Chapter 11

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ESTIMATING THE RATE OF DECLINE IN THE FUNCIONAL VALUE OF POLYOLEFIN PACKAGING FILMS INTENDED TO COME INTO CONTACT WITH FOODSTUFFS

Abstract: All products made of plastic change their functional properties due to the passage of time, which in consequence leads to a decline in their functional value and it is by far one of the most crucial determinants of packaging materials' quality. In case of storage and usage this problem gains particular importance. That is why it is vital to create a model of the rate of decline in the functional value of polyolefin packaging films as well as to describe a model enabling to determine the time which results in removing the packaging material from usage.

KEY WORDS*:* quality of polyolefin packaging films, critical parameter, decline in the functional value

11.1. Introduction

One of the main characteristics of polyolefin packaging films used for packing food products on high-efficiency filling and packing machines is a different suitability for use. Preserving functional properties of packaging materials in determined period of time can be regulated based on knowledge of the real mechanisms of impact of such factors as conditions and storage time as well as the type of adverse exposure, which was proven by the research conducted by G., Michler, F. Ballta-Caleja (MICHLER H. BALLTA –CALEJA F.J. 2005) and P. Jouinot,

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V. GANTCHENKO, M. STASI (JOUINOT P. GANTCHENKO V. STASI M. 1999). In addition, durable packaging materials to a large extent determines the durability packaged product (KONDRATOWICZ-PIETRUSZKA E. 1995, GUSTAW W., SZWAGIER D. 2012, SOŁOWIEJ B. 2013). THE consequences of interactions between climate factors which have impact on packaging films determine the storage expiry date as well as the speed of change of the properties characterizing the functional value (ELSNER T. HIRTH P. EYERER P. 2008).

In practice the manufacturers of polyolefin packaging films do not specify the requirements concerning microclimate conditions of storage and normally do not point out permissible period of storage (GALOTTO M. ULLOA J. HERMANDEZ P. AND CO. 2008). That is why predicting changes in functional properties of packaging films in the course of storage which were caused by an aging process is vital in terms of economical practice. Article in its content refers to the study of polyolefin packaging films, whose aim was to create a model of changes in their performance. Detailed characteristics of research material and form a general model as a basis for estimating the degree of deterioration of stored film was presented in the Polimery No. 11-12 (see LISIŃSKA-KUŚNIERZ M. CHOLEWA-WÓJCIK A. 2011).

The purpose of this study was to create a model allowing to estimate the rate of decline in the functional value of polyolefin packaging films during storage and enabling prediction of time when the packaging material should be removed from usage.

11.2. Material and methods

Research material were both homogenous films (a film under the trade name of TB, which is a copolymer of ethylene and octane-1 and a film under the trade name of BG, which is a biaxially oriented PP film) and ones produced from two kinds of polyolefin (a film under the trade

name of BIAXFOL, which is a biaxially oriented heat shrink polyolefin film and a film under the trade name of CRISTEL which is a combination of PE and PP), as well as a film under the trade name of ECOR, which is an example of packaging material produced on the basis of polyolefin with a 49,5% fraction of chalk and talc.

The films were stored for a period of 12 months in the following microclimate condition variants:

- Variant I - stable microclimate conditions with the following parameters: T= 20±1°C, RH= 65±2% (normal atmospheric research conditions according to PN EN-ISO 554:1996),
- Variant II- stable microclimate conditions with the following parameters: T= 40±1°C, RH= 65±2% (the temperature is 20°C higher in relation to the normal conditions with the relative air humidity as given above),
- Variant III- stable microclimate conditions with the following parameters: T= 20±1°C, RH= 90±2% (the temperature on a normal conditions level with the relative air humidity on a dramatically high level),
- Variant IV- stable microclimate conditions with the following parameters: T= -20±1°C, RH= 40±2% (the conditions include the usage of films for packing deep-frozen products),
- Variant V- changeable microclimate conditions with the following parameters 10±1°C<T<22±1°C and 56±2%<RH< 64±2% (monitored in the warehouse of the packaging film manufacturer without the possibility of regulating the conditions of the surrounding environment).

The basis of estimating the rate of decline in the functional value of polyolefin packaging films has been the model of functional value described by the following equation:

$$\hat{Y}_t = a_0 + a_1 t + b_2 X_2 + \ldots + b_k X_k + c_2 Z_2 + \ldots + c_j Z_j;$$

where:

a_0- an absolute term,

a, b, c- estimated parameters' indicators,

t – a variable describing the time which has passed from the beginning of the test (in months),

k= 2,…,K- the number of tested variants of microclimate conditions

j= 2,…,J- the number of tested packaging films,

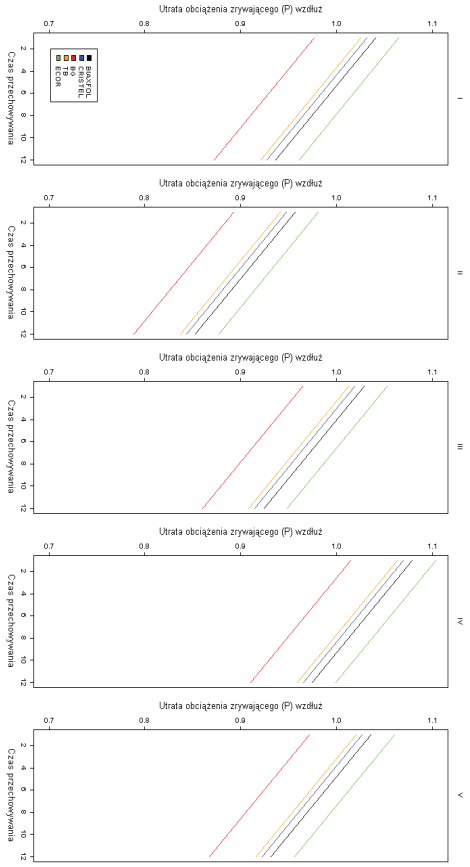
$\mathbf{X_k}$ – artificial variable, takes value 1, when the k-th variant of microclimate conditions of the packaging films' storage is analyzed, in all other cases it takes value 0.

$\mathbf{Z_j}$ – artificial variable, takes value 1, when the j-th type of the packaging film is analyzed, in all other cases it takes value 0.

Based on the functional value model which includes the impact of microclimate conditions in the course of storage, the changes in functional value of the polyolefin packaging films considering the value loss of their critical parameters (break load, elongation and molecular weight) were calculated (HERMANDEZ P. 2009), (WEST B. ARBOR. WELCH. 2006), (MANLY. 2004).

The analysis of changes in functional value of the packing films which were tested in the course of 12 months under different microclimate conditions variants are presented in fig. 11.1÷11.3.

The decline in the value of elongation along the length

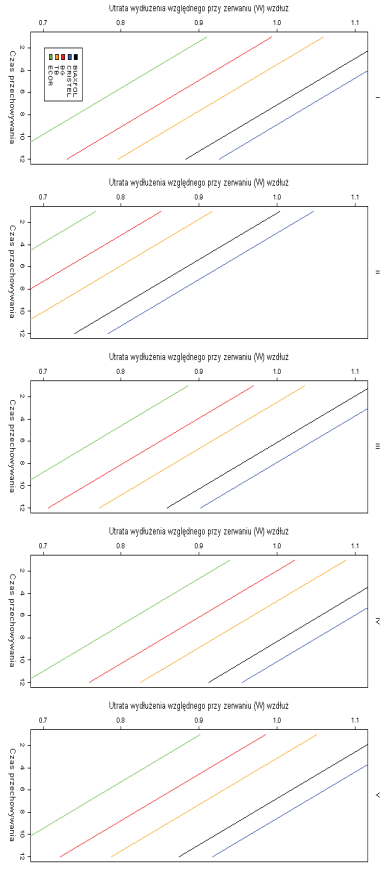


Time of storage (months)

Fig. 11.1. Change of quality of tested packaging films which were stored under different microclimate conditions variants, designated based on the decline in the value of break load along the length.

Source: own work.

The decline in the value of elongation along the length



Time of storage (months)

Fig. 11.2. **Change of functional value of tested packaging films which were stored under different microclimate conditions variants, designated based on the decline in the value of elongation along the length.**

Source: own work

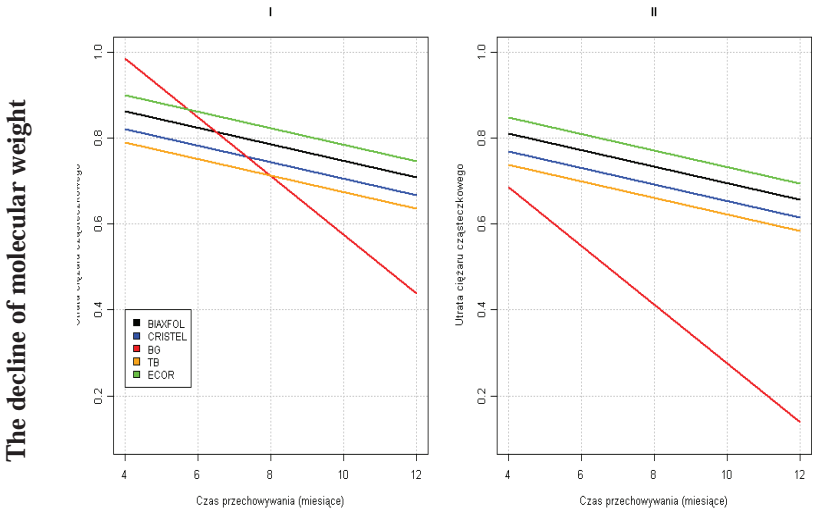


Fig. 11.3. Change of functional value of tested packaging films which were stored under different microclimate conditions variants, designated based on molecular weight.

Source: own work.

The basis of determining so called critical usage time, after which a tested property changes by a fixed value (HAKKARAINEN AND ALBERTSON 2004). Based on the results of research conducted by P. Jouinot, V. Gantchenko, M. Stasi the loss of 50% of given properties is

equivalent to reaching critical time and results in removing the packaging material from usage (JOUINOT and GANTCHENKO and STASI, 1999).

By the application of models with linear impact of time and additive impact of the packaging film's type and microclimate conditions variant during storage, it was predicted how much time must pass until 50% loss of the tested property in terms of parameters characterizing the packaging material can be observed (VILLETTI AND CRESPO AND SOLDI & CO 2006).

A prediction of the rate of decline in packaging film's functional properties was done based on the model described by the following equation:

$$PUWF = Z_f + X_{wwm} + A + Yt + t;$$

where:
PUWF- predicted decline in packaging film's functional properties,
Z_f – packaging film's factor,
X_{wwm}- microclimate conditions variant factor,
A – model's constant
Yt- impact of time,
t- storage time.

By using linear models, which were the basis of determining critical usage time, the time of decline in usage, analyzed based on critical characteristics' parameters, was calculated.

Based on the estimated values of time of the decline of parameters characterizing mechanical properties and structural changes, regardless the analyzed packaging film type it can be stated that the time of decline significantly depends on microclimate conditions applied in the course of storage. The analysis of the achieved results shows that the time of decline of mechanical properties is the lowest in case of temperatures below 0°C, which was reflected in microclimate conditions variant IV.

Depending on the parameter analyzed and the packaging film's type the predicted time of decline in functional value is as follows:
For:

- Break load in direction along the length: 55-65 months;
- Break load in another direction of force: 48-62 months,
- Extension along the length: 19-31 months and
- Extension in another direction of force: 21-32 months.

Whereas the highest values of the time of decline of functional properties were observed in variant II, in which the temperature was dramatically elevated. Depending on the parameter analyzed and the packaging film's type the predicted time of decline in functional value is as follows:
For:

- Break load in direction along the length: 42-52 months,
- Break load in another direction of force: 32-48 months,
- Extension along the length: 12-24 months and
- Extension in another direction of force 17-29 months.

In case of all remaining microclimate conditions variants, namely I, III and V, the results of the statistical analysis did not show significant differences in estimated periods of functional property loss.

Based on this it is possible to state that for the molecular weight describing structural changes the estimated values of the time of decline are statistically the most relevant. It is the parameter, in case of which based on estimated point forecast the decline of functional properties is the quickest. Whereas from among the parameters describing mechanical characteristics, statistically speaking the significant difference in the rate of decline of the functional value only in case of the elongation along the length was observed.

Summing up it can be stated that regardless of analyzed packaging materials' type the most significant role is played by the microclimate conditions to which the packaging films are exposed in the course of storage. The higher temperature the shorter period of reaching the time of

removal of the packaging material from usage. Such conclusion has been scientifically proven by J. POSPSIL, Z. HORAK, Z. KRULIS & CO (POSPSIL J. HORAK Z. KRULIS Z. & CO. 1999), W. K. MASSEY, LIESL (MASSEY W. LIESL. 2003), M. HAKKARAINEN, A. ALBERTSSON (HAKKARAINEN M. ALBERTSSON A. 2004). Additionally it was observed that the packaging film's type has an impact on the changes of mechanical characteristics in the course of storage in different microclimate conditions variants. Deterioration of mechanical characteristics with the temperature growth is easier in case of the packaging film with PP because of the presence of tertiary carbon atoms in its chains which are susceptible to oxidation. However the intensity of these changes significantly relies on quantitative share of PP in the composition (the higher share of PP the stronger intensity) (WAGNER J. 2010).

11.3. Results and conclusion

Predicting changes in functional value based on determining critical usage time enables to designate the time range, after which the tested property changes by a certain value. The presented model of estimating packaging film's rate of decline in the functional value allows its assessment to be performed based on the changes of any given functional properties.

Created models also allowed to suggest the requirements concerning microclimate conditions of polyolefin packaging films' storage and their permissible storage time. Microclimate conditions of packaging films should be established according to following requirements: air temperature up to 25°C (with possible diurnal fluctuations), elimination of exposure to sunlight. Permissible storage time of packaging films in such conditions can reach 18 months.

The methods of predicting changes of characteristics which have impact on functional value presented above create a possibility to

determine and monitor changes in system: plastic film – microclimate conditions in the function of time.

Bibliography:

1. ELSNER T., HIRTH P., EYERER P. 2008, *Polymer Engineering: Technologien und Praxis*, Springer Publisher, Germany.
2. GALOTTO M., ULLOA J., HERMANDEZ P., FERNANDEZ-MARTIN D., GAVARA F., GUARDA A. 2008, *Mechanical and thermal behaviour of flexible food packaging polymeric films materials under high pressure/temperature treatments* "Packaging Technology and Science" 22.
3. GUSTAW W., SZWAGIER D. 2012, *Właściwości reologiczne mieszanych żeli β-glukanu owsianego i białek serwatkowych* „PolimerY 4.
4. JOUINOT P., GANTCHENKO V., STASI M. 1999, *The disk pressure test, a powerful investigition method to study mechanical properties and degradations of materials "Mechanika"* 18 (3).
5. HAKKARAINEN., ALBERTSSON. 2004, *Environmental degradation of polyethylene,* "Adven. in Polym. Scien." 169.
6. HERMANDEZ P. 2009, *Polymer Properties. The Wiley Encyclopedia of Packaging Technology*, Edited Kit L. Yan, 3 nd ed., J. Wiley and Sons.
7. KONDRATOWICZ-PIETRUSZKA E. 1995, *Kinetyczna analiza wybranych krzywych zmian jakości wyrobów,* Seria specjalna: monografie, nr 125 wyd. Akademia Ekonomiczna w Krakowie, Kraków.
8. LISIŃSKA-KUŚNIERZ M., CHOLEWA-WÓJCIK A. 2011, *Models of changes in the functional properties of polyolefin*
9. *packaging films* "Polimery" 56: 11-12.
10. MANLY. 2004, *Multivariate Statistical Methods: A Primer" 3 ed*, CRC Press, United States.

11. MASSEY, LIESL. 2003, *Permeability Properties of Plastics and Elastomers. A Guide to Packaging and Barrier Materials 2 nd ed.,* Elsevier Science & Technology Book, Burlington.
12. MICHLER H. BALLTA-CALEJA F.J. 2005, *Mechanical Properties of Polymers Based on Nanostructure and Morphology*, CRC Press, United States.
13. POSPSIL, HORAK, KRULIS & co. 1999, *Degradation and aging of polymer blends I. Thermomechanical and thermal degradation, "* Pol. Deg. and Stab.",65: 3.
14. SOŁOWIEJ B. 2013, *Wpływ preparatów serwatkowych na przylegalność analogów serów topionych do różnych materiałów opakowaniowych.*, „Żywność. Nauka. Technologia. Jakość" 2 (87).
15. VILLETTI, CRESPO, SOLDI & co. 2006, *Thermal degradation of natural polymers, "*Journ. of Therm. Anal. and Calor." 67.
16. WAGNER JR. 2010, *Multilayer Flexible Packaging: Technology and Applications for the Food, Personal Care, and Over-the-Counter Pharmaceuticals Industries* ,Plastics Design Library. United States.
17. WEST B., ARBOR, WELCH. 2006, *Linear Mixed Models: A Practical Guide Using Statistical Software*, CRC Press, United States.