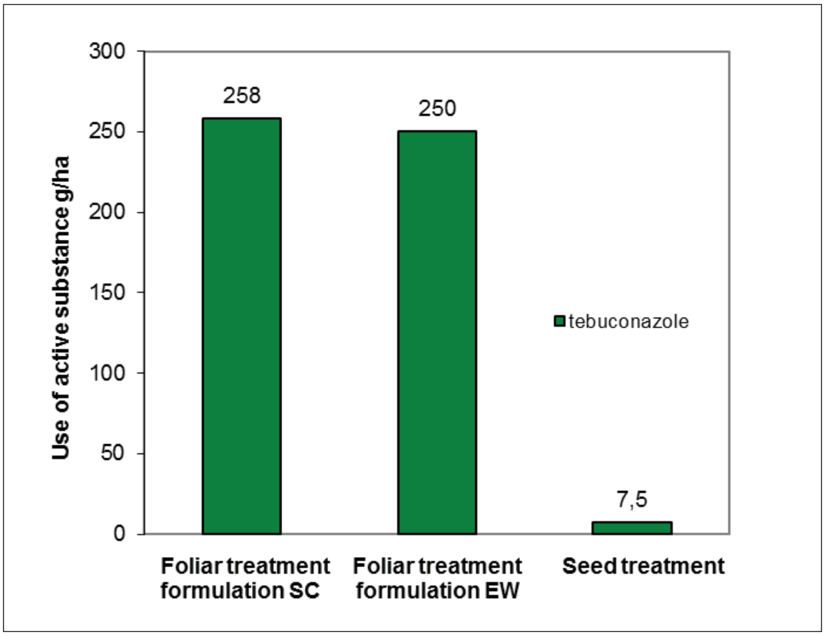

Fig. 2. Influence of application method on the use of active substance in protection of spring barley against barley net blotch (harmful organism *Pyrenophora teres*)

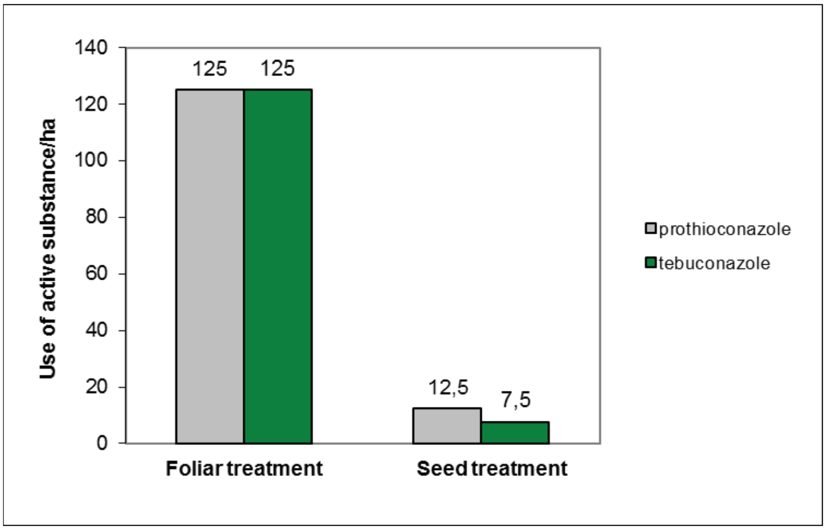

Fig. 3. Influence of application method on the use of active substance in protection of winter barley against barley net blotch (harmful organism *Pyrenophora teres*)

4. Conclusion

The data collected confirm the statement commonly presented in the literature that the environmental burden connected with the amount of an active substance used, is indeed lower in the case of seed dressings, when compared to foliar treatments.

The difference depends on the particular active substance and use. In the studied examples, the lowest difference (1.6 fold for fluquinconazole and 4 fold for prochloraz) was noted in the case of protection of winter wheat against foot rot. The most significant difference was an over 34 times higher use of tebuconazole which was noted in the protection of spring barley against barley net blotch.

It can be concluded from the study that indeed, in the case of the fungicide seed dressings, the active substance is used in lower amounts than in the case of foliar treatments. Sometimes the difference is surprisingly high. As such, the use of seed dressing fits well into integrated pest management requirements. On account of differing reasons, it is of course not always possible to replace foliar treatment with seed dressing. However, when the probability of harmful organisms' occurrence is high and the possibility to replace application methods does exist, the use of seed dressings should be recommended.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Mechanization costs in Walloon livestock farms

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Abstract

Accountings data from 255 livestock farms have been analyzed in order to determinate their mechanization cost. A weighted average value of each part of this cost has been calculated after a classification of the inquired farms. This classification is based on the technical orientation, the size and finally the localization of the farm. The weighing factor depends on the relative importance of each group at the regional level and was determined through the national statistical data.
Major differences appear between farms specialized in milk or beef meat production. With more than 750 €/ha, dairy farms need more mechanization than 'beef meat' farms which only spend 440 €/ha in average in 2013. The use of external mechanization, mainly through contractor's works, is quite important and represents between 30 and 34% of the total mechanization expenses.
We notice that dairy farms with higher gross margin require also higher mechanization costs. In situation of low milk price, the limit where higher mechanization costs are not compensated by higher gross margin is almost achieved. For 'meat beef' farms higher mechanization costs are not compensated by higher gross margin. The management of these two kinds of production must be clearly different.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: mechanization; costs ; accountancy ; livestock.

1. Introduction

In order to increase their competitiveness, farmers have to keep their operative costs under control. Among these, mechanization costs are relatively important and represent around 29% of the production cost in dairy farms (Reuillon et al, 2008). In the Walloon region we often ear that our farms suffer from 'over' mechanization. Nevertheless, it is

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.013

difficult to find objective mean values and to clearly identify parameters influencing the individual values. For these reasons, accountings data of almost 255 livestock farms from our network have been analyzed for the years 2008 to 2013. Our accountancy farm network is the base of the regional contribution to the Farm Accountancy Data Network (FADN) of the EU (Direction de l'Analyse économique agricole, 2015).

2. Material and Method

The data related to mechanization extracted from our accountings arise under various components.

A list of the machines is drawn up with the agricultural machinery, the milking equipment, the tools, the storage tanks, and some major repairs on this equipment. This list indicates the purchase (or sale) price and date, the information on the state at the acquisition (new or second hand), the type of machine (tractor, plough, etc.). For each machine a rate of depreciation is fixed and used to determine the annual depreciation, calculated on the replacement value. Interests on the capital are also determined as well as a replacement value. Other more general data are also registered. It includes insurances, fuel and repair or maintenance costs. The latter are simply broken down between the tractors, the milking equipment and the other machines.

The machine rental and the expenses for machines cooperatives are indicated as a global amount. The costs of contractor's works are allocated at the concerned crops or livestock.

This analysis is made in two steps:

- the research of correlation between costs and characteristics of the farms directly from the observed data,
- the determination of the weighted average mechanization costs following some farm characteristics.

Three levels of classification have been taken into account to obtain homogeneous groups of exploitations in which a detailed analysis can be conducted: the technical orientation, the size and the agricultural area in which it stands. Indeed, according to the technical orientation and to the size of the farm, the investments in equipment will be more or less important. In the same way, according the location, differences of working methods exist. Concerning the type of farm, we only focus on three technical specializations:

- the dairy farms whose main product arises out of milk production,
- the "beef meat" farms whose main product arises out of beef meat production,
- the "cattle" farms producing milk and meat, in which a double herd is very often bred.

In order to have a more homogeneous sample, farms having agricultural contractor's activities, agro-tourism, pig breeding or poultry have been eliminated from our observations.

The farm's dimension is expressed through its standard output (SO). This value represents the expected products from the farm, depending on its various productions and their relative importance. For a given specialization, this value is thus primarily connected to farm size (area or livestock). Four size classes are considered according to table 1. Small holdings having a standard output smaller than 25 000 € are not taken into account.

Finally, the third level of classification of our exploitations is the agricultural area. We distinguish three major 'areas' in Wallonia:

- the 'crop' area including the agricultural regions 'limoneuse and sablo-limoneuse' where the highest percentage of field crops (cereals, beets, potatoes,…) is found,
- the 'grass' area including the agricultural areas : 'herbagère Liégeoise, Fagne, Famenne, Ardennes, Haute Ardenne and Jurassique'. The breeding with milk and/or meat production is prevailing there,
- the 'Condroz' which is a mixed area.

Table 1. Limits of the size classes of the farms.

Size group	Standard Output min (€)	Standard Output max (€)
1	25 000	100 000
2	100 000	250 000
3	250 000	500 000
4	500 000	/

By combining the three orientations, the four sizes and the three localizations, 36 groups are obtained. For each one, the components of the mechanization costs have been calculated. As few observations exist for holdings of dimension 4, values from farms of dimension 3 have generally been used. Then, for each technical orientation a weighted average of these expenses have been calculated. Weighting is carried out according to the relative surface importance of each category defined by the class of size and the localization. This information are available at the General Direction of Statistics (SPF Economie). By this weighting method, we compensate the variations of representativeness of the groups within our sample.

3. Results

The mechanization costs of livestock farms are related to their size, but their evolution depends on the farm specialization (Fig. 1). A standard output increase of 100 000 € results in higher mechanization costs from 17 500€ to 18 000 € and 19 000 € for respectively ‘cattle’, ‘beef meat’ and dairy farms. Wide variations can also be noted within each group.

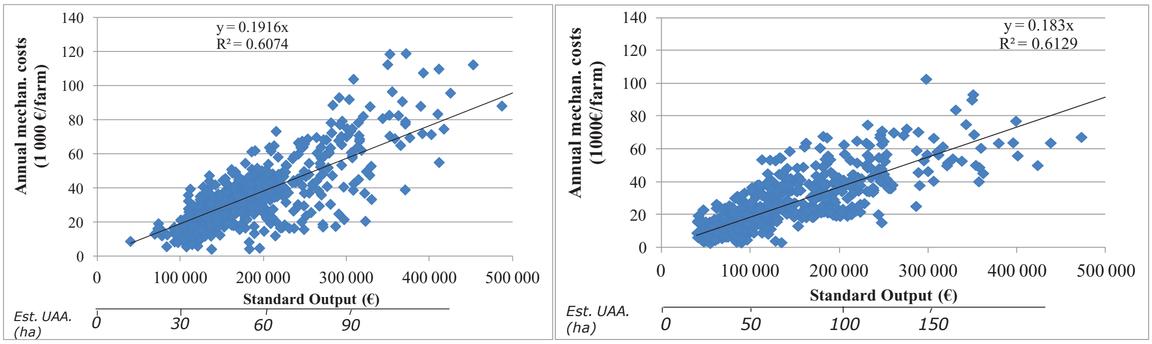

Fig. 1. Evolution of the mechanization costs related to farm size (left : example of dairy farms and right : example of ‘beef meat’ farms– year 2008 to 2013)

If the total annual cost is an interesting information, it is necessary to express this amount by a size characteristic (area, production, etc.) in order to compare the farms.

The mechanization costs of the dairy farms exceed 700 €/ha since 2012 (Fig. 2). They increase continuously as well for their own machines as for the external mechanization (contractors, cooperatives, etc.). The milking equipment represents an annual cost of about 60 €/ha and approximately 54 € per dairy cow.

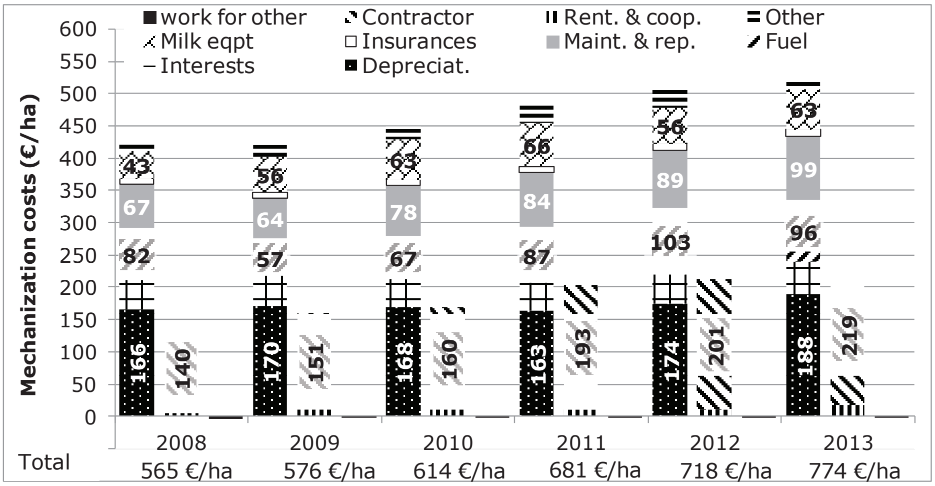

Fig. 2. Detail of the mechanization costs for the dairy farms (weighted means).

The expenses for mechanization in the "beef meat" farms are lower and reach a level of 440 €/ha in 2013 (Fig. 3). For the 'cattle' farms, the situation is intermediate with a value of 575 €/ha (Fig. 4).

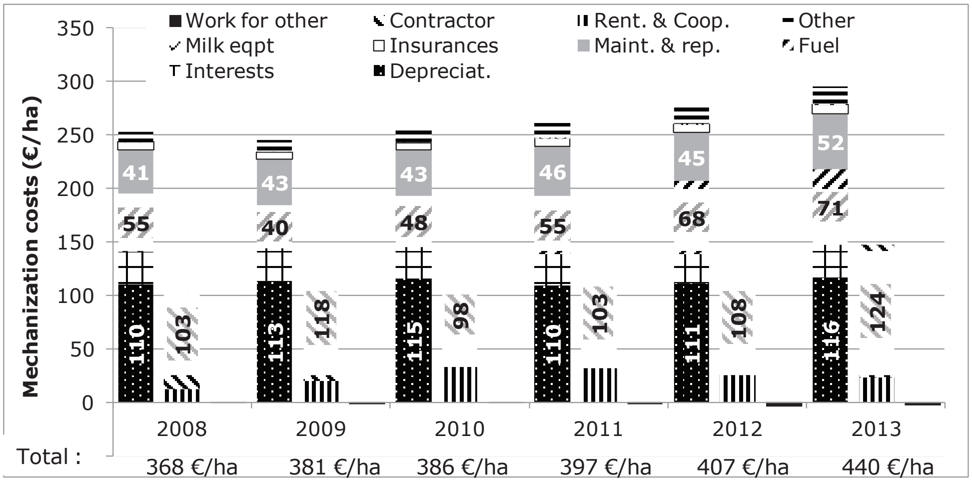

Fig. 3. Detail of the mechanization costs for the "beef meat" farms (weighted means).

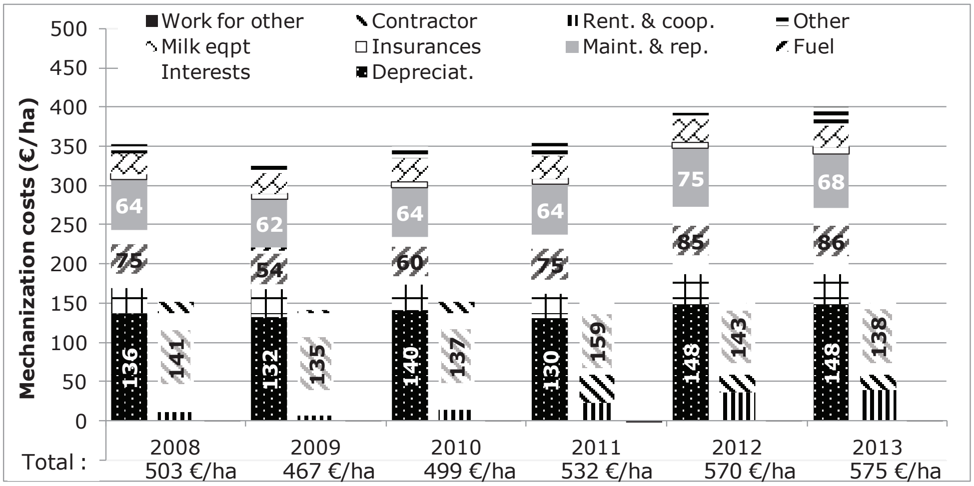

Fig. 4. Detail of the mechanization costs for the "cattle" farms (weighted means).

For the three kinds of farms, the use of external mechanization, mainly through contractor's works, is quite important and represents between 30 and 34% of the total mechanization expenses.

The fuel consumption of the farm machines depends on the farm specialization (Table 2). Dairy farms have a higher fuel consumption ranging between 120-130 l/ha comparatively to 'beef meat' farms with less than 90 l/ha. The evolution of the fuel expenses through the years is directly related to the fuel price, the consumption per ha is quite constant.

It is important to note that, these last years, the variable costs (fuel and maintenance) exceed the depreciation amount. Higher investments for reliable and fuel efficient machines can be economically worthwhile. The average investment amounts range between 1 500 and 3 300 €/ha following the technical orientation of the farm (Table 2).

Table 2. Comparisons of technical and economical characteristics between livestock farms following their specialization.

		Farm specialization		
		dairy	'beef meat'	'cattle'
Average size (UAA)	ha	53-59	53-56	68-78
Mechan. Costs (2011-2013)	€/year	42 500	23 000	41 000
Spec milk eqpt	€/year	3 000 – 3 800	/	1 500 – 2 500
Invest. amount	€/ha	2 800 - 3 300	1 550 – 1 900	2 200 – 2 400
Fuel consumption	l/ha	120-130	75-90	105-120

On average, it can be noted that, for each specialization, when sorting the livestock farms by their mechanization costs, those having the lowest costs are also those having the weakest gross margin of the livestock and fodder crops (Fig. 5). On the contrary, good gross margin, generally related with intensive breeding (LSU/ha), results in higher mechanization costs. Nevertheless, there is a great difference in the evolution following the breeding specialization. For the dairy and cattle farms, the increase of the gross margin compensates more than the rising of mechanization costs. We quantify this by the coefficient 'Z' which is the ratio: increase of mechanization costs by 100 € of gross margin increase. For the 'meat beef' holdings, the increase of gross margin is insufficient to compensate the higher mechanization costs.

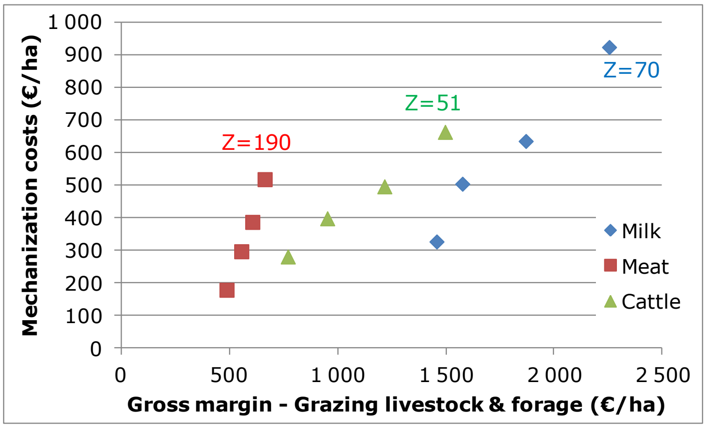

Fig. 5. Relation between mechanization costs level and gross margin of grazing livestock & forage for the different livestock farms (Z = increase of mechanization costs for 100 € gross margin increase).

For the dairy farms, the impact of the economic situation is analyzed by comparison between the years 2009 with a milk price around 0.23 €/l (1) and 2013, with a price around 0.36 €/l (Fig. 6). If we compare these two years, we note that the gross margins are naturally lower for the year 2009 and the limit where higher mechanization costs are not compensated by higher gross margin (Z = 89) is almost achieved. This situation is quite logical as mechanization can't be reduced so quickly and easily. So the mechanization costs remain quite constant but the gross margin is more affected for high level production farms when the production prices decrease.

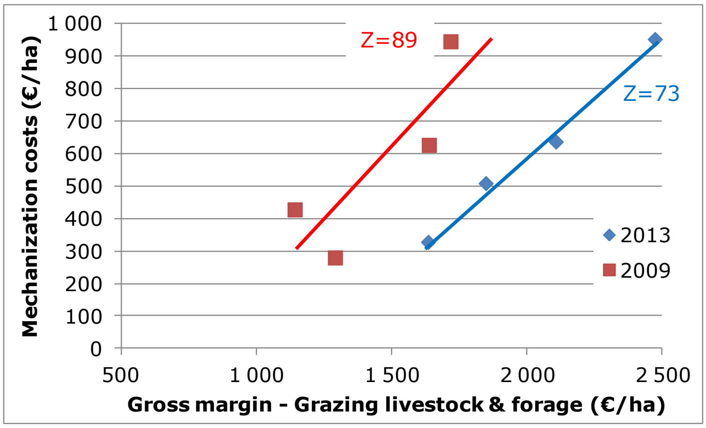

Fig. 6. Comparison of the relation mechanization costs – gross margin for dairy farms in different economic conditions (milk price : 2009 ≈ 0.23 € /l – 2013 ≈ 0.36 € /l)

Finally, for dairy and meat beef farms, conventional and organic production modes have been compared. For the meat production, the difference in mechanization costs is low but the gross margin is lower for organic farms. For dairy farms, mechanization costs are about 100 €/ha higher for conventional farms but these achieve also a higher gross margin of about 225 €/ha.

Table 3. Comparison of mechanization costs between conventional and organic farms for milk or meat production (data 2008-2013).

	Milk		Meat	
	Conv. (n=407)	Org. (n=39)	Conv. (n=430)	Org. (n=82)
UAA (ha)	63	62	79	82
LSU/ha	2.34	1.53	1.69	1.14
Mecha. costs (€/ha)	584	479	341	326
Gross margin (graz. livest. - €/ha)	1 774	1 549	576	397

4. Discussion

The analysis of the mechanization costs show differences between the various breeding specializations. With more than 750 €/ha, the dairy farms register the highest expenses. On the opposite the ‘beef meat’ farms with 440 €/ha have the lowest value. These costs must be compared with the expected gross margin of these activities. During the study period, the milk production generated higher gross margin than the meat production.

Within each specialization and for a given farm size, great variations exist. For the different technical orientations, those having the highest gross margins have also higher mechanization costs. In the case of dairy and cattle farms, the increase in gross margin compensates the rising in mechanization costs. This is not the case for meat production. For the dairy farms, a comparison between a bad and good year on the economical point of view has been tried. Despite of the paucity of observations, it seems that when economic situation becomes harder it is more and more difficult to compensate higher mechanization costs through an increase in gross margin.

Use of ‘external’ mechanization, generally provided by agricultural contractors, is quite common in our region where it represents about one-third of the annual mechanization costs. However, it must be mentioned that this amount also includes labour costs as there is a driver with the machine.

The analysis of the components of the costs shows that the variable costs (fuel and maintenance) are higher than the depreciation costs. When buying a new machine, the farmer has to keep this in mind.

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Agriculture and Agricultural Science Procedia 7 (2015) 177 – 183

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Evaluation of the efficiency of celeriac fertilization with the use of slow-acting fertilizers

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Abstract

The goal of this work was to determine the applicability of slow-acting fertilizers in optimization of the effectiveness of celeriac production under conditions of integrated plant production. The goal was realized by performing a strict experiment. Celeriac (Diamant cultivar) was the test plant. A controlled-release fertilizer was used for fertilization; its NPK composition (%) was 18-05-10+4CaO+2MgO. Moreover, conventional fertilizers of ammonium nitrate, granular triple superphosphate and potassium salt were used. Based on the results of the conducted experiments, indices that reflect the efficiency of nitrogen fertilization (agronomic effectiveness, productivity coefficient, and physiological effectiveness) were calculated. The yield of plants in the control treatment amounted to 32.1 Mg · ha^{-1}. The highest yield (49.73 Mg · ha^{-1}) was obtained in the treatment with the addition of 400 kg of the slow-acting fertilizer and full doses of phosphorus and potassium. The most optimal values of the indices of fertilization effectiveness were obtained in the treatments where 400 and 500 kg · ha^{-1} of the slow-acting fertilizer had been added. Calculated indices of fertilization efficiency indicate that, in relation to integrated methods of production with the use of conventional fertilizers, fertilization optimization with the use of slow-acting fertilizers may improve fertilization efficiency.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

*Keywords:*integrated production; the effectivensess of fertilization; sustainable fertilization; slow-acting fertilizer, celeriac.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.014

1. Introduction

Plant production in the integrated system forces producers to use techniques which will help to reduce the use of production means and at the same time maintain high productivity and obtain good quality yield. Taking environmental and health aspects into account in plant production, particularly in production of vegetables, requires usage of precise techniques connected with plant protection and fertilization. Results of numerous scientific research studies point to the unambiguous positive effect of implementation of integrated plant protection on the quality of products and on the reduction of the negative impact of farming on the environment (Danis et al., 2011; Shahpoury et al., 2013). Plant fertilization is associated with introducing to the soil ecosystem considerable amounts of components that can create disequilibrium in this ecosystem. Among the negative aspects of fertilization, the most commonly named are: soil acidification, disturbance of equilibrium between elements available for plants, or decreasing amount of organic matter. Fertilizer components introduced into soil and unused by plants can disperse in the environment, which leads to an increase in emission of greenhouse gases or intensification of water eutrophication processes (Oenema et al., 2009; He et al., 2011; Wu et al. 2015, Ma et al. 2015). Therefore, increasing the fertilization effectiveness has strategic importance in limiting the impact of farming on the natural environment. A strategic element of the integrated production system is to use the smallest amounts of pesticides; but these amounts must ensure crop protection at the threshold of production harmfulness. In the first instance, biological and agricultural engineering methods should be used in order to protect crops (Directive, 2009). Using the knowledge on the widely understood biological protection of crops with the use of agricultural engineering methods or methods associated with formation of specific biocenoses of natural enemies of pests, one can obtain production results as in the case of conventional protection (Perdikis et al., 2011; Tuomisto 2012). The most important problem connected with implementation of integrated production is that producers have too little knowledge on alternative ways to fight pests and on the possibility to increase the fertilization effectiveness by changing the range of fertilizer products and by optimizing the technology of fertilizer application (Morris and Winter, 1999; Mucheru-Muna, 2010). Fertilization plays key role in plant production because it influences the yield quantity and quality. It also modifies physical, biological, and physicochemical properties of soil, affects the quality of surface waters, underground waters, and of atmosphere. From the producer's point of view, fertilization is an important factor that shapes production costs (Pypers et al., 2011). Due to insufficient knowledge on physiological and climatic aspects of plant nutrition, producers are reluctant to use modern fertilization technologies, fearing that their yields might decrease (Deike et al., 2008). A rational policy on supplies of plant nutrients is very difficult due to the fact that the nutrient uptake by plants and processes of nutrient dispersion in individual parts of the environment are associated with the type of cultivation, climate, and also with the widely understood agricultural engineering. However, a number of researchers of this problem point to the possibility of improving the utilization of fertilizer components by several percent, even by making small changes to fertilization technology (Oenema et al., 2009; He et al., 2011; Jin et al., 2012). That is why it is important to conduct studies concerned with creation of technologies that use the latest scientific achievements and their implementation into agricultural practice (Li, 2011). Carlsson et al. (2007) draw attention to the necessity to organize campaigns encouraging the farmers to use production technologies that reduce the negative effects on the environment. These authors draw attention to the economic advantages of reducing the use of mineral fertilizers and to the fact that producers start to feel that their actions protect the environment. Shaping awareness among consumers who more and more often reach for products with the logo of integrated production is the reason why this system is gaining more and more trust among consumers.

The goal of the carried out research was to determine the applicability of slow-acting fertilizers in optimization of the effectiveness of celeriac production under conditions of integrated production. The efficiency of nitrogen fertilization was evaluated based on indices of fertilization efficiency such as: agronomic effectiveness, physiological effectiveness, and productivity coefficient (IFA. 2007).

2. Objective, data and methodology

The experiment was set up on soil with the granulometric composition of medium loam. Pickling cucumbers were the forecrop for the studied crops. In autumn 2011, organic fertilization (mixed manure) in the amount of 35 $Mg \cdot ha^{-1}$ was applied. Mineral fertilizers in full dose (which is characteristic for intensive cultivations) were used in the cucumber cultivation. Celeriac (Apiumgraveolens var. rapaceum) of Diamant F1 cultivar was the test plant. The experiment was set up on 2 May 2012. The plants were harvested on 29 October 2012. The plants were cultivated at

50 × 30 cm spacing, from seedlings prepared in multi-cell trays (VEFI system). Varied fertilization was the factor of the experiment. Cultivation and protection of the plants were carried out based on the methodology of integrated production. Owing to the fact that the Main Inspectorate of Plant Health and Seed Inspection had not developed the methodology of integrated production of celeriac, the system of production was elaborated basing on framework principles for integrated plant production. Celeriac is a plant with great nutritional, soil and water requirements. Therefore, the experiment was located on a soil with properties meeting the requirements of this plant, and the crops were irrigated up to the optimum moisture content in order to eliminate the impact of water stress on the result of the experiment. Prior to setting up the experiment, analyses of physicochemical and chemical properties of the soil on which the experiment was set up had been conducted (Tab. 1). The following were used in the experiment: a controlled release fertilizer (with NPK composition (%) of 18-05-10+4CaO+2MgO), ammonium nitrate, triple superphosphate, and potassium salt 60%. The experiment comprised 9 levels of fertilization based on the principles of integrated plant production, the control treatment without fertilization, and the treatment fertilized in the conventional manner in an intensive cultivation of celeriac in the region where the research was being carried out. The controlled release fertilizer was applied pointwise under each plant during planting. Phosphatic and potassium fertilizers were applied in their entirety prior to sowing, whereas ammonium nitrate was divided into 3 doses: 50% of the dose was applied prior to planting and 40% after planting with splitting into two topdressing doses. The date for topdressing was selected based on the observations of meteorological conditions and monitoring of the condition of the plants. The first topdressing dose was applied in the 2nd half of June, whereas the second dose in mid-August. The scheme of the experiment is presented in Table 2. The value of the studied parameters compared between themselves with the use of Tukey's test. The difference between value of the parameters was evaluated at a significance level of p=0.01.

Table 1. Selected properties of the soil used for experiments

pH in H_2O	pH inKCl	[%]		[mg · kg^{-1}]				
		N tot.	C org.	N min.	P	K	Mg	Ca
7.01	6.65	0.324	4.69	347	147.8	478.5	212.5	1240

Table 2. Experiment design

Object number	Fertilizer quantity				Component dose		
	Slow acting fertilizer NPKCaMg (18-05-10-4-2)	Ammonium nitrate	Triple superphosphate	Potassium salt	N	P_2O_5	K_2O
	[kg · ha^{-1}]				[kg · ha^{-1}]		
Control	0	-	-	-	-	-	-
1	200	-	87	163	36	50	120
2	400	-	65	122	72	50	120
3	500	-	54	108	90	50	120
4	600	-	43	90	108	50	120
5	800	-	21	53	144	50	120
6	200	218	87	163	130	50	120
7	300	165	76	145	130	50	120
8	400	112	65	127	130	50	120
9	-	441	244	325	150	112	195
10	-	588	326	433	200	150	260

3. Results

The size of agricultural production is influenced at various degrees by soil properties, availability of water in individual vegetation periods, and by shaping of weather conditions (Nendel, 2009; Sun et al., 2012). Proper approach to agricultural production should be to take the decision on fertilization, plant protection or agricultural engineering based on the results of plantation monitoring. It is difficult to work out and unify the principles of integrated production due to the variability of soil conditions in space, different climatic conditions in individual years. Since the effectiveness of the widely understood agricultural engineering depends greatly on temperature and water availability, cultivation technologies should be developed. These technologies should be based on a comprehensive analysis of atmospheric and soil conditions, but they should not require the use of costly equipment or specialistic knowledge. In the integrated plant cultivation all doses of organic and mineral fertilizers are established based on nutrient requirements of plants, the expected yield, soil type, soil richness in nutrients, and on the position in crop rotation. Special attention should be drawn to the use of organic fertilizers as the basic source of humus and nutrients for plants (Oenen, 2009).

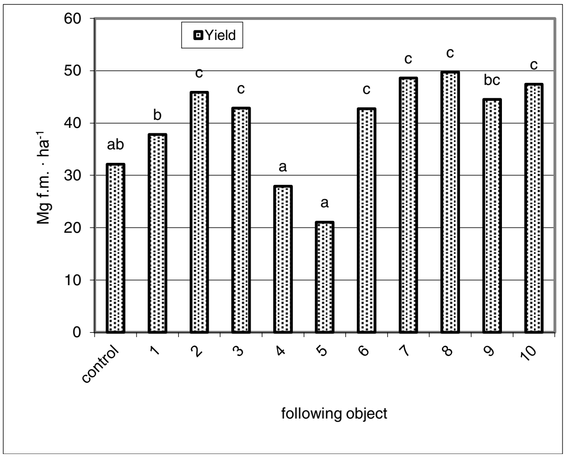

Fig. 1. The yield of celeriac in the successive objects of experiment

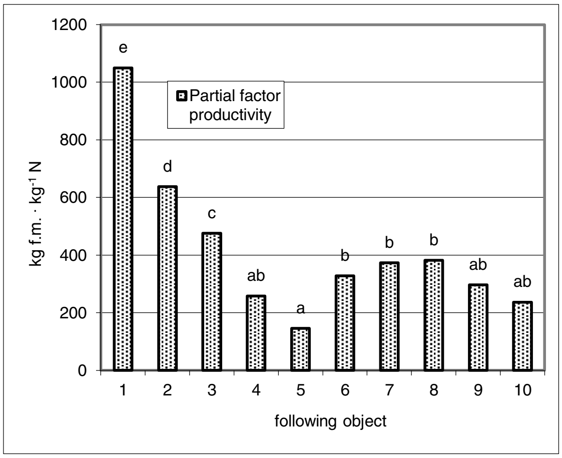

Fig. 2. The values of partial factor productivity in the successive variants of fertilization

Root yield in the control treatment in the conducted experiment was at the level of 32.14 Mg · ha^{-1} (Fig. 1). Due to the organic fertilization applied in the previous autumn and substantial soil richness in nutrients, no strong reaction of the plants on the applied fertilization was observed. Fertilization with 200 kg of the slow-acting fertilizer and with full doses of phosphorus and potassium increased yielding by more than 5 Mg. The highest root fresh matter yield (49.72 Mg · ha^{-1}) was obtained in the variant of fertilization that combined fertilization with conventional and slow-acting fertilizers, all in compliance with the principles of integrated production. Increasing the dose of the slow-acting fertilizer (applied under the root) to certain extent caused an increase in plant yielding. A positive yield-forming effect was observed in the treatments where 200 and 400 kg of the slow-acting fertilizer was applied under plant roots. Further increasing the fertilizer dose resulted in decreasing the level of plant yielding. Partial factor productivity determines the size of yield obtained after application of 1 kg fertilizer component. It is the simplest indicator of production effectiveness, but does not cover the issue of ecological aspects of agricultural production(Aulakh et al., 2012). Values of this parameter in the authors' own research ranged between 146 kg · kg^{-1} roots and 1049 kg · kg^{-1} roots (Fig. 2). In terms of dry matter, these values are between 19.35 and 151.76 kg · kg^{-1} roots. The lowest value of this parameter was found in the treatments with the largest nitrogen dose, both in the case of using slow-acting fertilizers and conventional ones. The highest value of the partial factor productivity was observed when the smallest dose of the slow-acting fertilizer was applied. Increasing the slow-acting fertilizer doses successively decreased the value of this parameter. Increasing the nitrogen dose in the form of slow-acting fertilizers did not influence the proportional increase of biomass production. In the case of combined fertilization, smaller differences were observed. Niemiec(2014) obtained similar results after application of slow-acting fertilizers in cultivation of Chinese cabbage. This author determined that the value of the partial factor productivity in cultivation of Chinese cabbage ranged between 650 and 1825 kg · kg^{-1}. Dua et al., (2011) give values of this parameter in potato production between 111 and 428 kg · kg^{-1}, whereas Larena et al. (2011) – approximately 200 kg · kg^{-1}. These authors draw attention to a significant relationship between the level of fertilization of environmental factors and the value of the productivity coefficient. Cassman et al., (2002) point to a significant relationship between the amount of applied nitrogen fertilization and the value of the productivity coefficient. In systems with low fertilization the value of this coefficient is usually high. It is not, however, indicative of great efficiency of the fertilization. When assessing the productivity coefficient you must always take into account the production capacities of a cultivated plant in specific soil and climatic conditions. According to data provided by (IFA, 2007), the mean value of this parameter in conventional agriculture fluctuates from 40 to 80 kg · kg^{-1} in terms of dry matter. Values above 60 can be found in well managed systems, at a low nitrogen content in soil. In the authors' own research, the value of the partial factor productivity in treatments fertilized in the conventional system amounted to approximately 50 kg · kg^{-1}. The best production effect under conditions of the experiment was reached at a dose of the slow-acting fertilizer in the amount of 400 kg and at full doses of phosphorus and potassium.

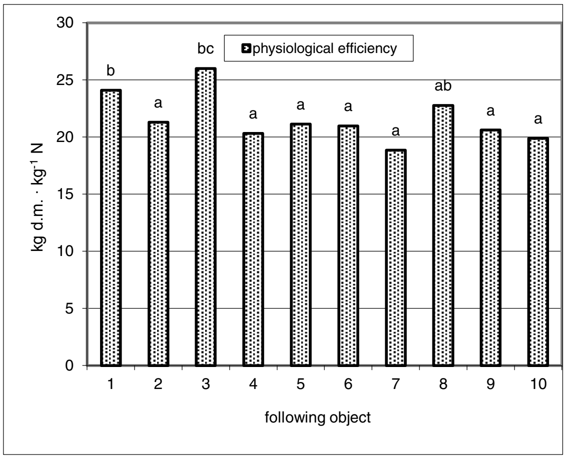

Fig. 3. The values of physiological efficiency in the successive variants of fertilization

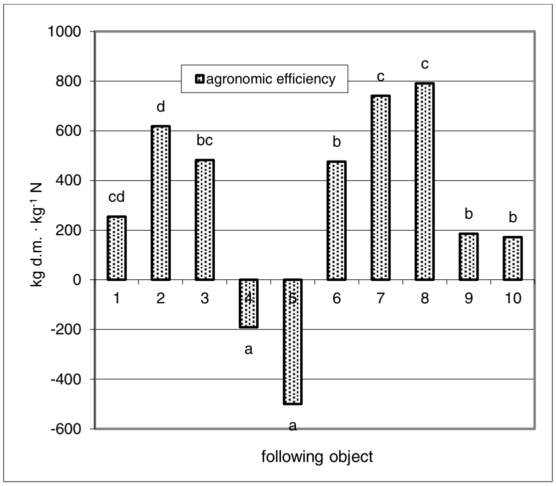

Fig. 4. The values of agronomic efficiency in the successive variants of fertilization

The physiological efficiency index tells us about the increase in agricultural production per kg of component taken up by plants as a result of the applied fertilization. The value of this index is equivalently influenced by the effect on the production potential of plants in certain conditions and by the widely understood agricultural engineering whose main element is fertilization. Therefore, it is an index which allows comprehensive assessment of the agricultural system (Cassman et al., 2002). Low values of the physiological efficiency index suggest occurrence of a stressor for plants. The physiological efficiency index ranged between 19.89 and 26.01 in the other variants of the experiment (Fig. 3). Its highest value was obtained in the variant with the addition of 400 kg. Its lowest value was found in the treatment fertilized conventionally with the maximum dose. Environmental conditions in all variants of the experiment were identical, that is why the obtained differences resulted from the differences in fertilization in individual treatments. Due to the limited yielding of plants, the studied parameter assumed a negative value in two treatments with the largest dose of fertilizers. In well managed systems with good conditions for plant growth and development, the value of this parameter is more than 50 kg · ha^{-1}(IFA, 2007).

Index of agronomical efficiency determines the increase in plant yield when using 1 kg of nitrogen fertilizer. It is the most reliable index that determines the efficiency of agricultural systems. Specialization in cultivation of plants with greater production potential connected with implementation of precise fertilization and irrigation technologies usually lead to an increase in the value of this parameter (Cui et al., 2008). In general, when using cultivars with greater production potential without applying precise fertilization technologies, one can observe deterioration of the value of the index of agronomical efficiency(Cassman et al., 2002). The value of this parameter in cereal production in poorly developed agriculture is from 10 to 30 kg · kg^{-1} (Dobermann, 2007). Xu et al. (2014) give the value of the index of agronomical efficiency at a level of 11.4 kg · kg^{-1}. The value of the index of agronomical efficiency in individual variants of the experiment ranged between -10.23 and 27.41 kg · kg^{-1} in terms of dry matter yield from the celeriac roots (Fig. 4). In relation to the control treatment, a decrease in yield was observed in two variants with the highest dose of the slow-acting fertilizer. That is why the value of the parameter being discussed assumed negative values. The highest value of the index of agronomical efficiency was obtained in the variant where 400 kg · ha^{-1} of the slow-acting fertilizer was applied. Higher doses of the slow-acting fertilizer caused a decrease in plant yielding. In all probability, it was caused by caused an increase in soil salinity in the root zone. Niemiec (2014) obtained similar results in cultivation of Chinese cabbage, but reaction of that plant to the increase in the amount of fertilizer was not as violent as in the case of celeriac. The value of the parameter being discussed under conditions of fertilization in the conventional system was approximately 12 kg · kg^{-1}. The best production results were obtained in treatments fertilized both with slow-acting fertilizers as well as conventional ones. Values of agronomical efficiency at the application of 200 and 400 kg of slow-acting fertilizer and conventional fertilizers were approximately 19 kg · kg^{-1}.

The highest value of the index of agronomical efficiency was found at the application the smallest amounts of the slow-acting fertilizer. After application of 200 kg fertilizer, a high yield and very high indices of efficiency of the fertilization were obtained. It is a result of increasing the use of nutrients from soil reserves. In intensively fertilized soils, with high organic matter content, there is a high potential of nutrients absorbed in the sorption complex. Introduction of techniques that increase the use of nitrogen from soil reserves is the key factor that increases the economic efficiency of production and reduces the negative impact of production on the environment (Chuan et al., 2013). Rational fertilization, particularly with nitrogen, should not increase the amount of this component in soil because after plant harvest a substantial part of nitrogen will disperse in the natural environment. The amount of nitrogen in soil after plant harvest should not exceed 30 kg · ha^{-1} (Helander et al., 2004). If the content of assimilable nitrogen in soil after harvest is below 30 kg, the risk of washing out of this element deep into the soil profile or into surface waters is low. Soil that was used in the experiments had a very high content of mineral nitrogen. It is indicative of improper approach to the issue of fertilization with this component for at least several years. The obtained results point out to great potential for applications of modern fertilization techniques, but which should be preceded by an examination of a soil that will determine its richness. Application of slow-acting fertilizers under the root, even in small amounts, caused an increase in celeriac yielding. The lowest doses of the slow-acting fertilizer provided the best productive and environmental effects in the form of nitrogen from soil being used by plants. Under conditions of very high contents of nutrients in soils, it is justified to implement cultivation techniques that increase the uptake of nutrients from soil reserves. It will allow to improve the economics of production, reduce the negative impact of agriculture on the environment, and to keep soil in good agricultural culture. Application of slow-acting fertilizers gave positive outcomes in the form of increased yield and improved indices that reflect the effectiveness of production. However, at a dose of 600 kg of the slow-acting fertilizer a decrease in yielding of the plants was observed. In all probability, it is a result of increased soil salinity. The experiment was conducted under conditions of an irrigation system. In a system without irrigation, in a situation of prolonged periods with no rainfall, the effect of limiting the yielding of plants can be noticeable already at smaller fertilizer doses. Other authors draw attention to this problem (Delogu, 1998; Berenguer, 2009).

4. Summary and conclusion

1. Under conditions of the conducted experiment, a considerable effect of the applied fertilization on the obtained yield amount was determined.
2. The most favourable productivity coefficient was reached when 400 kg of the slow-acting fertilizer was used.
3. The highest physiological effectiveness was determined when 500 kg · ha^{-1} of the slow-acting fertilizer was used.
4. Taking into account both the yield amount and the values of coefficients of the nitrogen fertilization efficiency, the most beneficial variants are to fertilize with slow-acting fertilizers under the root and to fertilize with traditional fertilizers applied in a conventional way.

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Agriculture and Agricultural Science Procedia 7 (2015) 184 – 191

Agriculture and Agricultural Science
Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Efficiency of celeriac fertilization with phosphorus and potassium under conditions of integrated plant production

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Abstract

The goal of this work was to assess the efficiency of celeriac fertilization with phosphorus and potassium under conditions of integrated plant production. The goal was realized by performing a strict experiment.Celeriac (Diamant cultivar) was the test plant. A controlled-release fertilizer, with NPK content of 18%, 5% and 11%, was used for fertilization. Moreover, the following conventional fertilizers were used: ammonium nitrate, granular triple superphosphate, and potassium salt. The efficiency of the fertilization was evaluated by calculating the following indices: agronomic effectiveness, productivity coefficient and removal efficiency. The most favourable productivity coefficient and agronomic effectiveness were reached when 300 and 400 kg of the slow-acting fertilizer was used along with additional fertilization with ammonium nitrate, and this variant of fertilization under conditions of conducting the experiment would be optimal. In the conventionally fertilized treatments, values of these parameters were several times lower. That is why measures that improve the efficiency of production may bring positive results. Results of the conducted research indicate that optimization of fertilization under conditions of intensive production may significantly increase the efficiency of production.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

*Keywords:*integrated production; the effectivensess of fertilization; phosphorus; potassium; sustainable fertilization; slow-acting fertilizer; celeriac.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.015

1. Introduction

Sustainable agriculture is based on the use of cultivation techniques which make it possible to obtain high yields of good quality with a rational use of soil resources, energy, and chemical means of production. The idea of sustainable agriculture is being implemented within various quality systems such ecological farming, integrated farming, Euro G.A.P., Global G.A.P., and many other private or national standards. The aim of implementing quality systems in initial agricultural production is to produce high quality yields, while simultaneously respecting the aspects of environmental protection. Intensive development of quality systems for agricultural production that took place at the turn of the 15th and 16th centuries was the answer to problems connected with global degradation of the environment. It was also connected with more and more common cases of detecting substantial amounts of harmful compounds in food, which was a consequence of improper use of pesticides. Measures that were taken in order to reduce pesticide use made it obligatory for agricultural producers to use integrated methods of protection (Mzoughi, 2011). Inspections connected with the use of pesticides and campaigns that promote products with the quality systems logo among consumers, increases the awareness among producers and consumers. This in turn causes that there is an increase in the market in the amount of food produced basing on systems which ensure good quality of products. The quality of a plant will determine the suitability for consumption or processing. The quality of plant raw material is influenced by factors connected with cultivars and by the widely understood agricultural engineering factors. Contents of dry matter, micro- and macro-elements, and of organic chemical compounds which influence the quality of plants are connected with properties of a soil on which these plants grow, its abundance, and with fertilization. The problem of improper plant fertilization, connected primarily with unilateral fertilization with basic nutrients, has been brought up by many authors. In most cases, excessive nitrogen fertilization is indicated because it leads to a decrease in the amount of dry matter of a product, deterioration of storage properties, and to accumulation of too large amounts of nitrates which have a harmful effect on human health (Ferrise et al., 2010;Masoero et al., 2011). Nitrogen is an element that has the greatest effect on the amount of yield. It is also inexpensive, and that is why its excessive use is a great problem for the present day agriculture. Traditionally, fertilization is connected with supplying the basic elements, such as the nitrogen, phosphorus, potassium, magnesium and calcium to soil. Unilateral fertilization with these elements without paying attention to the necessity to introduce microelements to the soil ecosystem initially leads to production of yields with worse chemical composition, and then to growth and development disorders in plants (Pypers et al., 2011). Phosphorus and potassium are fertilizer elements; their contents in soils are more and more often very high. It is common to find too high contents of these elements (particularly phosphorus, which is sorbed in soil) in soils used intensively in agriculture (Bennett et al., 2001). Excessive fertilization with phosphorus and potassium leads to disordered functioning of plant organisms, primarily due to modification of metabolism of other elements. The goal of the conducted research was to assess the efficiency of celeriac fertilization with phosphorus and potassium under conditions of changeable level of fertilization with nitrogen as well as variable doses and form of fertilization with the studied elements. The efficiency of fertilization was evaluated based on indices of fertilization efficiency such as: agronomic effectiveness, productivity coefficient, and efficiency of removal(IFA, 2007).

2. Objective, data and methodology

The experiment was set up on soil with the granulometric composition of medium loam. Pickling cucumbers were the forecrop for the studied crops. In autumn 2011, organic fertilization (mixed manure) in the amount of 35 $Mg \cdot ha^{-1}$ was applied. Mineral fertilizers in full dose (which is characteristic for intensive cultivations) were used in the cucumber cultivation. Celeriac (Apiumgraveolens var. rapaceum) of Diamant F1 cultivar was the test plant. The experiment was set up on 2 May 2012. The plants were harvested on 29 October 2012. The plants were cultivated at 50 × 30 cm spacing, from seedlings prepared in multi-cell trays (VEFI system). Varied fertilization was the factor of the experiment. Cultivation and protection of the plants were carried out based on the methodology of integrated production. Owing to the fact that the Main Inspectorate of Plant Health and Seed Inspection had not developed the methodology of integrated production of celeriac, the system of production was elaborated basing on framework principles for integrated plant production. Celeriac is a plant with great nutritional, soil and water requirements. The crops were irrigated up to the optimum moisture content in order to eliminate the impact of water stress on the result of the experiments. Prior to setting up the experiment, analyses of physicochemical and chemical properties of the soil on which the experiment was set up had been conducted (Tab. 1).

Table 1. Selected properties of the soil used for experiments

pH in H_2O	pH inKCl	[%]			[mg · kg^{-1}]			
		N tot.	C org.	N min.	P	K	Mg	Ca
7.01	6.65	0.324	4.69	347	147.8	478.5	212.5	1240

The following were used in the experiment: a controlled release fertilizer (with NPK composition (%) of 18-05-10+4CaO+2MgO), ammonium nitrate, triple superphosphate, and potassium salt 60%. The experiment comprised 9 levels of fertilization based on the principles of integrated plant production, the control treatment without fertilization, and the treatment fertilized in the conventional manner in an intensive cultivation of celeriac in the region where the research was being carried out. In the first 10 treatments, fertilization with phosphorus and potassium was applied based on the demand of the plants calculated in accordance to the principles of integrated production, but the share of the component applied pointwise with the slow-acting fertilizer and of the component applied with the conventional fertilizer were different. Fertilizers that were used in the experiment meet the standards included in the Directive: Directive of the European Parliament and of the Council of 24 November 1997 (Dyrektywarady, 1997). After harvest, the plants were washed; total and technological yields were determined; dry matter content in the roots and in the above-ground parts was determined. The laboratory samples were subjected to dry mineralization in an open system. The sample was digested in HNO_3 acid. Concentrations of phosphorus and potassium in the obtained solutions were determined by atomic emission spectrometry with electrothermal atomization, using the Optima 7300 manufactured by PerkinElmer. The scheme of the experiment is presented in Tab. 2. The value of the studied parameters compared between themselves with the use of Tukey's test. The difference between value of the parameters was evaluated at a significance level of p=0.01.

Table 2. Experiment design

Object number	Fertilizer quantity				Component dose		
	Slow acting fertilizer NPKCaMg (18-05-10-4-2)	Ammonium nitrate	Triple superphosphate	Potassium salt	N	P_2O_5	K_2O
	[kg · ha^{-1}]				[kg · ha^{-1}]		
Control	0	-	-	-	-	-	-
1	200	-	87	163	36	50	120
2	400	-	65	122	72	50	120
3	500	-	54	108	90	50	120
4	600	-	43	90	108	50	120
5	800	-	21	53	144	50	120
6	200	218	87	163	130	50	120
7	300	165	76	145	130	50	120
8	400	112	65	127	130	50	120
9	-	441	244	325	150	112	195
10	-	588	326	433	200	150	260

3. Results

Phosphorus and potassium are strategic elements in agricultural production. Many authors draw attention to the very small usage of phosphorus applied in mineral fertilizers (Simpson et al., 2015). The cause of the poor usage of phosphorus from mineral fertilizers can be found in retardation of this element in soil or in its losses as a result of soil washes and runoffs (Dodd et al., 2014). In intensive agricultural systems (particularly in vegetable, fruit, and also industrial cultivations), very high levels of fertilization with phosphorus are often observed, significantly higher levels than the nutritional needs of cultivated plants might suggest. Such policy of managing fertilizer component leads to a successive increase in the content of assimilable and total form of this element in soil. High phosphorus contents in soil do not cause direct negative effects in agroecosystem, but lead to increase in cultivation costs crops and to an increased risk of water eutrophication. In addition, more and more attention is being drawn to the fact that phosphorus is an element whose global reserves are limited, and we should try to use it effectively within the scope of sustainable production management (Cordell et al., 2009; Zeng and Wang, 2015). Too large amounts of the used fertilizer components such as phosphorus and potassium lead to intensified processes of their immobilization, which makes them unavailable for plants (Tóth et al., 2014). In the case of potassium, effective fertilization is also of key importance during plant production with defined qualitative parameters (Niu et al., 2013). Potassium, thanks to its functions in a plant organism, determines the dry matter content of sugars and contents of other elements which decide on the nutrition value and on the suitability for industrial purposes (Holthusen et al., 2012). Therefore, the challenge for modern fertilization technologies is to use fertilizers in amounts that will meet the demands of plants and which will ensure the quality of the yield. In connection with the growing problem of too large doses of potassium and phosphorus fertilizers on intensively used soils, modern quality systems such as Integrated Production and Global G.A.P. are paying more and more attention to rationalization of fertilization in terms of the amount of a component introduced into the environment and the amount of a component uptaken with yield. When designing a system of fertilization it is very important to determine the production potential of a soil on which cultivation is conducted. The production potential is influenced by soil category, dynamics of climatic and microclimate conditions in the area of cultivation, amount of precipitation and its distribution during vegetation season, and also by cultivar. In order to create a rational system of fertilization, all the aforementioned aspects should be taken into account, and both doses and dates of fertilization should be matched so as to reduce the losses of components and ensure sufficient demand on the plants in subsequent developmental stages. Very low fertilization efficiency in present-day agriculture is connected precisely with insufficient knowledge and universal approach of agricultural producers to the issue of fertilization. In sustainable agriculture, the use of controlled release fertilizers is an attempt to deal with the problems connected with the necessity for optimization of fertilization (Niemiec, 2014; Zhang et al., 2014). Slow-acting fertilizers prevent fast leaching of nutrients that have not been uptaken by plants. Thanks to that it is possible to apply a larger dose of nutrients prior to sowing. Gradual release of nutrients will allow to deliver them to plants as they grow. Using slow-acting fertilizers also gives a possibility to apply them in direct neighbourhood to the root zone, which additionally should increase fertilization efficiency (Mucheru-Muna et al., 2010). Gradual release of fertilizer components does not lead to a sudden increase in soil salinity as it is in the case of using conventional fertilizers. In the conducted experiment, different levels of nitrogen fertilization as well as phosphorus and potassium fertilization were applied, corresponding to the demands of the plants. Nutrient requirements of plants at the assumed yield of 45 $Mg \cdot ha^{-1}$ amount to: 315 kg N, 112 kg (P_2O_5), 315 kg (K_2O), 72 kg MgO, and 225 kg CaO. Fertilization needs were calculated basing on the content of assimilable forms of elements in the soil, organic fertilization, nutritional needs of plants, and basing on the history of the field, as specified in the methodology of integrated production. N, P_2O_5, K_2O fertilization needs were determined at a level of, respectively: 130 kg, 50 kg and 120 kg. The amount of plant fertilization was much lower than nutrient requirements due to large amounts of nutrients in the soil. In addition, in one treatment, fertilization at a level close to the one used in celery cultivations on the described research area was applied.Results of the conducted experiment point to differences in plant yielding in individual research objects. The highest yields were obtained in the treatments where a combination of nitrogen fertilization in the form of slow-acting fertilizers and in the form of conventional fertilizers had been used. The largest doses of slow-acting fertilizers limited plant yielding (Szeląg-Sikora et al., 2015). The productivity coefficient is the most important indicator of the efficiency of fertilization. In the conducted research, the value of this parameter for phosphorus varied from 533.3 to 2237 $kg \cdot kg^{-1}$ roots (Fig. 1). In practice, this index provides information on the amount of production in terms of 1 kg of the applied fertilizer component. Considerable differences in the value of this parameter were found in treatments fertilized according to the principles of integrated production**.** The value of this parameter for potassium varied from 210.2 to 497.3 (Fig. 2). The highest values of this parameter were determined in treatments with the addition of 300 and 400 $kg \cdot ha^{-1}$ of the slow-acting fertilizer and in treatments fertilized with conventional fertilizers. Similar results were obtained in the case of fertilization with the slow-acting fertilizer in the amount of 400 and 500 kg without additional nitrogen fertilization. Generally, values of the productivity coefficient in treatments fertilized in accordance with integrated production differed slightly between individual treatments. No effect of the form of the applied phosphorus or of the level of nitrogen fertilization on shaping the value of this parameter was observed. A much lower value of the productivity coefficient was observed in the conventionally fertilized treatments. The obtained results point unambiguously to possibilities of improving the fertilization efficiency in production practice by means of simple agricultural engineering procedures. Niu et al. (2013) draw attention to considerable differences in the value of the productivity coefficient for winter wheat depending on fertilization with phosphorus or potassium. Evaluation of the efficiency of agricultural production based on analysis of the efficiency coefficient should be always connected with the obtained yield. The productivity coefficient is the most important indicator for farmers because it point to efficiency of the use of nutrients, which translates into production profitability (Aulakh et al., 2012).

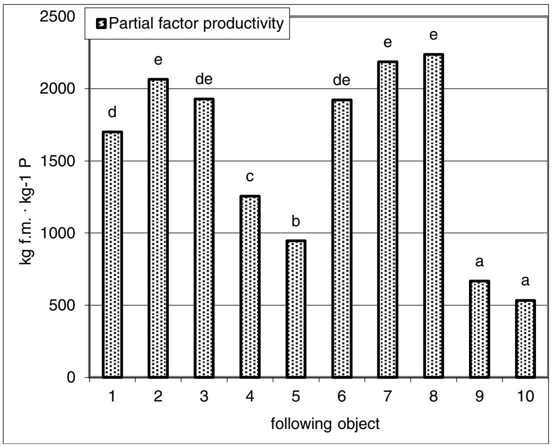

Fig. 1. The values of partial factor productivity in the successive variants of fertilization

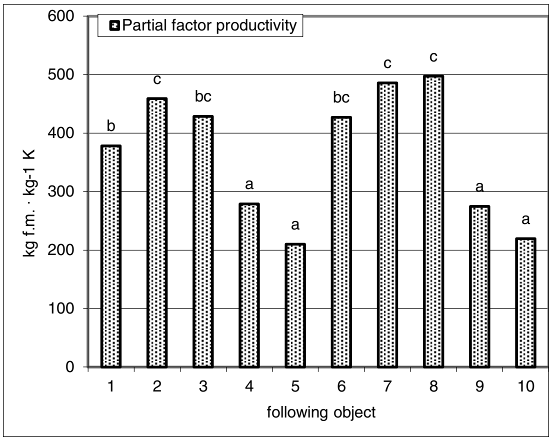

Fig. 2. The values of partial factor productivity in the successive variants of fertilization

The efficiency of removal is an indicator which determines the amount of a fertilizer component taken up with the yield in relation to its amount that has been introduced with the fertilizer. The value of this parameter for phosphorus in the performed experiment varied from 0.425 to 1.631 (Fig. 3). Efficiency of potassium removal varied from 0.740 to 2.205 (Fig. 4). The highest value of this parameter in the case of both elements was determined in treatments fertilized with the slow-acting fertilizer in the amount of 300 and 400 kg with conventional nitrogen fertilization. It is connected with the amount of yield obtained in these treatments. In treatments fertilized conventionally, the value of this parameter amounted to 0.513 and 0.425 for phosphorus, and 1.176 and 969 for potassium. This means that approximately a half of the applied phosphorus dose had been discharged with the main yield. In the case of potassium, the uptake of the component by plants was at a level close to the amount of this component introduced with fertilization. Excessive phosphorus fertilization is defined as a problem associated with rational management of natural resources. Phosphorus that has not been taken up by plants accumulates in soil and as a result of various processes undergoes retardation and is not available for plants (Bennet et al., 2001; Childers et al., 2011). Removal efficiency is an indicator of the efficiency of fertilization. However, in the case of phosphorus management it can also be an indicator of rational use of this element. The value of the removal coefficient in most agricultural systems around the world fluctuates from 0.2 to 0.8 (Dobermann and Cassman, 2002). In the case of potassium, it is more common to observe negative balance of this element in agricultural systems (Qiu et al., 2014). Agronomic efficiency index determines the increase in plant yield when using 1 kg of nutrient. Its value best reflects the efficiency of agricultural systems. As agriculture develops, the value of this parameter generally increases (Cui et al., 2008). However, the value of this indicator in most agricultural systems is at a low level. It is a consequence of relatively low prices of mineral fertilizers as well as lack of knowledge and lack of competence of the people who manage production.

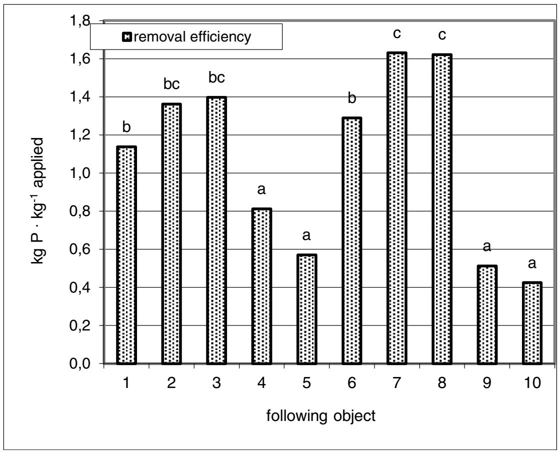

Fig. 3. The values of removal efficiency in the successive variants of fertilization

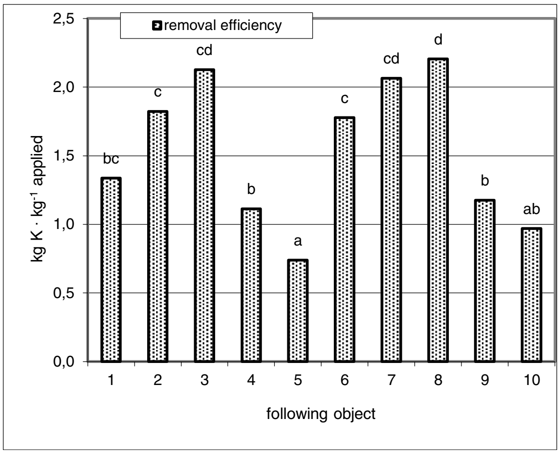

Fig. 4. The values of removal efficiency in the successive variants of fertilization

In the conducted research, the value of agronomic effectiveness of phosphorus fertilization varied from 171.69 to 791.1 kg · kg^{-1} in terms of dry matter yield from the roots (Fig. 5). The value of the index of potassium agronomic efficiency ranged between 56.53 and 175.9 kg · kg^{-1} in terms of dry matter yield from the roots (Fig. 6). The agronomic efficiency index determines the increase in the amount of yield thanks to application of 1 kg of nutrient in the form of fertilizer. The lowest value of this parameter was found in the variant with conventional fertilization with a phosphorus dose at a level of 150 kg. Almost five times higher value of the agronomic efficiency index was obtained in the treatment with a 400 kg dose of the slow-acting fertilizer with additional nitrogen fertilization in the form of ammonium nitrate. In the treatment with a 200 kg dose of the slow-acting fertilizer, the value of this parameter amounted to 254.4 kg · kg^{-1}. Increasing the fertilizer dose by 100 kg caused an increase in the studied parameter to 618.2 kg · kg^{-1}. Similar relationships were determined in the case of the potassium agronomic efficiency index. However, in the conventionally fertilized treatments they were approximately a half lower compared to the most effective fertilization in the variant with the addition of 400 kg of the slow-acting fertilizer and additionally fertilized with ammonium nitrate.

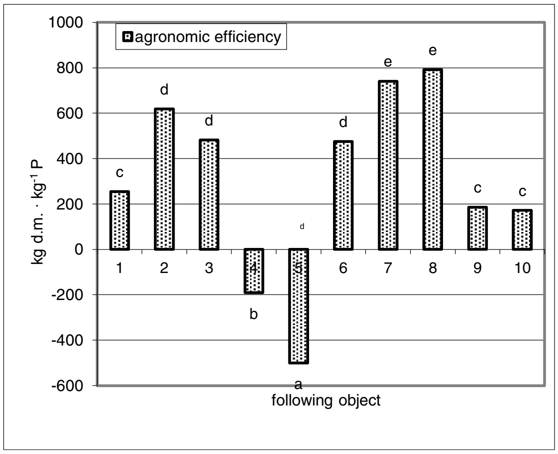

Fig. 5. The values of agronomic efficiency in the successive variants of fertilization

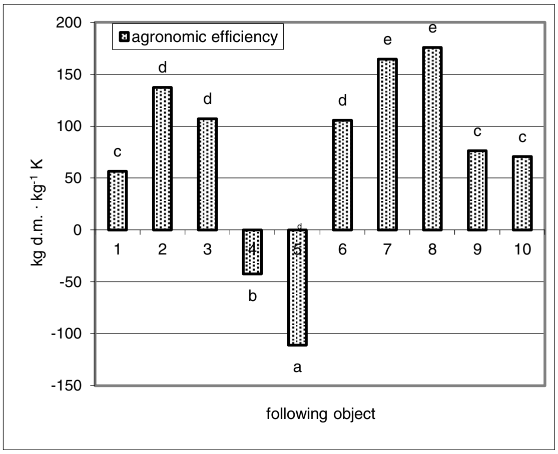

Fig. 6. The values of agronomic efficiency in the successive variants of fertilization

In the case of the treatment with a 200 kg dose of the slow-acting fertilizer, an effect of induced usage of both nutrients stored in soil was observed. Niemiec et al., (2014) obtained similar relationships. Agricultural engineering measures that make it possible to use supplies of elements on soils which were intensively fertilized in the past are an important part of sustainable agriculture. The obtained results suggest that there is great potential for using the innovative fertilization techniques in optimization of phosphorus and potassium fertilization. Introduction of techniques that increase the use of nitrogen from soil reserves is an important factor that increases the economic efficiency of production and reduces the negative impact of production on the environment (Chuan et al., 2013). One of the strategic goals of the present day agriculture is to increase the efficiency of fertilization that will lead to reduction of the production costs, reduction of the negative impact of agriculture on the natural environment, and to production of plants with chemical composition that is good for the consumer's health. Actions that are taken in order to reduce negative impacts of agricultural production are included in principles of various quality systems. This is associated with the need of many consumers to take actions to protect the environment and their own health. Labeling a product with the quality mark, which guarantees production that observes environmental standards, makes it easier to sell the product. That is why continuous development of various quality systems around the world can be seen (Carlsson et al., 2007). The most important problem connected with implementation of precise fertilization systems is that producers have too little knowledge on fertilizer application technologies (Mucheru-Muna, 2010). Fertilization plays a very important role in plant production because it is an important part of production costs, influences the quantity and quality of the yield, and modifies soil fertility (Pypers et al., 2011).

4. Summary and conclusion

1. The most favorable productivity coefficient and agronomic effectiveness were reached when 300 and 400 kg of the slow-acting fertilizer was used along with additional fertilization with ammonium nitrate. In the conventionally fertilized treatments, values of these parameters were several times lower.
2. In variants with combination of fertilization with slow-acting fertilizers and conventional ones, the value of the phosphorus removal coefficient reached a level of above 1.5, whereas in the case of potassium that value exceeded 2.
3. The area where the research was conducted was determined to have very low fertilization efficiency. This can be seen in treatment 11 which was fertilized according to the production practice
4. Using a fertilization technology based on the share of controlled release fertilizers may simplify rational management of nutrients in sustainable agriculture.

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Agriculture and Agricultural Science Procedia 7 (2015) 192 – 197

Agriculture and Agricultural Science
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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Effect of processing conditions on selected properties of starch-based biopolymers

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Abstract

Process management of biopolymers is very important according to processing conditions and stability. This paper presents the results of the extrusion-cooking of thermoplastic corn starch enriched with fillers in the form of flax fibers, using the modified single screw extrusion-cooker TS-45 (Polish design) with L/D = 16 and an additional cooling section of the barrel. Discussed are the influence of the screw speed and the quantity of the filler used in the blends containing 20% of glycerol (plasticizer) on the processing efficiency, process stability, energy consumption, radial expansion index during the extrusion-cooking process of thermoplastic starch (TPS).

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: extrusion-cooking; breakfast cereals; wholegrain wheat; physical properties; texture, sensory.

1. Introduction

One of the major challenges of the modern polymer technology is to provide substitutes for rapidly dwindling non-renewable natural resources and to address the already taxing problems of plastic waste management. The

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.016

economic development and the global technological progress entail the increasing production of various plastics. Nowadays, consumers are becoming increasingly discerning as regards the quality and appearance of merchandise and the quality of packaging. Only a fraction of used packaging is recycled. This is attributable to the high cost and a relatively low level of selective wastes collection. The mounting volume of waste deposits is anything but a huge burden to the environment. Most of this waste resists degradation because polymers are known for their very long time of decomposition in the environment (Czerniawski and Michniewicz 1998; Janssen and Mościcki 2006; Oniszczuk and Pilawka 2013). The rising awareness of 'green' societies and the fashion for healthy lifestyle have contributed to the development of a research field covering the so-called "biodegradable plastics". Particular attention has been paid to examining the group of natural materials, such as biopolymers produced from starch. Biopolymer is obtained after mixing starch with a plasticizer (mostly glycerol) to facilitate the disposal of the material at a temperature lower than the decomposition temperature of starch. This form of starch is referred to as thermoplastic starch (TPS) (Combrzyński et al. 2012; Mościcki et al 2012). It may be regarded as complementary to alternative plastics. Unfortunately, products made from TPS are not widely applied because of certain defects. In order to improve the physical properties of biopolymers, and even reduce the price of the finished product, natural fibers can be added in the amount from 1 to even 50%, depending on the fillers used in the mixture. The most commonly used fillers are: flax, hemp, jute, coir, cotton, and waste of the wood industry. Large-scale studies on the increasing of the share of TPS in packaging materials have been initiated in recent years. Today, a noticeable growth of biodegradable material application is seen in the manufacture of various products. These products are increasingly present in our homes, and manufacturers do not cease to seek newer and better technologies of their production. Moreover, the fact that they can be fully degradable resolves a problem for storage of used packaging. If properly treated, they can be composted and used for agricultural or horticultural purposes. In the anaerobic process, they yield methane, which is further used for heating or as a propellant (Fritz et al. 2001; Oniszczuk et al. 2012; Oniszczuk et al. 2013).

The aim of the study was an evaluation of the influence of the screw speed and the quantity of the filler – flax fibers used in the blends containing 20% of glycerol (plasticizer) on the processing efficiency, process stability, energy consumption, and radial expansion index during the extrusion-cooking process of thermoplastic starch.

2. Materials and Methods

The study was performed with application of the single screw extrusion-cooker TS-45 (Polish design), equipped with an additional cooling system of the barrel, L/D = 16/1, the die of 3 mm in diameter and a screw rotations of 60, 80, 100 rpm. Extrusion-cooking process temperature ranged from 60 to 110°C, which was determined by appropriately adjusting the intensity of the cooling agent flow. The electronic tachometer DM-223AR Wireless was employed to measure the screw speed; the processing temperature was measured by thermocouples installed in the barrel of the extruder, registered on the control panel.

The main component was corn starch, mixed with glycerol (the plasticizer) and fillers in the form of flax fibers added to improve the quality of the TPS. Technical glycerol of 99% purity was added to all prepared blends in a quantity of 20%, the fillers were added selectively with 0, 10, 20, and 30% content of the entire mixture weigh. The blends were mixed for 20 minutes in a laboratory ribbon mixer until homogeneous mass. After mixing, the samples were stored in sealed plastic bags for 24 hours in order to increase the penetration of glycerol in the starch granules. Immediately prior to extrusion, the blends were again mixed for 10 minutes, which facilitated the acquisition of uniform and powdery mixtures to be fed into the extruder.

The efficiency of the extrusion-cooking was conducted by setting the extrudates weight obtained at a given time for all the mixtures of raw materials used and processed at the established parameters. The measurement was made using an electronic timer and the WPS 210 weigh in six repetitions for each series of the tests. The efficiency was determined by the following formula (Wójtowicz and Mitrus 2010):

$$Q = \frac{m}{t} \ [\mathrm{kg \cdot h^{-1}}] \quad (1)$$

where: Q – efficiency, m – mass of the extrudate obtained during measurement [kg], t – measurement time [h].

The energy consumption measurement was performed using a standard Wattmeter connected to the power unit of the extruder. After considering the type of motor installed in the extruder, setting the load and obtaining the individual samples output, the values obtained were converted to specific mechanical energy (*SME*), accordingly to the formula (Ryu and Ng 2001; Janssen et al. 2002):

$$SME = \frac{N \cdot O \cdot P}{N_m \cdot 100 \cdot Q} \quad [\text{kWh·kg}^{-1}] \tag{2}$$

where: N – screw speed [min^{-1}], N_m – maximum screw speed [min^{-1}], P – power [kW], O – motor load [%], Q – efficiency [kg·h^{-1}].

The radial expansion index was determined as a ratio of the pellet diameter (*d*) and the diameter of the die (*D* - 3 mm) (Wójtowicz and Mościcki 2014). The measurement of the extrudate diameter was performed by a micrometric screw with an accuracy of 0.01 mm. The measurement was repeated 10 times; the adopted result was the average of all measurements.

3. Results and Discussion

The operational test carried out on the single-screw extruder TS-45 fitted with a plasticizing system with L/D=16 demonstrated temperature stability of the process during the pressure and thermal modification of starch throughout the entire applied process parameters.

Table 1. Results of temperature measurements during the extrusion of corn starch pellets with the addition of flax fibers.

Flax fibers content [%]	Screw speed [rpm^{-1}]	Temperature of extruders' 1st section [ºC]	Temperature of extruders' 2nd section [ºC]	Temperature of extruder head [ºC]	Temperature of product [ºC]
0	60	86	96	72.8	108.0
	80	86	94	75.0	105.0
	100	84	90	77.4	103.0
10	60	96	110	71.0	97.0
	80	93	103	73.0	95.0
	100	85	99	74.0	95.0
20	60	85	100	69.8	98.0
	80	81	96	70.4	97.0
	100	85	100	72.8	92.0
30	60	86	100	65.1	77.0
	80	80	94	67.9	81.0
	100	80	96	68.1	74.0

Changes in the cylinder temperature of ± 10°C from set temperature were observed. During the extrusion of corn starch, the material travelled through the extruder in a stable manner. The addition of flax fibers – for all the applied extruders' screw speeds – had an adverse effect on the process stability: the uneven feeding and problems with dosing the mixture were observed. Table 1 shows the temperature measurements in the individual sections of the single-screw extruder.

During tests, a significant effect of the screw speed on the efficiency of the extrusion-cooking process was reported. The process efficiency was directly proportional to the screw speed: the higher rotational speed, the higher output was obtained. Increasing the flax fibers addition in the formulations influenced the decline in efficiency of the extrusion process of reinforced thermoplastic starch.

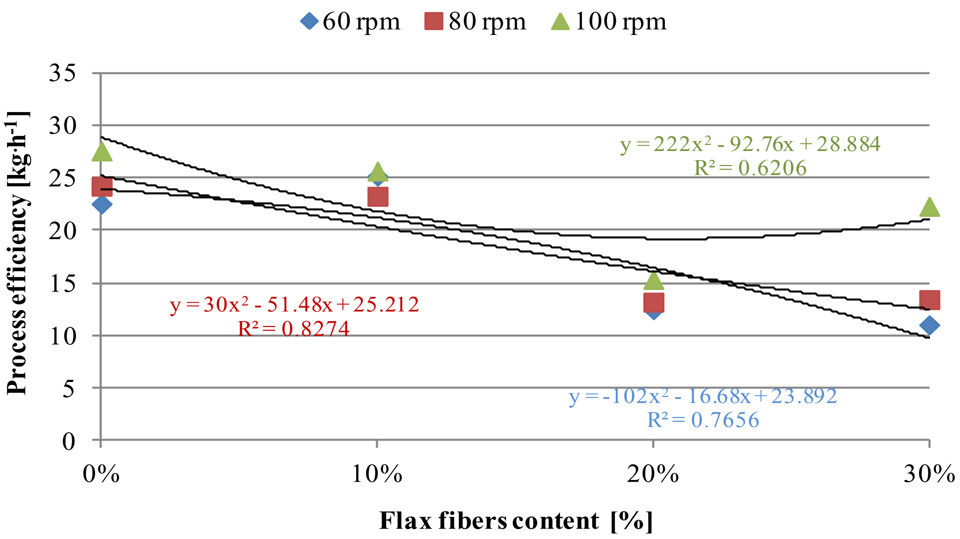

Fig. 1. Influence of the flax fibers content and the extruder screw rotation speed on the efficiency of the extrusion process of thermoplastic starch.

The addition of flax fibers caused the decline in efficiency during the extrusion process used for all blends. This is due to the greater fibers length and the lower degree of mixing of the sample. During processing, problems emerged with the dosing of the mixture – the material blocked the inlet easily. The lowest efficiency of 11.04 $kg{\cdot}h^{-1}$ was obtained during the TPS extrusion using the additive of 30% flax fibers, processed at the lowest screw speed of 60 rpm. The highest value of 27.6 $kg{\cdot}h^{-1}$ was obtained for blends processed at the highest screw speed of 100 rpm.

When using the extrusion-cooking technology for the processing of TPS, one of the most important factors is to determine the specific mechanical energy (*SME*) required.

During the extrusion process of the thermoplastic corn starch, it was noticed that energy consumption was growing with the increasing screw speed. The highest *SME* was recorded during the production of TPS pellets containing flax fibers. This is due to a greater length of flax fibers and hence higher resistance during the baro-thermal treatment; however, its amount did not affect the final value of the *SME* significantly. The lowest value of the *SME* was measured during the extrusion of samples without the addition of flax fibers (0.056 $kWh{\cdot}kg^{-1}$), and the highest of 0.226 $kWh{\cdot}kg^{-1}$ for the samples containing 30% of flax fibers, processed at 100 rpm of the screw (Fig. 2).

Based on the tests, it was found that the extruder screw speed had a considerable impact on the level of radial expansion index of the extrudates. It was reported that along with the increasing extruders' screw speed and addition of flax fibers to pellets the radial expansion index was regularly decreasing. The top values were evaluated for pellets without addition of flax fibers and extruded at the screw top speed (Fig. 3). On the other hand, the lowest values were recorded in two cases: in pellets containing 10 and 30% of flax fibers at the highest speed of the extruders' screw.

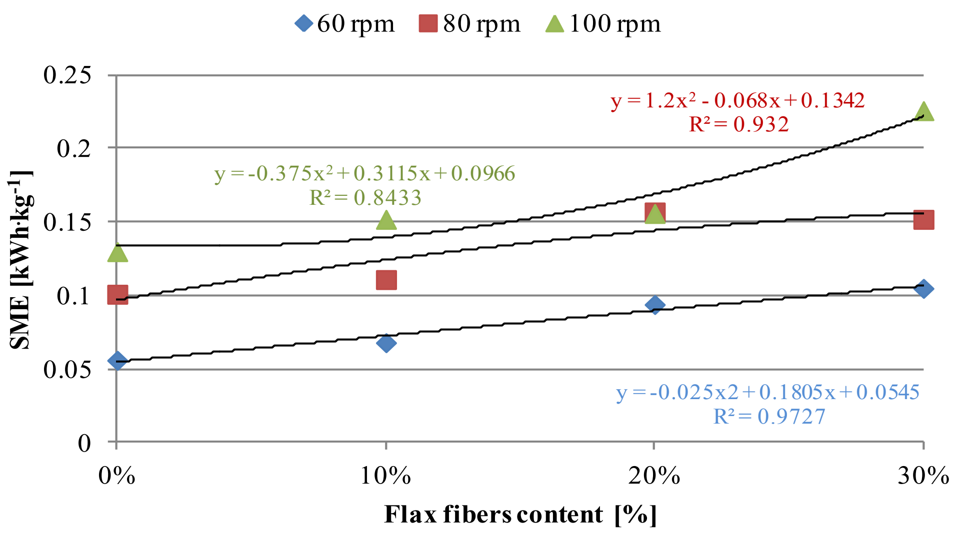

Fig. 2. Influence of the flax fibers content and the extruder screw rotation speed on the changes in the energy consumption (*SME*) during the extrusion of biopolymers.

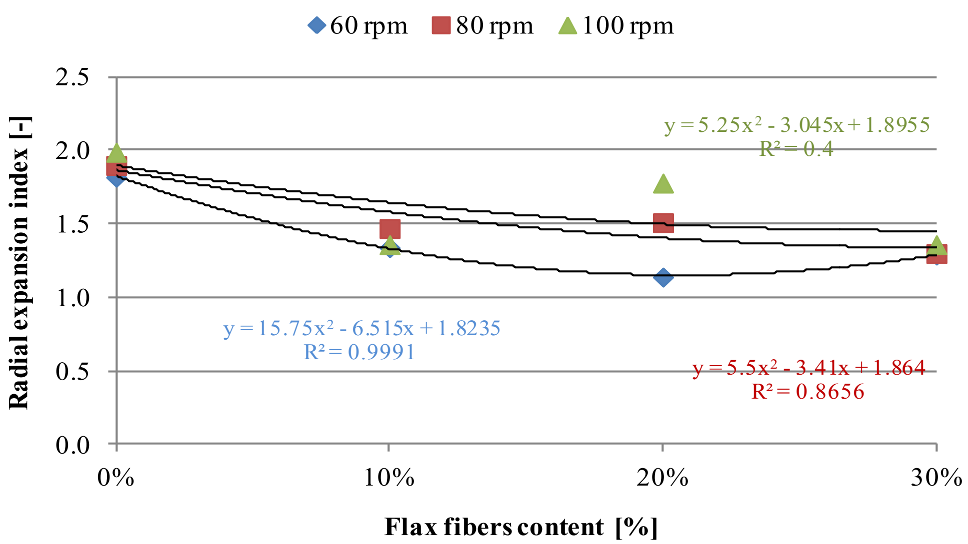

Fig. 3. Influence of the flax fibers content and the extruder screw rotation speed on the changes in the radial expansion index of the TPS pellets.

4. Conclusions

Based on the obtained results the following conclusions can be drawn:

The efficiency of the extrusion-cooking process is directly proportional to the screw speed; higher rotational speed resulted in the higher output of the process.

The addition of flax fibers caused a decrease in the process efficiency for all mixtures of the raw materials used.

The highest energy consumption was noticed during processing of TPS blends containing flax fibers. This was due to length of fibers and residence time occurred during the processing.

The tests of the expansion index of TPS pellets with fillers demonstrated typical changes to this parameter occurring during the extrusion of plant materials. The values of expansion index were reduced along with the increasing amount of flax fibers used.

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Agriculture and Agricultural Science Procedia 7 (2015) 198 – 202

Agriculture and Agricultural Science
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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Agricultural equipment in Greece: Farm machinery management in the era of economic crisis

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Abstract

The mechanization of the Greek agriculture began in the early 60s as a way to overcome the lack of labor force, due to the rural exodus. The approval from the farmers was encouraged by the financial support provided via national and European programs. Nowadays, thanks to this support, the index of mechanization of the Greek agriculture exceeds country's needs. However, there is inefficient use of farm machinery, due to the lack of the necessary complementary parts or overwhelming power of the tractors. The aim of this paper is to examine the management of farm machinery in Greece, during the economic crisis, a period of volatility in the markets and need for reduced production costs. It is shown that farmers got used to a mentality of fast-track farm management and farm machinery selection which can no longer be continued.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: Farm machinery management; agricultural equipment; economic crisis; agribusiness approach.

1. Introduction

The development of the Greek agriculture and its passage from traditional to modern production systems began in the 60s, the same period when its mechanization took place. The perspectives for growth in Greece's exports due to the country's association to the Common Market (1962), and a system of advantageous bank offers, subsidized in a large part by the state, encouraging farmers to buy on credit, triggered this modernization process. After the massive rural exodus of the 50s and the early 60s, farm mechanization was a way to overcome the lack of labor force, while

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.017

through the created automations farm productivity was improved.

The mechanization procedure succeeded: a drop in production costs (thanks to the decreased labor cost), increase in agricultural income (automation etc.), preservation of farmers' income through the acceleration of farm activities (harvesting), and it was observed that both the farmer and his family was relieved from the tiring works in the field, the warehouse or the barn. All these factors encouraged farmers to expand their farms.

Mechanization has been combined, especially from the beginning of the 70s, with an increasing use of irrigation, fertilizers, pesticides and improved seeds (HYVs). This production system was vastly applied in the flat and fertile regions of central and northern Greece. On the other hand, the southern regions, with less favorite or mountain areas and the islands have specialized more in labor intensive cultivations.

However, the initial euphoria of all European farmers, which was caused by the abolition of barriers to international market access and thus providing them with increased expectations for export opportunities, during 60s and 70s, contributed to the increase of intensification, concentration and specialization of cultivations, which reach their limits in the begging of the 80's, due to market saturation. The farming income decreased, while at the same time it became depended on the fluctuations of a more and more limited number of markets. Many hundreds of thousands of farmers have disappeared because of competition and others become pluriactive, cultivating crops which are less labor-demanding. All these problems have put the utility of the "productivist farming system", characterized by a continuous modernization and industrialization of agriculture, into question (Ilbery et al, 1997).

Although, after Greece's integration to the EEC in 1981, the level of mechanization continued to rise, mostly by exploiting funds from European programs, Greek agriculture is obliged to adjust to a new era of "post-productivist transition". Its objectives have been progressively reoriented: from maximizing the production of food towards reducing food output, providing environmental goods and producing within the context of an increasingly competitive international market (Bowler & Ilbery, 1997). During the 90s, the austerity and adjustment policy that were imposed in the process of the EMU of the EU aggravated the situation and had a severe impact in the countryside, forcing to elimination thousands of small and inefficient farmers.

From 2008, the burst of the economic crisis, and onwards, Greece undergone the imposition of the austerity measures, a decreased demand even for agricultural products, the cancel of the subsidized oil and a very high taxation for the farmers. Taking all these into consideration, the present state constitutes a crucial point for the future of the Greek agriculture.

The aim of this paper is to analyze the way Greek farmers adjust into the new conditions of "post-productivist transition" and the economic crisis, taking into account the evolvement of a major input of their production system, the farm machinery. We firstly approach the evolution of farm machinery in Greece in general, and then we present a part from the results of a research which is based on the level of mechanization of the prefecture of Achaia in Peloponnese during the period of the economic crisis.

2. Farm machinery management in Greece

In the mid-60s people working in the primary sector accounted about the 35% of the labor force of the country, in 1991 this percentage dropped to 22% and the 2001 census shows even further decrease (16.1%). The population census in 2011 and the data of Hellenic Statistical Authority (HSA) in 2013, present a continued decline at the percentage of people working in the primary sector in relation to the total labor force, 10.2% and 9.9% correspondingly.

The number of farm holdings decreased from 950,000 in 1983, the first period of Greece accession to EEC, to 817,059 in 2000. The data of the Farm Structure Survey (2009) estimate that there are 723,007 farm holdings, 716,823 of them with utilized agricultural land (UAL), and a later survey (2013) estimates them to be 703,535, accounted for 3,381,500 hectares (ha). The average of UAL per farm is estimated to be 4, 8 ha.

Table 1. Greek agricultural equipment in use.

Year	Agricultural Tractors	Harvester-threshers (combines)	Irrigation spray systems	Wheat sewing machines	Milking machines
1965	31,519	3,763	12,836	5,780	4,050
1970	61,945	4,151	49,042	12,662	4,300
1975	93,424	5,234	83,476	19,277	4,600

Year	Agricultural Tractors	Harvester-threshers (combines)	Irrigation spray systems	Wheat sewing machines	Milking machines
1980	140,305	6,109	114,576	30,815	5,200
1985	183,410	6,566	136,211	39,970	6,180
1990	215,755	6,247	184,820	45,306	12,366
1995	236,197	6,100			14,155
2000	253,785				13,865
2005	259,766				13,289
2010	257,385				

Source: HSA (Statistical Yearbook) and FAOSTAT Database

Table 1 shows that after 2000 the number of tractors remains stable, with only some few fluctuations. The small drop in 2010 can be easily explained due to the economic crisis. However, the records from the National Bank of Greece present that during the last 5 years there has been a rise in the prices for the products belonging in the category of “Farm machinery and equipment”. With base year 2005, between 2010 and 2011, 2011 and 2012, 2012 and 2013 there is a rise of 0.6%, 1.2% and 1.0% correspondingly.

From 1970, various forms of mechanization have been applied and expanded rapidly. K. Vergopoulos (1978) and other authors argue that there has been an over-mechanization and there are indeed cases where farm machinery (tractors, etc.) is used as prestige or status symbols. There is also, on the average, a low degree of its utilization. The inefficient utilization of a large portion of the Greek agricultural equipment is due to, on the one hand, practical reasons relevant to the special characteristics of the land and the structure of the farms, and on the other hand the perception of the farmers in relation to the management of their farms and their input.

The vast majority of farmers, affected by serious structural weaknesses and productivity problems, do not strive for a macroscopic approach of farm management. These problems involve the small size of holdings, the multi-fragmentation of farms, the low level of farmers’ education and training, the irrational use of modern technology and the high production cost as well as the underdeveloped marketing of agricultural products, and the state of the cooperative movement and of the bureaucratic public administration.

After Greek accession to the EEC, income increase and the improvement of standard of living was the result of extraneous interventions in relation to the conventional Greek agricultural farming system and many of its advantages remained unexploited by the great majority of producers. This seems to confirm what Harrison and Kennedy had noted in 1977: “Supporting domestic production at artificially high prices may detract from the competitive advantage of the nation by inhibiting the development and adoption of new technologies”.

Furthermore, the cutback in private investments, irrational management of EU funds and ineffective structural policy appear to have played a decisive role in the fall in the competitiveness of Greek agriculture (Demoussis 2003; Petropoulos 2007). A substantial part of the increased income is directed towards consumption and urban real estate, disregarding investments which would improve the infrastructure of their farms. Between 1980 and 2007 the gross fixed capital investments in agriculture were reduced from 7, 8% to 4%.

Beyond all forecasts, the accession of Greece to the EU did not set in motion the integration of its agricultural structures, but rather it seems to have reinforced the heterogeneities and inequalities at many levels. The vast majority of farmers pursue a survivalist model of farming depending on various combinations of land, labor and capital (Daskalopoulou & Petrou 2002). Furthermore, individual or family pluriactivity of the agricultural household tends to be the norm.

A vastly accepted index of the mechanization of a farm, a region or a country is the number of medium power tractors (for Greece is 4,5 kW/ha) which correspond to 100 ha of UAL. The Farm Structure Survey (2009) estimates the UAL to 3,477,900 ha and the number of tractors to 257,385 units, which means that mechanization index is 7.4 tractors per 100 ha of UAL. Furthermore, if we add to the calculation the uniaxial tractors (132,624 units), our index rise to 11.2. Taking into consideration that in south-eastern European countries the number of (axle) tractors (per 100 ha of arable land) is in range from 1.5 (Bulgaria) to 25.0 (Croatia) and the installed power engine of the tractors (per 1 ha) is from 0.3 to 5.4 kW/ha, we see that Greece is at a relevant high level of mechanization.

3. Farm machinery during the economic crisis

The following results are part of the preliminary processing of a research for farm machinery in Achaia, landed in the northern-west of Peloponnese. The research took place during the winter of 2015. The prefecture is divided into 5 sub prefectures and encapsulates the three typical zones of the Mediterranean landscape, lowland, hilly and mountainous. The UAL is estimated at 53,275.4 ha and there have been recorded 4,309 tractors. The mechanization index is 8 tractors per 100 ha, which is assumed to be satisfactory. Although, the power of tractors is big, the fieldwork showed small rate of utilization. This was, mainly, due to the lack of the necessary complementary parts (mechanical seeder, mechanical fertilizer spread, etc.) in order to have complete farm mechanization.

Table 2. Registered tractors in the prefecture of Achaia during the last five years.

	2010	2011	2012	2013	2014
New	47	28	22	36	43
Used	88	80	52	6	76
Total	135	108	74	98	119

Source: Ministry of Agriculture, Direction of Patras.

As far as new tractors are concerned, for the last three years before the recorded period there were registered: 93 in 2007, 55 in 2008, and 52 in 2009. There have been a great drop in tractors' market from 2009 and then, due to the economic crisis. It is observed that only after 2012, the market has started to adjust, presenting a relevant rise for used and cheaper tractors.

Two programs contributed mostly in the mechanization of the farms during the last years, encouraging farm machinery purchase, European Union Young Farmers Program (Aggelopoulos et al, 2015) and Program for Young Farmers to buy land with subsidized interest (see Table 3).

Table 3. Young Farmers of Achaia in Programs.

Year	Young Farmers Program	Program for Young Farmers to buy land
2000	102	
2001/2	226	
2003	131	
2004		26
2004/5	172	
2005		52
2006	79	27
2007		23
2008		36
2009	248	41
2010		20
2011		26
2014	394	
2015		4

Source: Ministry of Agriculture, Direction of Patras.

4. Conclusion

Although rural exodus in the 60s facilitate the modernization of production systems and the approval of mechanization as a mean to improve both the productivity and the quality of agricultural activity, the crisis and the industrial decline since the mid-70s have forced Greek authorities into a support policy for the maintenance of rural population in the countryside, which led farmers to get used to a supported modernization. The CAP has also promoted a similar policy until the mid-80s. The growth of the Greek agriculture was forged, which led, apart from few exceptions, farmers to have passive attitude towards every change of their operational environment.

During the last 25 years, Greek agriculture while being fully integrated in the European agricultural system is called to survive in a very competitive and volatile environment, without thus far being able to compete, except for some very big farming corporations. The farm management and the management of farm inputs should be made in a different way in order to succeed a competitive production cost with high product quality. The current economic crisis could constitute a chance for setting a stricter and an effective productive system, in order to contribute not only in alleviating sort-term impacts of the economic crisis, but also to help in the mid and long term growth of the farms.

Through observing the mechanization index we conclude that the real problem of the Greek agricultural production system, is not the lack of agriculture equipment, but the inefficiency of the whole productive procedure. Due to bad management, the application of farm machinery is unsuccessful.

The main setback of the Greek agriculture is the false mentality of Greek farmers and their lack of responsibility and professionalism towards their agribusiness approach.

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Agriculture and Agricultural Science Procedia 7 (2015) 203 – 208

Agriculture and Agricultural Science
Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

The influence of the water quality on the droplet spectrum produced by agricultural nozzles

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Abstract

The aim of the studies was to check if the quality of water, which was taken from different sources, to plant protection treatments influences the change of the droplet size generated by an agricultural nozzle. For the study water taken from 3 different sources was used and demineralized water was used as a reference. The water quality was evaluated as far as its hardness was concerned. Water hardness was measured with a droplet test. One of the most frequently used by farmers type of agricultural nozzle TeeJet VP of the size 110/02 was used in the study. The study was performed in two combinations. One of them was carried out for the pure water and the second one for water with addition of agricultural spray adjuvant Superam 10AL. The measurements were done with three pressure values: 2 bar, 3 bar and 4 bar in three repetitions. The droplet size was measured with a laser diffractometer HELOS/R by Sympatec. The study showed that water hardness did not have any significant influence on the droplet size formed by agricultural nozzles. Adding of agricultural spray adjuvant to the water did not cause any significant change in the droplet size, however, the difference in water hardness caused the decrease of a diameter of formed droplets. The results were compared in a tabular and graphic form. In the next phase of the study for individual types of waters agricultural spray adjuvant was added to check how it influences the change of the size of droplets produced by the nozzles with sliding pressure in the whole range of the stream sprayed by the nozzle.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: agricultural nozzle; droplet size; adjuvants; water hardness.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.018

1. Introduction

According to the Directive 2009/128/EC of the European Parliament and of the Council establishing a framework for Community action to achieve the sustainable use of pesticides the ways of limiting the influence of pesticides on the environment and what follows maintaining safety of crops without their deterioration are searched. Particularly great attention is paid to the precise use of pesticides on protected plants. A very important issue is the pesticide application in such a way so that it is effective in use and at the same time safe for the environment (Hołownicki et al. 2011). Safety of using pesticides in the agricultural area to a large degree depends on techniques of their application. At present great attention is paid to eliminate the phenomenon of drifting of the used liquid in the time of carrying out plant protection treatments (Doruchowski et al. 2012). The quality of applying liquid on sprayed plants depends on parameters of used treatment such as a kind of the nozzle, working pressure and a direction of setting the stream of sprayed liquid against sprayed things (Kierzek 2009, Szewczyk et al. 2013) showed this in their works. The kind of nozzles used and working pressure of the liquid decide the size of droplets created by them.

Nozzles, when they are exploited, wear out and parameters of their work change. These changes are expressed by the increase in both individual outflow and spectrum of formed droplets (VMD) (Reichard et al. 1991, Czaczyk 2001).

At present the most frequently used method of measurement of the droplet size is a method with the use of an electro-optical transducer where the measurement is done in a non-contact way in the real time of relocation of droplets created by nozzle. This device allows to measure size of droplets in over a dozen size classes within droplet diameters from 20 to 1000 μm (Szponder 2006).

With a development of technological progress laser diffractometers are used for basic studies of the quality of the work of agricultural nozzles. They allow measuring the droplet size of sprayed liquid with a high precision; the measurement range of these devices is from 0.5 to 1750 μm. The laser diffractometer for measurement of the droplet size received from different types of nozzles and with different pressures was used by (Schick 2006) in his work.

One of the methods of improving physical properties of applied liquid to plant protection treatments are adjuvants, substances which are used together with plant protection agents or fertilizers to improve the quality of the treatment. Adjuvants are used as a component of produced plant protection agent or also added to the tank and mixed with pesticides (Lin et al. 2007). They improve effectiveness of spray by equalization of the droplet size and limiting drifting by wind.

They decrease surface tension of working liquid thanks to which they enable to cover the bigger part of a leaf blade and at the same time they contribute to better absorption of liquid to plant cells (Butler et al. 1996, 1998). The additional advantage of adjuvants is the possibility of combining different plant protection agents and using them during one treatment which has an important influence on decreasing the risk of drifting of applied liquid (Combellack et al. 1996).

2. Material and methods

In the study water taken from three different intakes which are in the area of agricultural commune Sosnówka, Lublin Voivodeship and water from the water supply system of Lublin city. Demineralized water was used as a reference.

A - water from the water supply system on the farm located in Sosnówka commune,

B - water from the well located on the farm in Sosnówka commune,

C - water from the water supply system of Lublin city,

D - demineralized water.

Water from each intake was tested for hardness. Water hardness was determined with the use of the droplet test and its size was determined with the use of so called "scale of German degrees (ºn)" (instalreporter.pl) The following degrees of water hardness were received: A - 10 ºn, ,B - 11 ºn, C - 22 ºn, D - 1 ºn. According to this scale water from A and B intakes was classified as medium hard water, water from intake C – as hard water and demineralized water D as soft water.

To create spectrum of droplets a new agricultural atomizes TeeJet VP 110/02 was used. The nozzle was tested for values of intensification of outflow at the measurement point to control unit consumption from agricultural nozzles by

ITEQ, Belgium. The size of intensity of the liquid outflow from nozzle for individual pressure values corresponded with nominal values for this nozzle.

Measurement of the size of intensification of the outflow and tests of the droplet size were done for the pressure: 2, 3 and 4 bar.

Measurement of the droplet size was done by the laser diffractometer HELOS/R of Sympatec company equipped with an optical set enabling measurement of the particle size from 1 to 3500 μm. The tested nozzle was placed on the height of 500 mm above the laser light. The measurement was done in seven locations, that is: location 0 nozzle center in the laser light axis and with three locations on the left side marked with (-) sign and right side marked with (+) sign. Each of these locations was in the distance of one another every 200 mm from the nozzle axis.

These tests were carried out for pure water and with addition of the adjuvant called SUPERAM 10 AL in a dose recommended by the manufacturer that is 50 ml per 100 l of water.

3. Results

The measurement of the droplet size was done in three repetitions. The nozzle worked constantly, measurement of the droplet size was carried out in 10 seconds for each of settings of the nozzle towards the light stream of the laser diffractometer. Received mean values for each done measurements are presented in table 1.

Table 1. The droplet size received in the stream of sprayed liquid and the VMD value for water of different hardness without any adjuvant.

Type of water	Pressure [bar]	Nozzle position towards the laser light							VMD
		Left side (-) [mm]			center	Right side (+) [mm]			
		-600	-400	-200	0	+200	+400	+600	
A	2	290	239	216	200	215	249	290	254
	3	257	221	193	178	198	230	270	237
	4	221	210	190	165	184	210	230	225
B	2	298	265	231	213	226	259	301	256
	3	254	218	194	177	186	215	258	220
	4	234	200	182	150	177	200	244	199
C	2	296	259	235	213	222	258	292	247
	3	249	210	190	175	194	215	258	219
	4	219	196	171	150	172	191	225	197
D	2	282	236	213	183	208	250	296	261
	3	248	212	185	155	178	210	256	219
	4	220	190	171	149	169	188	216	211

On the basis of conducted research it can be stated that water hardness has a slight influence on the size of droplets produced by the agricultural nozzle. In each case regardless of water hardness a significant influence of working pressure on the size of produced droplets was noticed. This size can be noticed considering the mean value of VMD for the whole stream of sprayed liquid. The smallest values of droplets were received for demineralized water classified as soft water. Observing the change in droplet sizes in individual places of the stream of sprayed liquid it can be noticed that the smallest droplets are produced in the nozzle axis.

Going away from the nozzle axis on the left and right a steady increase of the droplet size is seen. The biggest droplets are seen on the edges of the sprayed liquid stream. For the pressure of 2 bar, the difference between the center of the sprayed liquid stream and distances 600 mm (+) and (-) equal about 80 μm, whereas with the increase of pressure, the difference between the center of the liquid stream and extreme measured up to about 50 μm. Values of droplet sizes received from the left and right side of the sprayed liquid stream at the same distances are comparable and indicate equal work of the nozzle.

Next, for each type of water the adjuvant was added and the test of the size of received droplets with the same parameters of nozzle work like for clear water was done. The results of received sizes of droplets are presented in table 2.

Table 2. Droplet size received in the sprayed liquid stream and MD value for water of different hardness with adjuvant SUPERAM 10AL

Type of water	Pressure [bar]	Nozzle position towards the laser light							VMD
		Left side (-) [mm]			center	Right side (+) [mm]			
		-600	-400	-200	0	200	400	600	
A	2	278	243	236	215	232	256	285	252
	3	239	225	209	184	201	227	259	198
	4	217	202	190	163	181	197	225	198
B	2	287	254	249	217	240	260	286	242
	3	244	224	208	189	206	223	257	213
	4	221	200	187	162	187	206	227	206
C	2	287	252	235	211	236	246	280	239
	3	240	229	201	176	197	221	247	208
	4	216	202	185	163	179	207	226	188
D	2	292	271	237	214	244	275	298	242
	3	253	230	201	181	201	223	250	211
	4	230	221	191	179	185	209	228	191

Addition of the adjuvant caused a slight difference in the size of droplets produced by the nozzle. This value can be observed considering the mean size expressed by VMD. A slight increase of the diameter of received droplets was observed in the nozzle axis for demineralized water; whereas, for medium hard water and hard water this increase was small. With the increase of distance from the center of the nozzle to the left or right side it was observed that the size of produced droplets increases but it is to a lower degree like for water without any adjuvant. Increase in the size of working pressure caused decrease in the size of droplets produced by the nozzle.

The influence of adjuvant for hard water (C) and the amount and frequency of occurrence of droplets produced by the atomiser were presented in Figure 1, whereas for demineralized water it was presented in Figure 2.

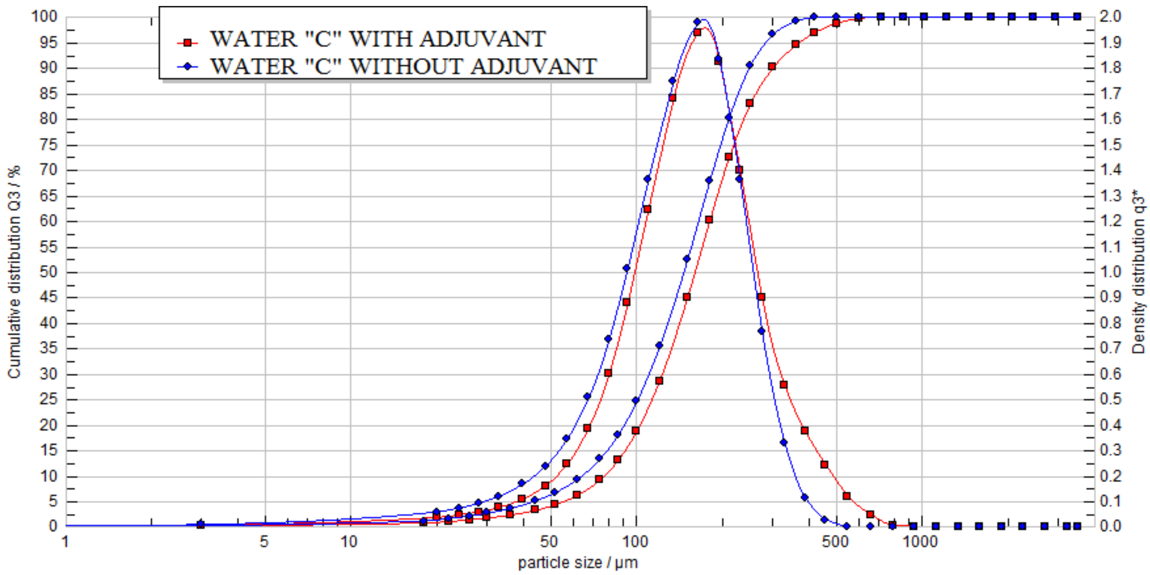

Fig. 1. The amount and frequency of occurrence of individual sizes of droplets produced by the atomiser TeeJet VP 110/02 with the pressure of 3 bar for hard water C.

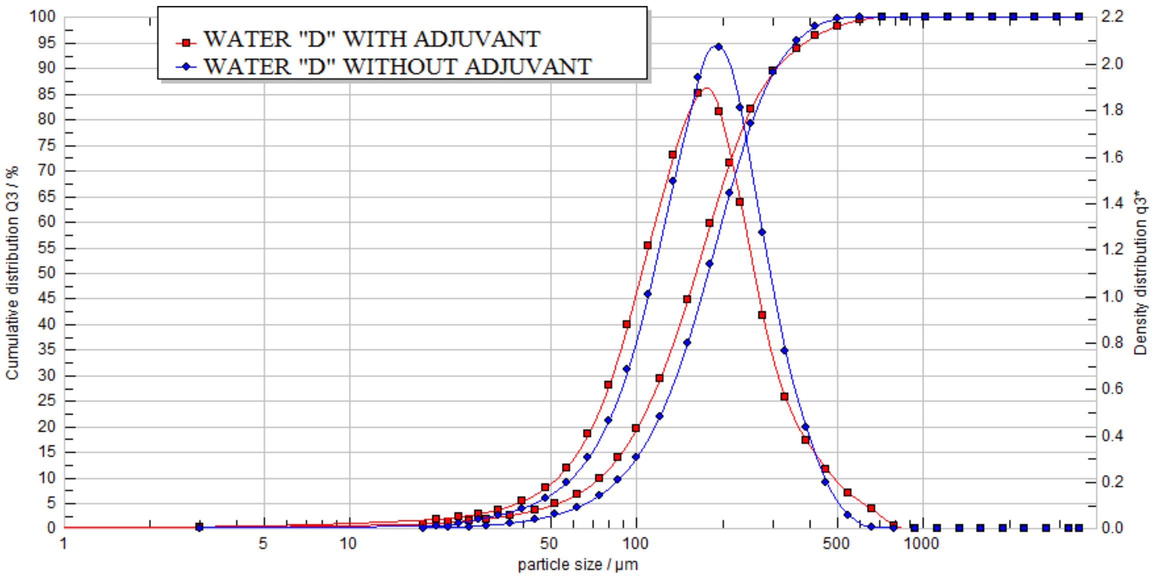

Fig. 2. The amount and frequency of occurrence of individual sizes of droplets produced by the atomiser TeeJet VP 110/02 with the pressure of 3 bar for demineralized water D.

4. Summary

In the implementation in the agricultural practice of the principle of balanced application of pesticides the attention should be paid to the technique and safety of plant protection treatments. Effectiveness of the treatment depends, to a large degree, on the precision and degree of covering. That is why a suitable matching of the techniques of spraying, while taking into consideration received sizes of droplets, is an important issue. For agricultural practice the size of droplets produced by the nozzle is most often given taking into consideration the norm ANSI/ASAE S572.1 (2009). Using a suitable nozzle type influences the level of covering but also the phenomenon of occurrence of uncontrolled drift of sprayed liquid (Hołownicki et al. 2012). Information about the most suitable size of droplets for a given treatment should be written on the label of the plant protection agent (Czaczyk 2014). Forming of the sprayed liquid stream regarding the amount of fall and size of formed droplets has not been mastered by the manufacturer of nozzles yet. The solution would be to create an ideal nozzle which will keep its homogeneity and equalization of the liquid stream (Huyghebaert 2015). For many years, substances improving physical properties of liquid, such as adjuvants, have been used. In agriculture, water used for plant protection treatments comes from many sources of different hardness. The study of the droplet size received from the agricultural nozzle showed that water hardness does not have a significant influence on their size. Addition of the adjuvant to little degree causes decrease in disparity between droplets produced in many places of sprayed liquid stream.

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Agriculture and Agricultural Science Procedia 7 (2015) 209 – 214
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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Agriculture: accident-prone working environment

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Abstract

The article presents the analysis of agriculture as working environmentally prone to accidents. A questionnaire has been used for the evaluation which included 15 questions for establishing causes of accidents at work in agriculture. Studies have shown that haste, mess and failure to comply with basic safety rules is the most common cause of accidents. It is therefore necessary to raise farmers' awareness about the risks of accident.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: accidents; agriculture; prevention.

1. Introduction

Working on a private farm is considerably different to working on an industrial farm. It can be described as seasonal and it entails frequent changes of performed activities as well as conditions in which they are performed. It takes more than 12 hours a day for people working in the countryside to do their tasks whatever the season and weather conditions (Pawlak and Hołaj, 2012; Cież, 2010). Their workplace is not only the house but also the yard, farm buildings, the field and sometimes ponds. Farmers changing their workplace, the level of its mechanization, working tools and daily working time change, which along with the exposure to many hazardous mechanical factors including thermal, dust, biological and chemical ones, leads to fatigue and increases the risk of an accident (KRUS, CIOP, 2015; Juliszewski, 2007; Nowakowicz-Dębek et al., 2011; Nowakowicz-Dębek et al., 2014; Pawlak et al.,

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.019

2013). The act of social insurance for farmers defines an occupational accident as an unexpected occurrence caused by an external factor which happened whilst conducting an activity on a farm, on the way from the house to the farm and on the way back, as well as during usual activities conducted away from the farm but connected with the farm (Dz.U., 2009; Dz.U., 2015). In the year 2014 21,939 accidents were recorded in agriculture in Poland. One-off compensations were paid, for damage to health or death accruing from occupational accidents, to 15,649 cases. The number of accidents is smaller compared to 2013 (6.1% decline), however, the overall number is still high (fig.1). KRUS statistics (2015) show a downturn as accidents with children are not recorded.

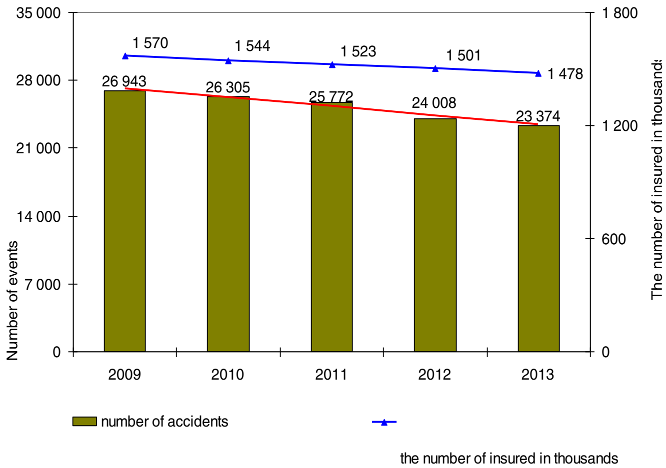

Fig.1. Number of farming accidents between 2005 and 2014 (KRUS, 2015)

According to statistics, most fatal accidents happened due to 'being run over, being struck, being caught by a moving vehicle' and 'falling' – 15 victims, 'falling objects' – 14 victims, 'sudden attack of illness' – 11 people, but the cause of fatal accidents mentioned was mostly badly organized work (GUS, 2014). Taking into consideration types of incidents, most people were injured because of 'falling' – 7,647 (49 % of all one-off paid compensations), 'being caught or hit by moving parts of machines and devices' – 2,047 (13.1 %) and 'being hit, crushed or bitten by animals' – 1,867 (12 %).

Statistics show that there is no voivodeship (territorial unit) in Poland where there have been no recorded agricultural accident. There are still a high number of accidents in this economic sector. This is why a detailed analysis of this particular work environment has been conducted.

2. Material and methods

The analysis was conducted amongst farmers running medium-size and small agricultural holdings in central and eastern Poland. An independent survey was used to conduct the analysis; it included 15 varied multiple-choice questions, open questions, yes/no questions. The questions were arranged into thematic sections: principles of OHS, training, maintenance of machines and equipment, use of personal protective equipment, causes and effects of accidents. The group of respondents selected for the study consisted of 100 farmers aged 20-48. The results were analysed statistically.

3. Results and analysis

Taking preventive actions leads to raising awareness concerning hazards occurring in a farmer's work environment. Access to information about prevention measures and their usage at work indirectly causes the

reduction of a negative effect of hazards, which leads to a decrease in accidents.
In the study conducted, the respondents point to the fact that they actively participate in training organized by different institutions (fig.2).

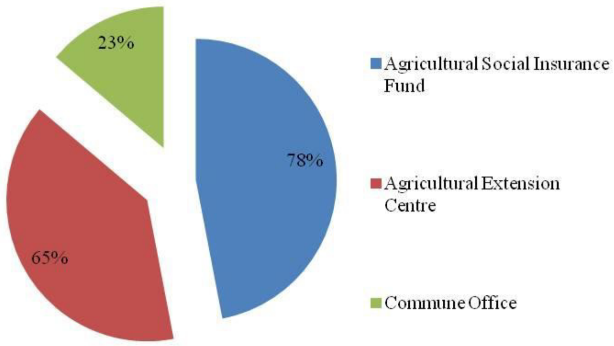

Fig.2. Does he/she participate in OHS trainings?

The most popular training sessions and lectures are those organized by Agricultural Social Insurance Fund. One of the causes of accidents in agriculture is the lack of knowledge of OHS principles and unwillingness to familiarize oneself with safety instructions for the maintenance of machines and equipment (fig.3).

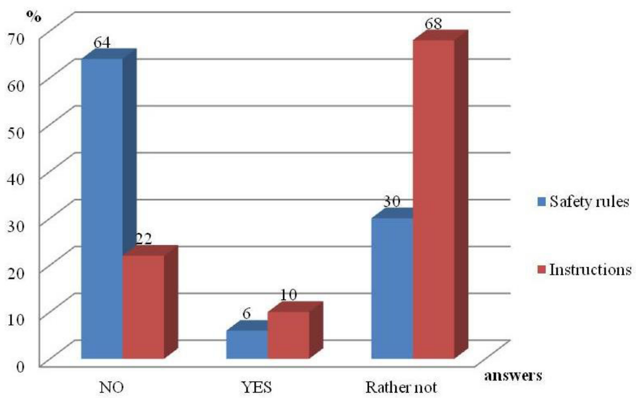

Fig.3. Does he/she know OHS principles used in agriculture, does he/she familiarize himself/herself with safety instructions for machines/equipment?

Another hazard occurring in agricultural holdings is the misuse of machines/equipment. Over 20% of the respondents indicate such a possibility of equipment usage depending on the existing need or the organization of work in the agricultural holding (fig.4).

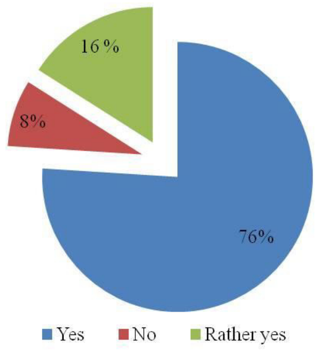

Fig.4. Are the machines/equipment used according to their proper usage?

During training sessions for farmers the issue of usage of personal protective equipment is raised. The respondents indicate that they willingly use such equipment; however, using it is often dependent on economical factors (fig.5). Most often the interviewees use safety goggles (55%) and protective masks (38%) as prevention measures.

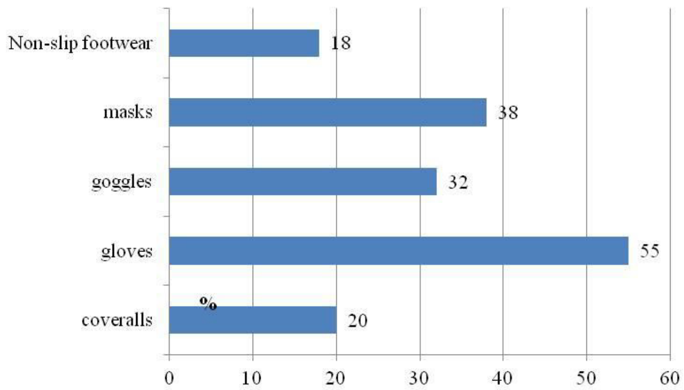

Fig.5. Do you use personal protective equipment?

In contrast, coveralls, and non-slip footwear are not frequently used (20% and 18%). Probably, because their use requires additional costs.

The interviewees indicate that even though their awareness concerning OHS and the use of personal protective equipment has been raised, accidents occurred in almost 40% of agricultural holdings (fig.6).

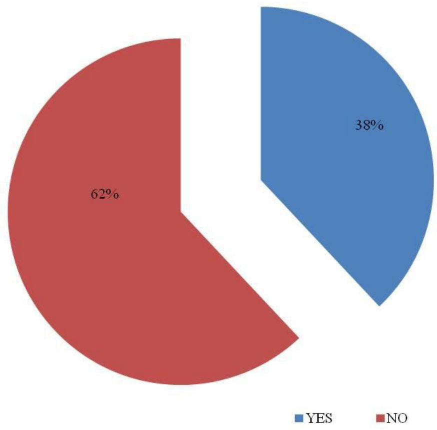

Fig.6. Were there any accidents in the agricultural holding last year?

Respondents asked about other causes of accidents definitely indicated the lack of planning activities, the rush and clutter on the farm.

4. Conclusions

Agriculture is a high-risk sector, in which thousands of occupational accidents happen every year. In this sector there is a wide variety of ages. Young people's knowledge does not correlate with experience of older farmers. Scientific studies confirm a strong relation between the quality of work in agriculture, observing the principles of OHS and the risk of injuries and fatalities. It has been shown that practical training sessions for young farmers have a big influence on the quality of their agricultural holdings and reduction of hazards. Moreover, important differences have been observed in how agricultural holdings are run by men and women (Ramaswamy and Mosher, 2015; Kuta and Cież, 2013). Pompeii et al. (2015), just like our own analysis, points to a frequent misuse of agricultural equipment and use of equipment which has no appropriate protection. It has been shown that being in a hurry, mess in the agricultural holding, misusing machines are the most common causes of accidents, the number of which is still the same. In the studied region the accident rate is 13.8 for a thousand of the insured. During the summer of 2014 there were 6 fatalities and over 1,500 injured.

This is why it is necessary to constantly train farmers and emphasize the importance of being familiar with safety instructions and health and safety regulations for work safety. The formation of custom to maintain order in the area around the farm and the organization of the working day, is another factor to eliminate accidents in agriculture. It is also important to transfer of such information already at the stage of vocational training.

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Agriculture and Agricultural Science Procedia 7 (2015) 215 – 222

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

The impact of structural and operational parameters of the centrifugal disc spreader on the spatial distribution of fertilizer

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Abstract

The objective of this study was to specify the impact of structural and operational parameters of the centrifugal disc spreader on the spatial distribution of fertilizer varied in terms of physical properties (urea, ammonium sulfate, nitrochalk). The spatial distribution was characterized by parameters of the stationary spread pattern in the polar coordinate system: average angle and average radius of the stationary spread pattern of fertilizer. In the study, the selected parameters which significantly affecting spread quality were: rotation speed of the disc, feed position of fertilizer on the disc and the vanes angle on the disc. In order to determinate the impact on spatial distribution, the results were statistically analyzed based on the analysis of variance. The study showed that the factors impacting greatly the average angle of the stationary spread pattern are: the feed position of fertilizer on the disc, the vanes angle on the disc and the fertilizer type. Finally the fertilizer type and the rotation speed of the disc influence greatly the average radius of the stationary spread.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: centrifugal disc spreader; mineral fertilizers; stationary spread pattern; spatial distribution.

1. Introduction

The fertilization quality using centrifugal disc spreaders is assessed primarily by an image of the transverse distribution of fertilizer on the surface of the field, which affect three groups of factors (structural and operational

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.021

parameters, physical properties of fertilizers, external conditions). In operational conditions the settings of transverse distribution of spread fertilizer are based on the spreading tables or mobile measuring test stations (Kweon and Grift, 2006; Lawrence et al., 2006; Olieslagers et al., 1996; Tissot et al., 2002).

An important parameter determining the efficiency of spreading fertilizer is the throwing width according to the European Standard EN 13739 which is defined as the distance between the left and right border of a single crossing through entire field. While the term working width is defined as maximum spreading area between outward and return passes and it achieves total coverage, at which coefficient variation of transverse distribution does not exceed the limit value 15% (PN-EN 13739-2: 2004).

In order to assess the main operating parameters of centrifugal disc spreader the spatial distribution of spreading fertilizer should be determined, which shows the amount of mass fertilizer referred to the surface of spreading pass unit. Dintwa et al. (2004) distinguished several types of fertilizer distributions to estimate the quality of spread process. For example, the first one is tangential distribution pattern that shows the location of the fertilizer around the disc and specified distance (radius) measured from its center. The other is static (stationary) distribution pattern represented by two-dimensional distribution of fertilizer on a field in the absence movement of centrifugal disc spreader. The parameters of this distribution are defined by the average angle and average radius of the stationary spread pattern.

It is known, that standard centrifugal disc spreaders are designed to achieve a uniform distribution across an entire field after overlapping [Jones et al., 2008]. Even in agriculture is possible to observe problems with deficit or overdosing fertilizers, which are reflected through the image of multi-colored stripes on the surface of the field crop. Further research in this subject, the relationships between the type of fertilizer and spreader design parameters can minimize this adverse phenomenon. However, it is necessary to improve the fertilizer application quality especially to avoid growing concerns about environmental impact of fertilizers applied to the soil.

Nomenclature

$\bar{\beta}$	average angle of the stationary spread pattern of fertilizer
$\bar{R}$	average radius of the stationary spread pattern of fertilizer
f_{ij}	mass fraction of particles in the collector tray, g
β_{ij}	angle of the ij-th collector of particles in the collector tray, °
n	number of rows of trays
m	number of columns of trays
r_{ij}	radius of the ij-th collector of particles in the collector tray, m.

2. Materials and methods

The study about the impact of structural and operational parameters of the centrifugal disc spreader on the spatial distribution of fertilizer had been carried out in an indoors measuring position was shown schematically in Figure 1. It consisted of trays with dimensions 0.5 m × 0.5 m × 0.15 m, made in accordance with PN-EN 13739-2 2004, which arranged in sixteen columns and eleven rows (0.5 m distance between rows and columns). On the right-hand edge of the ninth column trays and at a distance 0.7 m from the first edge of the first row was located in the center of the centrifugal disc spreader [with coordinates (0,0) in the 0XY system].

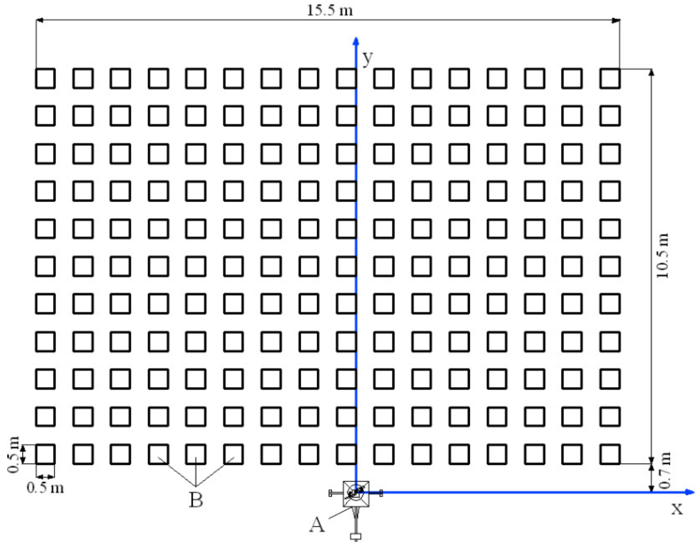

Fig. 1. The scheme of measuring position in coordinate 0XY system: A – centrifugal disc spreader, B – collecting trays.

In the tests three mineral fertilizers were used (urea, ammonium sulfate and nitrochalk), whose choice was made due to the different physical properties. The measuring station was located in a close hall so wind speed and direction were not registered. Relative humidity of the air contained in the range from 52 to 57.7% and a temperature from 13°C to 17°C. Selection of rotation speed of the disc (400 and 600 rpm) was based on the analysis of literature and dimensional possibilities of the hall where studies were conducted. The feed positions were chosen from the solutions used in series-produced centrifugal disc spreaders. As a feed position was assumed the angle between semi-axis OY from second quarter of the Cartesian coordinate system and half line determined by origin of coordinate system and passing through the vertical projection on the disc at a given centre of feed orifice (A and B), figure 2.

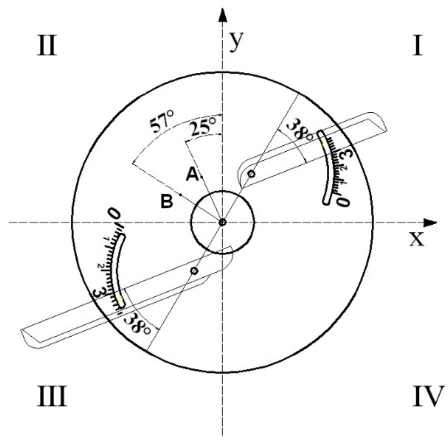

Fig. 2. The location of the orifice centers dosing fertilizer (A and B) on surface of the disc and the vanes angle in configuration L3.

In order to achieve the assumed research program was assumed two positions of the vanes on the disc (configuration L3 according to the scale on the disc), which allowed to obtain of the stationary spread pattern fertilizers differing in shape and dimensions. The study used the vanes which are equipped with centrifugal disc spreader N0X produced by Sipma. As a position meter of the vanes was assumed the concave angle included between the edge of positioning shorter vanes and a straight defined by the points of rotation both vanes during their changing position on the disc, Figure 2. The setting of vanes in the utmost position according with the direction according to their rotation on the disc. For this configuration both angles of vanes are equal and are 38°. When the vanes are in the second utmost position (configuration L0) the angles are varied and are: 65° for short vane and 84° for long vane.

On the basis of the research results the parameters of spatial distribution were determined in the polar coordinate system with centre located at the point of rotation disc, Figure 3.

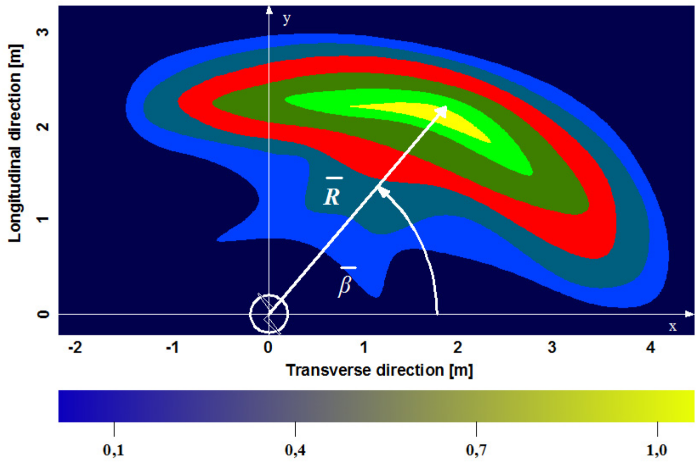

Fig. 3. Determining the parameters of spatial distribution for the stationary spread pattern in the polar coordinate system.

The parameters of this field are the average angle ($\bar{\beta}$) and average radius ($\bar{R}$) of the stationary spread pattern of fertilizer, which is calculated by the following equation (Koko and Virin, 2009; Kweon et al., 2009):

$$\bar{\beta} = \sum_{i=1}^{n}\sum_{j=1}^{m} f_{ij}\beta_{ij} \quad (1)$$

$$\bar{R} = \sum_{i=1}^{n}\sum_{j=1}^{m} f_{ij} r_{ij} \quad (2)$$

In order to present the total impact of factors on the stationary spread pattern parameters of mineral fertilizers assumed the four-way orthogonal cross-classification model with three observations in each subclass. The results of analysis of variance was developed in the SAS 'Local', XP_PRO (significant level $\alpha = 0.05$). Accuracy of model fitting is described by determination coefficient R^2. Significance of differences between variations levels of studied objects were done using T-Tukey procedure.

3. Results

The results of the physical properties of fertilizers used in the studies are shown in Table 1 and the particle mass distribution in Figure 4.

Table 1. The physical properties of mineral fertilizers

Characteristic	Kind of fertilizer		
	Urea	Nitrochalk	Ammonium sulfate

Bulk density (loose), kg·dm^{-3}	0.758	1.029	1.018
Bulk density (shaked), kg·dm^{-3}	0.789	1.062	1.104
Mass density, kg·dm^{-3}	1.340	1.800	1.780
Mass powdery fraction (< 1 mm), %	10.35	0.03	52.50

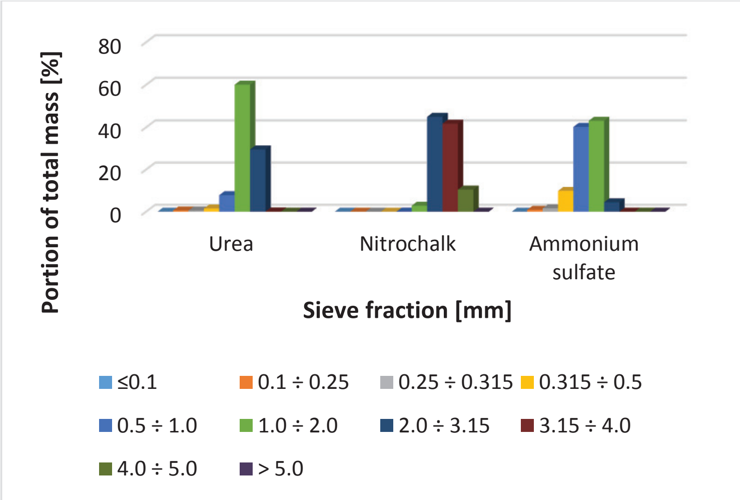

Fig 4. Particle mass distribution for urea, nitrochalk and ammonium sulfate.

Figures 5 and 6 are shown the results for average angle and average radius of the stationary spread pattern for three different mineral fertilizers according to the three independent variables: rotation speed (400 rpm; 600 rpm), feed position (A; B), vanes angle (L0; L3).

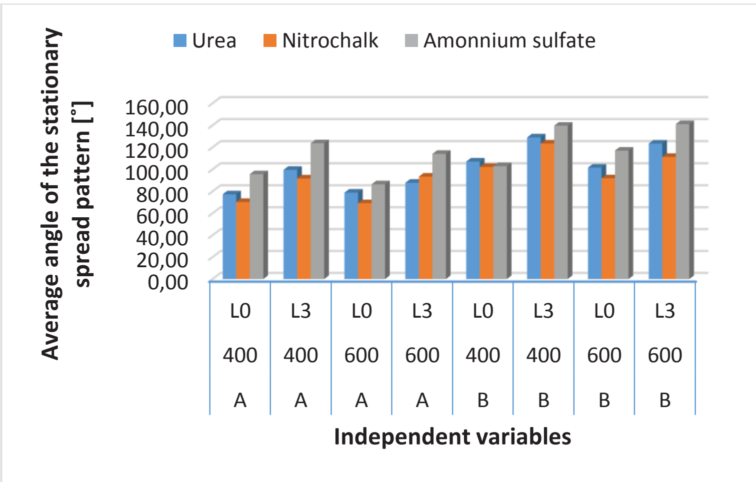

Fig.5. The average angle of the stationary spread pattern for urea, nitrochalk and ammonium sulfate.

The calculated values for the average angle and average radius of the stationary spread pattern for the three investigated fertilizers of substantially different physical properties are shown in Figure 5 and 6. The information contained in Tables 2 and 3 are for statistical analysis of results, which included an analysis of variance. The data given in Figure 4 indicate that the fertilizers differ significantly in terms of their susceptibility to spreading by centrifugal disc spreaders. This is particularly evident when comparing parameters of the stationary spread pattern for ammonium sulfate and nitrochalk. The average angle of the stationary spread pattern from the first listed fertilizers is 141.10° (feed position B, 600 rpm, vanes angle L3). The stated value is double more than compared with the smallest angle of nitrochalk, which was characterized spread by parameters: feed position A, 600 rpm, vanes angle L0. The minimum average angle of the stationary spread pattern for nitrochalk (feed position A, 600 rpm, vanes angle L0) was only 69.27° and was slightly smaller than angle spread at 400 rpm (70.36°).

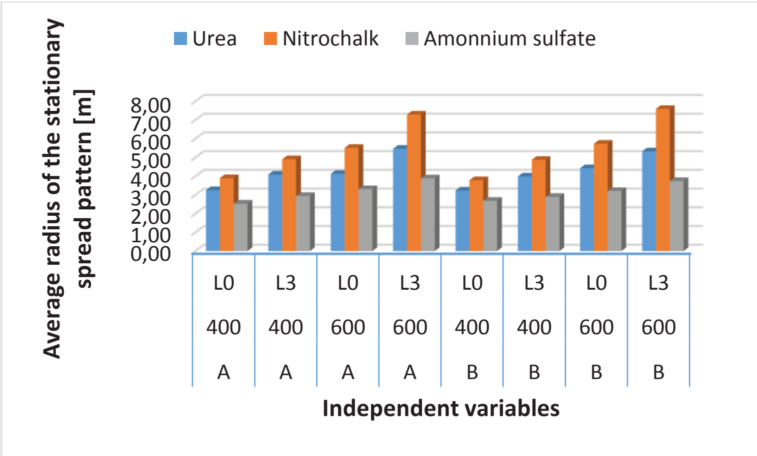

Fig. 6. The average radius of the stationary spread pattern for urea, nitrochalk and ammonium suflate.

By analyzing data relating to the average radius of the stationary spread pattern, it should be noted that the greatest value of this parameter was observed during the nitrochalk tests. The average value of this radius is even 7.59 m for the experimental conditions: feed position B, 600 rpm, vanes angle L3. The specified value is almost three times greater than the average radius of the stationary spread pattern for ammonium sulfate: feed position A, 400 rpm, vanes angle L0.

Figure 7 shows an example of spatial distributions for urea, which it follows that shifting the vanes from position L0 to L3 at the same rotation speed of the disc (600 rpm) and feed position (A) contribute to change of the stationary spread pattern parameters.

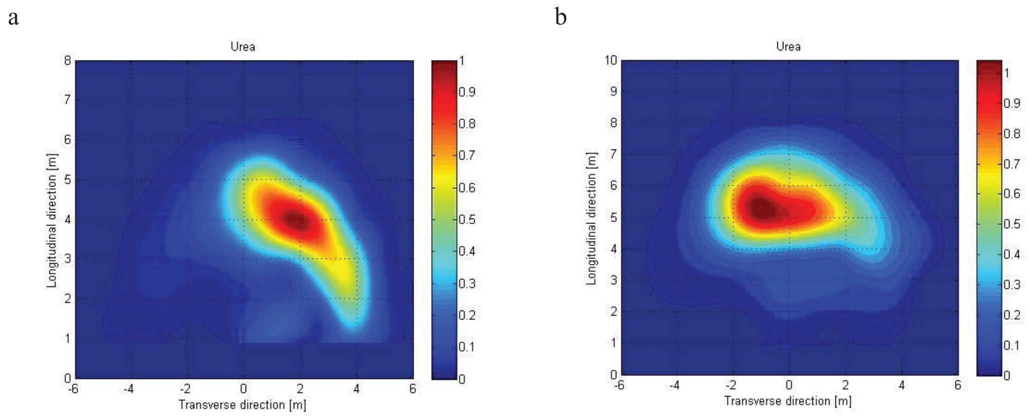

Fig. 7. The stationary spread pattern for urea: a) L0 ($\bar{R}$= 4.12 m, $\bar{\beta}$ = 78.88°) ; b) L3 ($\bar{R}$= 5.46 m, $\bar{\beta}$ = 87.88°).

The analysis of variance for the average angle of the stationary spread pattern for fertilizers based on the four-way classification (N × O × M × L) with three observations in each subclass showed that the independent variables included in 96.86% explain variance of dependent variable. A slight value of coefficient of variation (3.82%) indicates a good choice independent variables and properly carried out studies. Table 2 shows that the three effects of two-way interaction (fertilizer × rotation speed, feed position × vanes angle) turned out to be significant (at the required level of significance α = 0.05) in explaining variability of average angle of the stationary spread pattern.

Tab. 2. Analysis of variance for average angle of the stationary spread pattern model based on the four-way classification (N × O × M × L) with three observations in each subclass

Source of variation	Degree of freedom	Sum square	Quadratic mean	Value of a function F	Probt.>F
Model	14	27571.96	1969.43	126.64	< 0.0001
Error	57	886.39	15.55		
Sum	71	28458.35			
R^2= 96.86%; Mean value of average angle of the stationary spread pattern 103.30°; Coefficient of variation 3.82%					
Fertilizer (N)	2	5465.86	2732.93	175.74	< 0.0001
Rotation speed (O)	1	266.65	266.65	17.15	0.0001
Feed position (M)	1	11421.36	11421.36	734.45	< 0.0001
Vanes angle (L)	1	9617.47	9617.47	618.45	< 0.0001
N × O	2	81.68	40.84	2.63	0.0811
N × M	2	251.11	125.55	8.07	0.0008
N × L	2	351.97	175.98	11.32	< 0.0001
O × M	1	12.33	12.33	0.79	0.377
O × L	1	83.18	83.18	5.35	0.0244
M × L	1	20.34	20.34	1.31	0.2575

The analysis of variance for the average radius of the stationary spread pattern for fertilizers showed that included variables independent in 99.48% explain variance of dependent variable. It should be noted, however, that from the main effects only the feed position of fertilizer on the disc turned out to be irrelevant for explaining variability of the average radius of the stationary spread pattern. Its share in explaining the variance of dependent variable is only 0.008%. The participation of the others effects (kind of the fertilizer, rotation speed, vanes angle) in explaining the variability of the dependent variable is 91.74%. It should be mentioned that only one two-way interaction effect (kind of the fertilizer × feed position) turned out to be irrelevant in explaining variability in average radius of the stationary spread pattern.

Tab. 3. Analysis of variance for average radius of the stationary spread pattern model based on the four-way classification (N × O × M × L) with three observations in each subclass

Source of variation	Degree of freedom	Sum square	Quadratic mean	Value of a function F	Probt.>F
Model	14	123.82	8.84	783.26	< 0.0001
Error	57	0.64	0.01		
Sum	71	124.46			
R^2= 99,48%; Mean value of average angle of the stationary spread pattern 4.28 m; Standard error of estimation 0.106; Coefficient of variation 2.48%					
Fertilizer (N)	2	63.44	31.72	2809.03	< 0.0001
Rotation speed (O)	1	34.24	34.24	3032.2	<0.0001
Feed position (M)	1	0.01	0.01	0.94	0,337
Vanes angle (L)	1	15.92	15.92	1409.65	< 0.0001

N × O	2	6.16	3.08	272.55	<0,0001
N × M	2	0.05	0.025	2.16	0.1241
N × L	2	3.02	1.51	133.76	< 0.0001
O × M	1	0.05	0.05	4.21	0.0448
O × L	1	0.89	0.89	79.54	<0.0001
M × L	1	0.050	0.05	4.12	0.0471

4. Conclusions

1. Mineral fertilizers used in tests (urea, ammonium sulfate, nitrochalk) differed significantly, bulk density, mass density and size grading. The ammonium sulfate contained up to 52.50% of powdery fractions. The specified value is more than 1.7 thousand times greater in comparison with the content of nitrochalk powdery fractions. The content of powdery fraction in urea was 10.35%. The highest bulk density (1.029 $kg \cdot dm^{-3}$) and mass density (1.800 $kg \cdot dm^{-3}$) was observed for nitochalk. The smallest density was observed for urea, which represented approximately 74% of nitochalk density (comparison within the same category). Bulk density and mass density of ammonium sulfate accounted for around 99% of the density of nitrochalk.

2. The analysis of variance for the average angle of the stationary spread pattern showed that the three independent variables (feed positon, vanes angle, kind of fertilizer) explain 93.14% variance of dependent variable. The feed position of fertilizer on the disc explains 40.13% of the total variation in average angle of the stationary spread pattern of fertilizers. It is worth emphasizing the insignificant share of rotation speed of the disc in explaining variability of dependent variable (only 0.94%).

3. The analysis of variance for average radius of the stationary spread pattern showed that the two independent variables (the kind of fertilizer and rotation speed of the disc) explain in 78.48% variance of dependent variable. A further effect of an important contribution to explaining variation in the dependent variable is the vanes angle on the disc. This share is 12.79 %. The participation of all dual interactive effects in explaining the variance of average radius of the stationary spread pattern for fertilizers does not exceed 8.21 %. However, the feed position of fertilizer on the disc turned out to be the parameter completely not influencing the average radius of the stationary spread pattern.

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Assessment of GHG emissions and their variability of meat production systems in Wallonia based on grass and maize

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Abstract

Within the framework of the Optenerges project, funded under the Interreg IV program, the greenhouse gas (**GHG**) emissions of 62 cattle farms representative of the main production systems in the Province of Luxembourg in Wallonia, Belgium were assessed. The main goal of this study was to give reference values for GHG emission intensity in meat production systems based on grass **(G)** and on grass and maize (**G-M**). A second goal was to analyze emission variability in order to identify potential mitigation options. On average, for every kg live weight the G systems emitted 18.2 CO_2 eq.. and the G-M systems 19.2 CO_2 eq.. The difference reflected differences in feed and mineral fertilizer purchases, in manure emissions and in mineral fertilizer application. There were large variations in GHG emissions both between and within the two systems, particularly the latter. This variability was not due to the division of the farms into G and G-M systems, indeed production system types did not allow explaining the variation. When carbon credits were included in the assessment, there was an emission reduction of 31% and 23% for the G and G-M systems, respectively, indicating an opportunity for the systems using grassland to increase their advantage.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: GHG emissions; carbon footprint; efficiency; meat production; system approach.

1. Introduction

The environmental impact of agricultural systems, especially livestock breeding systems, has become an issue of public concern, among other, due to their greenhouses gas (**GHG**) emissions, particularly methane (CH_4) and nitrous

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.023

oxide (N_2O) originating from rumination and manure management.

In 2012 in the world, agriculture was responsible for 11.2% of total GHG emissions (Tubiello et al., 2015) and these agricultural GHG emissions showed an upward trend (+1% from 2011 to 2012), although they did not rise as fast as GHG emissions from other human activities. There are important regional differences, too (e.g., agricultural GHG emissions grew fastest in Asia, but decreased in Europe). In Wallonia, the agricultural sector is responsible for 13% of the total GHG emissions, with the CH_4 and N_2O emitted by the sector representing 78% of the total regional emissions of these two gases (AWAC, 2015).

On the positive side, agriculture can play an important role in mitigating GHG emissions globally through carbon storage in grassland soils (Meersmans et al., 2010; Soussana et al., 2007), which occupy about 50% of the agricultural area in Wallonia, and through biomass production (it has been estimated that miscanthus and short willow rotation in Wallonia represent a potential of 1010 Gwh/year; Valbiom, 2010).

At farm level, there are various management options for reducing GHG emissions (Pellerin et al., 2013). The farm should be considered as a whole system, including the impacts of inputs production, in order to ensure that interactions between the various components (e.g., soil, crop, manure, feed, cattle) and their effect on GHG emissions are taken into account (Schils et al., 2007; Weiske et al., 2006).

The importance of assessing GHG emissions at farm level is indicated by the huge variability existing between farms (Mathot et al., 2014; Lioy et al., 2012) and the relatively high environmental impact of the production stage of processed agricultural products (Poritosh et al., 2009; Weidema et al., 2008; Basset-Mens et al., 2007). Calculating GHG emissions also highlights opportunities for reducing emissions and provides information on the carbon footprint of agricultural products.

The main goal of this study was to provide reference values for GHG emissions related to production in meat production systems based on grass and on grass and maize in Wallonia. A second goal is to analyze the variability in these emissions in order to determine practicable mitigation options.

2. Material and methods

Within the framework of the Optenerges project, funded by the INTERREG IV program, data from 62 cattle farms in the Province of Luxembourg in Wallonia, Belgium were collected in 2008 and 2009. The farms were representative of the main production systems in this area and were classified according to a typology based on the GENETYP method (Landais, 1998; Perrot, 1990), adapted for Wallonia (Hennart et al., 2010). Functional types were defined partly according to the ratio of grass and maize used to feed animals. In this study, the farms were divided into two systems: meat production based on grass (**G**) or on both grass and maize (**G-M**).

GHG emissions were estimated using a method developed by CONVIS (an agriculture cooperative society in Luxembourg), which uses emission factors in the literature (Lioy et al., 2012) and considers emissions from three sources: inputs; cattle breeding and crop production for animals (e.g., forage, cereal for feed). Carbon credits due to measures taken to increase carbon sequestration (e.g., no-till, conversion of cropland to grassland; Vesterdal and Leifeld, 2010) are included, using reference values from the literature (Lioy R., 2012). The production of renewable energy on farms (e.g., heat and electricity from biogas production, colza for biofuel production) that replaces the use of conventional energy is also taking into account (Lioy R., 2012).

Where a farm is producing several products (e.g., milk and meat), this method enables the GHG emissions from the different herds to be identified. In this study, however, the results refer only to meat production from a suckler-cow herd system and the associated land occupation. The emissions were measured in relation to live weight (**LW**) production and to land occupation (farm hectarage used).

Carbon storage in grassland soils was added as a credit based on values used in the literature: 500 kg C/ha for permanent grassland less than 20 years-old and 200 kg C/ha for more than 20-years-old grassland (Gac et al., 2010, derived from Arrouay et al., 2002). The net GHG emissions were assessed by subtracting the total credits from the total GHG emissions of the production system.

The statistical analysis was performed using Minitab statistical software (13.31) for analysis of variance (ANOVA) and an Excel calculation spreadsheet for sample description and testing variances (F-test) and means equality (t-test).

3. Results and discussion

Table 1. Sample description: mean ± standard deviation for meat production (all farms; grass-based farms; grass and maize-based farms).

Variable	All farms (meat production part)	G	G-M
% farms (number)	100% (51)	53% (27)	47% (24)
Bovine Livestock Unit (BLU) - meat	210 ± 116	206 ± 133	214 ± 92
Farm area (ha*)	84 ± 48	87 ± 57	81 ± 34
Grassland (ha*)	76 ± 38	79 ± 40	73 ± 29
Maize (ha*)	5.3 ± 8.1	3.5 ± 9.8	7.5 ± 3.8
% maize/total area	5.9 ± 5.9	2.8 ± 5.1***[a]	9.9 ± 4.2***[b]
Livestock stocking rate (BLU/ha*)	2.54 ± 0.63	2.41 ± 0.73	2.69 ± 0.45
Meat production intensity (kg LW/ha*)	594 ± 270	605 ± 298	582 ± 235
Productivity (kg LW/BLU)	236 ±88	252 ± 97	218 ± 72

[a,b] Means quoted with different letters are significantly different at the level $p<0.0001$(***), LW: live weight, BLU: bovine livestock unit,
* ha: area dedicated to meat production, G: grass-based, G-M: grass and maize-based

Table 1 presents the key features of the two farm systems (G and G-M). The variability within the two systems is significant and is larger than that observed between them. Apart from the percentage under maize, the other characteristics of the two systems are similar (no significant difference). Both systems are intensive and their meat production intensity (kg LW/ha or kg LW/BLU) is comparable.

Table 2. GHG emissions sources and credits in kg eq. CO_2 per product (kg live weight) for systems based on grass (G) and grass and maize (G-M) (mean ± standard-deviation).

Emissions	kg eq. CO_2/kg LW	
	G	G-M
Total GHG emissions	18.22 ± 8,42	19.16 ± 6.16
Inputs		
Fertilizer	0.28±0.26**[a]	0.63±0.41**[b]
Feed	2.18±1.89*[a]	1.24±1.21*[b]
Energy	1.14±1.27	0.96±0.52
Other inputs	1.52±1.09	1.28±0.67
Cattle breeding		
Enteric fermentation	7.09±3.54	8.04±2.59
Manure storage	0.31±0.23*[a]	0.45±0.22*[b]
Manure spreading	0.52±0.39**[a]	0.86±0.43**[b]
Grazing	2.52±1.46	2.78±1.16
Crop production		
Soil	1.76±0.99	1.58±0.57
Mineral fertilization	0.29±0.27**[a]	0.65±0.44**[b]
Fuel	0.60±0.48	0.61±0.40
Credits		
C storage in grassland soils	2.63±1.57	2.14±0.75
Other credits	3.03±3.02	2.32±2.24
Net GHG emissions	12.57 ± 6.44	14.39 ± 6.25

[a,b] Means quoted with different letters are significantly different at the level $p<0.001$(**) or $p< 0.05$(*), LW: live weight, G: grass-based, G-M: grass and maize-based

On average, the farm's meat production activities resulted in emissions of 18.7 kg eq. CO_2/kg LW. Enteric fermentation, manure (production and use) and feed purchase, together, represented 70% of the total GHG emissions. The G system emitted 18.2 kg eq. CO_2/kg LW and the G-M systems emitted 19.2 kg eq. CO_2/kg LW.

There were large variations in the modelled GHG emissions and net GHG emissions around the mean, with the variability within one system higher than the variability between the two systems.

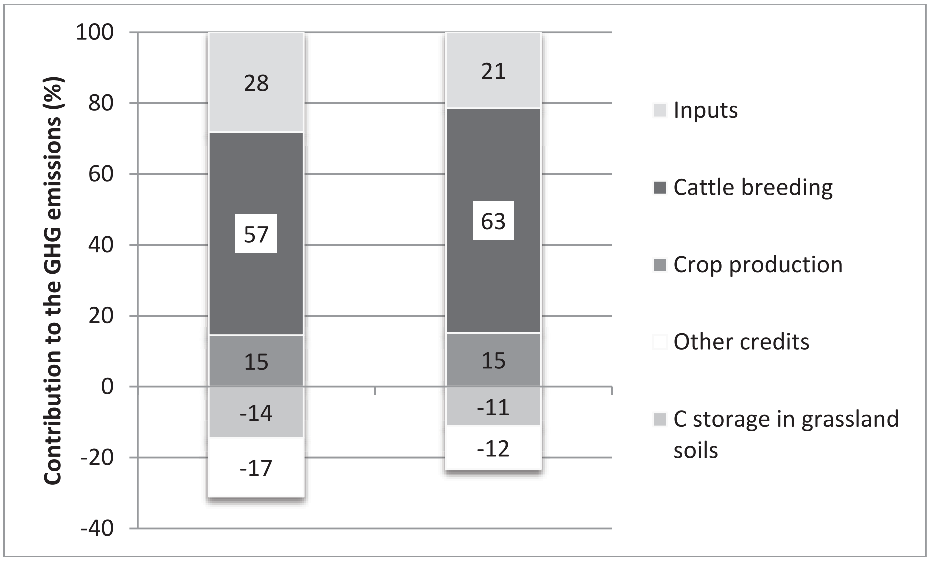

Fig. 1. Meat production credits and contribution (%) to GHG emissions

The difference between GHG emissions from the two systems reflected differences in:

- purchase and use of mineral fertilizer (more mineral fertilizer is needed for growing maize in G-M systems)
- purchase of feed (more feed is purchased in G systems than in G-M systems)
- manure storage and spreading (the livestock stocking rate is higher in G-M systems; 2.69 v. 2.41 BLU/ha)
- carbon storage under grassland (the area under grassland is greater in G systems; 79 ha v. 73 ha).

The total and net GHG emissions in kg eq. CO_2/kg LW for both systems, however, did not differ significantly due to compensation between the GHG sources and the high variability in the modelled GHG emission within the groups. The “systems” factor explained less than 1% of the variability in the modelled GHG emissions. The typology used was not adapted to show differences in GHG emissions.

When credits were included in the assessment (net GHG emissions expressed by kg LW), there was a reduction of the impact by 31% and 23% for the G and G-M systems, respectively. The carbon storage in grassland soils accounted for 59% (G) and 48% (G-M) of these reductions. There is still some debates within the scientific community about the use of a recognized value for carbon storage in grassland soils; the value used could have a significant impact on the net GHG emissions of suckler-cow systems based on grass (Gac et al., 2010). Taking account of the carbon credits could provide an opportunity to reduce emissions from cattle breeding systems.

The GHG emissions were influenced by the intensity of production (see

Fig. 2) and therefore by livestock stocking rate because those parameters were correlated. Other factors, such as bovine livestock unit (BLU), total area dedicated to meat production, area under grass and maize and percentage under maize, had no influence on the emissions.

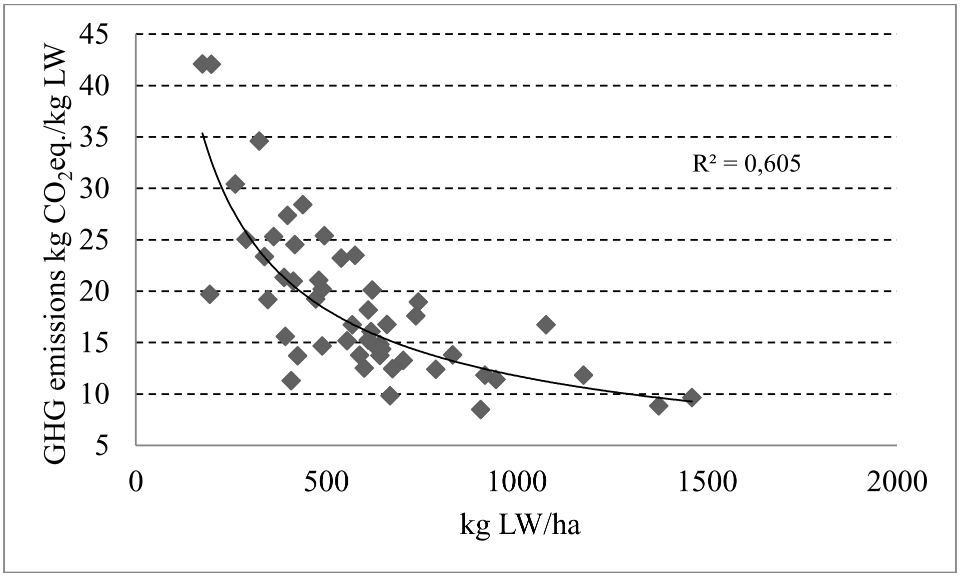

Fig. 2. Relationship between GHG emissions and production intensity (kg LW/ha) in kg CO_2 eq. / kg LW

The GHG emissions per product unit tended to decrease with production intensity, explained by the dilution of emissions on the product quantity.

This effect could be reinforced by a better rationalization of some inputs (e.g., energy), but the relationship was not linear and was tempered beyond a certain level (between 800-1000 kg LW/ha). Indeed, the increase of the productivity meets a limit: loss of the connection to the soil and strong dependence on inputs. For very intensive systems, every additional kg of meats is completely produced from standardized and imported inputs. With sufficient data, it would be possible to identify an optimum that allows a balance between productivity and environment.

A complementary approach could be to express the GHG emissions per ha in relation to production intensity in order to assess the impact of meat production on the environment (footprint), but in this case the farm hectarage used to produce the resource (feed) would need to be included in order to avoid erroneous assessments at farm level.

4. Conclusion

On average, in order to produce 1 kg live weight (LW), Walloon systems emitted 18.7 kg eq. CO_2. The differences between both systems (G and G-M) occurred in feed and mineral fertilizer purchase, in manure emissions and in mineral fertilizer application. There was a large variation in the assessed GHG emissions between and within the two systems but there is no effect of the feeding type (based on grass or grass and maize), this means that the typology used was not adapted to show differences in GHG emissions.

The GHG emissions per product unit tended to decrease with production intensity to a certain level of intensification from which the carbon footprint of meat remain steady, more data are needed to identity an optimum between productivity and environment.

Including carbon credits in the assessment resulted in a reduction of 31% and 23% in the carbon footprint of meat production for the G and G-M systems, respectively. These values need further investigation because the integration of carbon storage in grassland soils is still not unanimously recognized in GHG inventories, but this could be an important issue for grass-based suckler-cow systems.

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Agriculture and Agricultural Science Procedia 7 (2015) 229 – 235

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Monitoring and control possibilities of leaf miners (*Agromyzidae*) in winter wheat in Poland

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Abstract

Nowadays the higher occurrence of cereal insects is observed. Until recently it has been considered to be of little economic relevance. Today cereal insects develop better, thanks to the climate warming, simplification of agricultural techniques and extensive farming in large areas. One of the most pervasive species is leaf miners from the *Agromyzidae* family, which larvae feed on inner side of the cereal leaves. In Poland there is more than a dozen species of leaf miners (Walczak 1995). They may occur locally in large numbers, and cause substantial damage to the crops which reduce quality and quantity of the harvest. Larvae of the leaf miner feed on the parenchyma, causing damages (so-called mines).

Effective methodology of fighting the insects with chemical means have not been developed yet. Studies of integrated methods of cereals protection carried out so far, have shown that a good practical method of chemical signaling is to control the number of adults trapped on yellow traps._Monitoring of cereal leaf miner flights in winter wheat was carried out in Słupia Wielka and Baborówko (Greater Poland Voivodeship) in the 2011/2012 and 2012/2013 growing seasons. Yellow traps were placed above the tops of wheat during vegetation period. The number of damaged wheat stems was recorded. Fluctuations in weather conditions during the research affected the dynamics of leaf miner flies considerably. The most common species were: *Chromatomyia nigra (*Ztt.), *Chromatomyia fuscula* (Ztt.) and *Poemyza superciliosa* (Ztt.).

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: leaf miners, *Agromyzidae*, winter wheat, monitoring, yellow traps

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.025

1.Introduction

In Poland flies of leaf miners (*Agromyzidae)* on cereal are a common occurrence. Their larvae, which are a harmful stage, feed on parenchymatic tissue of cereal leaves, causing characteristic damages (mines). Occurrence of leaf miners in big numbers contributes greatly to the reduction of the leaves' assimilation surface. The larvae damage mostly first and second flag leaves, which has a negative impact on the yield and locally can produce losses which are economically significant.

The aim of the research was to determine the intensification of occurrence, harmfulness and dynamics of leaf miners (*Agromyzidae*) on winter wheat.

2.Objective, data and methodology

Experiments with winter wheat were conducted in the 2011/2012 and 2012/2013 growing seasons in Słupia Wielka (średzki district) and in the 2012/2013 growing season in Baborówko (szamotulski district). Observations regarded the dynamics of flight of leaf miners and the developmental stages of leaf beetles. The validity of determined times for chemical control was reflected in the yield. The pests were caught using 3 yellow plates covered with glue with dimensions of 25x40 cm (producer BioBest, Belgium) placed randomly on the plantation. The plates were positioned on poles which enabled for them to be placed higher and higher as the plants grew so that the plates would always be immediately above the field. The traps were replaced in the time April 16 and June 24 in 2012 and between April 22 and June 23 in 2013. The result was presented as an average number of caught flies from the three plates on each plantation.

Selected winter wheat plantations were also sites for observations aimed at determining the number of blades with damaged leaves. The result was presented as a number of mines per 100 analyzed blades. Moreover, in order to determine the count of miners, in May the researchers collected leaves with visible larvae or casters from experimental fields and selected plantations. The specimens were later bred until they became imagines. Mines on the leaves of winter wheat characteristic for particular species were identified using a key (Beiger 2004). The identification of species of leaf miners was done based on preparing male genital apparatuses (Beiger 1989).

The main tool used to analyze the research hypotheses made in the study was a single factor analysis of variance ANOVA. The correlations between the count of miners and the yield was determined using a correlation coefficient (Kozak et al. 2010). Multiple regression analysis was used to verify the hypothesis of whether the temperature and precipitation significantly determined the occurrence of leaf miners. All calculations within the data analysis were performed using the Statistica 10 statistical package.

3.Results

Meteorological conditions in towns where the research was conducted in the years 2012-2013 did not vary in terms of temperature ($F_{1.34}$ =0.232 p =0.633) or precipitation ($F_{1.34}$ =0.284 p =0.597). Moreover, it was shown that in both towns the average number of mines was at the same level ($F_{1.34}$ =3.011 p = 0.091).

The dynamics of flight of leaf miners onto winter wheat plantations in particular growing seasons did not vary ($F_{1.34}$ = 0.058 p = 0.811) (Fig. 1, 2).

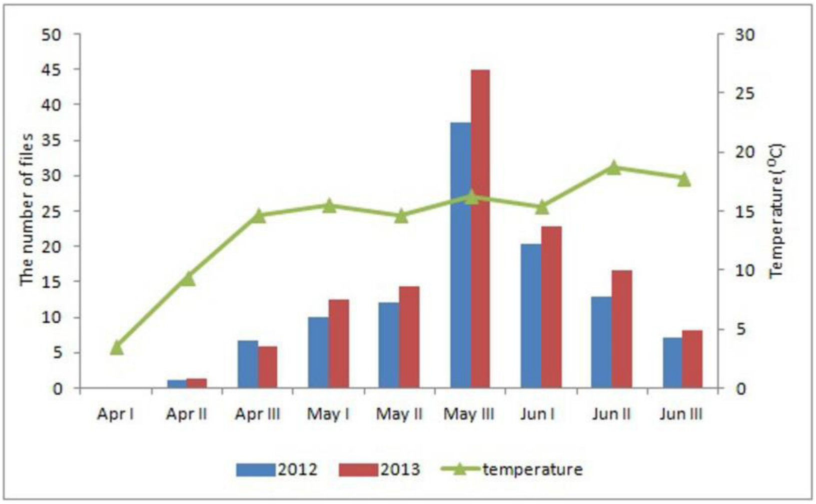

Fig.1 The dynamics of flight of leaf miners occurring on winter wheat in the years of the research taking into account air temperature.

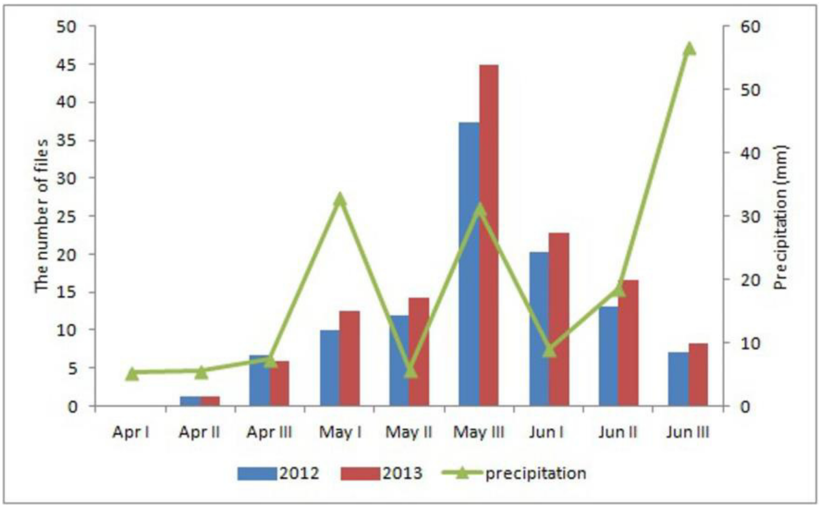

Fig.2 The dynamics of flight of leaf miners occurring on winter wheat in the years of the research taking into account precipitation.

The dynamics of flight of leaf miners onto winter wheat plantations in particular growing seasons varaied. In 2012 the first miners were observed in mid-April, while in 2013 the first miners appeared on winter wheat plantations a week later compared to 2012 (Fig. 1, 2).

Based on trapping of flies and observations regarding the development of leaf beetles the researchers were able to determine the dates for chemical treatments against both pests as well as estimate the size of yield obtained from particular combinations (Tab. 1), (Fig. 4). The dates of chemical treatments were as follows: in Słupia Wielka – May 14, May 21 and May 28, in Baborówko – May 15, May 25 and May 30 in 2012; in 2013, Słupia Wielka – May 20, May 24 and June 3, in Baborówko – May 20, May 27, June 6. In both towns, in both years of the research the optimum time for the chemical treatment fell during the numerous flight of flies and when the oldest larvae of leaf beetles reached the length of about 2mm.

The result of the variance analysis did not show a statistically significant influence of the date of the treatment on the size of obtained yield ($F_{3.44}$ =0.1194 p = 0.948) (Tab. 1).

Table 1. Yield and standard deviations for different treatments.

Treatment	Average yield (kg)	Standard deviation (kg)
K	9.62	1.45
Z1	9.95	2.07
Z2	9.80	1.58
Z3	9.60	1.56
Total	9.74	1.63

Correlation analysis indicated that the number of mines had a statistically significant imfluence on the obtained yield (r=0.2619 p=0.072) (Fig. 3).

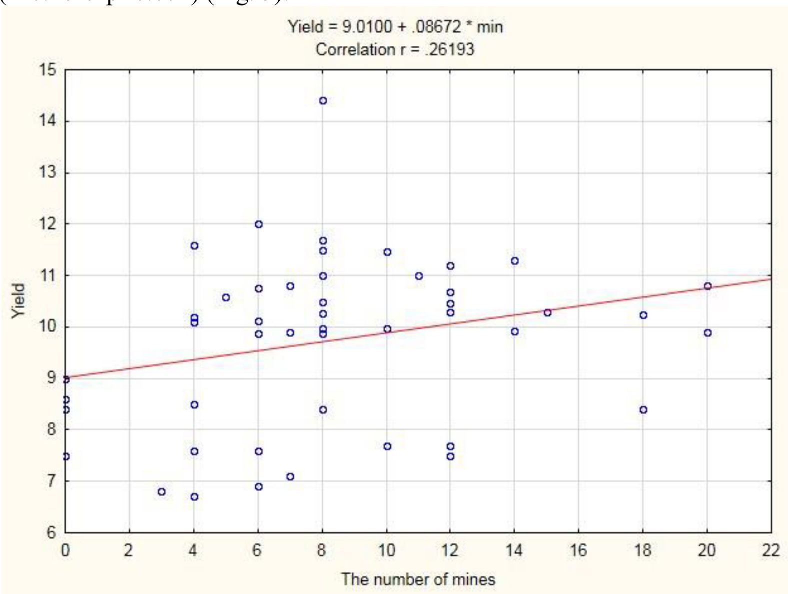

Fig.3 Observed yield depending on the number of mines.

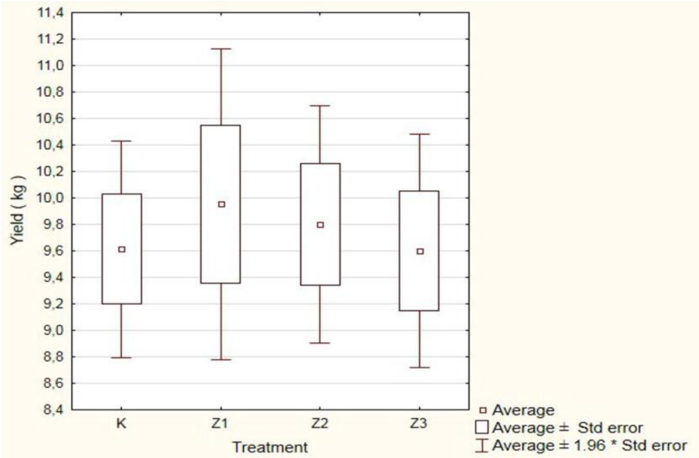

Fig. 4. Breakdown of the size of yield depending on the date of the treatment (K-control, Z1-I date of treatment, Z2- II date of treatment, Z3- III date of treatment)

Multiple regression analysis indicated that out of all meteorological factors only temperature had a significant influence on the number of mines. The temperature coefficient obtained in this model was 0.4367 and indicated that the increase in temperature was reflected in the increase of the number of mines. Further simple regression analysis studying the influence of temperature on the number of mines showed a statistically significant regression coefficient r=0.4216 for p=0.0104. The correlation between the number of mines and temperaturę was shown on the figure below (Fig. 5).

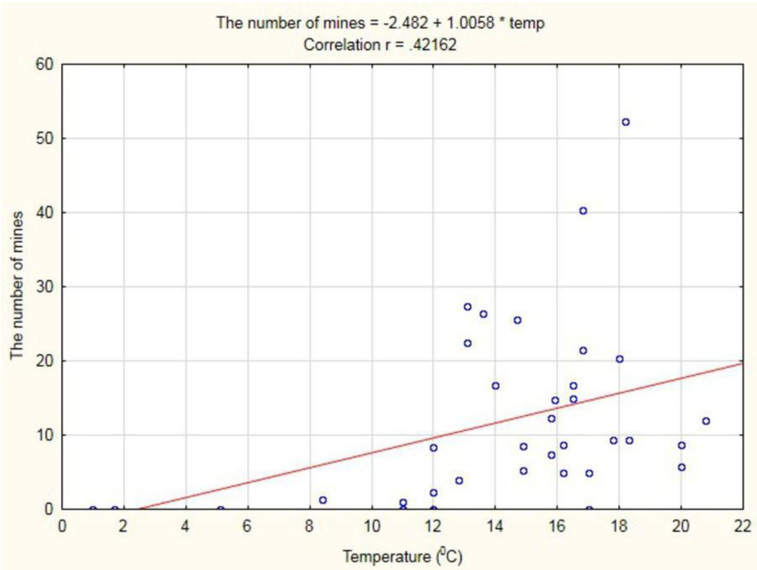

Fig.5 Breakdown of the number of mines depending on air temperature.

There is a statistically significant correlation between the date of the treatment and the number of miners ($F_{3.44}$ =4.88 p =0.005) (Tab. 2), (Fig. 6).

Table 2. The number of mines and standard deviations for different treatments.

Treatment	Average number of mines	Standard deviation
K	8.58	3.26
Z1	5.25	2.93
Z2	7.83	5.62
Z3	12.08	5.23
Total	8.44	4.94

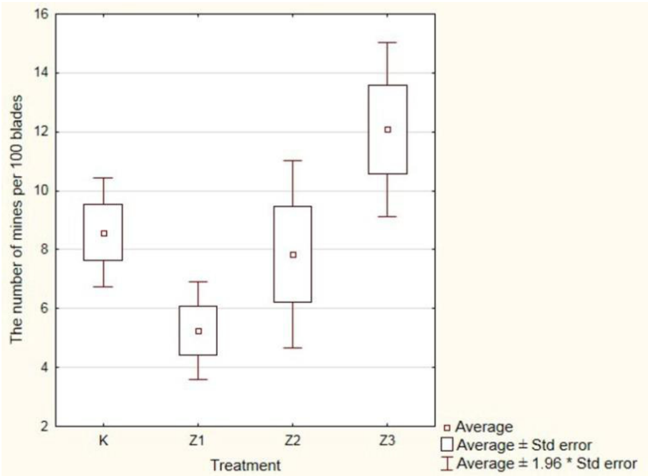

Fig.6 Breakdown of the number of mines depending on the date of treatment.

In 2012 a total of 161 leaves with larvae or casters inside the mines were collected for breading in a laboratory. The caster stage was reached by 126 specimens. The imago stage was reached by 98 specimens. Moreover, out of the larvae and casters collected for breading, the imago stage was reached by one *anagyrus pseudococci*.
In 2013 a total of 100 leaves with larvae or casters inside the mines were collected for breading in a laboratory. The caster stage was reached by 62 specimens. The imago stage was reached by 38 specimens. Moreover, out of the larvae and casters collected for breading, the imago stage was reached by five *anagyrus pseudococci* (Tab. 3).

The predominant species in the years of the research were: *Chromatomyia nigra* (Mg.), *Chromatomyia fuscula* (Ztt.) and *Poemyza superciliosa* (Ztt.).

When comparing the obtained results with research previously conducted by other researchers (Walczak 1995, 1998; Beiger 1988) it was established that the species composition of miners occurring on winter wheat changes in particular years. The results differed from the ones obtained in previous research. In the years 1995-1998 (Walczak) the miners occuring on winter wheat included the following species: *Phytomyza nigra* (Mg.) and *Agromyza ambiqua* (Fll.), *Agromyza mobilis* (Mg.), *Cerodontha pygmaea* (Mg.).

Table 3. The number of leaves, casters, flies of miners and *anagyrus pseudococci* in laboratory breading in 2012 and 2013.

Year	Number of leaves collected	Number of casters	Number of flies	Number of *anagyrus pseudococci*
2012	100	62	38	5
2013	161	126	98	1
Total	261	188	136	6

4. Summary and conclusion

1. The most intensive flight of flies onto winter wheat plantations in Wielkopolska in the years of the research occured in May.
2. The dynamics of flight of leaf miners onto winter wheat plantations in particular growing seasons did not vary statistically.
3. In both years of the research the optimum time for the treatment fell during the numerous flight of flies and when the oldest larvae of leaf beetles reached the length of about 2mm.
4. Variance analysis did not indicate a statistically significant influence of the date of the treatment on the size of the obtained yield.
5. Multiple regression analysis indicated that out of all meteorological factors only temperature had a significant influence on the number of mines.
6. Correlation analysis indicated that the number of mines had a statistically significant imfluence on the obtained yield.
7. A statistically significant correlation between the date of the treatment and the number of miners was observed.
8. The leaf miners species occurring on winter wheat in the years of the research were *Chromatomyia fuscula* (Ztt.), *Chromatomyia nigra* (Ztt.) and smaller in numbers *Poemyza superciliosa* (Ztt.).
9. The results of the research will enrich current knowledge regarding the count and harmfulness of leaf miners and leaf beetles on cereal plantations in the context of integrated cereal control.

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Agriculture and Agricultural Science Procedia 7 (2015) 236 – 240

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Extrusion of cereals with admixture of soya bean grains from traditional crops

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Abstract

The paper presents characteristics of mixtures of soya bean extrusion process with wheat and corn and soya beans' meals with these cereals. On the Polish market, soybeans come mostly from traditional crops, for this reason its cultivation is much more expensive than soybeans derived from GM crops. Refuse soybean contains a large amount of fat that can be used as an additive enriching animal feed fat. It is however essential first soybeans processing. The extrusion process is one of the processing method refused soybean or whole soybeans as a component in extruded blends. The study used with isolated hulled and unhulled soybeans. From the analysis of the results obtained for the extrudates of mixtures with wheat and corn with addition of soya bean grains, it can be concluded that both the cutting strength and the hardness of the extrudates was higher in the case of corn compound. The greatest ratio of expansion was achieved for the extrudates of wheat and unhulled soya bean compound. The highest hardness was obtained by subjecting to extrusion a mixture of unhulled soya bean meal with corn, while introducing meal of hulled soya bean resulted in extrudates with about 70% lower hardness.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

*Keywords:*soybean; extrusion process; traditional crops.

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2210-7843
Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.033

1. Introduction

Soya bean is a leguminous plant, which is classified among oilseeds due to the fat content that is higher than 15%. In addition to large amount of fat, it also has a high protein content, and hence soya bean products can serve as complete food. Fats contained in the grains are carriers of large amounts of polyunsaturated fatty acids in proper ratio to the monounsaturated ones. Essential unsaturated fatty acids, which include oleic acids, linoleic acids and α-linolenic acids are important compounds. These are the acids, which cannot be synthesized by body. Soya bean grains contain a lot of vitamins and minerals such as zinc, phosphorus, potassium, calcium, iron, B vitamins and vitamins A, C, E (Sikorski, 2007).

The development of biotechnology and genetics allows the modification of organisms in various ways, for example improving their resistance or altering components of their chemical composition. The first species of transgenic soya bean were obtained in 1988. An organism resistant to herbicide was the progenitor, thanks to which the technology of manipulation of the plant's genetics was developed. Subsequent varieties are characterized by pest resistance. There is also research carried out on alternation of nutrients in order to obtain better amino acid, carbohydrate, or fat profile. Thanks to the aforementioned modifications soya bean production has become cheaper, thus increasing the growth of the transgenic soya bean cultivation, which today can make up to 80% of the total world production (Borek, Galor, 2012).

Due to high fat content soya bean is used primarily in oil industry. In terms of usability for consumption soya bean meal is the most important by-product of oil extraction. It is rich in protein and amino acids, which play an important role in feeding livestock. On Polish market, soya bean meals come from conventional farms, hence production cost is higher than in the case of GM soya bean, the production of which is cheaper. Polish growers face strong competition from foreign producers of GM soya bean (Angulo et al. 1995, Jarczyk 2001, Świątkiewicz et al. 2013).

Nomenclature

No 1	Wheat grain + hulled soybeans
No 2	Wheat grain + soybeans
No 3	Malt residues after oil extraction from soybeans + corn
No 4	Malt residues after oil extraction from hulled soybeans + corn
No 5	Hulled soybeans + corn
No 6	Soybean+ corn

2. Aim of the study and methodology

The aim of the study was to characterize the extrusion process of mixtures of soya bean with wheat and corn and soya beans' meals with these cereals. Scheme of the research is shown in Figure 1. Since harvested soya bean is contaminated, during the cleaning step mineral impurities (sand, gravel, stones) and other biological contaminants such as grass and bits of other plants were separated. For the purpose of this study hulled soya bean grains and unhulled soya bean grits were used. After preparing samples with a total mass of 5 kg (and equal shares of 50%) the mixing process was carried out.

Obtained extrudates were tested for cutting and squeezing. Additionally, also the kinetic strength was determined using a Pfost method in accordance with PN-R-64834: 1998 norm.

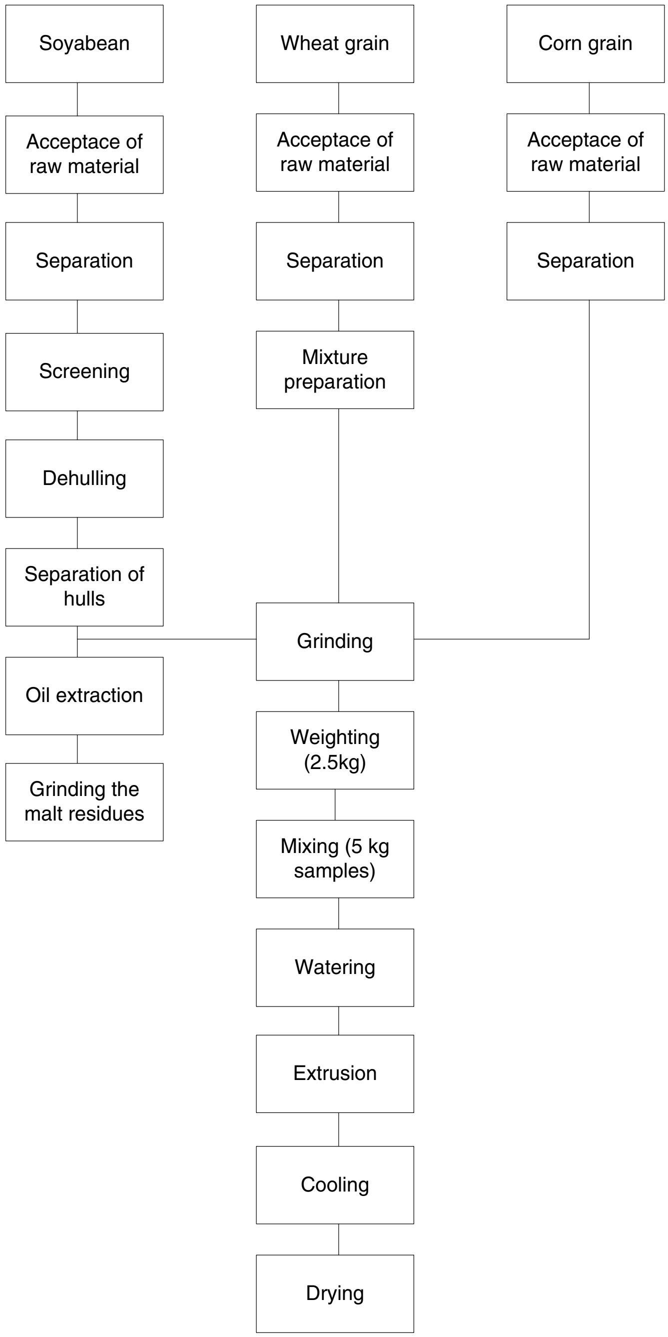

Fig. 1 Scheme of the study.

3. Results

The extrusion process characteristics are based on the measurements of the basic parameters of extrusion during its optimal operation. The results presented here are the outcomes of a series of preliminary tests with various parameters. Similar parameters was tested during extrusion of pasta and wheat flour by other authors (Abecassis et al. 1994, Andersson, Hedlung 1990, Arhaliass et al. 2009, Chinnaswamy , Hanna 1988).

Table 1 Extrusion process parameters.

Sample	Temperature [°C]			Rotations	Comments
	Head	Second section	Extrudates		
Nr 1	150	185	80	100	No comments
Nr 2	120	150	74	60	No comments
Nr 3	110	145	84	100	No comments
Nr 4	150	195	90	70,80,100	Increased screw rotation
Nr 5	139	179	100	60	Too dry
Nr 6	150	180	72	60	Too dry

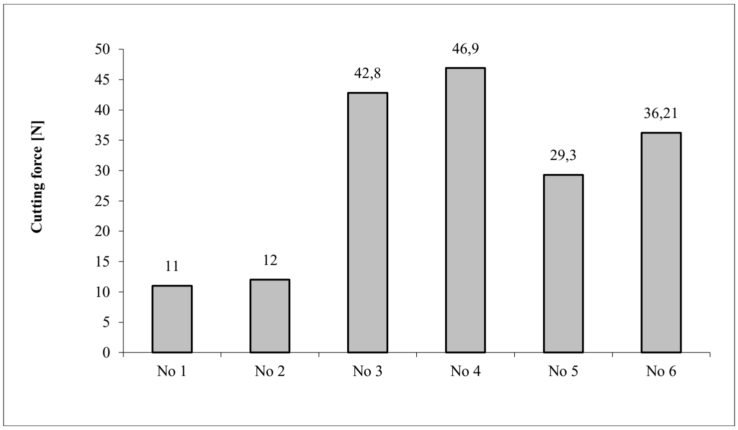

Fig. 2 Cutting force of extrudates.

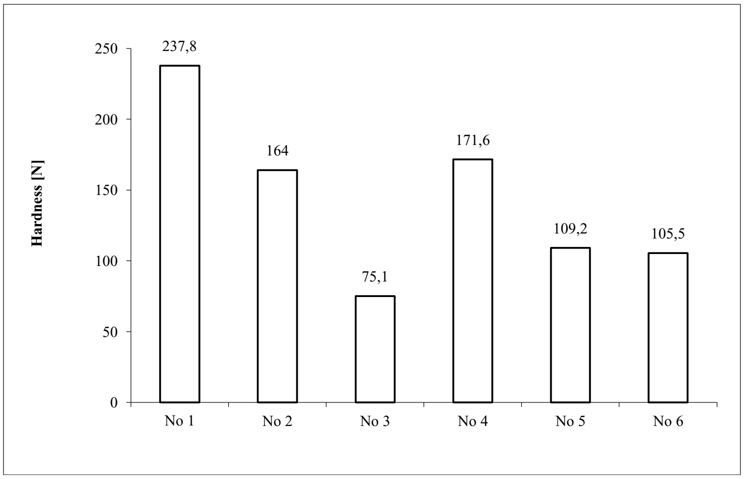

Fig. 3 Hardness of extrudates.

The resulting extrudates were characterized by final moisture content below 8%. The highest hardness was obtained by subjecting to extrusion a mixture of unhulled soya bean meal with corn, while introducing meal of hulled soya bean resulted in extrudates with about 70% lower hardness. A similar correlation was obtained when measuring the cutting strength in relation to the respective meal compounds. The value of the cutting strength decreased by circa 50%.

From the analysis of the results obtained for the extrudates of mixtures with wheat and corn with addition of soya bean grains, it can be concluded that both the cutting strength and the hardness of the extrudates was higher in the case of corn compound. The greatest ratio of expansion was achieved for the extrudates of wheat and unhulled soya bean compound. The extrudates with admixture of wheat were characterized by the lowest kinetic strength of 50.4% for hulled soya bean and 45% for unhulled soya bean. At the same time, the extrudates with corn admixture had kinetic strength of 82%, regardless of whether hulled or unhulled soya bean has been added.

4. Conclusions

The research on soya bean extrusion process with added wheat or corn showed its significant impact on the extruded products. Extrusion process parameters varied depending on the type of the mixture, which is the outcome of the chemical composition of the input materials. Both the compression force and cutting strength of the extrudates depend on the composition of the mixture. Addition of corn caused increased resistance to compression and raised the cutting strength. The wheat-soya bean mixture had a high expansion ratio, but at the same time low kinetic strength, which may lead to fast crumbling of the product.

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Agriculture and Agricultural Science Procedia 7 (2015) 241 – 248

Agriculture and Agricultural Science
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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Practical deviation in sustainable pesticide application process

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Abstract

Using agrochemicals becomes essential practice of modern farming but in the same time it puts risk to human, animal health and the environment. The initial actions to create balance between this negative impact and the necessity to use the pesticides concerning the environment, people's living conditions and the economic, those factors are defined as the sustainable development. In this paper the algorithm to gain the sustainability of pesticide application was set to highlight some places (during some logistic steps of pesticide application) where the sprayer operator has to make subjective decisions about the correct procedure; these decisions are subjected to the "practical deviations". The paper presents also some results of investigation on using nozzles with different physical wear. The results of laboratory test showed that damaged nozzles produced flow rate higher than the allowed limits of nozzles inspection regulations. Also, the decision to use damaged nozzles with lower pressure to compensate the increase of flow rate, results in bigger drop sizes comparing with the new nozzles, which may affect in turn the biological efficacy and put risk of pesticide non target contamination. The decision, which is made by sprayer operator, is an example of "practical deviations" during pesticide application process.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: pesticide application;agricultural nozzles;practical deviation;nozzles wear.

1. Introduction

Using pesticide poses danger and risk to human, animal health and the environment, but at the same time cease controlling the crop infections which may result in big loss of yield and probably unhealthy food.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.037

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Environmental and health hazards caused by pesticides were the basis for the development of regulations that prescribe rules for the safe trade and application of pesticide, for example: Directives; ISO Standards, National standards (in Poland: GIORiN (1999) recommendations), etc. "A common legal framework for achieving a sustainable use of pesticide should be established, taking account of precautionary and preventive approaches " this was one of the points to adopt the directive 2009/128/EC.

Agricultural nozzles are important for their effect on: biological efficacy (spray coverage, distribution, deposition and retention on plants); environment (drift, off-target deposition); pest control process efficiency (put the exact amount of pesticide on target) and doing the work in a variety of weather conditions, wide range pressure, different application rate with travel speed (flexibility). Worn nozzles produce more quantity of pesticide (bigger flow rate) with irregular distribution pattern, this means higher cost and risk to the environment and human life due to contamination of pesticide on plants or fruits. Irregular distribution of pesticide reduces the efficiency of the control process and put the risk of spreading the blight again and this requires repeating the control process again. Barber (2009) estimated the total cost of using worn nozzles by $182,800 by using nozzles that are spraying just 15% over the rated capacity and work 2080 hours per year.

Worn nozzles affect essential spray characteristics such as: flow rate; spray angle; droplet size. Sawa et. al (2012) suggested that one of the important factors is the good choice of the used nozzles and the measured parameters to evaluate the nozzles performances, also the spraying quality of nozzles is characterized by: flow rate, individual pattern (spraying angle, coefficient of asymmetry) and transverse distribution under the boom (Coefficient of Variation - CV). Reichard et al. (1991) compared different types of nozzles with 10% greater flow rates than the nominal flow rate, the stainless steel tips had average use times 5.6 and 2.1 times longer than brass and nylon tips, respectively, this stainless steel tips also had the least increase in flow rate while the brass tips had the greatest increase. The same authors mentioned the factors which influence nozzle wear include spraying pressure, duration of test , type and concentration of material used in the spray mixture, time of use of abrasive before it is changed during the test, and type of nozzle and size, shape and material of the orifice.

Sprayer boom with standard flat fan nozzles need to have nozzles overlapping to get uniform distribution along the boom because of the differences of spray quantity sprayed from standard flat fan nozzle across the spray pattern (tapered shape), this overlapping is affected by the nozzles height of the target and the spray angle, worn nozzles can affect this distribution by changing the spray angle or the uniformity of the distribution although Huyghebaert (2015) reported in his extensive study about the sprayers inspection that nozzle spray distribution deformation can be a weak indicator for the nozzle physical state, preferring the nozzle flow rate as indicator for nozzle wear and sprayer inspection and suggesting for the future inspection method of combining the flow rate and transverse distribution in one device for complete inspection of nozzles. Flat fan nozzles also provide different size of droplet along the spray spectrum, Ozkan et al. (1992) found out with their experiment on new and worn nozzles with 0.8 l/min flow rate that Dv5 for spray droplet spectrum were generally smaller in the center of the spray pattern for both new and worn nozzles, for the capacities 1.5, 2.3 and 3.0 L/min it decreased away first from the centers of the patterns, then began to increase at about ±20 cm away from the center of the pattern.

Agricultural production and the plant protection are *"business activities*" and they are subjected to economic activity (minimizing the cost for an effect or to maximize the effects while maintaining the level of costs). This situation forms the behaviour of the sprayer operator, which is reflected in the formation of specific plant protection treatment standards (parameters of the sprayer and accompanying measures) at their own discretion. These actions which referred to as "*practical deviations*" are depend primarily on a "*safety culture*" of sprayers users or the administration and may cause: Operating errors; Operational infractions, and even Operational violations.

This work is an attempt to identify risk activities (places where there is "practical deviations") in the process of plant protection and also present selected results of laboratory tests which refer to the consequences of use "*maximum practical deviations"* for some stages of the pesticide application. These activities, in practice, can decide about the quality of the operation, safety of work, or may cause environmental risks which limit the opportunities to implement sustainable use of pesticides, according to Directives 2009/128 / EC.

2. Material and methods

Reducing the amount and risk are the key points to maintain sustainability of pesticide use during the phase of preparing and application according to directive 2009/128/EC, an observation from a study conducted in 53 family farms all over the country (Poland) has been made during the implementation of research projects at the University of Life Sciences in Lublin, Sawa et al. (2004) and ITP Falenty Wójcicki et al.(2009) was used first to develop Table (1), later the key points in this table were applied to every step in the algorithm for the process of sustainable applications of pesticides figure (4). These observations were analysed to detect the possible risk „practical deviations" and the recommendation to avoid it.

The information presented in the algorithm and Table 1 relates to the organizational activities, but in each of these activities may occur decisions of a "practical deviations", an example would be the use of nozzles that are in various states of physical wear.

Nozzles wear is difficult to observe visually figure (1), it is difficult also to observe by human eye, which nozzle on the spray boom gives more quantity of pesticide or irregular shape of distribution, usually this task need measuring device to decide which nozzle is over wear, Krause et al. (2002) observed the nozzle wear and other changes of different types of fan-pattern nozzles by using scanning electron microscopy.

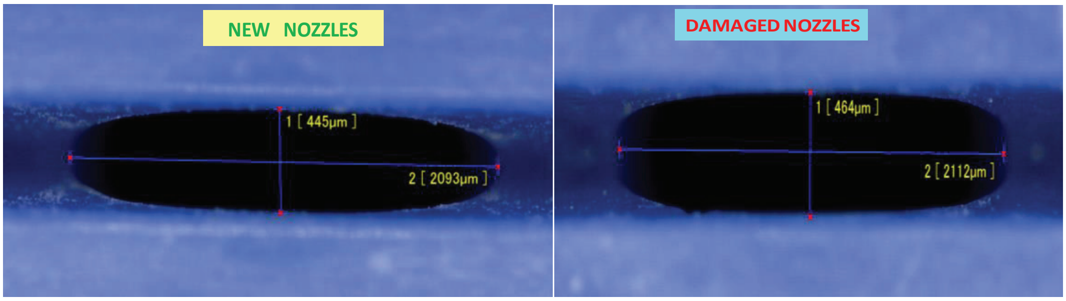

Fig.1. Dimensions of new and damaged nozzles

Widely used standard flat fan nozzles (24 Nozzles TeeJet XR 110/03 VP Spraying Systems Co.) was investigated in the test, 12 of them were exposed to the wear test inside the wear tank figure (2). In this 1000 L tank there were 5 pipes in the upper side, every pipe holding six nozzles, all nozzles were subjected first to 10 hours for warm-up with water only in the tank after this flow rate was measured figure (3) with 1, 1.5, 2, 2.5, 3 bar pressure (recommended from the manufacturer). Droplets size were measured with Sympatec GmbH Laser Diffraction device which uses HELOS/R system with measuring range from R1 to R8 (0.1-8,750 µm). The measurements were taken 50 cm under the nozzle orifice with 1, 2, 3 bar pressure and in seven positions to the left and right side of the spray centreline (across the long axis of the spray pattern), the distance between each two positions was 10 cm. These data considered to be for the new nozzles or nozzles before wear process.

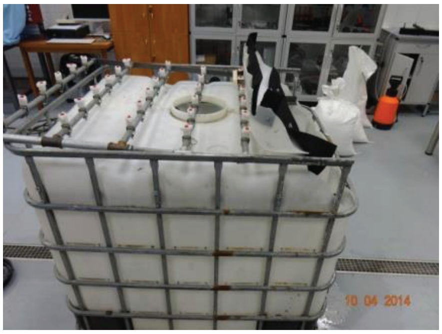

Fig. 2. Wear tank

Fig. 3. Measuring flow rate

After this, 12 nozzles were subjected to wear process in the tank with the mixture of water and the wear agent (Kaolin KOM 18.2 kg mixed with 300 L of water) for 100 hours with 4 Bar pressure, data were collected after this and considered to be data for damaged nozzles.

3. Results and discussion

The basic principles of pesticide application are shown in the algorithm (figure 4) and they include each step in the process of pesticide application from the planning and application of pesticide in the field, until the management of empty packages and residues or sprayer storage. These activities are linked to the decision-making process, and it could be loaded with "practical deviations" aimed at increasing the efficiency of the process, for example: a longer use of worn nozzles in spite of its efficiency.

Table 1. Possible risk and the recommended to prevent it

No.	Treatment action: possible risks	Recommended action to prevent risks (use GIORiN* recommendations)
1	Purchase of pesticide: purchase wrong types , not original pesticide .	Purchase only original , undamaged packaging which provided with a label by a person's having training certificates, predict or calculate the amount of pesticide.
2	Transport of pesticide : pollution to the environment , people, animals, food and feed through spillage of pesticide containers during transport .	Transport without contact with people, animals, food and feed. Pesticides containers should also pack during transport and put in separate place from passengers and luggage.
3	Storage of pesticide : poisoning people, animals and the environment through accidental ingestion and spillage .	Storage should be in rooms designed for this purpose (locked) with all safety precautions.
4	Preparing the sprayer for work: working with damaged devices or parts.	Checking the technical condition and the correct operation of the sprayer, in order to eliminate contaminates to the environment and defective performance and spraying threats, replace worn parts.
5	Parameters selection of sprayer operation: wrong dose of spraying agent, inappropriate drops size (drift), not good distribution of pesticide, inappropriate setting for weather conditions.	Test the operation of the sprayer(nozzle type and flow rate, spray pressure, travel speed of the sprayer, high of boom and sprays angel …. etc.). calibrate according to the pesticide label and weather conditions.
6	Preparing the mixture for work: pollution of the operator or the environment (spillage). Improper water source for mixing.	Use of protective clothing, compliance with recommendations and instructions for preparing the liquid, and information on using water for filling the sprayer tank, using induction hopper .
7	Start of the spraying action: direct risk to the operator, pollution of the environment (drift to rivers, lakes, and ground water), soil, air, nearby crops, residential area near the spray location.	Use of protective clothing, perform the treatment under favorable weather conditions. In special cases inform neighbors about the planned treatment, consider using buffer zones.
8	Checking the work of the sprayer during application: hidden defects on devices, technological or technical stoppages and bad weather conditions.	Replace or repair defective parts according to the sprayer manual, transfer the liquid to another sprayer, calibration according to new weather conditions, delay the spray process.
9	Disposal of pesticide residue and remnant: risk of operator, pollution of the environment and treated plants.	Dilute and spray the remnant of spray liquid in places designated by the terrain authorities, using biobeds.
10	Sprayer rinse: pollution of the environment and treated plants.	Wash all the sprayer and distribute the washing mixture in the field or farm land (as recommended). Avoid contamination point, using biobeds.
11	Recycling and disposal of packages: pollution of the environment and human health.	Triple rinse containers after using. Follow the information on the packaging or GIORiN instructions.
12	Cleaning and maintenance of the sprayer for storage: appearance of hazardous remnant spray mixtures during cleaning in a storage place, the development of corrosion of the sprayer units, threat to the surrounding places.	Clean with the addition of special cleaning agents, use of protective clothing, perform work in appropriate place. Washing liquid should not get to watercourses. Avoid contamination point, perform maintenance in accordance with the instructions of the sprayer.
13	Preparation the sprayer for the postseason storage: pump and pipe damage due to freezing.	Drainage of the control valve, pump, filters, protect working units from the weather, sprayer inspection.

*GIORiN - Main Inspectorate of Plant Protection and Seed Inspection Source: developed by using: Owczarczyk (2001)

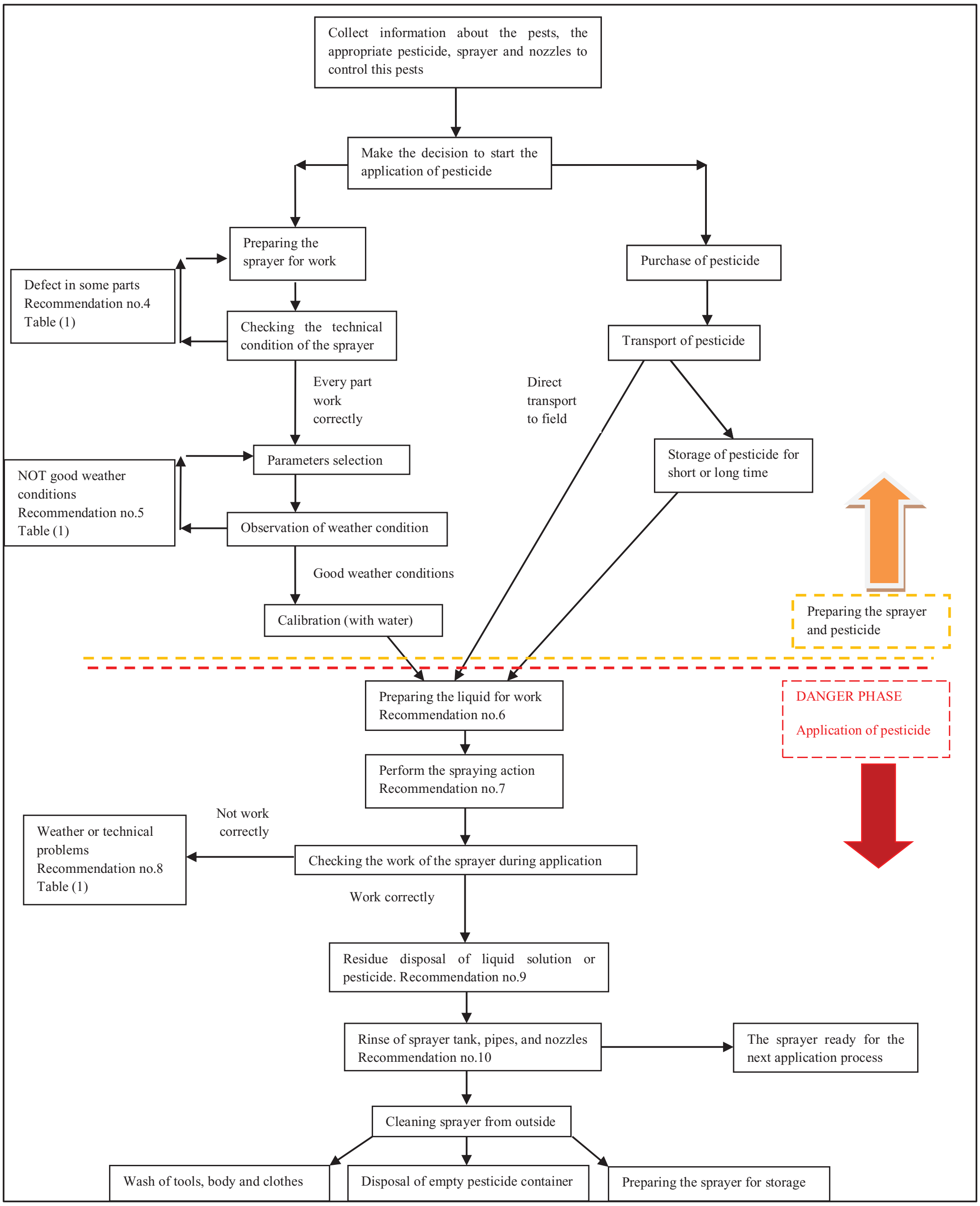

Fig. 4. The algorithm of process of sustainable pesticide application

Figure (5) shows the effect of 100 hours of wear on flow rate with different pressures, all the damaged nozzles with the pressures were out of the ± 10% limit permitted for the flow rate according to EN 13790-1 (2003). We can notice from the figure also that the flow rate for the new nozzles was slightly higher than the nominal flow rate provided by the manufacturer for every pressure. The percentage of flow rate increase with pressure for the damaged nozzles was 21%, 15%, 11%, 10% for the pressures 1, 1.5, 2, 2.5, 3 bar respectively, these increase percentages were almost the same for the new nozzles.

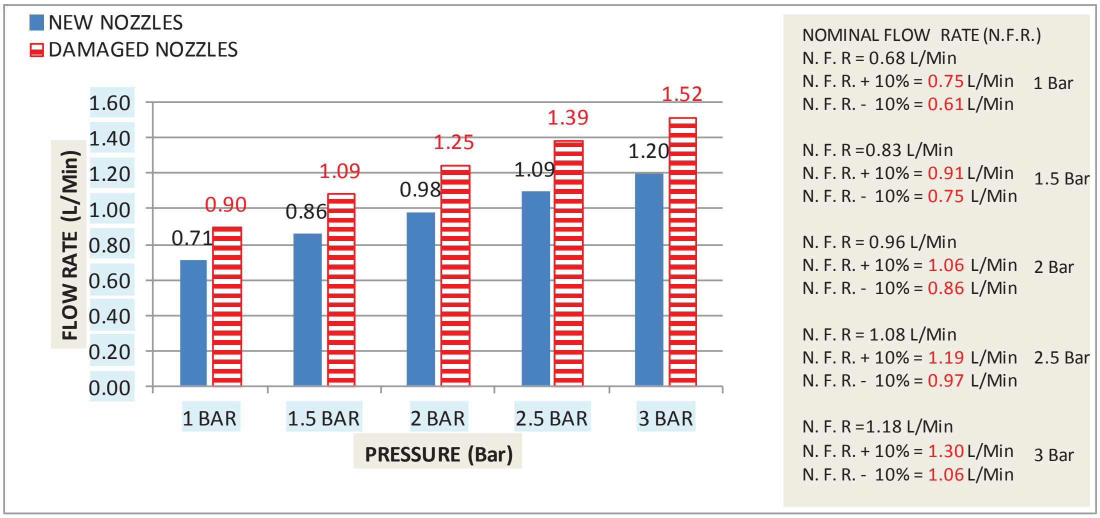

Fig. 5. Flow rate with different pressures

Figure (6) shows the VMD (volume median diameter) for the new nozzles with three bar pressure across the spray spectrum compared with damaged nozzles with three, two and one bar pressure. The drop size increased when reducing pressure from three bars to two or one bar, similar results was reported by Braekman et al. (2011) and Dorr et al. (2013) (although their measurement was close to the zone of drop formulation and also with using of concurrent airflow) for the flat fan nozzles.

Using damaged nozzles will give more quantity of water during calibrating due to the higher flow rate of these nozzles, to compensate this situation, the sprayer operator has another options beside replacing the nozzles , for example driving with higher speed which will result in higher drift percentage as indicated by Van de Zande et al. (2005) , Arvidsson (1997). As example of practical deviation is the situation when the sprayer operator will try to reduce the pressure for the damaged nozzles from three to two bar to get flow rate for his damaged nozzles similar to the flow rate for the new nozzles which he used to calibrate his sprayer with it (from 1.52 L/Min with three bar to 1.25 L/Min with two bar), this critical decision instead of replacing nozzles will affect the sprayed drops size which in turn may influence the biological efficacy (bigger drops mean less surface area of drops comparing with small size drops) of the applied pesticide as well as environmental hazards as reported by Nuyttens et al. (2007) indicating that the ideal nozzle– pressure combination will maximize spray efficiency for depositing and transferring a lethal dose to the target, whilst minimising off-target losses such as spray drift and user exposure. Using lower pressure will also produce lower drops velocity as reported by Dorr et al. (2013) which will affect the spray impact on target.

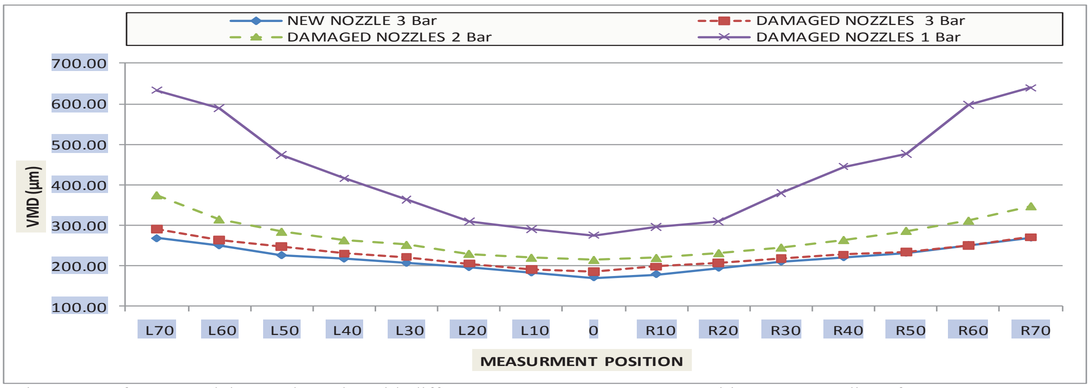

Fig.6. VMD for new and damaged nozzles with different pressures, Measurement position: 0 = centreline of spray spectrum; L = distance to the left of centreline, cm; R = distance to the right of centreline ,cm

Figure (7) shows the cumulative volume percentage of the drops size ranges for new and damaged nozzles on the left side of the spray spectrum (the right side was almost the same like the left side), the new nozzles produced bigger percentage of drops size under 150 µm in position L30 and centreline of spray spectrum, whilst the damaged nozzles gave the biggest percentage of drops size in the range 250-350 µm and ≥ 350 µm in all positions of spray spectrum.

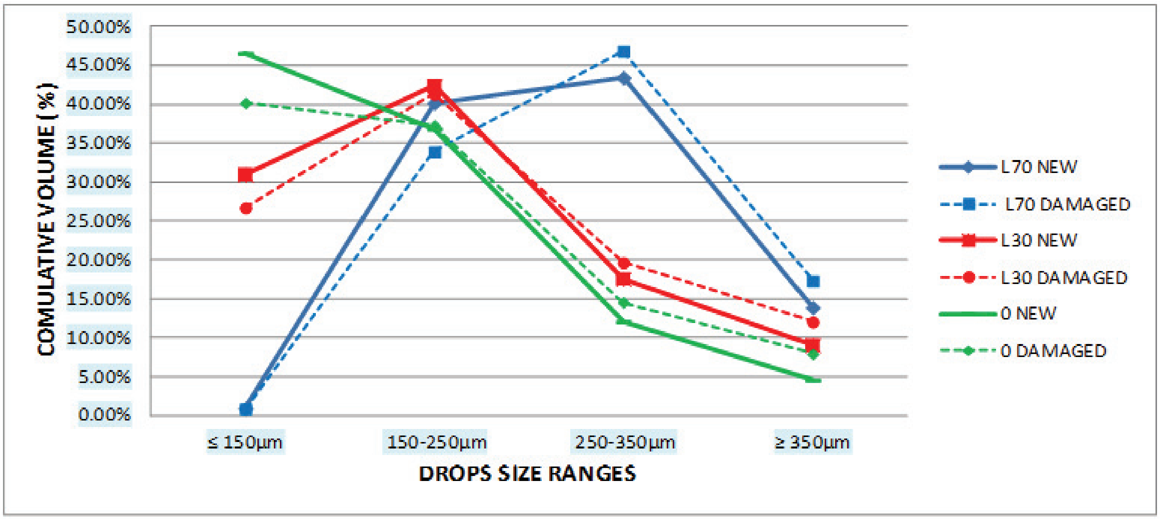

Fig. 7. Left side spectrum of drops for new and damaged nozzles, spraying pressure of 3 bar

4. Conclusion

Pesticides are poisons and their use requires a precise and well-organized implementation of clearly defined actions. Threats and methods of their elimination which occurred in the subsequent stages of plant protection are illustrated in the algorithm. If we analyse main points concerning the sustainable pesticide application in Directive 2009/ 128/ EC we can say that "*Sustainable pesticide application*" as part of "*Sustainable Agriculture*" it is more ethical than technical problem, and the implementation of its principles into practice is problematic.

Reducing the risk and achieving the sustainability of pesticide application is possible if users will take into account in this process all requirements of the Directive 2009/128 / EC concerning the sustainable use of pesticide during the preparation and application phase.

"*Practical deviation*" refers not only to the sprayer operator, but may be perpetrated services and by the authorities which put down the rules of pesticide application. These actions, in practice, can decide about the quality of the operation, safety of work or small environmental cause-risk which limit the opportunities to implement sustainable use of pesticides, according to Directives 2009/128 / EC.

The behavioural study of the sprayer operator which is so called "practical deviations " in the opinion of the authors is an important problem in the process of sustainable applications of pesticides.

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Agriculture and Agricultural Science Procedia 7 (2015) 249 – 254

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Intensity and labour consumption of integrated production in horticultural farms

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Abstract

The paper presents economic efficiency of work in the horticultural production in the selected farms which carry out the integrated production. At the average, one man-hour was paid 0.09 PLNk·man-hour-1. Taking into consideration the use structure in the investigated objects, the intensity of production organization was determined. The production was varied (it was within the intensity range of 213-393 points) and the differences resulted directly from the participation of the grain cultivation area and currant plantation in particular farms. A field work mechanization degree is, inter alia, a factor that influences the labour inputs level. Thus, an annual use of farm tractors was also determined. It was 400 hours. The paper covers farms associated in the formalized producer's group.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: machinery park; sustainable agriculture; optimisation; agricultural technology; agricultural software.

1. Introduction

Labour, as one of the production factors, is an essential element which influences effectiveness and competitiveness of agricultural farms which produce under any system, also in the sustainable one. A relation in the

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.040

Polish agriculture between land and capital is assessed as a sufficient, whereas a relation between work and capital as well as work and land, due to too high work resources, is negatively evaluated (Pepliński et al. 2002; Tabor and Prusak 2008). The research studies, which have been carried out so far (Szeląg-Sikora 2013; Sikora 2014) show that there is no clear substitution dependency between live and objectified labour in the crop production. It results from the fact that at an irrational organization of production processes, technical and technological innovations do not release high labour surpluses.

The integrated agriculture is defined as a farming method, which enables realization of economic and ecological aims through a conscious use of modern production techniques, systematic facilitation of management and introduction of various forms of biological progress in a manner which favours realization of these purposes (Perini and Susi 2004; Die Lage der Landwirtschaft in der Europäischen Union). In the Polish conditions, which should be emphasised, agriculture is integrated in the initial stage of development. Presently, approximately 2 million of individual farms existing in our country, with varied levels of farming: from primitive, extensive farms to modern, well-equipped with machines with a reduced labour consumption (Sawa, 2009). The integrated farming has the biggest number of properties of the sustainable production, at the same time it is a form of alternative farming, it consists in harmonious combination of the conventional and ecological farming (Figuski and Lorencowicz, 2008; Cupiał and Szeląg-Sikora, 2014). A rational mechanization of production processes is an essential element of efficient functioning of integrated farms (Alvarez and Arias, 2004). The state of the research studies on implementation of the integrated farming systems is advanced in many countries of Western Europe. For example, according to Dutch scientists, an integrated farm may obtain a 94% income of the income of a conventional farm (Helander and Delin, 2005). In Germany, introduction of the integrated system is carried out by, inter alia, the Crop Protection Institute in Stuttgart. Average surface of such an integrated farm is 17 ha (Musshoff and Hirschauer, 2008). The nature, size and production results of the German integrated farms may be an example for the Polish agricultural objects. The integrated agriculture research system similar to the German one, is carried out in Switzerland, however, implementation takes place in a considerably bigger number of farms, which form a network of farms with the controlled production system. Also in Great Britain, France, Denmark and Norway, macro-field experiments concerning the selected technological elements (e.g. crop rotation, reduction of agri-chemical products use, labour inputs, etc.) of the integrated agriculture are carried out (Mézière et al., 2013).

According to Woś (2001), efficiency is a factor determining the position of the Polish agriculture on account of economy sectors. He lists economic weakness of farming as one of the reasons of the current agriculture depreciation in the system of inter-branch flows, and consequently low ability of accumulation and investing. Disadvantageous agrarian structure of the Polish farms (especially in the Southern Poland) translates not only into their low competitiveness but also determines their efficiency of farming by too slow modernization process of the technical back and by this to also low labour efficiency and high production costs. Also, according to Kożuch (2000) relatively low efficiency of the Polish agriculture is in a considerable degree a result of fragmented agrarian structure, which makes fast increase of the labour efficiency, production efficiency and farmers' abilities to absorb technical and technological progress impossible. Moreover, full mechanization is in small farms the most frequently economically unjustified. The only way for its introduction is a common purchase of specialist equipment at a considerable participation of the EU funds in its funding.

The labour inputs often determine a production orientation and intensity in agricultural farms and the investment activity of farms is mainly oriented at the reduction of difficult working conditions and improvement of production profitability. Knowing labour resources, assets and production potential of a farm, they may be rationally modernized and developed, according to the sustainable development of principles (Kocira and Parafiniuk, 2010).

2. Objective, data and methodology

Research in the form of a guided survey was carried out in 2015 in 9 farms associated in the horticultural group. These are initial research studies with respect to the integrated farming. Detailed tests are going to be carried out in all member farms of the group.

The objective of the paper was to assess the economic efficiency of work and intensity of horticultural integrated production. To fully perform the assumed objective of the paper, firstly the land use structure, labour consumption of particular cultivation treatments were determined (harvesting, cultivation and treatments in orchards). Then, the

gross final production as a reference point for compensation for the incurred labour inputs was calculated and based on the Kopeć's method (1968) the intensity of production of the investigated farms was assessed. The paper also includes basic information concerning the quantity of the equipment of the machinery park as well as the annual use of farm tractors.
Calculation methods:
Intensity of the plant production organization is determined by multiplying participation of each plant in the sowing structure by a relevant intensity coefficient and then the obtained numbers of points are summed up:

$$I_R = \sum_{i=1}^{n} u \; x \; s \tag{1}$$

where:
I_R – plant production intensity,
u – percentage share of the cultivation surface of a given crop in agricultural land,
s – conversion factor of the crop intensity for particular groups of plants (points) acc. to Kopeć.

Average conversion factors for the following group of crops are assumed for calculation of the production intensity level: grains 1.0; orchards 2.5; berries plantations 5.0 (Gębska and Filipiak 2006 after Ferenc et al., 1998).

Table 1. Production intensity distribution (points)

Level of intensity	Intensity of production in points
Extensive	>200
Low-intensive	200-250
Medium-intensive	250-300
High-intensive	300-350
Very high-intensive	<350

(Gębska and Filipiak 2006 citing Ferenc et al., 1998)

Economic labour efficiency (EWP) informs on the production value generated in the time unit by one man or a group of people. Economic labour efficiency was determined for the entire farm according to a pattern quoted after Gębska and Filipiak (2006):

$$EWP = P/NP \qquad (\text{kPLN} \cdot \text{man-hour}^{-1}) \tag{2}$$

where:
P – gross final production (kPLN·ha^{-1}AL),
NP – labour inputs (man-hour).

Gross final production – constitutes a sum of the obtained plant and animal production value.
Plant and animal production value included:
- value of the main product,
- value of the side product (only in case it was the subject of the market exchange),
- domestic use value,
- subsidies to a product or to its cultivation area (these could be subsidies from the state budget ot the European Union budget within Common Agricultural Policy).

Value of production in case of particular activities of plant production was calculated for 1 ha of AL of cultivation or for 1 LU.

3. Results

Farms covered by the scope of research were oriented at plant production which was almost exclusively horticultural. Among trees cultivated by farmers there were apple trees, pears, plums, cherries and currant bushes. Only two farmers from the investigated group had, except for horticultural crops, small cultivations on arable lands were wheat was sowed (2). The research show that apple trees had the highest participation in the stocking structure and it was at the average for all 80.3%. Almost parallel on the second position were currant bushes - 7.2% and plum trees 6.8% of the stocking surface area.

Table 2. The structure of the land use and the organization intensity in the investigated farms

Specification		Farms									
		Average	1	2	3	4	5	6	7	8	9
		(ha)									
Orchards and plantations		3.8	5.5	2.7	3.5	5.3	2.1	2.9	3.7	5.0	3.5
including:	Apple trees	3.1	4.5	2.4	3.5	5.0	1.5	2.0	1.7	5.0	2.5
	Pear trees	0.1	-	0.1	-	-	0.5	-	-	-	-
	Plum trees	0.2	-	0.1	-	-	0.1	0.5	1.3	-	-
	Cherry trees	0.1	-	0.1	-	0.3	-	0.2	0.3	-	-
	Currant	0.3	1.0	-	-	-	-	0.2	0.4	-	1.0
Arable land (grains)		0.1	-	0.9	-	-	0.4	-	-	-	-
Total agricultural land		**3.9**	**5.5**	**3.6**	**3.5**	**5.3**	**2.5**	**2.9**	**3.7**	**5.0**	**3.5**
		(points)									
Intensity of production organization		**279**	**341**	**213**	**250**	**250**	**226**	**284.5**	**304**	**250**	**393**

The analysis, which was carried out, shows that the intensity level decreases along with the increase of the grain sowing area (minimum value of 213 points) and raises in case of currant plantations (maximum value of 393). According to a five-degree scale the plant production organization intensity was at the level of 279 points, which acc. to Kopeć's scale, corresponds to the medium intensive level of the production organization intensity.

The average final gross crop production (table 3) for the investigated horticultural farms was 21.2 kPLN·ha^{-1}AL. The maximum final gross crop production with reference to agricultural land was reported in farm no. 1 i.e. 24.0 kPLN·ha^{-1}AL, and no. 8 i.e. 24.0 kPLN·ha^{-1}AL. It should be noticed that those farms carried only a horticultural production as well as they had the biggest areas of orchards and currant plantations in comparison to other investigated objects. The minimum gross production was on the other hand reported in the farm no. 5 i.e. 19.2, whose acreage of orchards was the lowest.

Table 3. Economic balance of the economic efficiency of work

Specification	Farms									
	Average	1	2	3	4	5	6	7	8	9
	(kPLN·ha^{-1}AL)									
Gross final production	21.2	24.0	20.2	20.0	23.5	18.4	19.2	22.2	24.0	19.1
	(man-hour·ha^{-1}AL)									
Labour input	228	163	249	247	195	249	263	254	182	250
including: harvest	88	55	96	99	70	109	114	104	61	108
treatments and cultivation	140	108	153	148	125	140	149	150	121	142
	(kPLN·man-hour^{-1})									
Economic labour efficiency	**0.09**	**0.15**	**0.08**	**0.08**	**0.12**	**0.07**	**0.07**	**0.09**	**0.13**	**0.08**

A guided survey collected source information based on which labour consumption of the conducted production in particular farms with reference to 1 ha of AL was determined (Table 3). Time of harvest, cultivation and treatment was specified. In case of horticultural production it included cutting and winter formation, mineral fertilization, mechanical mowing, summer cutting and forming, sprouts thinning, spraying of interrows, spraying of trees and planting.

The research, which was carried out, shows that farms no. 6 and 7 incurred the highest labour inputs, respectively for the farm no. 6 - 271 man-hour·ha^{-1}of AL, and for the farm no. 7 256 man-hour·ha^{-1} of AL. Such circumstances resulted from the distribution of production and lack of orientation on the specific one group of plants. Farms 1, 4 and 8, which were oriented at production of specific fruit and which had the biggest areas of orchards and plantations from among the investigated farms, were defined by lower labour inputs with reference to 1 AL and in a farm no. 1 it was only 171.3 man-hour·ha^{-1}AL. In the remaining farms 2, 3, 5, 9 labour time inputs were at a similar level of approx. 250 man-hour ·ha^{-1}AL.

Achieving possibly the highest labour efficiency is a notable effect of agricultural production. Comparing the investigated objects on account of the value of the discussed factor, the most advantageous results were obtained in the first farm, where one man-hour was compensated with the gross final production value at the level of 0.15 PLN k and the lowest (almost doubled) value was obtained in farms 5 and 6 i.e. 0.07.

In order to define the investigated farms, the quantity equipment of the machinery park was analyzed (table 4). The presented results prove that the investigated objects had indispensable machines used for maintenance of orchards and plantations. On the other hand, there were no machines or tools for grain cultivation (which occurred in the use structure), because in farms, where these crops occurred, farmers declared that they use mechanization services.

Each investigated farm had 2 pcs·farm^{-1}. At the average 0.8 pcs·farm^{-1} of a tractor with 6kN towing class was per a farm and 0.7 pcs·farm^{-1} of 9 kN class. A producer group was responsible for the collection of fruit from farms, however, despite this, almost all farms were equipped with trailers and platforms for transport of fruit to the collection center. Fork lifts used for the so-called internal transport were only in 3 farms (1, 4 and 5). The remaining farmers used lifts mounted on tractors. Farmers had at the average 0.4 pcs·farm^{-1} of fertilization machines. All farms were equipped with sprayers, machines, which are the basic element of equipment in horticultural farms, but farmers from the farm no. 2 and 7 had 2 pcs·farm^{-1} each of these machines. Similarly, all farms were equipped with mowers which help to keep order in an orchard. At the average, 1.11 pcs·farm^{-1} was per one farmer.

Table 4. The number of machines in the machinery park and annual use of farm tractors

Specification	Farms									
	Average	1	2	3	4	5	6	7	8	9
Farm tractors	1.4	2.0	2.0	1.0	1.0	1.0	2.0	1.0	2.0	1.0
including: 6 kN class	0.8	-	1.0	-	1.0	-	2.0	1.0	1.0	1.0
9 kN class	0.7	2.0	1.0	1.0	-	1.0	-	-	1.0	-
Fork lifts	0.3	1.0	-	-	1.0	1.0	-	-	-	-
Trailers and platforms	0.9	1.0	-	-	1.0	1.0	2.0	1.0	1.0	1.0
Fertilizer distributors	0.4	-	-	-	1.0	-	1.0	1.0	-	1.0
Sprayers	1.2	1.0	2.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0
Mowers	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
Annual use of tractors in agriculture farm	(hour·year^{-1})									
	400	400	432	500	700	343	216	500	281	448
	(kPLN·ha^{-1}AL)									
	105.3	72.7	160.0	142.9	132.1	163.3	74.5	135.1	56.2	128.0

Average level of annual use of tractors in the investigated group was 400 hours·year^{-1}. A farmer from farm no. 4 used a tractor most intensively - at the average 700 hours·year^{-1}, and in the farm no. 6, which had 2 tractors, the use of machines was only 225 hours·year^{-1}. When referring the working time to the calculation unit of 1 ha of AL, at the average for the investigated farms, this index was 105.3 hours·ha^{-1}AL and for all objects it was within 72.7-163.3 hours·ha^{-1}AL. Big differences occurred as a result of the size of the owned area of orchards and plantations and the lack of proportional differences in case of an hourly use of agricultural farms in particular objects.

4. Summary and conclusion

To conclude it should be emphasized that the integrated production is a developing farming system. It complies with the sustainable agriculture principles which include the newest achievements of science and agricultural technique and has to ensure competitiveness of fruit, vegetables and other produces on the market and facilitate their sale. However, as every agricultural production it generates many inputs including the labour consumption. The analysis which was carried out proves that the investigated farms had average labour inputs at the level of 228 man-hour·ha^{-1}AL. Each farm aimed at obtaining a relevant farming effect, inter alia, through obtaining appropriate financial compensation for the time devoted for realization of particular production processes. The obtained value of economic labour efficiency index was at the level of 0.09 kPLN·man-hour^{-1}, it is an example of effective management in the investigated farms, since it indicates the relations between possible financial effects i.e. gross final production value and production labour consumption. The use of farm tractors, which as assumption, cooperate with the so-called cooperating machines (sprayers, mowers, etc.) are a indirect factor, which may influence the level of incurred labour inputs. In farms covered by these investigations, the value of this index was at the average within 216-700 hours·year^{-1}).

From the point of view of the rational farm management, the production organization is vital; the production organization intensity index, which for the investigated objects was at the average of 176 points, reflects this element of the production process.

The results presented in the paper are the effect of initial research of the project; extension of the research group and the substantive scope is planned to answer, inter alia, the question whether the integrated agriculture may be competitive for a conventional farming and how much the production processes in the mentioned production systems differ and what are those differences. Among many factors, the following factors should be analyzed: owned land resources, production trend, production intensity, production concentration level, owned technical equipment and human factor including ability for strategic management and creativity within enterprise. Since it is assumed, that the increase of consumers' awareness enforced actions in order to produce food which is safe for health and protects environment, the integrated agricultural production is a system which meets requirements of the sustainable production.

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Agriculture and Agricultural Science Procedia 7 (2015) 255 – 259

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Effects of thermal treatment of seeds on quality and oxidative stability of oils

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Abstract

Sustainable development, among other things, means seeking to improve the life quality associated with raising the requirements both for farmers and manufacturers producing and processing the agricultural goods. One aspect of a healthy diet is getting the good-quality agricultural products and their correct processing to maintain the highest quality and nutritional value. For this purpose, an attempt to assess the oxidative stability of cold-pressed vegetable oils, was undertaken. We analyzed two types of oil seeds and the oil produced therefrom. The study involved winter rape seeds and pumpkin seeds. Prior to the study, seeds were subjected to chemical analysis in order to determine the water, fat and protein contents in seeds and then oils were extruded and contents of carotenoids and chlorophylls, as well as acidic and peroxide numbers were determined. Value of the oxidative stability was determined using Rancimat accelerated oxidation test applying Metrohm 670 device. Among the tested varieties of oilseeds, the highest oxidative stability distinguished the oil made of two varieties of both rapeseed (Abakus and Bellevue) and pumpkin seeds (Miranda and Olga).

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: oilseeds; oxidative stability; vegetable oil; carotenoids; fat.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.041

1. Introduction

Sustainable development, among other things, means seeking to improve the life quality associated with raising the requirements both for farmers and manufacturers producing and processing the agricultural goods. One of the requirements is to search and use the production techniques that can reduce the negative impact of an agriculture on the environment and use the natural resources in a more efficient manner, taking into account the welfare of people and animals. This idea comes not out from fashion, but also an objective economic necessity and the need to preserve life on Earth (Cymerman and Hopfer, 1998; Woś, 1998).

Due to the ever-increasing environmental pollution and ubiquitous processed foods, and fast life pace, people tend towards finding a way of healthy eating. This problem affects both the selection of an appropriate food and its processing methods. Focusing on oil plants and products obtained from them, we can say that there are two ways of their processing, particularly the oil extraction: cold and hot. The oil obtained by cold pressing generally affects better keeping of its properties. This method allows for better performance and availability of desirable nutrients such as phytosterols, carotenoids or tocopherols. Therefore, there is an increasing demand of the market dealing with cold-pressed oil, but this method is less efficient in comparison with the method commonly used in the oleochemical plants (Neđeral at al., 2012). Cold-pressed oils, due to the presence of antioxidants, are characterized by the highest oxidative stability.

The oxidative stability is an important factor affecting the quality of oil and is particularly important in the case of its use for frying due to the temperature and duration of the process. Oxidative changes occurring during frying adversely affect the nutritional value, as well as sensory qualities of a fried product. Each vegetable oil has its characteristic stability to oxidation depending on the content of fatty acids, antioxidants and other minor ingredients (Nogala-Kalucka et al., 2005; Przybylski and Eskin, 2006). The scope of any oxidative conversion in oils also depends on the storage conditions such as temperature, oxygen, light and type of packaging (Szukalska, 2003). Applying an appropriate packaging in a form of metal can or a dark-glass bottle, the access of oxygen and light is limited, which can impair the process of oxidation by singlet oxygen characterizing by extremely high reactivity – 1450 times greater than the triplet oxygen (Bartosz, 2003; Tańska and Rotkiewicz, 2003). Plant oils, e.g. rapeseed oil or pumpkin seeds oil, are the most important plant-origin fats on the global market of edible fats. Seeds of these plants and crude oil contain high amounts of bioactive compounds: polyphenols, phytosterols, tocopherols, and other antioxidants, that play an important role in the prevention and treatment of certain chronic diseases such as heart disease, neurodegenerative diseases, aging, cancer, and arthritis (Caili et al, 2006; Kim et al, 2006; Stevenson et al, 2007; Zuhair et al., 2000; Jian et al., 2005). Their presence gives a protection of the active compounds against destruction of free radicals, that are responsible for the oxidative damage of lipids, proteins, and nucleic acids (Bouzid et al., 2005; Younis et al., 2000; Ghani, 2003). Fats are the most concentrated source of energy delivered to an organism with food, as well as being a carrier of essential unsaturated fatty acids (UFAs) (Kruszewski et al., 2013). Their presence makes the plant oils are relatively unstable products that are subject to oxidation processes. They are readily converted leading to the emergence of significant adverse changes in the quality known as “fat rancidity” (Krygier, 1997; Krygiet et al., 1998).

The purpose of this paper was to compare the impact of cold-pressing oil extraction on the oxidative stability of two types of oils produced from oilseeds. The raw material for the study included three varieties of winter rapeseeds and three varieties of pumpkin seeds. In the first stage, the analysis of physicochemical composition was carried out taking into account the water, protein, and fat contents in seeds, and then the seeds were subjected to “cold pressing” to achieve the edible oil and to determine chlorophyll and carotenoids contents, as well as peroxide and acidic numbers, and to estimate the duration of oxidative stability of these oils due to oxidation.

2. Materials and methods

Experimental material consisted of 2 kg samples of seeds from two oilseed plants such as Winter rape Abakus, Bellevue and Abakus, Seed-less pumpkin Olga, Miranda and Junona. All the plants were grown in South-East Poland in Lublin Province. All the crops were collected in 2014 year. Prior the experiments seeds were dried under natural conditions and stored under laboratory conditions at 20^0C and a relative humidity of 60-70%. Determinations of fat (CLA/GC/3b/2011) and protein (CLA/PSO/13/2013) were carried out at the Central Agro-Ecological Laboratory of University of Life Sciences in Lublin. Seed moisture content was determined using a moisture analyzer Radwag max 50/1/WH (oven-dry test). Analysis of moisture was carried out during drying at the sample load of 4g at 120^0C.

The oil was pressed using a screw press with variable nozzle with a diameter of 8 mm and a set of microscopic strainers from Farmet DUO (Czech Republic) in the continuous operation mode. Before starting the press was heated to a temperature of 60^0C. The press was started and after the stabilization of the working temperature the oil pressing process was commenced. The stabilization was achieved after the pressing of oil from a mass of about 1 kg of seeds when the temperature was about 70^0C. The temperature during pressing was measured with aim of ama-digit thermometer.

The oil after extrusion was stored in dark glass bottles at a temperature of 5^0C, in order to obtain natural decantation for 6 days and then subjected to analyses.

The contents of chlorophyll and carotenoids were determined by spectrophotometry with fresh oil using a double-beam UV - VIS Jasco V -630 spectrophotometer. Oil samples were diluted 20 times with acetone and the spectrum measured between wavelengths 350 and 700 nm. Calculations of concentrations of chlorophyll *a* and *b* and total carotenoids content (in mg/ml) were made in accordance with the procedure of Lichtenthaler and Buschmann (2003). All the measurements were done with three independent replicates.

Evaluation of the quality of oils included determination of the acid number (AN) by titration in accordance with DIN EN ISO 660: 2005 and the number of peroxide (LOO) by titration in accordance with DIN EN ISO 3960: 2005. The oxidative stability was measured using a Rancimat 670 apparatus (Metrohm AG). Oil samples (2.5 g) were weighed into reaction vessels and heated at 120^0C under a dry air flow of 20 l/h. The volatile compounds released during oxidation were collected into a cell containing distilled water, and the increasing water conductivity was continually measured. The time taken to reach the conductivity inflection point was recorded as the induction period (IP), and it is expressed in hours. All determinations were carried out in triplicate.

Results are presented as means ± standard deviation from three replicates of each experiment. A significance level $p < 0.05$ was used to denote significant differences between mean values determined by the analysis of variance, Pearson correlation, post–hock Tuckey tests (ANOVA) with the assistance of Statistica 10 software.

3. Results and discussion

The content of fat and protein in tested seeds along with their moisture content is presented in Table 1. A preliminary analysis of the chemical composition of seeds confirmed the significant difference in fat and protein levels. Among considered seeds, pumpkin seeds of Olga cv. were characterized by higher average fat content (47.5%), while the highest average percentage for rapeseed was 44.0% for Adriana cv. However, these are minor differences that may result from the varietal difference and habitat conditions. A similar situation occurred also for the protein content. The average protein concentration in pumpkin seeds ranged from 30.8% to 35.3%, which was remarkably higher than for rapeseed ranging from 20.40% to 22.30%. The statistical analysis referring to the correlation coefficient at the level of $p<0.05$ showed that there was a weak correlation between water content in seeds and fat percentage both in the rape and pumpkin seeds. A strong positive correlation at the level of 0.931 was recorded in the case of the fat content in both seed groups and duration of oxidative stability induction, which confirmed the relationship between the fat content and oxidative stability level for analyzed products.

Table 1. Profile of seeds.

Specification	Winter rape			Pumpkin		
Seed variety	Abakus	Bellevue	Adriana	Junona	Miranda	Olga
Water content in seeds (%)	6.89±0.26	7.35±0.29	6.19±0.42	9.57±0.12	9.33±0.29	10.10 ±0.35
Fat (% d.m.)	43.87±0.25	42.63±0.15	44.00±0.10	46.9±3.3	41.3±2.9	47.5±3.3
Protein (% d.m.)	20.40±0.30	21.90±0.26	22.30±0.44	34.2±2.4	30.8±2.2	35.3±2.5

During the extraction of fat from the seeds, chlorophylls and carotenoids are transferred to the oil in quantities depending on the species of raw materials, environmental conditions, degree of ripeness, storing method, and processing techniques. These factors affect the color of oil, which is one of the basic qualitative characteristics of the resulting oil (Rotkiewicz et al., 2002; Gandul-Rojas et al., 2000). Chlorophyll content has negative impact on the quality, especially the odor and stability of the oil – it has pro-oxidative properties and makes the oil darken (Fornal et al. 1994). Presence of carotenoids in the oil is equally important due to their antioxidant and pro-vitamin activities (Sujak et al., 2000; Sujak and Kachel-Jakubowska, 2012).

Table 2 shows detailed analyzes of the content of carotenoids and chlorophyll “a” and “b” in oils. The highest chlorophyll "a" content characterized the rapeseed oil, which comprised within the range from 1.76 to 6.68 μg/ml. Pumpkin seed oil was characterized by a low content of the chlorophyll.

The highest content of pigments in the form of carotenoids was recorded in the oil produced from pumpkin seeds. Its largest quantities were observed for Olga cv. (22.46 μg/ml). In the case of rapeseed oil, the largest amounts of carotenoids were observed in Bellevue cv. (18.10 μg/ml) and Adriana cv. (18.67 μg/ml). Statistical analysis of the correlation coefficient at significance level of $p<0.05$ demonstrated slight relationship between content of carotenoids in oils and the oxidative stability induction time. The *post-hock* tests also showed statistical differences in the content of chlorophyll "a" in the case of rapeseed Bellevue cv. in relation to other rapeseed and pumpkin seed oil types. Statistically significant differences were found for chlorophyll "b" content between pumpkin seed and rapeseed oil.

Table 2. Chlorophyll and carotenoid content of the oils.

Specification	Winter rape			Pumpkin		
Seed variety	Abakus	Bellevue	Adriana	Junona	Miranda	Olga
Chlorophyll *a* (μg/ ml)	1.76±0.47	6.68±0.98	3.52±0.19	1.13±0.92	1.21±0.10	1.26±0.11
Chlorophyll *b* (μg /ml)	2.02±0.79	3.14±0.41	2.37±0.92	5.89±3.22	7.17±1.18	7.83±0.84
Carotenoids (μg /ml)	8.41±0.76	18.10±2.90	18.67±3.80	17.30±5.89	13.91±2.24	22.46±2.51

The oxidative stability time obtained during the analysis allows for estimating the oil resistance to oxidation under accelerated conditions. The induction time for all the oils stored for 6-8 days was relatively low (Table 3). Analysis of the pumpkin seed oil showed exceptionally lowest oxidative stability amounting 0.26 hours on average and for Adriana cv. rapeseed oil to an average of 0.28 hours. For the same conditions, the highest oxidative stability was shown by oil produced from Bellevue cv. rapeseed amounting to an average of 4.26 hours and Olga cv. pumpkin seed – 4.75 hours. These results for rapeseed oil are comparable with those reported in the literature (Krygier et al., 1998). The factor determining the durability can be a high content of chlorophyll pigments in oils or free fatty acid content determined by the acidic and peroxide numbers. These are indicators that describe the hydrolytic and oxidative changes in triglycerides both in the seeds and in the oil. Normal results were shown by cold-pressed oils produced from particular rapeseed and pumpkin seed oils, for which the acidic number value did not exceed 4 mg KOH/g, and the peroxide number amounted for rapeseed oil to 1.13 (Abakus cv.) and to 1.03 mg KOH/g (Adriana cv.), while for pumpkin seed oil to 1.53mg KOH/g (Junona cv.). This means that all oils were characterized by a low content of AN and they meet the quality requirements set by the *Codex Alimentarius*. The statistical analysis on the correlation coefficient showed that in our case there is no association between the induction time of various oils and their acidic numbers. The Pearson correlation at the level of 0.574 was observed between induction time vs. the peroxide number for particular oils. There was no correlation between the carotenoid content and oxidative stability. The *post-hock* tests showed no statistically significant differences between the acidic and peroxide numbers vs. oxidative stability of various oils.

Table 3. Acid number, peroxide number and the induction time of oils.

Specification		Winter rape			Pumpkin		
Seed variety		Abakus	Bellevue	Adriana	Junona	Miranda	Olga
AN [mgKOH/ g]		1.13±0.01	3.24±0.04	1.03±0.03	1.53±0.01	2.44±0.04	2.03±0.06
LOO [mmolO/ kg]		1.43±0.06	3.57±0.06	1.17±0.12	1.37±0.06	1.17±0.12	1.23±0.12
Oxidative Stability [h]	Induction time	4.05±0.07	4.26±0.01	0.28±0.01	0.26±0.06	4.16±0.07	4.75±0.18
	Normal time	21.56±0.45	22.74±0.08	1.52±0.07	1.39±0.32	22.18±0.38	25.33±0.95

4. Summary and conclusion

This study demonstrates that both the rape and pumpkin seeds are a rich source of many important nutrients, which include fat and protein. Based on the results achieved, we can conclude that pumpkin seeds have a higher average both of fat (47.5% for Olga cv.) and protein (35.3% also for Olga cv.) than rapeseed, for which the highest parameters of these components were shown by Adriana cv. (44% fat, and 22.30% protein).

Oils produced due to cold pressing were characterized by good quality parameters both in terms of the peroxide and acidic numbers. In the case of carotenoids, that are generally considered the compounds with antioxidant and pro-vitamin properties, their largest amounts were recorded in the oil made from pumpkin seeds of Olga cv. (22.46 µg/ml). In the case of winter rapeseed, the highest quantity of carotenoids was observed in Bellevue cv. (18.10 µg/ml) and Adriana cv. (18.67 µg/ml). The statistical analysis showed no relationship between the content of this component and oxidative stability of the oils studied.

Studies upon the oxidative stability of both groups of oils were comparable. Each group contained one variety with very low oxidative stability of 0.28 h for oil made from rapeseed Adriana cv. and 0.26 h for Junona cv. pumpkin seed oil.

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Agriculture and Agricultural Science Procedia 7 (2015) 260 – 264

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Kernel carbohydrates concentration in sugary-1, sugary enhanced and shrunken sweet corn kernels

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Abstract

Sweet corn remains at its optimum harvest maturity for a very short period, and quality changes rapidly following its peak. This study investigates the changes in carbohydrate concentration of three genotypes of sweet corn: sugary (*su-1*), sugar enhanced (*se*) and supersweet or shrunken (*sh2*) at three stages of maturity. The analysis of variance revealed differences between genotypes for carbohydrates (sugars and starch) and between stages of maturity (moisture content). Average sugar concentration of *su-1* corn was 5% higher than that of *se* corn and 52% higher than that of *sh2* corn. The average starch concentration of *su-1* corn was 27% lower than that of *se* corn and 66% lower than that of *sh2* corn. The average moisture content of *su-1* corn was 3% lower than that of *se* corn and 1% lower than that of *sh2* corn.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: genotype;, maturit;, moisture; sugars; starch.

1. Introduction

In Europe, as well as in Poland, the areas cultivated with sweet corn (*Zea mays L. var saccharata*) have increased considerably, during the last ten years. Sweet corn eaten in the immature stage is widely used for human consumption throughout the world. It is important source of fiber, minerals, and certain vitamins. It is produced for

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.044

three distinct markets: fresh, canning, and freezing. The sweet corn varieties suitable for processing vary according to the products, canned or frozen. In recent years, sweet corn harvested for processing has been greatly improved by selective breeding and hybridizing. Nearly all commercially grown sweet corn is now of hybrid varieties. These varieties offer greatly increased yields and better uniformity, with excellent flavor, color, and processing quality (Kumar et. al, 2006). The primary components of fresh sweet corn eating quality associated with consumer performance are flavor (mainly sweetness), kernel texture and aroma (Azanza et al., 1996). Kernel sugar concentrations have been correlated with sweetness and taste panel preference (Evensen and Boyer, 1986; Azanza et al., 1994). Sweetness and tenderness were found to be the most important in overall quality, in a study conducted with fresh and processed sweet corn. Kernel sucrose concentration is regulated by endosperm carbohydrate metabolism during kernel development. New varieties of sweet corn have been developed with improved consistency, taste and shelf life (Kamol and Pulam, 2007). In sweet corns, the enhancement of sweet components in kernels is made successfully by reduction of starch synthesis activities and increase in sucrose accumulation. There are many different endosperm mutations in corn that influence kernel carbohydrate metabolism (Coe and Polacco 1994). Traditional sweet corn is homozygous for the sugary 1 (*sh1*) mutation. Comparison to normal field corn, *su1* endosperms accumulate more sugar and a highly branched, water soluble form of starch known as phytoglycogen at harvest maturity. Sweet corn *su1* varieties are characterized by a rapid loss of kernel quality after harvest due to the conversion of sugars to starch and moisture loss (Azanza et al., 1996). This rapid decline in quality restricts the time available for shipment from growing regions to major marketing areas and provides a narrow window to the sweet corn processing industry (Marshall and Tracy, 2003). Shrunken2 (sh2) and sugary enhancer1 (se1) are endosperm mutations of increasing importance to the sweet corn industry due to their superior eating quality. Preferred by consumers, owing to greater (two to three times more) kernel sucrose concentration (sh2) at fresh harvest retain higher sugar and moisture concentration for longer postharvest periods than the traditional variety (sh1). These varieties retain higher sugar and moisture concentration for longer postharvest periods and have only trace levels of phytoglycogen in comparison to su1 kernels (Malvar et al, 1997). This longer postharvest life provides the industry with more time to transport, process, and market a product with superior eating quality (Azanza, 1996). Sweet corn genotypes with either sh2 or su1 se1 have also been shown to be preferred by consumers in taste panels (Evensen and Boyer, 1986). Supersweet varieties have become the dominant type produced in virtually all the major sweet corn producing regions of the Poland. Despite the desirable attributes of sh2 and su1 se1 corn, the utilization of these two endosperm mutations has been hindered by reduced field emergence, seedling vigor and stand uniformity and stand uniformity (Douglass, 1993). Goldman and Tracy (Goldman and Tracy, 1994) reported that kernels containing the sh2 mutant have a much smaller endosperm than su1 due the effects of this mutant on starch synthesis. Reductions in endosperm size result in smaller, lighter kernels.

Several kernel characteristics in fresh sweet corn have been related to sensory quality. Pericarp thickness has been negatively associated with the sensory perception of tenderness (Juvik and Labonte, 1988). Sweet corn flavor and texture are associated with the chemical composition of the kernel, the structural compactness of starch granules, and the cellular structure of the endosperm (Tracy, 2001).

The objective of the study was to measure carbohydrates concentrations of three genotypes of sweet corn: sugary (*su-1*), sugar enhanced (*se*) and supersweet or shrunken (*sh2*) at three stages of maturity (SM).

2. Materials and methods

Three genotypes of commercial sweet corn cultivars, a cultivar recessive for the sugary (*su-1*) (Boston), sugar enhanced *(se)* (Anawa) and supersweet or shrunken (*sh2*) (Candle) were compared during maturation period for carbohydrate composition and yield for processing quality. Sweet corn for these studies was grown during 2013 in University of Life Sciences Research Station, near Lublin, Poland. The cultivars were grown in isolation, about 200 m, from one another to reduce the likelihood on cross-pollination.

Harvests of ears for physical and chemical analyses were made at 4 – day intervals from 20 to 32 days after pollination (DAP). These stages were chosen because sugars reach maximum levels at about 21 DAP and sweet corn typically is harvested at this stage of maturity (Carey et al., 1984). At each harvest date, ears were hand picked at random for each genotype. Directly after harvest, ears were husked and silk was removed. Next the ears were frozen in liquid nitrogen to stop all metabolic activity. Thirty kernels of corn ears were randomly removed and ground into powder in laboratory grinder, and stored in freezer at about -20°C for subsequent carbohydrate analyses.

Measurement of sugar contents was made using the DNS method following acid hydrolysis (PN-EN ISO 10520, 2002). The reducing sugars were determined prior to the hydrolysis by means of the DNS method. The starch content was determined through the difference between the total content of sugars and the content of sugars soluble in ethyl alcohol (40% vol/vol). The sucrose content was established through the difference between the content of sugars soluble in ethyl alcohol and the content of reducing sugars. To determine the reducing sugar content with the DNS method, a test tube was filled with 0.5 cm^3 of the tested solution and 1.5 cm^3 of 3-5-dinitrosalicylic acid (DNS) and then boiled for 5 minutes in a bath of boiling water. After cooling down, 6 cm^3 of distilled water was added to make a total volume of 8 cm^3. Next, the sample extinction was read against a reagent assay at a wavelength of $\lambda = 550$ nm. The extinction measurement results were referenced to the model curve. The sugar content was determined in relation to the kernel dry mass. The experiments were replicated thrice in 100-gram samples for each variety and the average values were reported.

The moisture content of the kernels was determined using the ASAE (1983) method. This involved oven drying of seed samples at 103°C for 72 h. The samples were allowed to cool in a desiccator after which the weights were recorded. Three samples were used and the average moisture content was reported.

Data were subjected to analysis of variance (ANOVA). Comparison of means was conducted with Tukey's least significant difference (LSD) test, at a significance level $p = 0.05$. All statistical analysis was performed using the Statistica 6.0.

3. Results and discussion

Sweet corn kernel concentration of carbohydrates and moisture are presented in Table 1.

Table 1. Mean sweet corn kernel concentration of carbohydrates and moisture of three fresh sweet corns at three stages of maturity.

Genotypes	Varieties	Stage of maturity	Carbohydrates		Moisture, %
			Sugar, % Sugar, %	Starch, % Starch%	
su-1	Boston	I	5.2^{a}	15.7^{a}	74.6^{a}
		II	5.3^{b}	20.1^{ba}	69.4^{ba}
		III	4.6^{cab}	24.6^{cab}	64.2^{cab}
	Bonus	I	5.9^{a}	16.1^{a}	72.5^{a}
		II	5.7^{b}	19.2^{ba}	67.1^{ba}
		III	4.9^{cab}	23.8^{cab}	60.2^{cab}
	Jubilee	I	5.4^{a}	15.2^{a}	74.6^{a}
		II	5.1^{b}	19.6^{ba}	66.8^{ba}
		III	4.6^{cab}	23.7^{cab}	58.7^{cab}
	Mean	-	5.1	19.7	67.5
	$LSD_{(0.05)}$	-	0.4	3.2	5.1
se	Anava	I	6.5^{a}	12.3^{a}	72.3^{a}
		II	5.2^{ba}	16.3^{ba}	61.2^{ba}
		III	4.7^{ca}	18.8^{ca}	59.4^{ca}
	Champ	I	6.2^{a}	11.9^{a}	71.9^{a}
		II	4.8^{ba}	14.2^{ba}	65.5^{ba}
		III	4.3^{ca}	17.2^{cab}	57.8^{cab}
	Dallas	I	6.8^{a}	12.8^{a}	74.6^{a}
		II	5.6^{ba}	15.6^{ba}	65.7^{ba}
		III	5.1^{ca}	19.9^{cab}	59.7^{cab}
	Mean	-	5.4	14.4	65.3
	$LSD_{(0.05)}$	-	1.1	2.1	4.3
sh2	Candle	I	8.3^{a}	6.3^{a}	71.9^{a}
		II	7.6^{ba}	6.8^{b}	67.1^{ba}
		III	7.2^{cab}	7.6^{c}	59.6^{cab}
	Challenger	I	8.9^{a}	6.1^{a}	73.6^{a}
		II	7.6^{ba}	6.7^{b}	67.3^{ba}
		III	6.9^{cab}	7.5^{c}	58.6^{cab}
	Sheba	I	8.7^{a}	5.8^{a}	75.2^{a}
		II	8.2^{ba}	6.6^{b}	67.2^{ba}

Genotypes	Varieties	Stage of	Carbohydrates		Moisture, %
		III	7.6^{cab}	7.3^{c}	61.6^{cab}
	Mean	-	7.8	6.7	66.9
	LSD $_{(0.05)}$	-	0.4	1.6	4.6
	Genotypes LSD $_{(0.05)}$		0.6	5.4	66.9

Within each column, the same letter indicates the significant difference at $p < 0.05$.

The analysis of variance showed significant difference between genotypes type, and stage of maturity for carbohydrates and moisture concentration. Carbohydrates per kernel did not differ between cultivars.
The delay of the corncobs harvest date affected the changes of moisture, sugars and starch concentrations. A similar trend was reported by Simonne et al. (1999), Suk and Sang (1999), Waligóra (2002), Warzecha (2003) and Liu-Peng et al. (2003). The results show that delaying the harvest date decreasing moisture and sugars and leads to an increase in the starch concentrations. Negative associations between sugar content and starch content were also observed by Dudley and Lambert (1992), Ha (1999), Kumari et al. (2006).

The highest decrease of moisture contents (21.3%) was obtained for the Jubilee variety and the lowest (13.9%) for the Boston variety. The average moisture content of the su-1 sweet corn varieties (17.3%) was 19.6% lower than the moisture content of the *se* varieties (13.9%) and 21.3% lower than *sh2* varieties (21.3%).

The average sugars concentrations of the three cultivars of su-1 genotype types (5.6%) for I stage of maturity was 16% lower than the sugars concentration of III stage of maturity (4.4%). Respectively for cultivars of *se* and *sh2* genotype types this was obtained: 27.6% and 15.8%. Results from the investigation demonstrate that sugars concentration in *sh2* kernels is significantly higher by about 32% in I date of harvest, by about 50% in II date of harvest and by about 53% in III date of harvest than sugars concentration in se kernels and by about 48% in I date of harvest, by about 47% in II date of harvest and by about 53% in III date of harvest than sugars concentration in *su-1* kernels. Table 1 indicates starch concentration was 56.0% higher in *su-1* in III stage of maturity than in I stage of maturity. The starch concentrations of *se* and *sh2* genotype types were 51.5% and 19.6% higher, respectively.

Starch concentration in *sh*2 kernels is significantly lower by about 105% in I date of harvest, by about 143% in II date of harvest and by about 151% in III date of harvest than sugars concentration in se kernels and by about 160% in I date of harvest, by about 192% in II date of harvest and by about 224% in III date of harvest than sugars concentration in *su-1* kernels.

4. Conclusion

The results of this study indicate clearly that the date of sweet corn harvest is the most important factor in maintaining fresh sweet corn quality. It was observed that the more mature sweetcorn (III date of harvest) had larger kernels and the kernels were more compact on the cob, while the less mature (I date of harvest) kernels were smaller and there were still some spaces between the kernel rows. The delay of the corncobs harvest date affected the sweet corn quality. The moisture content and sugars concentration decreased but starch level increased. The rise of starch concentration was more quickly between *su-1* sweet corn varieties than *se* or *sh2*.

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Agriculture and Agricultural Science Procedia 7 (2015) 265 – 271

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Analysis of energy-consumption of bioethanol production in agricultural distilleries in Poland

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Abstract

The paper analyses the process and impact of selected factors on energy efficiency of potato-derived ethyl alcohol production process in Poland. Data from a variety of agricultural distilleries in Poland were used, and 10 selected indices of the process were taken into account. The research involved using sophisticated tools such as cluster analysis, sensitivity analysis and artificial neural network.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: ethyl alcohol; distillery; potato; energy efficiency; neural model

1. Introduction

Alcohol is produced from three main types of raw material including materials that contain carbohydrates in the form of sugar (molasses, sugar cane), materials that contain carbohydrates in the form of starch (e.g. potatoes, corn and rye), and materials that contain carbohydrates in the form of cellulose (e.g. wood and agricultural waste) Kwong and Valerie (2001).

In Poland, ethanol is produced in two types of distilleries, agricultural and industrial ones. Agricultural distilleries, with the capacity of approx. 2 million litres of spirit per year have contended with a difficult financial situation, caused by low price of spirit paid by buyers, increased demand of imported bioethanol and high price of

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.046

agricultural distillate, Golisz and Wójcik (2013). Moreover, industrial distilleries are competitive as their production capacity is over 10 to a few dozen greater than the capacity of an agricultural distillery. Economic situation of agricultural distilleries necessitates searching for new innovative solutions that can be implemented in the process of ethyl alcohol production. Good management of the ethanol production process can help to lower the manufacturing costs of the finished product, and to improve the energy efficiency of the process.

Energy efficiency (EE) is defined as a ratio of the obtained use effect value of a given device, in normal exploitation conditions to the amount of energy used by the device, necessary to achieve the above mentioned result. Energy-consumption of production in the agricultural and food-processing sector was described by, among other authors, Ferrari et al. (2012), Sieghart (2012), Wojdalski and Dróżdż (2012), Zhang (2010), Kowalczyk and Netter (2008), Wang (2008), Kaleta and Wojdalski (2008), Laudański (2007). However, there are no publications on energy-consumption of potato-derived alcohol production. Jodkowski et al. (2010) only partially address this problem and demonstrate a significant role of stillage in the production of biogas. In Poland, potatoes are the main raw material in the distillery industry. In winter and spring farmers sell potatoes to agricultural distilleries, as the potatoes are of lower quality at this time of the year and are not suitable for direct consumption (Gurgul and Kielesińska 2001). Table 1 presents data related to the efficiency of ethyl alcohol production from selected raw materials.

The last few years show a decline of the share of potato-derived spirit in the market. This situation is caused by high price of potato compared to grain. More ethanol can be produced from 1 ha of potatoes than 1 ha of cereal. However, given the market prices for both grains an potatoes, production of alcohol from rye is more profitable, Lipińska (2013).

Table 1. Efficiency of ethyl alcohol production from selected starch-containing materials.

Raw material	Starch content [1)]	Efficiency ethanol		
	%	l/t raw product [2)]	kg/t raw product [2)]	m^3/ha of crop [3)]
Corn	65.0	417	330	1500
Potato	17.8	120	95	2500
Rye	62.0	390	308	950

[1)] Samborski (2005); [2)] Marczak (2012); [3]) Szewczyk (2004)

2. Methods

2.1. Data set

237 data cases from over a dozen distilleries were used to examine energy efficiency of the process of potato-derived alcohol production. 10 factors that affect the process were identified, including:

p pressure of water vapour [MPa],
LZ number of mashes [-],
zs starch content [%],
wr total efficiency of chemical reactions [%],
eta coefficient of heating performance of the steam boiler, it is a ratio of an amount of heat transferred to the medium in the boiler to the stream of heat input to the boiler,
Q_w^{rz} heating value of real fuel measured by means of a device called bomb calorimeter, heating value is a ratio of the amount of heat produced from the complete combustion of a unit of fuel [MJ/kg],
t_1 temperature of the condensate leaving the coil pipes of the rectifying column [˚C],
t_2 temperature of fresh water at the input of the steam boiler [˚C],
JZP specific steam consumption in the rectifying column [kg/dm3],
D hourly steam consumption in the column steamers [kg/h].

The following two indicators can be calculated using the input data:

- SEC Specific Energy Consumption - an index of unit consumption of real fuel [kg/dm^3],
- SEFC Specific Equivalent Fuel Consumption - an index of unit consumption of equivalent fuel [kg/dm^3].

The output data of the model being constructed is energy efficiency for a unit of equivalent fuel *EE* expressed in [dm^3/kg] determined on the basis of the above indices.

2.2. Process design

Ethanol is obtained as a result of fermentation of material that contains monosaccharides disaccharides and polysaccharides. There are two methods of alcohol production, fermentation, being the main method (75-90% of the total global production) and hydratation. (McMillan 1997). Materials that contain polysaccharides (starch) are the basis of fermentation industry. Potato has high content of soluble saccharides. The yield of ethanol from potatoes amounts to approx. 0.4 l/kg (Mattiasson 2004). In distilling industry, potato-derived spirit production includes the following stages: steaming, malting, fermentation and distillation, fig.1 (Cieślak and Lasik 1979, Komorowicz 2006, Tasic 2011, Lay 2012, Zhang 2013).

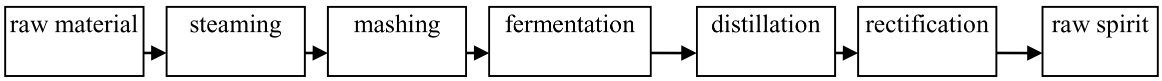

Fig.1. A block diagram for obtaining ethyl alcohol

In order to define energy efficiency of potato-derived ethyl alcohol production it is required to perform a few stages of calculations for individual cycles of production, Kaleta and Wojdalski (2008). On the basis of data was calculated the energy efficiency *EE(PU)* of production, which ranged from 0.9 to 2.1 dm^3/kg of equivalent fuel.

2.3. Modelling and analysis

The first stage of analysis involved standardization of data that describe production of bioethanol. The dataset following standardization was then analysed using cluster analysis. EM algorithm (Expectation, Maximization) was used, which algorithm groups cases by fitting a mixture of probability distributions to data, Witten and Frank (2001).

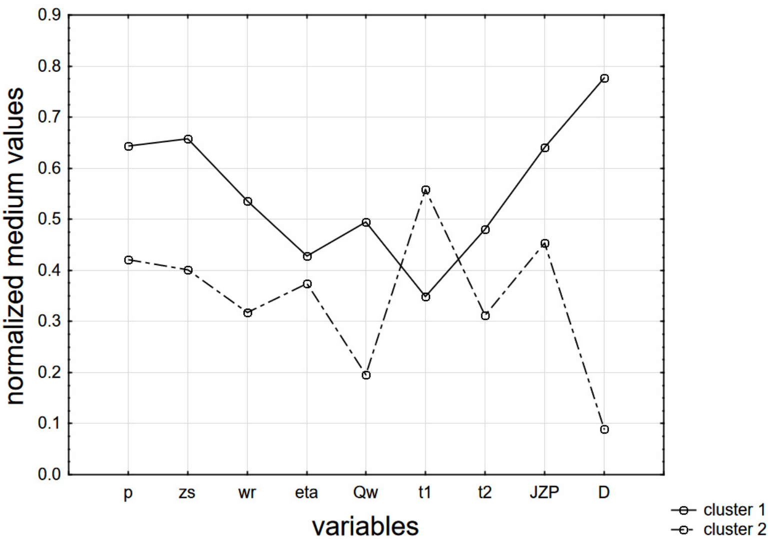

Fig.2. Plot of normalized medium values for two clusters in the set of data related to bioethanol production

The analysis allowed to group similar cases that describe the process of bioethanol production. Based on cluster analysis, data were divided into two groups, fig.2. The first cluster, whose characteristic is higher average starch content in potatoes, consists of 105 cases of bioethanol production, and the second cluster consists of 132 cases of the process.

2.3.1. Neural network testing

Two neural models were developed for the above mentioned clusters. All variables that describe the process were used in the process of development of both neural networks:

- as quantitative input variables p, zs, wr, eta, Q_w, t_1, t_2, JZ, D
- as qualitative input variables: LZ,
- as output variable EE.

A diagram of neural networks, with data divided into input and output data is presented in fig. 3.

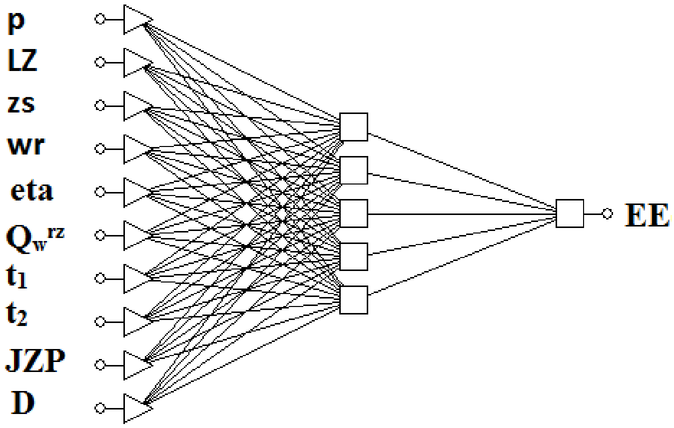

Fig. 3. A diagram of a neural network with data divided into input and output data

For cluster 1, *MLP 14:4:1* proved to be the best network structure, for which sensitivity analysis (table 2) indicates that the least important parameters that have impact on the process is pressure *p*, heating value of real fuel Q_w and temperature of temperature of the condensate leaving the coil pipes of the rectifying column t_1 as well as temperature of fresh water at the input of the steam boiler t_2, number of mashes *NM*.

Table 2. Sensitivity analysis of the MLP 14:4:1 network for cluster 1

Sensitivity analysis										
	eta	**zs**	**D**	**wr**	**JZP**	**LZ**	**t_1**	**p**	**t_2**	**Q_w^{rz}**
1.MLP 14-4-1	550.6	358.7	102.9	65.6	20.1	10.9	3.2	1.4	1.3	1.0

Variables of lesser importance were reduced in order to improve the quality of the network and increase the effectiveness of calculations. Use of such a great number of input variables with only 105 data resulted in network overlearning, i.e. too good fit of the model to the training data. As a result of reduction of these variables, an MLP 5:3:1 network was obtained, for which sensitivity analysis is shown in table 3.

Table 3. Sensitivity analysis of the reduced network MLP 5:3:1 for cluster 1

Sensitivity analysis					
	eta	**zs**	**D**	**wr**	**JZP**
1.MLP 5-3-1	116.8	73.5	23.9	11.3	4.8

Based on the obtained results, it may be concluded that the coefficient of heating performance of the steam boiler is the most significant parameter of the process, followed closely by starch content, unit consumption of steam in the steamer, reaction efficiency and specific steam consumption in the rectifying column.

In case of cluster two, the procedure was identical. This group consists of cases with lower average starch content and higher number of mashes than in cluster 1. Results of the developed neural network for all variables and for a reduced number of input data are presented in tables 4 and 5, respectively.

Table 4. Sensitivity analysis of the MLP 16:4:1 network for cluster 2

Sensitivity analysis										
	eta	**zs**	**D**	**wr**	**LZ**	**JZP**	**t_1**	**t_2**	**p**	**Q_w^{rz}**
2.MLP 16-4-1	1219.8	232.0	224.4	126.5	37.4	16.1	3.3	2.9	2.3	1.4

Table 5. Sensitivity analysis of the reduced network MLP 5:3:1 for cluster 2

Sensitivity analysis					
	eta	**zs**	**D**	**wr**	**JZP**
2.MLP 5-3-1	312.3	60.9	59.0	25.6	5.9

In cluster 2, the order of input variables is identical to the previous analysis. As in cluster 1, the most significant parameter is the coefficient of heating performance of the steam boiler, followed by starch content, unit consumption of steam in the steamer and reaction efficiency. However, the importance of these factors has different weights.

2.3.2. Verification of neuronal models

The results of empirical verification (Trajer et.al. 2012) of the best models for both clusters are presented below, where the quality of testing is the correlation coefficient R of individual models for the test set, and the test error δ is the sum of squared difference between the input values and the values obtained at the outputs of each output neuron for the test set.

Empirical verification for the 1.MLP 5:3:1 model for cluster 1: $R = 0.996$; $\delta = 0.00012$.
Empirical verification for the 2.MLP 5:3:1 model for cluster 2: $R = 0.998$; $\delta = 0.00001$.
The results indicate high effectiveness of both models.

3. Results and discussion

Example results of simulations are presented for factors that are most significant as regards energy efficiency of the process of potato-derived ethyl alcohol production: the coefficient of heating performance of the steam boiler, starch content, unit consumption of steam in the steamer and reaction efficiency.

Graphs below (figs. 4-6) present the results for each cluster: figures “a)” for cluster 1 and figures “b)” for cluster 2.

Analysing all the graphs can be noticed that the energy efficiency achieves higher values for data from cluster 1 than cluster 2. As can be seen, higher values of coefficient of heating performance of the steam boiler, starch content in the material and efficiency of reaction allow to obtain higher energy efficiency of bioethanol production process. In the case unit consumption of steam in the steamer, with the increase of this parameter, value of the energy efficiency decreases. Energy efficiency of the process, can achieve the highest value, for the coefficient of heating performance of the steam boiler of 0.7, the starch content of approx. 20%, efficiency of chemical reaction of approx. 0.9 and unit steam consumption in the steamer of approx. 550 kg/h.

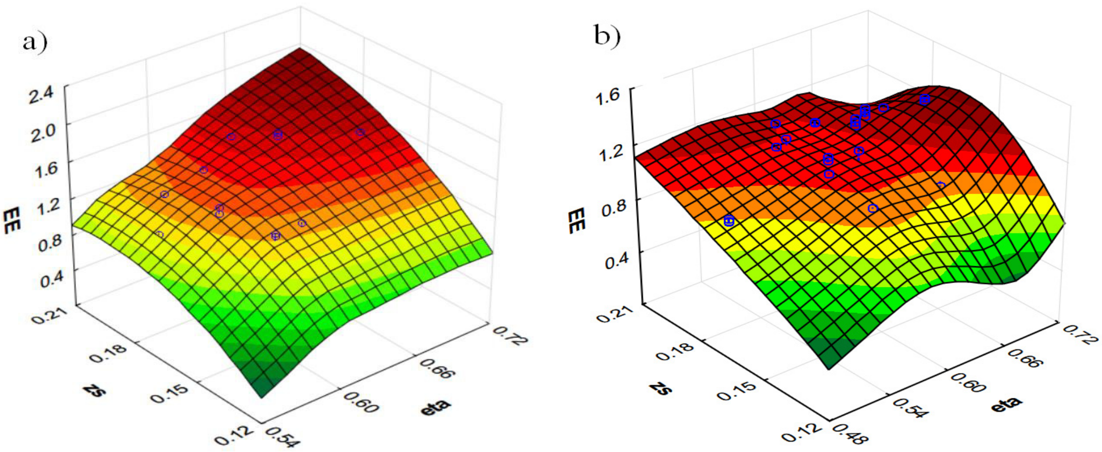

Fig. 4. The impact of the coefficient of heating performance of the steam boiler and of starch content in the material on energy efficiency .

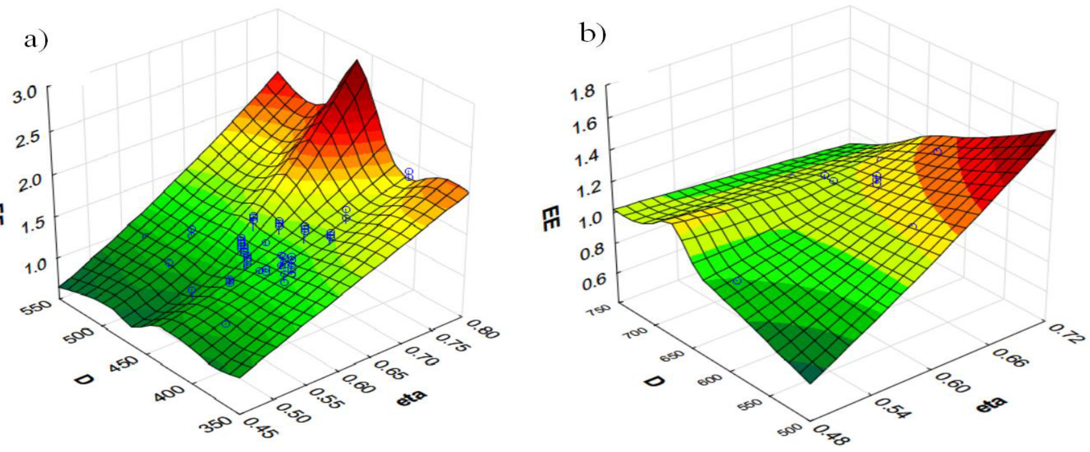

Fig. 5. The impact of the coefficient of heating performance of the steam boiler and unit steam consumption in the steamer on energy efficiency.

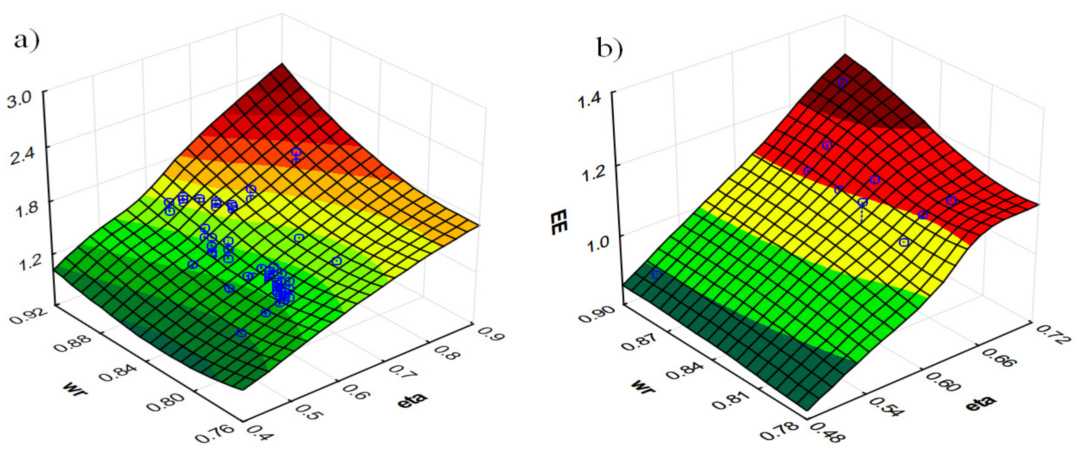

Fig. 6. The impact of the efficiency of reaction and the coefficient of heating performance of the steam boiler on energy efficiency of the process.

4. Conclusions

Based on the conducted research and analysis of the results, it may be concluded that energy efficiency of bioethanol production depends on selected parameters of the process and their values. Parameters were grouped into two clusters, according to their values. Efficiency of the process is different for data that belong to each cluster, with the higher values for cluster 1. The sensitivity analysis indicates that the most important process parameters that affect on energy efficiency of bioethanol production there are: coefficient of heating performance of the steam boiler (eta), starch content (zs), unit steam consumption in the steamer (D) and the efficiency of reaction (wr).

It is possible to reduce energy-consumption of bioethanol production for cases from both clusters by using steam boilers with higher performance. Another option is to isolate steamers and use more enzymes for hydrolysis of starch contained in potatoes. Also the rectifying column may save energy. The innovations that may be widely used in distilling industry include using stillage for biogas production, which allows decreasing the amount of fuel required for vapour production.

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Agriculture and Agricultural Science Procedia 7 (2015) 272 – 279

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Organic *versus* conventional farming: the case of wheat production in Wallonia (Belgium)

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Abstract

The environmental impact of wheat production was assessed through Life Cycle Assessment (LCA). Local data were collected to characterize Walloon conventional and organic wheat production systems. Two functional units (FU) were investigated: 1 kg of wheat grains at 15% humidity and 1 ha used for wheat cropping. An uncertainty analysis assessed the significance of differences between conventional and organic systems. Using 1 kg of grains as FU, results are not significantly different in global warming and cumulative energy demand. Very highly significant differences for soil acidification and eutrophication, and significant differences for agricultural land occupation were found to be in favor of conventional wheat production. Due to the high yield level in conventional farming (8.5 t/ha at 15% humidity against 4.5 t/ha for organic wheat), organic winter wheat has an equivalent or even, in some impact categories, a higher impact than conventional winter wheat. Using 1 ha as FU, organic production is less impacting than conventional production, except for soil acidification and eutrophication. The choice of the FU has proven to be very sensitive. This study could be improved by accounting for rotation effects, by using more specific models to calculate emissions due to organic and mineral fertilization, and by accounting for carbon storage in soil.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: Life cycle assessment (LCA); organic farming; wheat; environmental impact.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.047

1. Introduction

There is an increasing awareness among western consumers regarding their behavior matching sustainable development, translated by a modification of some food consumption habits. The demand for organically sourced products is in constant increase in Europe, as in Wallonia (southern Belgium) where, between 2005 and 2011, the number of organic farms has risen of 49% (DGSIE, 2010) and represents up to 7% of the Utilized Agricultural Area (UAA) (Debode *et al*., 2013). Organic products are often perceived as more environmentally-friendly than their conventional counterparts. Do these prejudices reflect the truth? European consumers ask for more information on environmental impacts of food products (European Commission, 2013). This explains why European countries are eager to promote environmental labeling and sustainable food products.

It is therefore crucial to be able to determine more precisely the carbon footprint and more globally the environmental impacts of food products. The Life Cycle Assessment (LCA) methodology is appropriate to reach such a goal (Andersson, 2000).

Using the LCA standardized method (ISO 14040, 2006), the aim of this study is to assess and compare the environmental impacts of organic and conventional wheat. It aims at highlighting environmental hotspots of both production modes and identifying limitations of LCAs conducted on organic productions.

2. Methods

The system boundaries of both systems include all production steps from the field to the farm gate, including machinery production and use, inputs (fertilizers, pesticides and seeds) production, transport and use, and land occupation. Two functional units (FU) are investigated and compared: 1 kg fresh matter (FM, 85% of dry matter) of wheat and 1 hectare (ha) of wheat-cropped area.

2.1. Inventory data collection

Data on conventional wheat production in Wallonia (reference year 2010) are provided by Van Stappen *et al*., (submitted to the International Journal of Life Cycle Assessment). This conventional wheat has a grain yield of 8,350 kgFM/ha and a straw yield of 3,600 kgFM/ha. Generic data are extracted from the ecoinvent database (Nemecek and Kägi, 2007).

Table 1. Itinerary of organic and conventional wheat

Process	units	Conventional wheat	Organic wheat
Area in Wallonia	ha	139 488	584
Skim ploughing		1.5 passages, tractor 300 cv, deep skim ploughing before sowing	1 passage, tractor 100 cv, disc tiller, mounted 3.5m
Seeds	kg/ha	160	200
Organic fertilizer	kg N/ha	7	144
	kg P_2O_5/ha	3.9	64.8
	kg K_2O/ha	5.8	145.2
Mineral fertilizer	kg N/ha	182	0
	kg P_2O_5/ha	3	0
	kg K_2O/ha	5	0
Crop protection		phytosanitary treatment, 3 passages sprayer	mechanical weeding, 2 passages, spiked chain harrow, 12m
Harvesting		1 passage, tractor 350 cv, combine harvester 7m30	1 passage, combine harvester 5m
Swath drying		0.5 passage, windrower 4m , tractor 120 cv	0.5 passage, windrower 4m, tractor 120 cv
Baling		1 passage, 120*7cm, tractor 120 cv	1 passage, 120*7cm, tractor 120 cv

Production data for organic wheat are provided by local studies (Montignies *et al*., 2011, Debode *et al*., 2013) (Table 1). Organic wheat has a grain yield of 4,500 kgFM/ha and a straw yield of 2,500 kgFM/ha. Agricultural work processes are based on agricultural pathways defined by experts. Data from the Mecacost tool (Rabier *et al*., 2008) are used to calculate emissions due to machinery use with the adaptation of fuel consumption, work duration, life duration, nominal and mean powers, and machinery weights. Emission factors for fuel combustion and tire abrasion come from Nemecek and Kägi (2007).

For both conventional and organic wheat production, impacts from the production of organic fertilizers are entirely attributed to animal rearing. Only fertilizers transport and use on field are considered in this study.

Field emissions due to inputs (fertilizers, pesticides, seeds) application during crop cultivation are assessed using emission models, following recommendations by Nemecek (2013). Ammonia (NH_3) emissions to air are calculated according to fertilizers nitrogen (N) content and using emissions factors from Tier 2 technology-specific models by EMEP/EEA (2013a, b). Nitrate ion (NO_3^-) emissions to groundwater are based on the model SALCA-Nitrat by Richner *et al*. (2006) adapted to local conditions with respect to cropping duration, date of N application, N mineralization potential in soils, N uptake by vegetation and risk of N leaching. Nitrogen oxides (NO_x) emissions to air are calculated from EMEP/EEA Tier 1 approach (EMEP/EEA, 2013b) and nitrous oxide (N_2O) are estimated from IPCC Tier 1 guidelines (IPCC, 2006). Phosphorous emissions to river (phosphorus (P) and phosphate ion (PO_4^{3-})) and to groundwater (PO_4^{3-}) are based on the SALCA-phosphor model by Prasuhn (2006). Trace metal (cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), zinc (Zn)) balances and related emissions to groundwater, river and agricultural soil are calculated from the SALCA-Schwermetall model by Freiermuth (2006) adapted to local conditions with respect to trace metal contents of mineral and organic fertilizers (Piazzalunga *et al*., 2012), soil (Sonnet *et al*., 2003), and plant material and annual deposition (Koch and Salou, 2013).

2.2. Allocation between co-products

Cereal cultivation is an indivisible multi-output product system delivering two co-products, grain and straw, both having agronomic and economic values. While cereals are generally cultivated for grain production, farmers sometimes choose to crop a few cereal hectares in order to harvest straw for animal litter or feed. Straw has no matter what an undisputable role in soil carbon and soil structure management, whether left on the field or returned to the latter as farmyard manure. For this reason the impacts of wheat production are allocated between grain and straw according to their respective prices on the Walloon market.

2.3. Life Cycle Impact Assessment

The evaluation of the environmental impacts or Life Cycle Impact Assessment (LCIA) is supported by a composite method at mid-point level constructed according to the ILCD handbook (European Commission *et al*., 2011). The LCA software used is SimaPro 8.0.4.30 (PRé, 2015). Selected impact categories, related indicator units and reference method are listed in Table 2.

Table 2. Selected impact categories, related indicator units and reference method used for LCIA.

Abbreviation	Impact category	Indicator Unit	Reference method
GWP	Global warming potential with a timeframe of 100 years	kg CO_2 eq.	(IPCC, 2013)
HTP	Human toxicity potential	10^{-6} CTUh (Comparative Toxic Units)	USEtox (Rosenbaum *et al*., 2008)
TAP	Terrestrial acidification potential	10^{-6} kg SO_2 eq.	(Posch *et al*., 2008)
EUP	Eutrophication potential	10^{-6} kg PO_4^{3-} eq.	CML-IA baseline v4.2 (Guinée *et al*., 2002)
AEP	Aquatic ecotoxicity potential	10^{-3} CTUe (Comparative Toxic Units)	USEtox (Rosenbaum *et al*., 2008)
ALO	Agricultural land occupation	m²y (m².year)	ReCiPe v1.11 (Goedkoop *et al*., 2009)
WDP	Water depletion potential	10^{-3} m³	ReCiPe v1.11 (Goedkoop *et al*., 2009)
POF	Photochemical oxidant formation	10^{-3} kg NMVOC	ReCiPe v1.11 (Goedkoop *et al*., 2009)

Abbreviation	Impact category	Indicator Unit	Reference method
CED	Cumulative Energy Demand	10^{-3} MJ	(Frischknecht *et al*., 2007)

2.4. Uncertainty analyses

Uncertainty analyses aim at determining how uncertainties in data and assumptions progress in the calculations and how they affect the reliability of the results of the LCIA (ISO, 2006b). In this work uncertainty analyses are run using Monte-Carlo (MC) simulations implemented in SimaPro 8.0.4.30 (Hedemann and König, 2003, PRé, 2015). MC simulations performed in SimaPro account for uncertainty in input and output inventory data but not for uncertainties tied to impact characterization factors. It is therefore proposed to mitigate our uncertainty results with semi-quantitative analysis based on expert judgment as recommended by Jolliet *et al*. (2010). They recommend minimum 10 % difference in order to declare results are significantly different in GWP and CED categories. For TAP and EUP, this minimum difference has to reach 30 %. Regarding HTP and AEP, one or even two orders of magnitude are necessary to declare two contributions are significantly different, considering the high uncertainty on impact characterization factors and the huge number of substances playing a role in toxicity impacts. In order to account for this uncertainty mitigation in our results, significant differences are invalidated when the above-mentioned minimum difference between compared results is not reached.

3. Results

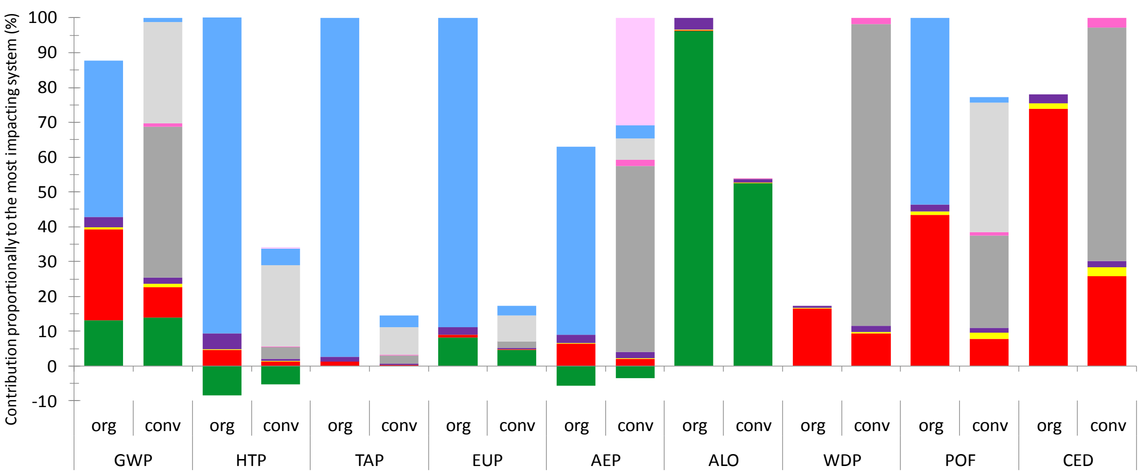

Fig. 1. LCIA results by impact category for the production of 1 kgFM of organic (org) and conventional (conv) wheat. ● Crop effect (emissions tied to land occupation), ● Mechanization, ● Transport, ● Seeds, ● Mineral fertilizers production, ● Pesticides production, ● Emissions due to mineral fertilizers use, ● Emissions due to organic fertilizers use, ● Pesticides emissions.

Environmental impacts results per kg of organic wheat (Table 3 and Fig. 1) show the major contribution of emissions due to organic fertilizer use in most impact categories. These emissions contribute to 51 %, 91%, 97%, 89%, 86% and 53% of the total impact in GWP, HTP, TAP, EUP, AEP and POF, respectively. Among these, we note that NH_3 emissions are directly responsible for 96% and 49% of the total impact in TAP and EUP, respectively, and indirectly, *via* N_2O emissions, responsible for 20% of the total GWP impact.

Regarding the conventional production of 1 kgFM of wheat, mineral fertilization is the most impacting step representing 74% of GWP, 94% of HTP, 95% of TAP, 69% of EUP, 63% of AEP, 87% of WDP, 87% of POF and

69% of CED. Mechanization has also a substantial impact in organic and conventional wheat production in the categories GWP (26 and 9%), WDP (16 and 9%), POF (43 and 8%) and CED (75 and 26%). In conventional cropping, the impact of pesticides production and application is limited to AEP (32%), WDP (1.8%) and CED (3%).

Table 3. LCIA results for organic and conventional wheat production, using 1 kgFM and 1 ha as functional unit (FU).

FU	Production mode	GWP kg CO_2 eq.	HTP 10^{-6} CTUh	TAP 10^{-6} kg SO_2 eq.	EUP 10^{-6} kg PO_4^{3-} eq.	AEP 10^{-3} CTUe	ALO m²y	WDP 10^{-3} m³	POF 10^{-3} kg NMVOC	CED 10^{-3} MJ
1 kgFM	Org	0.307	2.246	0.103	0.013	0.004	1.6	0.149	1.3	0.001
	Conv	0.349	0.150	0.015	0.002	0.007	0.868	0.861	0.993	0.002
1 ha	Org	1382	10109	462.7	56.6	18.6	7270	672	5793	6.7
	Conv	2991	1283	141.7	19.4	59.4	7419	7360	8489	163.6

Org: organic; Conv: conventional

MC simulations (Table 4) have been conducted to identify significant differences between organic and conventional wheat production. Using 1 kgFM as FU, MC simulations reveal very highly significant differences ($p < 0.001$) for TAP and EUP, and significant differences ($p<0.05$) for ALO and POF. MC simulations using 1 ha as FU conclude to very highly significant differences in GWP, TAP, EUP and CED, and highly significant differences in POF. Organic production shows lower impacts than conventional production in GWP, POF and CED, but higher impacts in TAP and EUP.

Table 4. Monte-Carlo (MC) simulations comparing organic and conventional wheat production, using 1 kgFM and 1 ha as functional unit (FU).

FU	GWP	HTP	TAP	EUP	AEP	ALO	WDP	POF	CED
1 kgFM	0.133	(**)	***	***	(***)	**	0.418	*	0.054
1 ha	***	0.222	***	***	(***)	0.468	0.456	**	***

*** $p<0.001$: very highly significant differences; ** $p<0.01$: highly significant differences; * $p<0.05$: significant differences; p values for not significant differences ($p\geq0.05$) are indicated; invalidated results (see section 2.4) are displayed between brackets.

4. Discussion

When using 1 kgFM as FU, organically produced wheat has significantly higher environmental impacts than conventional wheat in TAP, EUP, ALO and POF categories. This better performance of conventional wheat production is partly explained by yield differences: 8.5 tFM/ha for conventional wheat (DGSIE, 2010) against 4.5 tMF/ha for organic wheat (Montignies *et al*., 2013).

Additionally, for an equivalent nutrient supply, organic fertilization induces more important impacts than mineral fertilization. This is explained by model emissions factors for NH_3 volatilization which are higher for organic N fertilizers than for mineral fertilizers (EMEP/EEA, 2013b, IPCC, 2006, Nemecek and Schnetzer, 2011). These factors affect NH_3 and NO_x emissions and indirect N_2O emissions, contributing to TAP, EUP and GWP. Considering the important contribution of NH_3 emissions to these impact categories, a more accurate evaluation of those emissions is crucial.

Nitrogenous and phosphorous emissions from mineral and organic fertilizers application on field are calculated from Tier 1 or Tier 2 emission models accounting partly for specific soil, practices, crop rotations or climate conditions. Even though those models are recommended by widely used databases such as ecoinvent, they introduce uncertainty in the results. More specific crop models have proven their relevance (Bessou *et al*., 2012, Godard *et al*., 2012, Williams *et al*., 2010) and may be transposed to our region in order to refine our conclusions.

When using 1 ha as FU, organic wheat is more environmentally-friendly than conventional wheat in GWP, POF and CED impact categories.

Results are highly sensitive towards the choice of the functional unit, as already observed in other studies comparing organic and conventional farming (Hayashi, 2013, Mondelaers *et al*., 2009). Mass (kg) can be selected because this FU reflects more accurately the role of agriculture which is to provide biomass for food and non-food uses rather than to occupy land. Production is indeed the central purpose of agricultural systems, while landscape upkeep comes secondary (Charles *et al.*, 2006). The land area unit (ha) could be a suitable choice if the goal of the study is to assess which agricultural practices (organic or conventional) put less environmental pressure on land (land being seen as a finite and fragile resource) (Jolliet *et al*., 2010). The area FU brings information on the intensity in the use of agricultural inputs, while the efficiency of production systems is taken into account by a mass FU (Charles *et al.*, 2006). It is therefore essential to define the product function in a study comparing organic with conventional farming.

Results are also highly dependent on input application and on organic fertilization in particular. Any change in organic fertilization would therefore alter results substantially. In the definition of the cropping plan for organic wheat production used in this study, solid cattle manure has been considered as the sole organic fertilizer. However Abras (2014) showed that the organic fertilizer type, and its related N, P and K contents, influences wheat yields.

Furthermore, no information on nutrient and trace metal contents of organic fertilizers was available and conventional data were used. According to Cooper *et al*. (2011), it seems, however, that, in the case of wheat production among others, fertilization practices in organic production would decrease trace metal export by grains by 42% for Cd, 11% for Cu and 18% for Zn, but on the contrary increase Ni export by 23%. Trace metal contents of animal diets and manure are consequently influenced by agricultural practices (organic or conventional). Field emissions from organic fertilizer application may therefore have been overestimated. Laboratory analyses of nutrient and trace metal contents of organic fertilizers would be useful to refine those emission calculations.

Finally considering whole rotations and not only the annual wheat crop would enable to account for nutrient leftovers by preceding and for subsequent crops. It is indeed likely that subsequent crops benefit from cattle manure applied on organic wheat (van Zeijts *et al*. 1999). Besides, wheat crops do not generally come first in the rotation scheme and as such do not receive P and K nutrition. However they benefit from leftovers from preceding crops and these nutrients influence their yields. Allocating the organic fertilization at the rotation level would enable to consider the impacts attributable to the considered crop only and may reduce estimated impacts from the fertilization of organic wheat.

For lack of specific data, stock changes in soil organic carbon (SOC) were not accounted for. However, in future works, accounting for SOC stock changes using IPCC (2003) Tier 3 or other methods already tested in agricultural LCAs in Western Europe (Godard *et al*., 2012, Godard *et al*., 2013, Saffih-Hdadi and Mary, 2008) would be an asset, especially for assessing SOC changes induced by management practices such as reduced tillage or no-till (Snyder *et al*., 2009) used in conventional or organic farming.

5. Conclusion

Using the LCA methodology, this study aimed at comparing the environmental impacts of organic and conventional production of wheat.

Results are very sensitive to the choice of the functional unit. When compared on the basis of the mass (kg), organically cropped wheat seems to induce more environmental impacts than conventionally cropped wheat in terms of acidification, eutrophication, land occupation and photo-oxidants formation. Overall the most influential parameter seems to be the yield. With yields among the highest in the world, the well mastered production of conventional wheat in Wallonia shows smaller impacts than lower yielding organic wheat. However, on the basis of the land area (ha), organic wheat is more environmentally-friendly than conventional wheat in terms of global warming, photo-oxidants formation and energy demand.

Emissions from fertilizer application on field predominate in the results. Using more specific emission models would improve the quality of the results. Specific data for nutrient and trace metal contents would also enable to enhance results precision.

Accounting for the whole rotation would also help to allocate more accurately fertilizers applied for the whole rotation and benefiting to successive crops. Considering organic carbon storage from managed soils would also help refine results.

Beside environmental criteria, taking account of social and economic impacts, such as working conditions and added value distribution all along the processing chain, would allow to encompass other aspects of the sustainability of organic and conventional wheat production in Wallonia.

Acknowledgements

The authors wish to thank the Walloon Agricultural Research Centre (CRA-W) who finances this research. They are grateful to the numerous agricultural advisors and experts who patiently gave their time during data collection.

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Agriculture and Agricultural Science Procedia 7 (2015) 280 – 286

Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Pesticide spray characterisation using high speed imaging techniques

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Abstract

Spray droplet characteristics are important features of an agricultural spray. The objective of this study is to measure the droplet size for different types of hydraulic spray nozzles using a developed backlighted image acquisition system and image processing technique. An in-focus droplet criterion was established to decide whether a droplet is in focus and can be measured in an accurate way. Tests included five different nozzles (Albuz ATR orange and red, TeeJet XR 110 01, XR 110 04 and Al 110 04).

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: Spray characterization; droplet size; droplet generator; high speed imaging

1. Introduction

In recent years, advances in plant protection have contributed considerably to increasing crop yields in a sustainable way. Most of the pesticides are applied using agricultural sprayers equipped with hydraulic nozzles. These nozzles atomize the liquid into droplets with a wide droplet size range and determine the spray pattern.

In the past, various measuring techniques (Rhodes et al., 2008) have been employed in the research on spray and atomization to investigate spray characteristics including droplet sizes and velocities. Few optical measurement techniques are able to perform simultaneously a non-intrusive measurement of both droplet size and velocity: Phase Doppler Particle Analyzers (PDPA) (Nuyttens, 2007; Nuyttens et al., 2009), laser diffraction analyzers, e.g.,

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2210-7843
Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.048

Malvern Analyzer (Stainier et al., 2006) and optical array probes (Teske et al., 2002). However, the limitations of the non-imaging techniques and the recent improvements in digital image processing, sensitivity of imaging systems and cost reductions have increased the interest in high speed imaging techniques for agricultural applications (Hijazi et al., 2012) in general and pesticide applications (Lecuona et al., 2000) in particular.

Imaging analyzers are spatial sampling techniques consisting of a light source, a camera and a computer with image acquisition and processing software. The small droplet size and high velocity of the ejected spray droplets make it a challenge to use imaging techniques for spray characterization.

This paper presents a technique based on image processing and an established in-focus droplet criterion for measuring the droplet size characteristics of agricultural hydraulic spray nozzles using an image acquisition system developed by VulgarakisMinov et al. (2015).

2. Materials and Methods

2.1. Image acquisition sytem

The image acquisition system for the development of the in-focus droplet criterion is shown in Figure 1 and has been described in detail by VulgarakisMinov et al. (2015a). The system consisted of a powerful xenon light (WOLF 5132, Knittlingen, Germany, 300 W) used as a background illumination against the droplet generator (Université de Liège, Gembloux, Agro-Bio-Tech, Belgium) combined with a N3 HS (high speed) camera (IDT, Lommel, Belgium) with a 6 µs exposure time, a K2/SC Long-Distance Microscope System Lens (Infinity, USA) and a frame capture device Motion studio (IDT, Lommel, Belgium).

The piezoelectric droplet generator was positioned at 320 mm from the xenon illumination and at a distance ranging from 420 and 430 mm from the lens. The camera, lens and illumination were aligned horizontally. A precision linear micro translation stage (Edmund Optics, 0-25 mm) with a straight line accuracy of 10 µm moveable in the Z direction was attached to the lens. The droplet generator was implemented in continuous mode (using glass nozzles with orifice sizes of 261, 123, 67, 50, and 40 µm (VulgarakisMinov et al., 2015b). These nozzle orifice sizes were chosen in order to produce a range of droplet sizes from around 100 µm up to 500 µm which is typical for most agricultural hydraulic spray nozzles.

The set-up resulted in a pixel size of 8.23 µm which made it possible to measure small droplets accurately. The images were taken in full resolution (1280 x 1024 pixels) with a field of view (FOV) of 10.5 mm x 8.4 mm at 1000 fps.

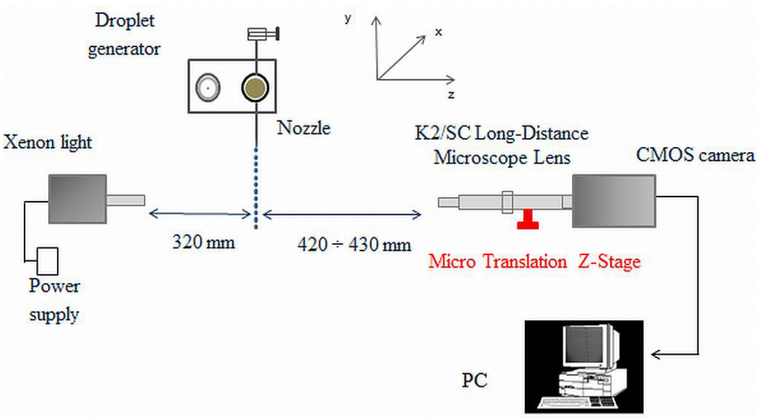

Fig. 1.Image acquisition system for establishing the in-focus droplet criterion.

2.2. Image analysis for setting up the in-focus droplet criterion

For establishing the in-focus droplet criterion, images were taken at different distances from the focal plane using all glass nozzles. This was performed by moving the translation stage (lens) towards and away from the focal plane in the range between 420 mm and 430 mm in steps of 50 µm (Figure 1).

The image analysis for setting up the in-focus criterion consisted of 3 steps: image pre-processing, image segmentation and droplet sizing, calculation of (critical) in-focus parameter and in-focus droplet criterion (Figure 2).

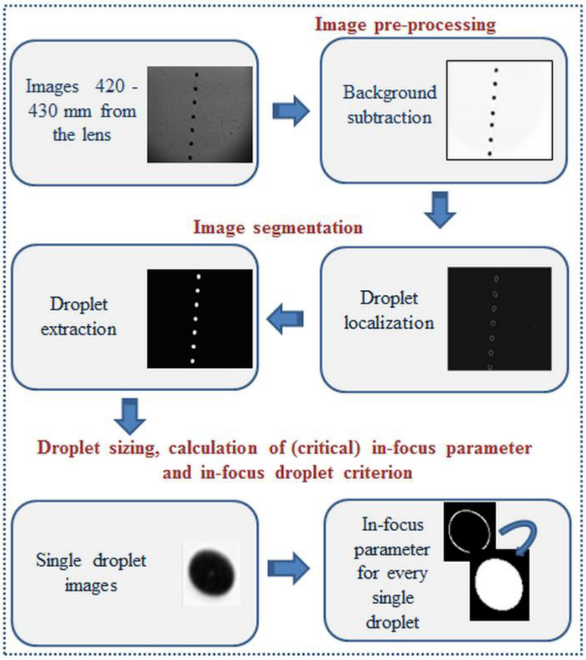

Fig. 2.Flow chart of the image analysis algorithm for establishing the in-focus droplet criterion.

Image pre-processing aims at resolving problems due to lighting patterns or dirt on the lens and was performed by background subraction from every droplet image. In addition, to increase the contrast and highlight the pixel intensity across the droplet boundaries, image normalization was done. Furthermore, image segmentation was introduced by computing the intensity gradient using a Sobel filter (Gonzalez et al., 2004). Besides, the images were binarized and the highlighted droplet contours were filled. Because the droplets were not perfectly spherical, they were considered as elliptical shapes for the diameter. Their long and short axes were measured to calculate the equivalent droplet diameter from the area (Dong et al., 2013). Finally, single droplet images of each detected droplet were derived from every droplet image. The extracted droplets did not have the same gray level intensities and edge gradients because of their different positions relative to the focal plane. Therefore, the concept of the in-focus parameter was introduced to select the in-focus droplets based on the gray level gradient, droplet diameter and gray level intensities of the background and droplet (Lecuona et al., 2000):

$$In-focusparameter = \frac{grad_{edge}}{I_{back} - I_{droplet}} * d \tag{1}$$

Where I_{back} (-) and $I_{droplet}$ (-) are image background and droplet gray level values, respectively, d is the droplet diameter (µm) and $grad_{edge}$ (-) is the gray level gradient at the droplet edge. This parameter was calculated for every detected droplet.

To separate the droplets that are in-focus from the ones out of focus, a critical in-focus parameter (Inf_c) was calculated in several steps for each droplet size. Firstly, the minimal droplet diameter was estimated from the polynomial trend line of second order using all measured droplet diameters (Fig. 3). Then, an acceptable one pixel error value to this minimal droplet diameter was set meaning that we accept a deviation of up to 1 pixel between measured and actual droplet diameter. Next, another second order polynomial curve was fit only through these droplets considered in focus with an acceptable measured droplet diameter. From this equation ($y = 0.3953\ x^2 - 336.95\ x + 71835$) and the droplet diameter of 28.6 pixels the corresponding distances to the lens were calculated (424.4 mm and 428.1 mm). Combining these distances to the lens with the second order polynomial curve through the in-focus parameters, resulted into the critical in-focus parameter value (around 6).

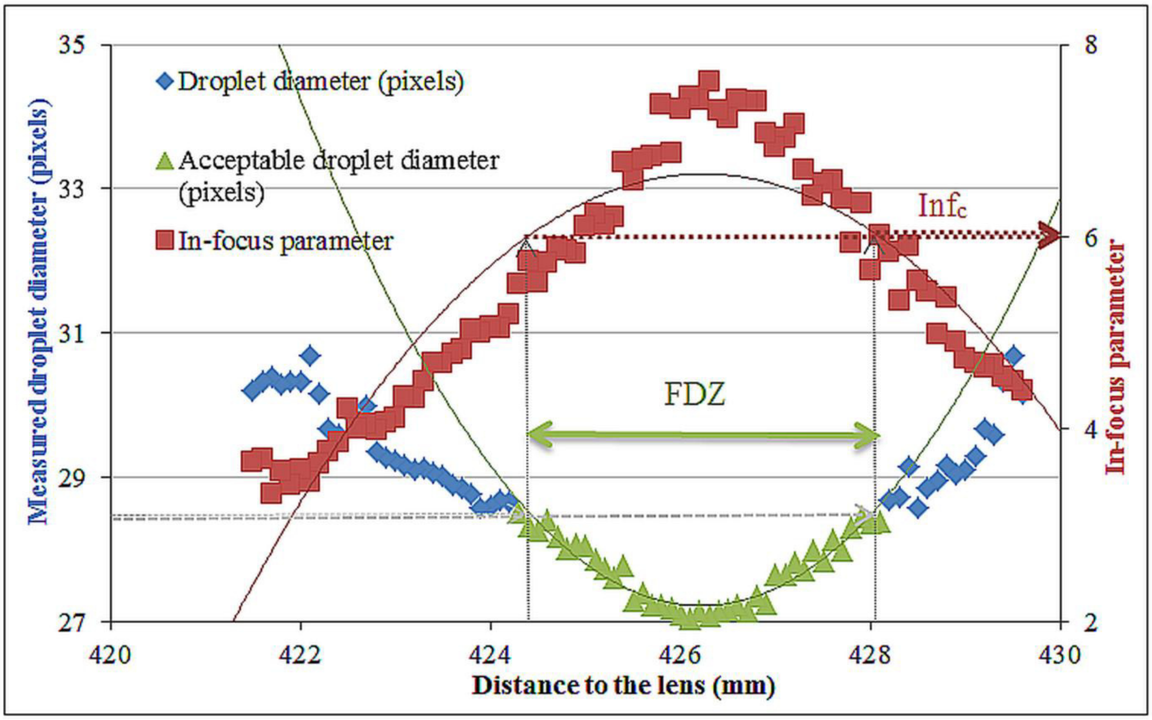

Fig. 3.Critical in-focus parameter and FDZ for images taken of the 222.9 µm droplet diameter.

All droplets with an in-focus parameter above Inf_c were considered in-focus. Besides, based on the distances from the lens at which the droplets were considered in focus, a focused droplet zone (FDZ) was defined. This is the zone around the focal plane in which droplets of a certain size are considered in-focus. For the 222.9 µm droplet size, the FDZ was 3.7 mm.

In order to evaluate the relations between $Inf_{c,}$ FDZ and droplet size, the procedure above was followed for all droplet sizes. This resulted into a first order relation between $Inf_c$and droplet diameter (d) and this equation is used for selecting only the focused droplets in a real spray application:

$$Inf_c = 0.017 * d + 2.04 \qquad (2)$$

3. Results and Discussion

3.1. Spray droplet characterization using the in-focus droplet criterion

A similar set-up as described in Fig. 1 was used for the spray droplet characterization. The nozzle was always set between the lens and light source. In this study, five different hydraulic spray nozzles were selected: two hollow cone (ATR orange, ATR red), two standard flat fan (XR 110 01, XR 110 04) and one air inclusion flat fan (AI 110 04). Images were acquired at 500 mm below the nozzle at three different positions: in the centre, at 200 mm and at the edge of the spray.

Furthermore, the spray image analysis (Fig. 4) consisted of different steps: image pre-processing, image segmentation and droplet sizing and selection based on the in-focus criterion (Eq. 2). Droplets having an in-focus parameter bigger than the corresponding Inf_cwere considered in focus and included in the spray distribution results. All other droplets were rejected and not further used in the analysis.

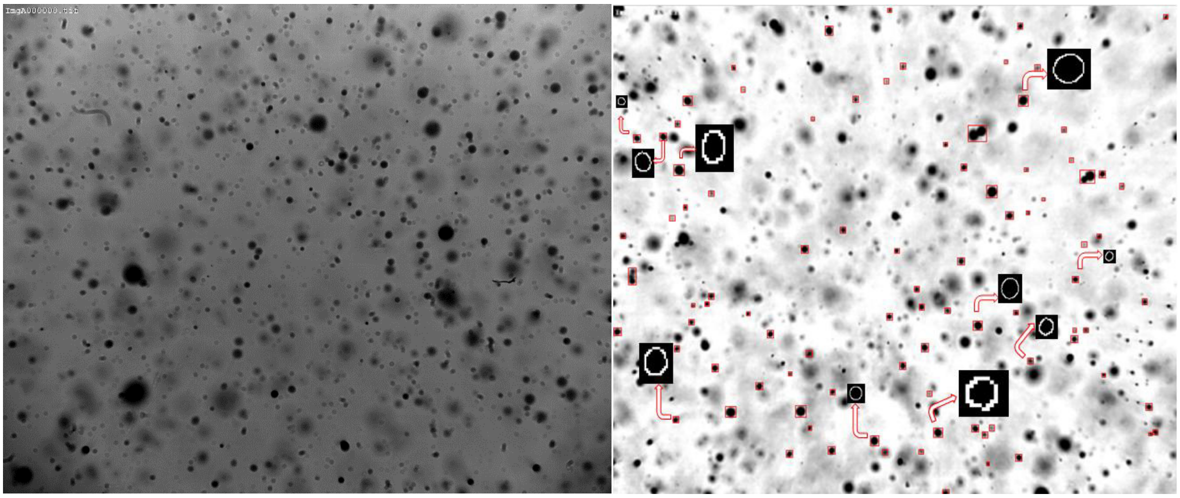

Fig. 4.Example of spray droplet image with XR 110 04 nozzle at 400 kPa in the centre(left) before image analysis and (right) after image segmentation.

3.2. Spray droplet size distribution

Fig. 5 presents the cumulative droplet size distributions below the nozzles for the five nozzle-pressure combinations. In the centre of the spray, finest droplet size spectra were found for the hollow cone nozzles (ATR orange and red) followed by the standard flat fan nozzles (XR 110 01 and 110 04) while the coarsest droplets were found for the air inclusion flat fan nozzle (AI 110 04) which confirms previous results from, among others, Nuyttenset al. (2007, 2009).The difference between the ATR orange at 600 kPa and the ATR Red at 800 kPa was limited which confirms the PDPA results published by Dekeyseret al. (2013).Similarly, no differences were found in measured droplet sizes between the XR 110 01 and the XR 110 04 nozzle at this position.

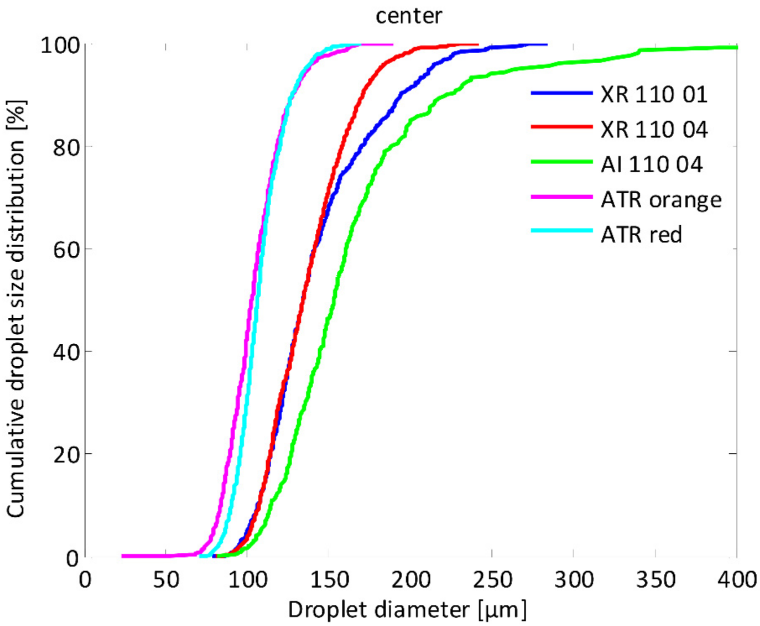

Fig. 5.Cumulative droplet size distributions below the nozzles for the five nozzle – pressure combinations.

4. Conclusions

This paper presents a technique based on image processing for measuring the droplet size of agricultural hydraulic spray nozzles using developed image acquisition system. Differently sized droplets generated with a droplet generator and glass nozzles in continuous mode at different distances from the focal plane and lens using a micro translation stage were measured. From this, a critical in-focus parameter (Inf_c) was established for every droplet size and an in-focus droplet criterion was deduced to decide whether a droplet is in focus or not depending on its diameter and in-focus diameter. Afterwards, the in-focus droplet criterion was applied to spray images of different hydraulic nozzles and the droplet size characteristics were calculated. The droplet size results from the imaging technique have shown that is possible to measure the spray droplet characteristics in a non-intrusive way using image acquisition set-up and image processing.

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Agriculture and Agricultural Science Procedia 7 (2015) 287 – 291

Agriculture and Agricultural Science
Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Ecological and social sustainability of agricultural production in the Roztocze Region

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Abstract

The level of sustainability of agricultural production in the surveyed holdings was assessed both in ecological and in social terms. The balance of reproduction and degradation of organic matter was prepared using the calculation method, with coefficients provided by the Institute of Soil Science and Plant Cultivation (IUNG). The level of sustainability of organic matter in the soil was the most favourable in holdings that were the biggest territorially and economically and with the highest amount of subsidy and business income. They also had the greatest net commodity production. This group of holdings (area of 70 ha UAA) showed the highest level of decomposition of organic matter in crop production, but the overall balance was positive due to large-scale animal production. In contrast, small farms with lower production do not produce a sufficient mass of organic matter. Environmental sustainability was found in holdings using more than 30 ha of arable land that received subsidies in the amount over 100 thousand Polish zlotys and showed a balance of organic matter above 0.26 tons per hectare of arable land. Social sustainability was shown in households using more than 30 ha of arable land, where the level of mechanization reduced the workload (less than 2,000 working hours per employee per year and less than 100 man-hours per ha UAA).

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

*Keywords:*ecological sustainability; social sustainability; renewability; balance of organic matter.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.049

1. Introduction

Agri-environmental undertakings are a priority of the Common Agricultural Policy system and are implemented by all EU member states (Program... 2014). Instruments that can help farmers to achieve sustainable farming are agri-environmental-climatic measures including, among others, the package "Sustainable Agriculture". The aim of the package is to promote the introduction of crop rotation and balancing the use of fertilisers, which helps to reduce the pollution of soil and water with compounds from agricultural sources. Rational crop rotation reduces the growth of fungal diseases of cereals and weeds, maintains an adequate organic matter content in the soil. If a high proportion of cereal crops is a long-term phenomenon, it leads to the so-called soil fatigue, manifested by a decrease in harvest. In this case, more funds are spent on crop protection and fertilizers. Measuring dosages and limiting yield-increasing measures on farmland makes it possible to minimize the loss of nutrients and to reduce pollutants from agricultural land. Another activity is "Organic Farming" consisting of several packages that are included in the Rural Development Programme (Program... 2014). It represents a specific area of agricultural production, performed without the use of fertilizers or pesticides that may adversely affect the environment or result in the presence of residues in agricultural products. By means of appropriately selected crop rotation and rational choice of livestock, holdings can balance the global level of organic matter on their farmland (Golka and Wojcicki, 2006, Wojcicki, 2009). It is particularly very difficult to determine the effects of environmental sustainability (Wibberley, 1995, Morris and Winter, 1999, Leiva and Morris, 2001). Obtaining reliable information in this field requires years of research, since both degradation and renewal of organic matter in soil takes 5-30 years (Stelow, 2003). The negative balance of organic matter, persisting for several or dozens of years, can lead to soil degradation and loss of soil fertility and productivity. Decomposition of organic matter is usually associated with the release of large amounts of minerals, especially nitrogen, which can lead to the contamination of groundwater and surface water.

2. Materials and methods

The level of sustainability of agricultural production in the surveyed households was assessed in ecological and social terms (Kaufmann and Cleveland, 1995, Czyż, 2000, Niewęgłowska, 2005, Pawlak, 2005, Sawa et al., 2006, Van Passel et al., 2007). The following metrics were used as the basis for the evaluation: direct surplus value ($PLN\cdot PFE^{-1}$; $PLN\cdot ha^{-1}$UAA), operating costs ($PLN\cdot ha^{-1}$UAA; $PLN\cdot mh^{-1}$; $PLN\cdot PFE^{-1}$), commodity production in cereal units (CU ha^{-1}UAA), gross value added ($PLN\cdot ha^{-1}$ UAA; $PLN\cdot PFE^{-1}$), the cost of labour (man-hours ha^{-1} UAA), workload ($mh\cdot PFE^{-1}$), and the balance of organic matter renewability ($t\cdot ha^{-1}$UAA). Reproduction of organic matter takes place in perennial field crops (legumes and their mixtures with grasses), as well as permanent grassland (Code... 2002).

In 2004-2009, 70 farms were studied in the Roztocze region, benefiting from EU subsidies for technical modernization. To determine the ecological and social sustainability of agricultural production, all the holdings under evaluation were divided according to the criterion of the aid, surface of UAA, economic size (ESU) and income of the business. Maintenance costs of means of mechanisation include the purchase of fuel and lubricants, electricity charges, purchases of spare parts, materials for repairs, charges for repair services etc. The presented group of costs enables the assessment of the current engagement of technology in in agricultural production processes. The operating costs of technical measures were calculated using a method developed by IBMER in Warsaw (Goć et al., 1994, Muzalewski, 2009):

$$K_e = K_u + K_{\text{uż}} \qquad (1)$$

where:

K_e - operating costs of technical measures PLN · year $^{-1,}$

K_u – fixed cost (depreciation and amortization, storage, insurance, taxes).

$K_{uż}$ - running costs (repair, use of energy, fuels and lubricants, auxiliary materials).

The balance of reproduction and degradation of organic matter was prepared using the calculation method, using coefficients provided by the Institute of Soil Science and Plant Cultivation (IUNG). On this basis, it was estimated how much organic matter accumulated or decomposed in the soil on the area of 1 ha under cultivation of a given crop or how much of it accumulated as a result of the use of 1 tonne per 1 ha of farmland manure or straw. It was assumed that in a year 1 LSU produces 10 tons of manure, and the straw left to be ploughed constitutes 80% of the yield of crops per hectare of arable land.

3. Results and Discussion

Degradation processes are dominant under bulb and root plants, maize and, to a lesser extent, cereal crops. After changing the crop structure, there can quickly take place the decomposition and loss of organic matter content in the soil if organic fertilization is not used (manure, liquid manure, straw, etc.). In the surveyed households, obtaining subsidies was associated with the expected change in the structure of crops or livestock. It was found that two farms with the highest number of animals (303 and 655 LSU) had signed a contract for the sale of manure, which was included in the overall balance of organic matter. In each of the examined groups of households, the direct surplus (Table 1) was directly proportional to their size and reached by far the highest value in the largest ones. By contrast, gross value added, only in farms with an area of 50-70 ha of arable land, did not preserve this relationship (1.91 10^3 PLN·ha^{-1}UAA) and was lower than in those obtained on 30-50 UAA (2.24 10^3 PLN·ha^{-1}UAA). Holdings of an area of 50-70 hectares of UAA also achieved lower operating costs (1.31 thousand. PLN·ha^{-1}UAA) and lower net commodity production (47.3 JZ ha^{-1}UAA) had, accordingly, a direct impact on their weaker economic results.

Table 1. Balance of production process in the studied farms.

Household groups per:	Direct Surplus		Operating Costs			Nett Commodity Production	Gross Value Added		Labour Costs	Workload	Balance of sustainability of organic matter, tonne·ha^{-1} UAA	
	10^3 PLN pfe^{-1}	10^3 PLN ·ha^{-1} AL	10^3 PLN ·ha^{-1} AL	PLN ·mh^{-1}	10^3 PLN ·pfe^{-1}	CU·ha^{-1} AL	10^3 PLN · ha^{-1} AL	10^3 PLN · pfe^{-1}	mh·ha^{-1} AL	mh per year· pfe^{-1}	Total	Including plant production
Amount of subsidy (thous. PLN):												
up to 50	26.76	1.89	2.82	18	34.57	51.7	1.18	17.89	274	1967	-0.04	-0,51
50–100	35.46	1.96	2.72	21	39.93	53.6	1.30	25.19	255	1949	-0.13	-0,54
100–150	55.20	2.12	1.73	24	35.10	64.9	1.54	42.36	192	1833	0.08	-0,41
over 150	143.81	3.15	1.67	71	70.10	89.0	2.66	120.02	80	1524	1.64	-0,62
Area (ha AL):												
up to 10	11.15	1.51	3.42	12	23.63	41.0	0.63	5.09	477	2000	-0.35	-0,53
10–30	33.05	2.09	2.59	20	39.46	57.6	1.46	23.30	207	1967	0.02	-0,50
30–50	93.62	2.74	1.50	42	52.31	84.2	2.24	76.53	95	1611	0.26	-0,60
50–70	98.17	2.38	1.31	64	61.49	47.3	1.91	76.32	77	1444	0.64	-0,57
over 70	187.62	3.16	1.22	83	76.23	96.0	2.69	157.45	68	1444	2.12	-0,63
Economic size (ESU):up to 8	25.81	1.90	2.57	16	30.88	46.5	1.18	17.39	271	1965	-0.25	-0,51
8–16	33.36	1.90	2.98	22	41.03	54.1	1.23	23.49	255	1956	-0.03	-0,55
16–40	97.45	2.54	1.64	45	57.44	67.1	2.02	77.15	121	1745	0.92	-0,54
over 40	177.67	3.95	1.27	86	60.92	148.4	3.47	155.41	110	1200	1.96	-0,48
Business income (thous.PLN):												
up to 10	10.15	1.06	0.88	4	8.76	35.7	0.31	3.18	370	2000	-0.27	-0,52
10–20	28.11	1.90	1.76	13	26.22	57.7	1.23	17.58	226	2000	0.30	-0,52
20–50	47.78	2.58	2.21	22	41.77	55.8	1.98	36.51	157	1944	-0.24	-0,52
over 50	130.98	3.28	3.23	139	129.51	92.2	2.78	109.60	102	1540	1.06	-0,55
Mean for the whole community	57.47	2.20	2.40	31	43.74	61.8	1.57	44.52	216	1852	0.28	-0.53

pfe – persons in full employment, mh – man-hours, CU – cereal units

A factor that ensures the preservation of soil fertility is the implementation of a system of agricultural production that allows for systematic replenishment of organic matter. In the surveyed households, an assessment of the content of organic matter in the soil was performed (Fotyma and Mercik, 1992, Kuś and Krasowicz, 2001). It was found (Table 1) that the level of sustainability of organic matter in the soil was the most favourable in the biggest territorially and economically holdings, and with the highest amount of subsidy and income of the business. They had farm animals and their waste was used as an organic fertilizer. Their net commodity production was also the greatest (from 55.8 to 148.4 CU ha^{-1}UAA). It did not apply to farms of 50-70 ha of arable land, which may be caused by the lack of animal production. At the same time, the highest level of degradation of organic matter in crop production was found in households with the surface area of 70 ha UAA, but the overall balance was positive due to the large-scale animal production. In contrast, small farms with lower production did not produce a sufficient mass of organic matter. The results show that large farms are becoming more ecological and environmentally friendly.

4. Conclusions

The study confirms that in the recent years there has been a structural change in the shape of the organization of holdings, which is expressed in an increase in the intensity and level of sustainability in larger farms. This phenomenon, observed since Polish accession to the EU, is confirmed by the results of research in the FADN program (FADN, 2010). The assessment of relationships between obtained funds and technical modernization of the surveyed households, performed in the context of sustainable development processes, leads to the conclusion that:

Environmental sustainability has been found in holdings using more than 30 ha of arable land that received subsidies in the amount over 100 thousand Polish zlotys and showed a balance of organic matter above 0.26 tons per hectare of arable land.

Social sustainability has been found in households using more than 30 ha of arable land, where the level of mechanization reduced the workload (less than 2,000 working hours per employee per year and less than 100 man-hours per ha UAA).

The analysis is merely an attempt to determine the sustainability of the agricultural production process in the surveyed holdings. With a negative result of the balance organic matter, their administration should be changed. This may include increasing the share of perennial crops in the rotation, increasing the amount of natural fertilizers and the volume of catch crops and the introduction of protective cultivation of soil.

The results show that large farms are becoming more ecological and environmentally friendly, mainly due to large-scale livestock production, which in small-area farms is gradually being liquidated.

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Agriculture and Agricultural Science Procedia

Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

The effects of energy contributions into subsidiary processes on energetic efficiency of biomass plantation supplying biofuel production system

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Abstract

A number of technologies of biofuel production from various biomass crops are already in use, and many studies on new ones are carried out. Biomass production, like any other production processes, involves a number of necessary processes that facilitate subsequent production steps. Those subsidiary processes (e.g. tillage or logistic operations) are connected with consumption of energy. It is therefore important to assure that the sum of energy inputs into those technological steps does not exceed the energy output from the system. Obviously, large energy gain is desired. The paper is devoted to the estimation of energy inputs made into the subsidiary processes occurring in the agricultural subsystems in which various topological structures of plantations as well as for various technologies of tillage, and different requirements for transportation are allowed. Mathematical model describing above mentioned dependencies is derived, and appropriate algorithm elaborated for numerical computations, that have been performed for rapeseed plantations. The results demonstrate evident effects of the choices of technology, and organization of work onto efficiency of plantation as measured by EROEI - type indicator.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: biofuel; energy balance; modelling; rapeseed; biodiesel.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.050

1. Introduction

Emission of carbon dioxide, due to use of fossil fuels, is considered as one of the most important factors affecting global warming. Exhaust of the fossil resources, especially of crude oil, that might lead to petroleum shortages in relatively short time scale, and that of coal – leading to problems in more distant future - appears as the other problem of today's global economy. Mathews (2009) indicated that biofuels derived from biomass are considered the main remedy that can be offered. This situation motivates the search for various biomass resources and for the most effective technologies of cultivation as well as conversion of biomass to energy. In recent years a number of papers have been published concerning cultivation of several plants e.g. Abnisa at al. (2011) or Painuly at al. (1995) as well as various aspects of cultivation and processing cf. Juliszewski and Zajac (2007), Jasinska and Kotecki ((1999), Igilinski at al. (2009). Expectation that biomass derived fuels may substitute fossil fuels imposes natural expectation that biomass as energetic resource should provide a real gain of energy. It is well known that industrial processing of any fuel requires some inputs of energy in order to facilitate conversion processes. In terms of biomass it is equally related to both: agricultural as well as industrial processes occurring in production of biofuel. Already established characteristic called EROI or EROEI – „energy return on energy invested" cf. Pickard (2014) is defined as follows:

$$\varepsilon = \frac{\sum_{p=1}^{P} \left(E_{out}\right)_p}{E_{cr} + \sum_{p=1}^{P} \left(E_{in}\right)_p + E_{rem}} \tag{1}$$

where E_{out} – is total usable energy delivered by energy gathering system during the p-th year of its existence, E_{in} – represents total energy expended during that year, E_{cr} – is energy needed for creation of that system, and E_{rem} – is energy needed for remediation of that system after the end of its life at P-th year.

This quantity can be used as a measure of efficiency of production processes.

It should be pointed out that this is different than energy conversion efficiency that is expressed as:

$$\eta = \frac{E_{out}}{E_{in}} = \frac{E_{out}}{E_{out} + E_w} \tag{2}$$

where E_{in} and E_{out} – represent input and output energy to and from converter, while E_w – corresponds to energy wasted (dissipated) by that converter.

Despite similar form of both equations their meaning is different. The energy E_{in} introduced to the production system is not directly converted into output. This is only energy that is needed to maintain production process. E_{in} in some cases might be very small, while in the other cases - very large as compared to E_{out}, consequently the range of variation of this measure might extend in the limits $-\infty \leq \varepsilon \leq \infty$. The other quantity relates energies being directly converted one into other, and it can be easily proved that changes of this characteristic occur only in the limits: $0 \leq \eta \leq 1$. Recent literature offers a number of papers dedicated to the discussion of perspectives of biofuel production in several countries e.g. Raslavicius and Bazaras (2010), Fontaras et al. (2012), Painuly et al. (1995), Wasiak et al. (2008). Excellent review discussing various approaches to production as well as use of biofuels is given by Russo et al. (2012). Analysis performed by Talens et al. (2007) indicated low exergy loss in the process of biodiesel production, and also possibilities of further decrease due to possible improvements of technology. Results presented by Liao et al. (2011) for the case of bioethanol indicate, however, that production of this fuel not always fulfills the requirements of sustainability i.e. that bioethanol production is not sufficiently efficient. The mentioned earlier paper Talens et al. (2007) also introduces a notion of the scale of the techno-system showing different processes determining efficiency at various scale levels. The highest level in this approach is of global size, while the next are more and more local. Several papers are also concerned with empirical studies on energy efficiency of agriculture in general e.g. Schneider and Smith (2009) or Singh et al. (2008) or Alluvione et al. (2011), as well as dedicated especially to „energetic" plantations like Uril (1998), Karkaciera et al. (2006), Muller (2009), Meehan et al. (2013), Kim and Dale (2005) or Smith, Thelen and MacDonald (2013). Those works provide important sets of data that enable more general analysis of the factors deciding on the energetic efficiency of biofuel production systems. Slightly different approach to the scale of a techno-system is given by Prasad, Singh and Joshi (2007) or Giampietro et al. (1997) discussing feasibility analysis with respect to the size of the production system. The present paper is aimed to presents results concerning construction of the model that describes effects of subsidiary processes, operating at individual steps of biofuel production system, on energetic efficiency of that system, and also to present results of computations giving estimation of the main effects as related to the real characteristics of production equipment. The paper directly concerns agricultural part of the production subsystem, and only indirectly takes into account influences of the industrial subsystem.

2. Biofuel production system

The structure of biofuel production system assumed in this paper is built of two subsystems connected by flows of material and energy, as well as interacting with the surrounding. It can be represented by a scheme shown in Fig. 1.The subsystems involved are agricultural, and industrial ones. Arrows [1], [2], [3], and [4] represent energy flows from outside of the system – those can be solar, as well as fossil fuels derived energy. Arrow [5] shows the flux of energy derived from biofuel produced in the system. The arrow [6], in turn represents main flux of biomaterial produced in agricultural subsystem, and transported to the industrial one. Material fluxes [7], and [8] are the fluxes of byproducts and wastes that are rejected outside of the system, and not converted to energy. The flux [9] is the material returned to the agricultural fields to be used there.

Several processes occur in the system. Those are:

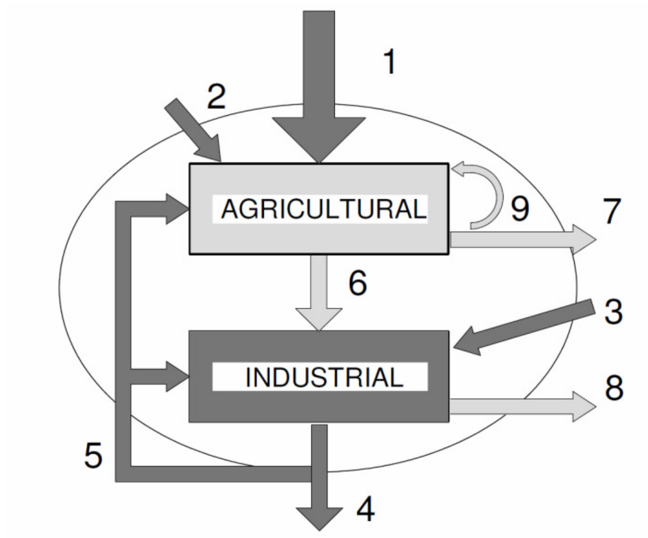

Fig. 1. Assumed structure of biofuel production system.

in agricultural subsystem

- tillage processes
- fertilizing
- crops collection
- transport of machinery
- transport of various goods
- separation of parts of crops
- storage of crops
- transport of crops

in industrial subsystem

- drying
- grinding
- chemical reactions
- cleaning
- storage of biofuel
- transportation of biofuel

Each of those processes requires input of some amount of energy to enable its functioning. The present paper is devoted to the analysis of energy inputs occurring in agricultural subsystem only. The effectiveness, however, is related to the energy output at the end of the whole system. The interaction between both subsystems is considered only as an effect of production size (the scale), that implicitly, depending upon demand for specific biomass being the raw resource for industrial part, determines the size of plantation area, because the yield of the field is limited. The secondary effect of an increase of plantation size might be an increase of transportation distances between parts of the plantation. The distance between plantation and industrial facilities plays also some role.

3. The model

As derived by Wasiak and Orynycz (2014) the energetic effectiveness, ε, related to one year of production of agricultural subsystem, can be expressed as follows:

$$\varepsilon = \frac{E_{bio}}{E_{ex} + E_{tr} + E_{emb}} \tag{3}$$

where:

E_{bio} – is energy obtained from the field,
E_{ex} – is energy expended on tillage operations,
E_{tr} – is energy consumed for transportation outside of fields,
E_{emb} – is a fraction of embodied energy contained in production means, that is spend during tillage operations and transport executed during production year.

The contributing energies are further expressed as follows:

Energy obtained from the plantation equals to:

$$E_{bio} = A \times M_{crop}\left(c_f, c_w, c_{cp}, \ldots\right) \times \gamma \times \sum_{k=1}^{n} \alpha_k \times W_{bio,k} \tag{4}$$

where:

A – is plantation area,
M_{crop} (c_f, c_w, c_{cp},) – is crop yield dependent upon concentrations of following factors: c_f – fertilizer, c_w – water, c_{cp} – crop protection means, maintained during cultivation. This dependence should be estimated on the basis of empirical field studies,
γ – general mass fraction of biofuel in the crop,
α_k – mass fraction of k species of biofuel,
$W_{bio,k}$ – low caloric value of k-species of biofuel.

The other term is the energy consumed on the field during agro-technical operations:

$$E_{ex,agr} = W_{fuel} A \times \sum_{i=1}^{m} \left[\frac{\omega_i}{d_i} \right] + \sum_{i=1}^{m} \sum_{k=1}^{K} \gamma_k \times Em_{ik} \tag{5}$$

where:

ω_i – the fuel consumption per unit of the distance passed during the individual agro-technical process,
d_i – width of the land strip operated in the single course of i-th operation,
W_{fuel} – the low caloric value of the fuel used for operations (might be fossil fuel or biofuel),
m – the number of the agro-technical operations (in each one of the operations the width of the worked field, d_i, and the consumption of fuel, ω_i, can be different),
γ_k – is a fraction of embodied energy contained in one of the, k technical means employed at i-th operation (machines, fertilizers, etc.). It may be estimated e.g. as ratio of the time of particular operation to the total expected life time of particular equipment,
Em_k – is embodied energy contained in k-th technical mean.

The next term (eq. 6) concerns transportation of goods (including crops) outside of the field. This term is especially important for big plantations that have to be arranged in several fields separated sometimes by quite long distances. Contribution of transport is also significant when crops have to be transported through long distance to industrial facilities for processing. It is expressed as:

$$E_{tr} = \sum_{p=1}^{p} L_p \times \left\{ \beta_p \times W_{fuel,tr} + Emt_p \right\} \tag{6}$$

where:

L_p – is a distance driven outside of the field in
p- th route,
β_p – is fuel consumption during p route,
$W_{fuel,tr}$ – is low caloric value of the fuel used in transport,
Emt_p – is fraction of embodied energy of a given transportation mean corresponding to the unit of distance driven.

As seen from the above formulas, individual contributions to the energetic efficiency are dependent upon various factors. Especially, E_{bio}, and $E_{ex,agr}$ depend i.a. on plantation area, A, while E_{tr} does not. Also embodied energy terms Em_{ik}, and Em_{tr} do not depend explicitly on A. It means that efficiency, ε, depend upon the size of plantation in complicated manner affected by various relationships. Numerical computations were performed to get deeper insight into relations described in the model.

It should be also noted that from definition given by formula (1) or (3) a simple additivity rule can be derived for the case when energy production subsystems are connected in series. It can be shown that, for such a case, the reciprocal of total efficiency of the composed system is given as a sum of reciprocals of efficiencies of subsystems i.e.

$$\frac{1}{\varepsilon_{tot}} = \frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} \tag{7}$$

where: ε_{tot} – is the energetic efficiency of the total system
ε_1, and ε_2 - are efficiencies of individual subsystems

This equation will be used after the model of efficiency of industrial subsystem is developed, and need for estimation of total efficiency will appear.

4. Computations

The computer program is developed for numerical estimation of the effects. The plantation being considered is built of several fields separated by some distances, and separated by another distance from the main base. This situation is illustrated in Fig. 2. Dimensions of the fields, distances between them, and distance from the base (B) are variables, values of each are inputs to the computations. The specific yield of the unit area of plantation, as well as the yield of biofuel from the mass unit of biomass are also introduced as variables.

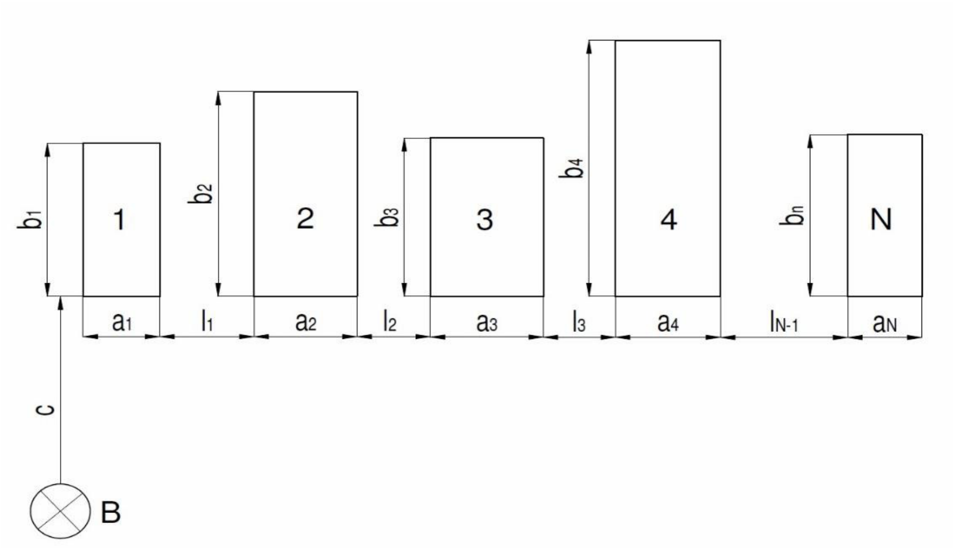

Fig. 2. Structure of plantation considered in computations.

All computations were made using program developed in spreadsheet EXCEL. The simulations presented in this paper are based on assumption of extreme values of agricultural machine's characteristics, and typical, average value of plantation yields. Besides of the above mentioned characteristics, an additional condition have been introduced, namely daily allowed working time, that forces the operators to return to the base – this obviously increases the distance driven outside the fields. This increase is higher when field's area increases.
Results presented in this paper have been computed for equal sizes of fields, however any arbitrary configuration of field's sizes can be considered.

5. Results

Energetic efficiency computed for the cases of different plantation areas, and very high biofuel yields are given in Table 1. Values presented are computed for inter-field distance equal to 200 m. The major effect on energetic efficiency results from distances driven on the field, and outside the field. The former is dependent upon size of the field and characteristics of machines used for particular operation.

It is seen that efficiency decreases with a number of operations. It is obviously due to the fact that the amount of energy consumed is assumed equal for each operation, while the amount of energy produced is independent of the number of operations. The efficiency, as could be expected, appears much higher when the machine with wider working strip is used.

Table 1. Values of energy efficiency computed for the system of separated fields as function of a number of operations (biofuel yield 1500 dm3/ha)

Operation width (m)	number of operations	A = 0,01 km^2			A = 0,25 km^2		
		c = 1	c = 5	c = 10	c = 1	c = 5	c = 10
4	1	1184	597	309	1672	1351	1089
4	2	592	299	299	836	676	545
4	3	395	199	199	558	451	363
4	4	296	150	150	418	338	273
4	5	237	120	120	335	271	218
0,5	1	224	189	159	216	184	155
0,5	2	112	95	80	108	92	78
0,5	3	75	63	53	72	62	52
0,5	4	56	48	40	54	46	39
0,5	5	45	38	32	44	37	31

Basing on presented data one can conclude that in spite of strong dependence of energetic efficiency upon factors determined by plantation size and characteristics of production means, obtainable energetic efficiency is in all cases higher that one. Consequently it means that, in general, energy is gained in agricultural processes. The values of energetic efficiency are strongly diverse and, as seen in Table 1, they change from several tenths to more than thousand. It clearly indicates that efficiency of the system is strongly dependent upon technology, and organization of the work.

It has also to be taken into account that further decrease of efficiency will take place in industrial subsystem of production, and therefore an effort should be made to assure as high as possible values of energetic efficiency of agricultural plantations. This task can be achieved by appropriate choice of technology.

Table 2 shows values of energetic efficiency obtained using empirical data, taken from various sources e.g. Perrier (2014), Lorencowicz (2012), on fuel consumption in operations on the field, and for various tillage styles. The values are computed with, and without consideration of contribution energy embodied in the production means. The values obtained in this computations show that real conditions in the fields correspond rather to the second part of simulated data presented in Table 1. This might be an evidence of potential perspectives for further improvement of real technology. The results of this computations also show that the effect of embodied energy is not very big in conditions of agricultural farming of energetic plants.

Table 2. Values of energetic efficiency obtained using empirical data on fuel consumption on the field, and various tillage styles.

1500	Without embodied energy			With embodied energy		
l/ha	traditional	simplified	direct sowing	traditional	simplified	direct sowing
I	26,7	36,9	40,1	21,24	27,26	28,9
II	12,4	14,3	14,7	11,12	12,57	12,91
III	7,75	8,43	8,58	7,21	7,8	7,93
IV	15	17,8	18,5	13,12	15,19	15,69
V	12,7	32		11,27	24,48	

Numbers in first column indicate variant of fore-crop used in particular case

6. Conclusions

Mathematical model developed in the present work allows quantitative analysis of the influence of various productive factors on energetic efficiency of agricultural subsystem dedicated to biofuel production. Results indicate that

1. Energetic efficiency of agricultural subsystem depends upon:
   a) the technical parameters of applied machines,
   b) the distance traveled on the field during agricultural operations,
   c) the number of operations (and consequently upon production technology),
   d) the distances travelled between fields (which depends on the degree of dispersion of the plantation and upon the sizes of individual fields,
   e) the distance between the plantation and the processing installation - transportation of the grain over the distance 350 km absorbs approximately 10% of energy contained in the produced biofuel.
2. Energetic efficiency depends on the scale of the industrial production subsystem, which extorts the suitable scale (size) of the plantation, and also affects the consumption of fuels (energy) during the agro-technical operations and transportation.
3. The following, more general conclusion may also be driven out conducted calculations:
   a) the model can be used to the analysis of various, different than the rapeseed, energetic plantations. Also different variants of energetic utilization of the crops, e.g. the grain of maize converted to bioethanol, as well as utilization of the stem for biogas generation,
   b) optimization of production can be one of the important uses of the model for the real plantations.

Acknowledgements

The research have been performed under financial support from Bialystok University of Technology. Statutory Research Project WZ/S/1/2015.

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Agriculture and Agricultural Science Procedia 7 (2015) 301 – 308

Agriculture and Agricultural Science
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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Selected physical properties, texture and sensory characteristics of extruded breakfast cereals based on wholegrain wheat flour

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Abstract

Directly expanded breakfast cereals were processed with a single screw extrusion-cooker TS-45 with L:D=16:1 at screw speed 120 rpm, shaped on the circular open die 2 mm in diameter. Wholegrain wheat flour in amount of 50, 60 and 70% of total mass was the basic raw material, additionally corn grit, rice flour, cocoa and sugar were used. The initial moisture content of raw materials was set to 17, 20 and 23%. Processing conditions, like process efficiency and energy consumption, as well as selected physical properties, like the expansion ratio, bulk density, water absorption and solubility indexes were tested. Texture profile with Ottawa cell for hardness, adhesiveness and chewiness, and sensory characteristics of breakfast cereals were evaluated. Higher wholegrain wheat flour content in the recipe and higher moisture of raw materials lowered energy consumption during extrusion-cooking of breakfast cereals. The expansion ratio, water absorption and solubility index values lowered with higher initial moisture content of raw materials. Increased moisture level before the extrusion-cooking increased bulk density and textural parameters, like hardness and chewiness of prepared for consumption breakfast cereals. Process management of extruded breakfast cereals according to various recipes and processing conditions allows creating desirable quality of final products.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: extrusion-cooking; breakfast cereals; wholegrain wheat; physical properties; texture, sensory.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.051

1. Introduction

Breakfast cereals play an important role in the diet and ensure the proper organism functioning e.g. nervous system and gastrointestinal tract (Frame 1994). Directly expanded breakfast cereals, next to müsli or conventional flakes, are the most popular type of breakfast products, especially in the Western countries. Wholegrain flour is an important source of dietary fiber in the diet, which is responsible for improving the function of gastrointestinal tract and affects the human cardiovascular system. Dietary fiber makes it easier to prevent obesity and give a satiety filling (Kaur et al. 2012). Consumption of wholegrain products improves the metabolism, reduces fat absorption by the human body and reduces the level of bad cholesterol in the blood (Ghattas et al. 2008; Marquart et al, 2006). Wholegrain foods consumption may effect on decreased risk of cardiovascular disease and certain cancers, favorable affects on blood lipids and glucose, improves insulin resistance, and higher intakes of dietary fiber and other nutrients (Jacobs et al. 1998; Franz and Sampson 2006; McKeown et al. 2002). Dietitians suggest to complement the diet of wholegrain products, which provide not only valuable digestive fiber, but also because of the presence in these products the large quantities of vitamins, particularly B group, vitamin E and the macro- and micronutrients, like selenium, zinc, copper, magnesium (Schneeman 1998; Slavin et al. 2001). Wholegrain foods contain also phytochemicals such as antioxidants, phenols, phytoestrogens and fermentable carbohydrates such as dietary fiber, resistant starch or oligosaccharides, which may be associated with cholesterol lowering, cardiovascular disease protection and cancer risk decreasing as well as bioactive nutrients that can play a role in protecting against chronic diseases (Adom et al. 2005; Baublis et al. 2000; Jones 2006; Hirawan et al, 2010; Likes et al. 2007). However, regardless of these benefits, the consumption of wholegrain products remains below the daily recommendations (O'Neil et al. 2010). That's the reason of developing of new kinds of products i.e. enriched breakfast cereals containing wholegrain flour, bran or germs (Franz and Sampson 2006; Zainuddin et al. 2014). Supplementation of extruded products with wholegrain flour instead of purified bran addition is a cost-efficient way of increasing dietary fiber content in these products. Extrusion-cooking of breakfast cereals is much easier and cheaper in processing compare to the conventional ones and many various components may be incorporated in the recipe (Brennan et al. 2008; Mościcki and Moster 2011; Mościcki and Wójtowicz 2011, Oniszczuk et al. 2014; Wójtowicz and Mościcki 2014).

The aim of the study was the evaluation of effect of wholegrain wheat flour level and initial moisture content on processing efficiency, energy consumption, physical properties, texture and sensory profile of extruded breakfast cereals.

2. Materials and Methods

2.1. Materials and extrusion-cooking

Breakfast cereals composition is presented in the Table 1. The main component was the wholegrain wheat flour (Lubella S.A, Lublin, Poland), additionally corn grit, rice flour, cocoa and sugar (from local market) were used. Raw materials were moistened up to 17, 20 and 23% of moisture content by proper amount of water added, mixed and rested for 1 h. Breakfast cereals were processed with modified single screw extruder TS-45 (ZMCh Metalchem, Gliwice, Polska) with L:D=16:1, compression ratio 3:1, with 2 opens forming die 2 mm in diameter each. Extrusion-cooking was carried out at the temperature ranged 130-145°C with constant 120 rpm screw speed. Process efficiency and energy consumption as *SME* calculations were evaluated during the extrusion-cooking (Mitrus et al. 2010). After processing extrudates were cooled down and stored at room temperature in closed plastic bags.

Table 1. Composition of extruded breakfast cereals

Recipe	Wholegrain wheat flour [%]	Corn grit [%]	Rice flour [%]	Cocoa [%]	Sugar [%]
I	50	20	20	5	5
II	60	15	15	5	5
III	70	10	10	5	5

2.2. Extrudates properties

The expansion ratio of directly expanded extrudates is an important factor of its quality and should be as great as possible, according to the consumers' preferences. The radial expansion index was evaluated in 10 replications as a ratio of extrudates' diameter to the diameter of the forming die (Wójtowicz and Mościcki 2014). Bulk density of the products was tested in five replications according to ASAE Standard (ASAE S269.3:1989) as mass of the sample volume ($kg \cdot m^{-3}$). Water absorption index (*WAI*) and water solubility index (*WSI*) were determined according to Mitrus et al. (2010). *WAI* was calculated as weight of gel obtained after centrifugation to amount of dry sample. *WSI* was calculated as percentage of residues from supernatant to dry sample mass. Tests were performed in triplicate. Universal testing machine Zwick BDO-FB0.5TH (Zwick GmbH & Co., Germany) was used for texture evaluation. Selected parameters of ready to eat breakfast cereals were analyzed using Ottawa cell with circular opens at the bottom (Bourne 2002). 10 g of extrudates after 5 minutes of preparation with 200 mL of water (20°C) and warm milk (60°C) were placed in the chamber and tested with a head speed 100 $mm \cdot min^{-1}$ under double-compression test cycle. The hardness, the adhesion and the chewiness were calculated with *testXpertII®v3.3* from data recorded during the tests as means of triple measurements. Sensory characteristics of breakfast cereals: shape, color, flavor, taste, consistency, and overall quality, were evaluated after 5 min of preparation with warm milk. A 15-member semi-trained panel judged products in a 5-point scale (1—for weak, 5—for very good). Overall quality of each sample was evaluated as mean of sensory characteristics (Wójtowicz et al. 2013). Products were considered as acceptable if their mean scores for overall quality were above 3.5.

3. Results and Discussion

Process efficiency registered during the extrusion-cooking of wholegrain wheat based breakfast cereals was the highest for recipe III with 70% of wholegrain flour and increased according to increase of initial moisture content of raw materials (Fig. 1a). This tendency was observed for each recipe irrespective on wholegrain wheat level. For the highest process efficiency, it was observed the lowest specific mechanical energy consumption and high correlation was evaluated for this trend (-0.939). Values of *SME* ranged from 0.15 $kWh \cdot kg^{-1}$ when processed recipe III with 23% of moisture content up to 0.23 $kWh \cdot kg^{-1}$ for recipe I and 17% of m.c. of raw materials (Fig. 2b). So, application of the high amount of wholegrain wheat flour made processing of breakfast cereals efficient with low energy consumption during single screw extrusion-cooking.

The results of radial expansion ratio of extruded breakfast cereals are presented on the Fig. 2a. It was observed for products processed at 17% of initial moisture content the highest expansion ratio with 3.5 in result for recipe I based on 50% of wholegrain wheat flour. The lowest values were recorded for samples processed at the highest moisture content of raw materials 23%, both for II and III recipe. It was concluded the expansion ratio mainly depended on initial moisture content of raw materials used, the higher moisture was applied, the lower expansion of extrudates were observed with high correlation coefficients (-0.89, -0.93, -0.98 for I, II and III recipe, respectively). An amount of basic wholegrain wheat flour had a lower impact on products expansion ratio, but combination of 60 or 70% of wholegrain wheat flour in the recipe with the highest moisture content applied resulted in the lowest expansion ratio of products. This is in agreement with results presented by Liu et al. (2000) for oat-corn extrudates processed with twin-screw extruder, Ryu and Ng (2001) for wheat flour and cornmeal extrudates and Singh et al. (2007) for rice-pea extrudates processed with single-screw extruder. The initial moisture content of raw materials had a strong impact on bulk density of breakfast cereals. Increasing of water added resulted in increasing the values of bulk density form 110 $kg \cdot m^{-3}$ at 17% m.c. up to 330 $kg \cdot m^{-3}$ at moisture content of 23% (Fig. 2b). This is in accordance to data presented by Garg et al. (2010) and Singh et al. (2007). The lowest amount of wholegrain wheat flour resulted in lower than others values of bulk density. Low bulk density suggests good porosity and aeration of extrudates structure, which is desirable mainly in snack foods (Mościcki et al. 2007; Wójtowicz et al. 2013). According to breakfast cereals tested in the present study negative correlations of bulk density with chewiness of extrudates prepared with water (-0.84) and with warm milk (-0.89) were observed. Bulk density may vary from 80 $kg \cdot m^{-3}$ up to 280 $kg \cdot m^{-3}$ and more, as presented by Jones et al. (2000) for commercial breakfast cereals.

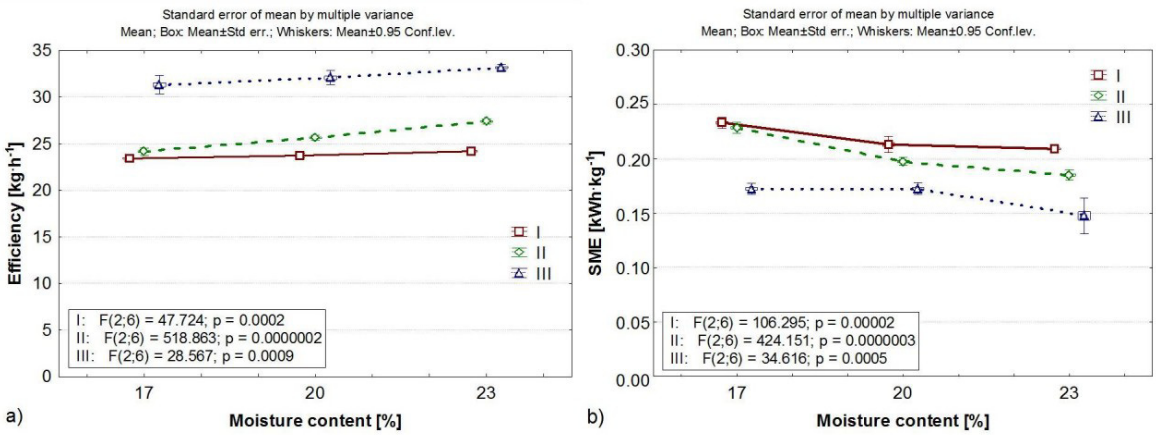

Fig. 1. Process efficiency (a) and specific mechanical energy consumption (b) results of breakfast cereals processed with various recipes and initial moisture content. Test *F* results and *p* values (ANOVA) are presented for each recipe.

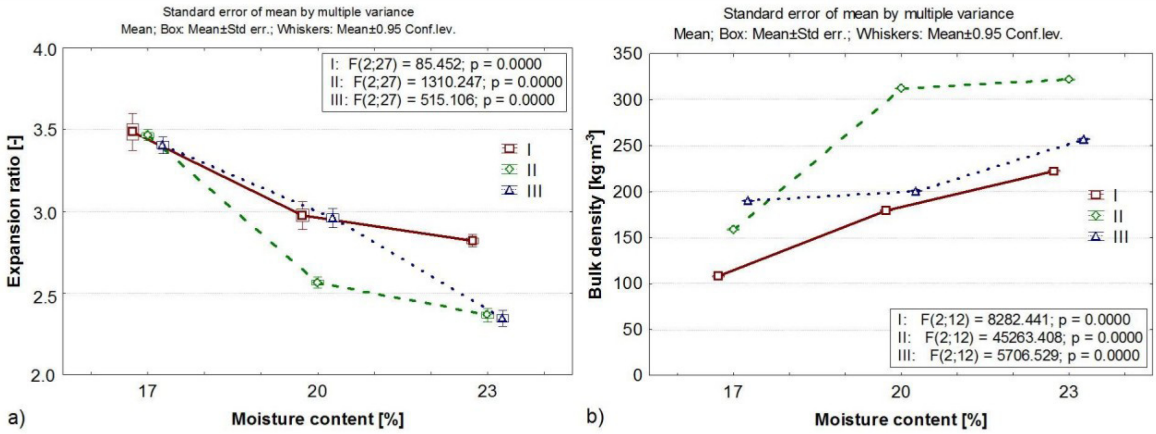

Fig. 2. The expansion ratio (a) and bulk density (b) results of breakfast cereals processed with various recipes and initial moisture content. Test *F* results and *p* values (ANOVA) are presented for each recipe.

The results of *WAI* and WSI measurements are presented on the Fig. 3. The highest *WAI* values (4.7 $g{\cdot}g^{-1}$) were reported for samples processed at 17% of m.c. with recipe I with the lowest amount of wholegrain wheat flour, which characterized porous structure, high expansion ratio and low bulk density. Increasing water addition to raw materials lowered *WAI* (cor. coef. -0.76) of these products. Samples with higher amount of wholegrain wheat flour in the recipe characterized lower values of *WAI* (Fig. 3a), which is in accordance to the results presented by Jones and others (2000), they concluded the *WAI* to be higher with higher starch content. *WAI* of extrudates processed with twin-screw extrusion as described by Geetha et al. (2012) ranged from 2.7 to 5.21 $g{\cdot}g^{-1}$ and were strongly affected by process conditions (temperature, screw speed and feed rate). Water solubility index is the amount of soluble polysaccharide released from the starch component after extrusion (Ding et al. 2006). *WSI* of tested samples lowered significantly with higher moisture content of raw materials processed with the extrusion-cooking (-0.96 and -0.98 for recipe I and II, respectively). Only for products processed on the base of 70% of wholegrain wheat flour at the highest moisture content it was observed significant differences in *WSI* trend compare to extrudates based on 50 and 60% of wheat flour (Fig. 3b). *WSI* values were correlated with the expansion ratio (0.70), bulk density (-0.75). At low moisture content of raw materials and a large amount of fiber in wholegrain wheat flour high values of *WSI* suggested insufficient integration of breakfast cereals components according to high amount of residues present in supernatant. *WSI* values, reported by Singh et al. (2007), increased with decrease in initial moisture content of raw materials for rice based extrudates.

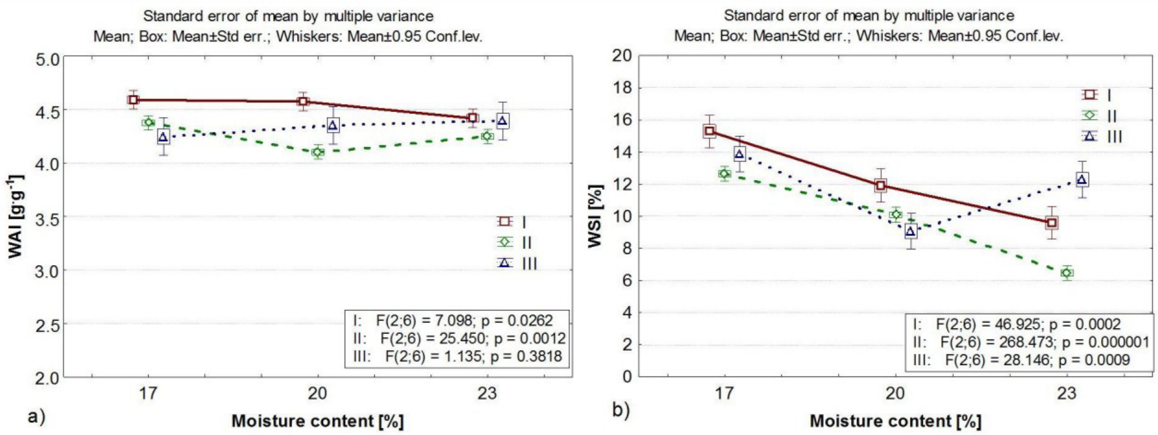

Fig. 3. *WAI* (a) and *WSI* (b) results of breakfast cereals processed with various recipes and initial moisture content. Test *F* results and *p* values (ANOVA) are presented for each recipe.

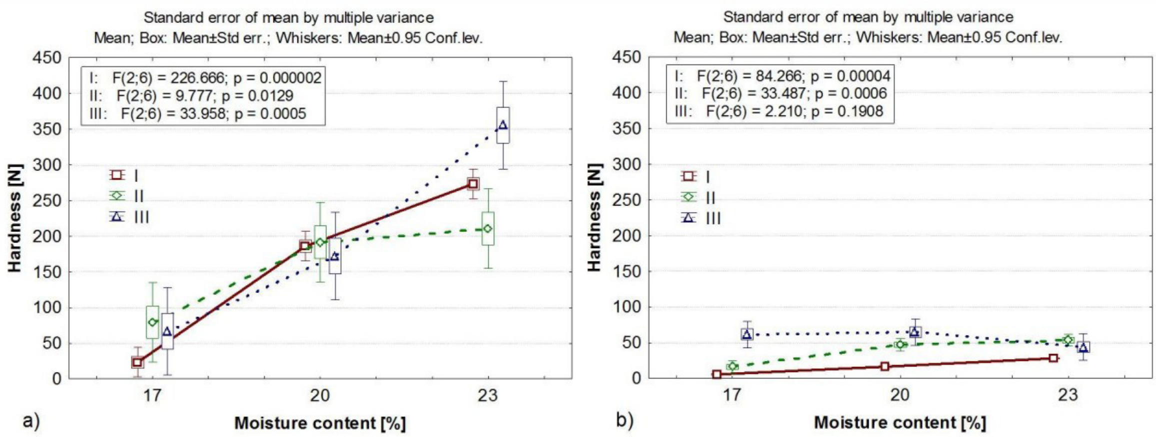

Fig. 4. Hardness of breakfast cereals prepared for consumption with: a) water, b) warm milk, processed with various recipes and initial moisture content. Test *F* results and *p* values (ANOVA) are presented for each recipe.

Textural characteristics of prepared for consumption breakfast cereals involved the evaluation of hardness, adhesiveness and chewiness of extrudates with double compression test. On the Fig. 4 the results of breakfast cereals hardness prepared with water and warm milk hydration are presented. High correlation coefficients of hardness were calculated according to increased initial moisture content of raw materials with values of 0.97, 0.81 and 0.95 for recipe I, II and III, respectively. More than three times higher results were noted for samples processed at 23% of m.c. than for 17% (Fig. 4a). These results are negatively correlated with expansion (-0.89) of products. The highest hardness was reported for breakfast cereals processed at 23% of m.c. with the highest level of wholegrain wheat flour in the recipe. Much lower hardness was observed for extrudates prepared with warm milk, values do not exceed 65 N, and differences between the samples were small (Fig. 4b). Breakfast cereals prepared for consumption by hydration with warm milk showed similar tendencies for recipe I and II with high correlation coefficients (0.98 and 0.89, respectively), only products processed with recipe III showed insignificant differences. During the tests of extrudates prepared with warm milk the hardness was more influenced by recipe, and increasing the amount of wholegrain wheat flour increased products hardness.

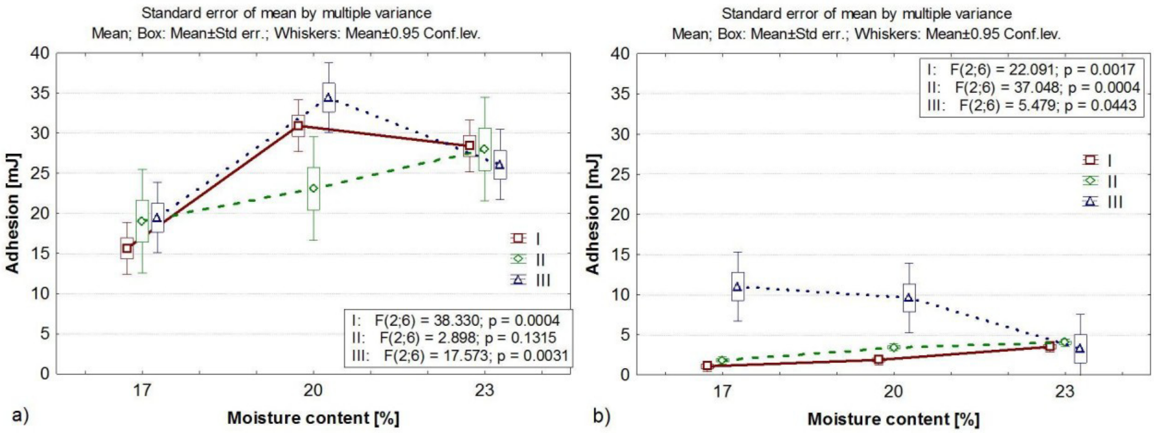

Fig. 5. Adhesion of breakfast cereals prepared for consumption with a) water, b) warm milk, processed with various recipes and initial moisture content. Test *F* results and *p* values (ANOVA) are presented for each recipe.

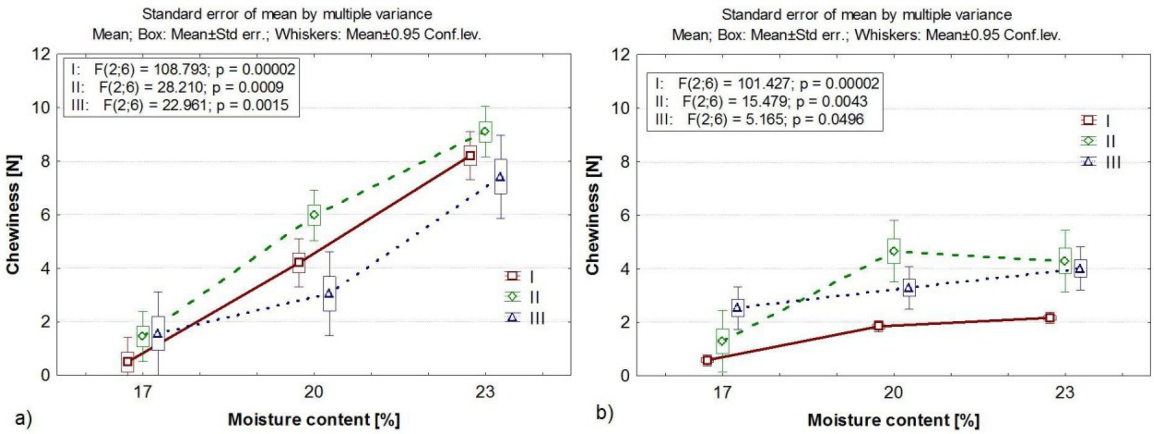

Fig. 6. Chewiness of breakfast cereals prepared for consumption with a) water, b) warm milk, processed with various recipes and initial moisture content. Test *F* results and *p* values (ANOVA) are presented for each recipe.

Adhesiveness results of prepared for consumption breakfast cereals processed from three different recipes with various initial moisture contents are presented on the Fig. 5, depend on the preparation method. When prepared with water adhesiveness of breakfast cereals was three times higher than for products prepared with warm milk. On the Fig. 5a, it is shown an adhesiveness increase of samples processed at 20% of initial m.c. compare to 17% and for recipe I and II slide decrease of adhesiveness was observed when the highest initial moisture was applied. Extrudates processed with recipe II showed continuous increasing of adhesiveness with increasing the moisture content of raw materials with high correlation coefficient (R^2=0.89). Much clear dependencies were reported during the tests of breakfast cereals prepared with warm milk (Fig. 5b). For products processed with I and II recipe high correlation was noted according to increased moisture content of raw materials (0.92 and 0.93, respectively), but negative correlation was observed for test results achieved for recipe III: samples with the highest amount of wholegrain wheat flour in the recipe showed decrease of adhesiveness (-0.84) according to higher initial moisture content. Low values of adhesiveness were the results of low stickiness, but also much low chewiness of tested products after preparation with of warm milk. These results were strongly correlated with hardness of products prepared with milk (R^2=0.82).

The results of extruded breakfast cereals chewiness showed the main influence of initial moisture content of raw materials depend on preparation method. For processed samples increasing the moisture content resulted an increase of chewiness of final products prepared both with water (Fig. 6a) (R^2=0.91-0.99) and with warm milk (R^2=0.80-0.93). The results of chewiness were highly correlated with the expansion ratio (-0.78) and bulk density (0.84).

Similar trends were noted when samples were prepared with warm milk (Fig. 6b), correlation coefficients were -0.80 for expansion ratio, and 0.89 for bulk density results. Applications of 17% of raw materials moisture content allowed achieving products with similar chewiness values both for water and warm milk preparation, significant differences were observed if 23% of initial m.c. was used; more than twice lower values were noted for these samples when prepared with warm milk.

Sensory assessment was performed for ready to consumption breakfast cereals prepared with warm milk for 5 minutes. The results of shape, color, flavor, taste and consistency and overall quality as the mean of results are presented in the Table 2. Analysis of results showed high correlation of sensory notes with the initial moisture content of raw materials, especially for recipe I (-0.95). Extrudates processed with 50% of wholegrain wheat flour in the recipe and processed with 17% of initial moisture content were the best noted for overall quality (mean 4.02). In the samples extruded with recipe I the decrease of overall quality notes with increasing the initial moisture content was observed. Increasing amount of wholegrain wheat flour in the recipes lowered the sensory notes of tested samples, but it was unclear dependencies for both the moisture content and wholegrain wheat flour amount in the recipe.

Table 2. Sensory results of extruded breakfast cereals prepared with warm milk.

Recipe	Moisture content [%]	Shape	Color	Flavor	Taste	Consistency	Overall quality
I	17	4.2	4.3	4.0	3.3	4.3	4.02^{a}
	20	4.1	3.9	3.5	3.3	4.2	3.80^{ab}
	23	4.0	4.1	3.6	3.2	3.8	3.74^{b}
II	17	4.0	3.7	3.6	3.1	4.0	3.68^{bc}
	20	3.9	3.8	3.4	3.2	3.8	3.62^{c}
	23	3.8	3.9	3.5	3.4	3.9	3.70^{b}
III	17	4.0	4.1	3.6	3.1	4.1	3.78^{ab}
	20	3.7	3.8	3.6	3.3	4.1	3.70^{b}
	23	3.8	3.9	3.7	3.2	4.1	3.74^{b}

(n=15), *a-b* Different superscript letters in the same column indicate significant difference, $p<0.05$

4. Conclusions

Process management of extruded breakfast cereals according to various recipes and processing conditions allows creating desirable quality of final products. Application of single-screw extrusion-cooking for processing of breakfast cereals in proposed parameters allows to process good quality of products containing 50-70% of wholegrain wheat flour in the recipe and at 17% of raw materials moisture content. Range of initial moisture content of raw materials had a significant influence on almost all tested parameters. Increasing level of moisture content lowered energy consumption, expansion ratio and WAI index, but increased process efficiency, bulk density, hardness and chewiness of breakfast cereals. Higher amount of wholegrain wheat flour in the recipe showed an influence on the highest hardness and adhesion of breakfast cereals prepared for consumption. Application of wholegrain flour instead of bran supplementation may be an easier and a cost-efficient way to process nutritionally valuable breakfast cereals with good quality.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

The influence of grain moisture content on specific energy during spring wheat grinding

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Abstract

Grinding is the fundamental operation in the processing of cereal grain. From the viewpoint of the processing technology, the significant aspect is the energy intensity of the process. Apart from the equipment used, the process of grinding is affected by grain moisture and its mechanical properties that are determined primarily by the cultivar factor. The principal objective of the study was the determination of the effect of moisture content of kernels of new spring wheat cultivars on specific energy needed to crash them by a laboratory hammer mill. In all the cases an increase of kernel moisture causes an increase of the specific energy. The lowest specific energy during grinding, throughout the entire range of kernel moisture, was characteristic of cultivar Arabella, while the highest values of specific energy were obtained in the case of cultivar Mandaryna. The relationship of the specific energy to the kernel moisture content was described by means of linear equations.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: spring wheat; grindig; specific energy.

1. Introduction

Knowledge of the mechanical properties of cereal grain is indispensable in the design of machines and technologies for the harvest, transport, storage, husking, grinding and flaking (Dziki et al. 2014, Andrejko et al. 2011, Laskowski et al. 2005). Grinding is the fundamental operation in the processing of cereal grain (Dziki 2008).

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.052

Mechanical grinders or mills for cereal grain are used both on individual farms and at large processing plants (Jasim and Ahmed 2012). Cereal grain grinding is performed primarily with the use of hammer mills and roller mills. From the viewpoint of the processing technology, the significant aspect is the energy intensity of the process. Apart from the equipment used, the process of grinding is affected by grain moisture and its mechanical properties that are determined primarily by the cultivar factor. An increase of grain moisture leads, as a rule, to increased energy requirements of the process, especially when decohesion of grain material is effected with the use of hammer mills (Dziki et al. 2011). Research by Dziki and Laskowski (2010) demonstrates that grain sprouting causes a significant increase of energy consumption for grinding. The process of grain grinding is also affected by its hardness. According to Dziki and Przypek-Ochab (2009) an increase of wheat grain hardness causes increased grinding energy consumption, the relation obtained being of a linear character. Kilborn et al. (1982) demonstrated that specific energy in the process of grinding of wheat grain amounts to from 46 $kJ \cdot kg^{-1}$ for common wheat cultivars to 124 $kJ \cdot kg^{-1}$ for durum wheat cultivars. Energy consumption depends significantly on the degree of comminution of the material. An increase of the degree of comminution causes an increase in the energy requirements of the grinding process, the relationship being most frequently described by an exponential equation (Laskowski et al. 2005). The principal objective of the study was the determination of the effect of moisture content of kernels of new spring wheat cultivars on specific energy needed to crash them by a laboratory hammer mill.

2. Material and Methods

The investigations were conducted on four Polish wheat cultivars: Arabella, Kandella, Mandaryna and Struna, harvested in 2014, acquired from the plant breeding station DANKO Hodowla Roślin Sp. z o.o. in Chorynia. Those are new cultivars, registered in the Polish Register of Cultivars in the years 2011-2014. Arabella has very good quality parameters (group E/A). Cultivars from groups E (elite), A (very good) and B (good) are suitable for baking bread. It is a very early cultivar, characterised by very high yield levels over the entire territory of Poland. It is suitable for cultivation on poorer soils. It is characterised by high protein and gluten content. Kandela is characterised by very good quality grain (group A). Its yields are stable all over Poland. It tolerates slight acidification of soil, which permits its cultivation on soils with non-regulated pH. It is characterised by high protein and gluten content. Mandaryna has very good quality parameters (group A). It is characterised by very good productivity over the whole territory of Poland. It is an early cultivar with very good resistance to lodging. Struna has very good grain quality parameters. It is characterised by very high yields. It displays excellent adaptability to various soil and climate conditions. It is characterised by high content of protein and gluten. All of the cultivars included in the study are characterised by good or high resistance to diseases. The material was divided into kernel size classes using a Retsch As 200 sifter (VERDER Group, Holland), and then material of uniform size (>2mm) was taken for the analyses. In this study, five levels of moisture content of wheat kernels were determined: 10%, 12%, 14%, 16%, 18%. In order to reach these levels, the grain was conditioned by adding specific amounts of distilled 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±2ºC. The grain was ground using a hammer mill of the type POLYMIX-Micro-Hammermill MFC (Glen Mills Inc., USA). The mill worked in conjunction with a computer system recording the power consumption. The mill was equipped with a replaceable screen with mesh size of 2.0 mm. The parameters determined in the tests were the specific energy of grinding and the ratio of the specific energy to the mass of grain ground. The test results were subjected to statistical analysis using one-factor analysis of variance ANOVA. The significance of differences was verified using the Fisher LSD test.

3. Results and Conclusion

The tests demonstrated that the specific energy during the grinding of grain of the wheat cultivars under study varied from 52.9 $kJ \cdot Kg^{-1}$ to 100.8 $kJ \cdot Kg^{-1}$ in the case of cultivar Arabella, from 81.2 $kJ \cdot Kg^{-1}$ to 124.1 $kJ \cdot Kg^{-1}$ in the case of cultivar Kandela, from 77.8 $kJ \cdot Kg^{-1}$ to 138.9 $kJ \cdot Kg^{-1}$ in the case of cultivar Mandaryna, and from 64.4 $kJ \cdot Kg^{-1}$ to 134.0 $kJ \cdot Kg^{-1}$ in the case of cultivar Struna. The changes in the values of specific energy in relation to kernel moisture are presented in Fig. 2.

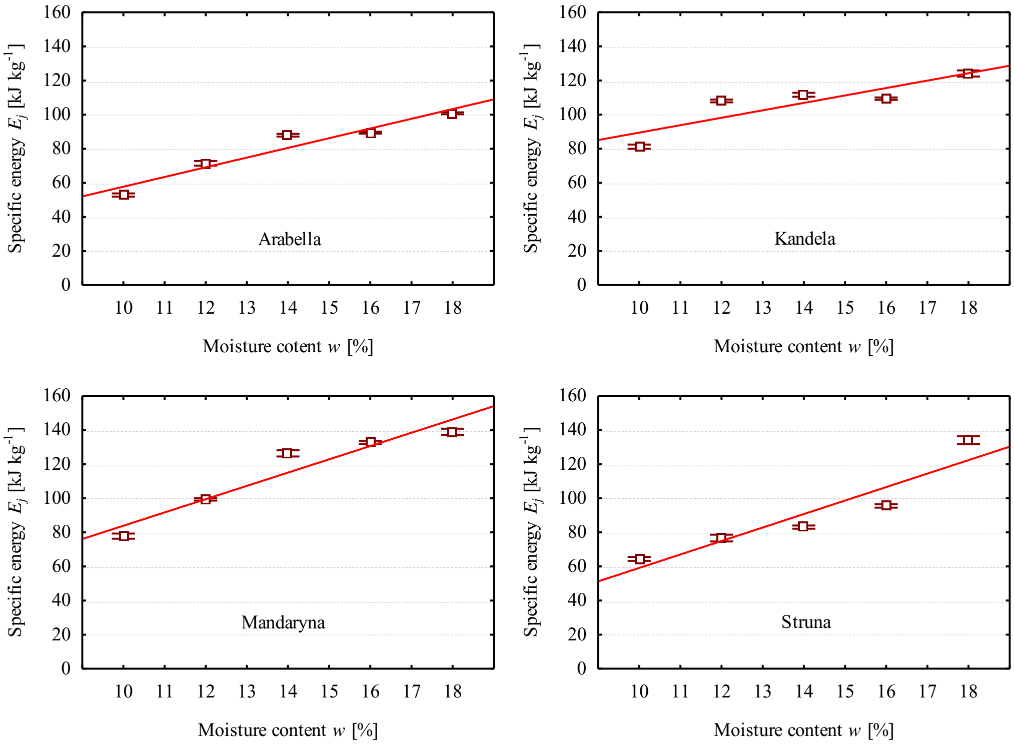

Fig. 1. Effect of kernel moisture content w on specific energy E_j in the case of the wheat cultivars under study

Analysis of the graph shows that in all the cases an increase of kernel moisture causes an increase of the specific energy. The lowest specific energy during grinding, throughout the entire range of kernel moisture, was characteristic of cultivar Arabella, while the highest values of specific energy were obtained in the case of cultivar Mandaryna. Within the kernel moisture range under study the highest increase of specific energy was noted in the case of cultivars Struna - by 108.1% and Arabella - by 90.1%, while the smallest increase was obtained in the case of cultivars Kandela - by 52.8% and Mandaryna – by 78.7%. The relationship of the specific energy to the kernel moisture content was described by means of linear equations (Table 1).

Table 1. Equations describing the relation between specific energy E_j and kernel moisture w

Cultivar	Equation	R^2
Arabell	$E_j = 5.69w + 0.81$	0.93
Kandela	$E_j = 4.36w + 45.82$	0.82
Mandaryna	$E_j = 7.79w + 5.94$	0.92
Struna	$E_j = 7.9w + 19{,}93$	0.89

The study indicates that, taking into account only the aspect of energy consumption, it is possible to select cultivars with low specific energy during grinding for cultivation and processing, which in effect will cause a reduction of production costs. The next stage of the study will be focused on research concerning the relations between selected strength properties of kernels and their susceptibility to grinding.

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Farm Machinery and Processes Management in Sustainable Agriculture, 7th International Scientific Symposium

Health risks associated with exposure to fungi

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Abstract

Occupational environment of farmers is full of biohazards. Especially frequent are molds found in grain, grain dust, and soil. People might be affected by diseases caused by these molds inducing: skin infections, bronchial asthma, allergic rhinitis and others.
The aim of the study was to detect and quantify colonization by molds in samples of grain and grain dust collected during combine threshing, as well as in soil samples from organic and conventional cultivation systems in south – east Poland. The following were used for the study: 20 samples of rye, wheat and barley grain, 20 samples of every grain dust collected during combine threshing and 20 samples of soil for every cereal were collected from an organic cultivation system. The same number of corresponding samples from a conventional system of farming was also obtained. The concentrations (CFU/g) of molds were determined applying the method of plate dilution on two media, and the species composition of molds was determined using taxonomic keys and atlases. The results show a potential risk for people engaged in agriculture. The presence of allergenic and toxigenic molds in the work environment of this working group creates serious occupational exposure. This subject is of high significance for the health of population engaged in agricultural production and calls for further studies.

Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)

Keywords: fungy; health hazards; agriculture.

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Peer-review under responsibility of the Centre wallon de Recherches agronomiques (CRA-W)
doi:10.1016/j.aaspro.2015.12.053

1. Introduction

Fungi are one of the known biological factors that have a negative impact on human health. According to the current scientific literature, molds constitute particular threat to health. Airborne spores of these microorganisms are ubiquitous, and under favorable conditions begin development cycle. Molds have the ability to produce secondary metabolites that have toxic effects on human body and on animals. Additionally, they may cause different types of diseases. Prolonged exposure to these pathogens may lead to serious respiratory diseases. Molds belong to parasites if the source of the organic substances is living organism,, and to saprophytes if these compounds are derived from dead wet organic material or substrates such as, for example: wood, paper, paint, dirt, debris, food and skin. Their share in the total ground biomass is estimated to be approx. 25% (Wiszniewska et al, 2004; Zukiewicz-Sobczak et al 2012, 2013).

The spores are mostly present and reach high concentrations during summer due to the presence of nutrients in the medium, favorable temperature and humidity. Therefore, in Poland – country with temperate climate the peak concentration of molds spores in the air occurs mostly in late summer and early autumn when the rainy days are followed by sunny days, which are dry and windy. The spores are commonly found in very large quantities, not only in outdoor environment, but also indoors. Fungal spores present in the environment enter indoors with air movement or are transmitted by humans and animals (Miklaszewska B. et al 2005; Ejdys E 2009; Żukiewicz-Sobczak W. et al 2012, 2013).

Another way of penetration of fungi into human body is the oral route. Eating foods contaminated with fungi and its metabolites is extremely dangerous to human health. Raw materials and food products used in food production for humans should meet hygiene requirements and high quality standards. Contaminated raw cereal or animals grown on contaminated feed should be disqualified as a semi-finished product for further processing. Until now, food technology does not have effective thermal treatment, or another way that would remove from contaminated food toxic metabolites of fungi. Therefore, we can talk about a huge immunotoxic threat to human health. These types of issues are very important, because quality control in the agri-food establishments operates on an unsatisfactory level. Preliminary testing of raw materials in factories is carried out through organoleptic methods, which exclude evaluation of changes in enzymatic and microbial raw materials, especially in the early stages of growth (Larone DH 2011; Lipiec A. et al 2010; Nolard N. 2001; Pokrzywa P. et al 2007; Zukiewicz-Sobczak W.et al 2012, 2013).

Moulds produce a tremendous amount of spores that can be transported over thousands of kilometres. They are even in the stratosphere. Very small size (3-10μm) spores also allow them to deeply penetrate the bronchial tree, which, in turn, promotes lower respiratory sensitization (Bożek A. et al. 2010). The residential indoor air level of fungal spores sometimes even exceeds $1000/m^3$ (Piotrowska M. et al 2001; Samoliński B. et al 2010). The species of fungi most commonly found at homes are: *Aspergillus, Penicillium, Mucor, Rhizopus, Aureobasidium and Cladosporium*. (Bożek A. et al 2010; Piotrowska M. et al 2001; Samoliński B.et al 2010; Zukiewicz-Sobczak W.et al 2012, 2013).

According to the research molds produce spores throughout the year, and their growth is dependent primarily on relative humidity, which, in turn, depends on ventilation, the presence of air and thermal insulation of the building. The process of release of spores depends not only on the type of fungus, but also on the weather and the concentration of spores at home environment and increases with increasing quantities of fungi in the environment. Certain spores are released when air is dry and their concentration in the air increases with the increased blast and reduced moisture during high solar radiation, for example. These are, among others, fungal spores from genera *Alternaria, Cladosporium, Helminthosporium.* On the other hand "wet" spores produced by fungi from class of *Ascomycetes* are released into atmosphere during rain, often overnight. The results of several studies show a significant correlation between increased concentration of spores and adverse health symptoms. Namely, higher levels of antigen fungi in the environment (residential, outdoor) generates the occurrence of various types of allergy symptoms (Etzel R. et al. 1999; Platts-Mills T.A. et al. 1987, Bush R. et al. 2001; Bousquet J. et al. 2001; Douwes J. et al. 2009; Cakmak S. et al 2002).

As shown spores are the most allergenic form of fungi; what is more substantial portion of secondary metabolites mycelium – mycotoxins accumulates in them. Even innocent-looking water droplets on the surface of the mycelium are the source of the highest concentrations of pathogenic metabolites. Some molds produce several toxins; some toxins are produced by more than one species of fungi. The most important mold toxins are aflatoxin (AF), ochratoxin A (OT), zearalenone (ZEN), trichothecenes and fumonisins (FRA) (Wiszniewska M. et al 2004). Mycotoxins are characterized by multidirectional action: mutagenic, neurotoxic, immunosuppressive and carcinogenic. In this respect, the greatest threats to human and animal health are filamentous fungi of genera *Aspergillus, Penicillium, Fusarium, Stachybotrys, Alternaria* and *Cladosporium*. Currently, minimum concentration of mycotoxins of different species of fungi found in enclosed spaces is not known, neither is the minimum exposure time required to induce adverse effects on human health (Hussein H.S. et al 2001; Dutkiewicz J. et al 2002, Barabasz W. et al 2001; Nabrdalik M. et al 2003; Piontek M. 2004; Hanke W. 2008; Helbling A. et al 2003; Soroka PM. et al 2008; Zukiewicz-Sobczak W. et al 2012, 2013).

Exposure to molds is linked largely to the work environment and life style (Barabasz W. et al 2001). The population employed in agriculture (including employees of certain sectors of the agri-food industry) is potentially exposed to harmful biological factors contained in dust grains. Biological factors in work environment are in the form of bioaerosols, especially organic dusts (Lipiec A. et al 2010). Studies of many authors have shown that the respirable organic dust contaminated with spores of filamentous fungi can cause allergic respiratory diseases. The most harmful biological agents present in dust are bacteria and fungi, and those produced by substances with allergenic and immunotoxic features (Bożek A. et al 2010; Mygind N. et al 1998; Zukiewicz-Sobczak W. et al 2012, 2013).

2. Aim of the study and methodology

The aim of the study was to detect and quantify colonization by molds in samples of grain, grain dust collected during combine threshing and soil samples from organic and conventional systems in south – east Poland. For the research the following were used: 20 samples of rye grain, 20 samples of wheat grain, 20 samples of barley grain, 20 samples of every grain dust collected during combine threshing and 20 samples of soil for every cereal were collected from organic cultivation system and same number of samples from conventional cultivation system. The concentrations (CFU/g) of molds were determined applying the method of plate dilution on two media: Malt Agar (Becton, Dickinson and Company) and Potato Dextrose Agar (Becton, Dickinson and Company) and the species composition of molds were determined using taxonomic keys and atlases.

3. Results

The research on the work environment of agricultural producers shows that there is a huge health hazards associated with exposure to molds.

The following genera and species of fungi were identified: *Cladosporium sp., Fusarium sp., Cladosporium macrocarpum, Cladosporium herbarum, Ulocladium sp., Mucor hiemalis, Mucor racemosus, Paeciliomyces variotti, Penicillium citrinum, Alternaria, Acremoniella Atma, Gonatobotrys sp., Aureobasidium sp*., and yeasts.

Molds enter body with food. Contaminated raw materials and food products are unfortunately available on the food market. The research conducted on raw food such as cereal crops and herbs shows that the biodiversity of fungi is enormous. The following were distinquished: *Aspergillus sp., Penicillium sp., Mucor sp., Rhizopus sp., Alternaria sp., Aspergillus flavus, Aspergillus versicolor, Penicillium expansum, Fusarium moniliforme* and *Alternaria alternata.* The fungi of genera *Absidia sp., Rhizopus sp., Mucor sp., Alternaria sp., Cladosporium sp.,* are considered highly allergenic fungi. Molds of *Aspergillus, Penicillium* and *Fusarium* genre with their allergic properties are of toxinogenic characteristics. Whereas, *Trichophyton* can cause outer body layer infections (Zukiewicz-Sobczak W. et al 2012, 2013).

Analysis of the literature on the subject of mycological health threats suggests that a person is exposed to fungal etiological factor not only in the workplace but also at home. Literature data indicate that the fungi present in residential and work environment may adversely affect human health. It is important to adhere to all kinds of recommendations for the elimination of fungi from buildings. The problem of the presence of fungi in buildings is still current and actions aimed at eliminating these microorganisms are associated with very important preventive health care actions on a wide scale (Zukiewicz-Sobczak W. et al 2012, 2013).

4. Conclusions

The problem of the presence of fungi in the building substance is still current and any action aimed at eliminating these microorganisms are also linked to the broader and a very important preventive care. Summarizing the above, it can be concluded that in the case of agricultural work environment, one can meet allergic etiologic factor in all spheres of life - work, food and household conditions. It is therefore extremely important to prevent the occurrence of etiologic factors in both the environment and human life. The research allowed determining and assessing the conditions and the close links between occupational exposure of grain producers with the two strategies of agricultural work environment - ecological and conventional. It has been shown that changing agriculture strategy affects the harmful mycological factor in the work environment of agricultural producers by reducing the biodiversity of species and quantity of the fungi concentration in organic dust. The results of the assessment of the implementation of the ecological system of cereals cultivation indicate a reduction in the quality and quantity of fungi in the raw material. Based on the results of the soil research it has been shown that organic farming is more environmentally friendly than conventional one due to the lower level of quantitative and qualitative mycological noxious agent in the soil. Research confirms that there is a need to develop specific standards for the exposure of farmers working in different field conditions threatened by the mycological harmful factors. (Zukiewicz-Sobczak W. et al 2012, 2013).

Acknowledgements

The project was funded by the National Science Centre allocated basing on the number of decision-DEC-2011/01 / B / NZ7 / 04300.

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