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Models of changes in the functional properties of polyolefin packaging films

Summary — During its usage, polyolefin packaging films undergo an aging process, which results in irreversible changes in their properties, which in turn can influence their functional value. The level of the packaging films' functional value is determined to a large extent, by climate factors, which react with these materials during their storage and the storage of the products packed in them. Therefore, the development of the model predicting changes in the functional properties of polyolefin packaging films including the impact of microclimate conditions seems to be important.
Keywords: polyolefin packaging films, functional value, aging.

MODELE ZMIAN WŁAŚCIWOŚCI UŻYTKOWYCH POLIOLEFINOWYCH FOLII OPAKOWANIOWYCH

Streszczenie — Poliolefinowe folie opakowaniowe podczas użytkowania podlegają procesom starzenia, w wyniku których zachodzą w nich nieodwracalne zmiany właściwości wpływające na wartość użytkową. Jest ona zdeterminowana w dużym stopniu przez czynniki klimatyczne oddziałujące na te materiały podczas ich przechowywania oraz przechowywania zapakowanych w nie produktów. Z tego względu ważne jest opracowanie modelu prognozowania zmian właściwości użytkowych poliolefinowych folii opakowaniowych z uwzględnieniem wpływu warunków mikroklimatycznych (rys. 1—6). Opracowany model ogólny pozwala na opis zmian parametrów krytycznych w funkcji czasu na podstawie statystycznej istotności oszacowanych parametrów modelu, modele szczegółowe zaś umożliwiają wyznaczenie współczynników folii oraz wariantów warunków magazynowych. Uzyskane za pomocą opracowanego modelu informacje stanowią podstawę do oszacowania stopnia pogorszenia właściwości przechowywanych folii.
Słowa kluczowe: poliolefinowe folie opakowaniowe, wartość użytkowa, starzenie.

INTRODUCTION

One of the basic attributes of packaging materials, important in terms of storage and usage, is their functional value [1], which can be described as the degree to which a set of the properties of these materials satisfies the requirements connected with their usage. The functional value of packaging materials can be encompassed in the range from 1 to 0. According to A. Ortiz, R. Salas, N. Allen [2] and T. Zaharescu [3] the level of the functional value of the packaging films in a given period of time of usage should be stable, however the derivative factors such as: conditions and the period of storage as well as the effect of exposure may impact on their properties, leading, in consequence, to the decrease of their functional value.

During the storage and usage of packaging materials several unfavorable changes may be observed, which are connected mostly with the exposure to climate conditions, in other words, the exposure is a reason of the destructive impact of climate factors on the products.

According to the research conducted by M. Hampel and V. Heidenbut [4] temperature, sunlight, oxygen, humidity or air pollution [5] are among the climate factors having a great impact on the properties characterizing the functional value of the plastic packaging films. The effects of the impact of the factors mentioned above depend mostly of the time of exposure (duration), or the type of investigated polymer (including its molecular structure) [6] as well as the general conditions of storage. This was confirmed by G. Wypych [7,] M. Villetti, J. Crespo M. Soldi [8] and A. Korzeniowski i N. Czaja [9]. According to M. Hakkarainen, A. Albertson [5] and Z. Kolek [10], the analysis of the influence of the unfavorable changes on the properties of packaging films is mostly based on the evaluation of the parameters changing most quickly in the course of storage and usage. In the case of polyolefin packaging films, these parameters are the elongation and breaking load, which characterize the mechanical pro-

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T a b l e 1. Overview of technical data analyzed polyolefin films declarated by producers*)

Film's parameter	Sample form	Kind of films				
		BIAXFOL/ Folmar	CRISTEL/ Plasticos	BIFOL BG/ Flexpol	POLITERM TB/ TB Packaging	ECOR FPO WRAP/Ecor
Thickness, μm	—	25	25	25	25	40
Apparent density, g/cm³	—	0.92	0.91	0.91	0.90—0.97	—
Breaking stress, MPa	along the length *KM*	110	115	120	115	—
	across *KP*	110	110	220	100	—
Extension, %	along the length *KM*	100	120	180	110	—
	across *KP*	115	100	100	100	—
Composition of the material	—	OPP-PE	PE Dowlex+ PP KS 400	OPP	Copolymer of ethylene and octene-1 (PE-LLD)	48.5 % — polyolefins, 51.5 % —minerals (chalk, talc)
Period of storage	—	not specified	24 months	not specified	not specified	not specified

*) Source: Technology card of Biaxfol film, Commercial specifications of Cristel film, Datasheet of Bifol BG film, Product card PolitermTB film, Datasheet of Ecor FPO WRAP film.

perties of these materials. Additionally, according to T. Zaharescu [3] a change of the structure of plastic materials as a result of the process of their functional value decrease should also be thoroughly observed. Taking into account the usage or usability of polyolefin packaging films for packing on high-efficiency filling and packing machines, it is essential to create a model that allowed to describe the changes in their functional value in the course of usage/storage in different microclimate conditions [11]. The main goal of this study was to develop polyolefin packaging films functional value models, which could synthetically describe the changes of each of the parameters characterizing the functional value and considering the impact of the different variants of microclimate conditions as a function of time.

EXPERIMENTAL

Materials

The basis of creating the polyolefin packaging films functional value general model were studies on changes of critical characteristics [5] (breaking load, elongation and molecular weight) of polyolefin films available on the market, comparable in price and of a similar packaging efficiency. All the analyzed films are used for packaging food products such as pastries, pasta, bread, snacks and frozen products. In order to ensure the universality of the model, both homogeneous 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 these 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 packaging material produced on the basis of polyolefin with a 49,5 % fraction of chalk and talc). For testing all films before the process of shrinking were selected. A detailed description of the research material presented in Table 1.

Condition variants

The films were stored for a period of 12 months in the following microclimate conditions variants [11]:

—Variant I — stable microclimate conditions with the following parameters: T = 20±1 °C, RH = 65±2 % (normal atmospheric research conditions according to 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).

Methods of testing

— The designation of the critical parameters characterizing the mechanical properties was carried out in the course of 12 months on a regular monthly basis with the use of the INSTRON model 4301 durability machine according to PN-EN ISO 527-1:1998 standard [12].

—The physical properties in the scope of the changes in the molecular weight of packaging films and their decomposition were studied for the packaging films stored in variant I and II of the microclimate conditions. The purposefulness of such a selection of microclimate conditions variants for analysis of the changes in the molecular weights values was proven by Z. Dobkowski [12]. The molecular weights were tested in 4-month periods with the use of a Alliance GPCV 2000 gel chromatograph manufactured by Waters with a differential refractometric detector and viscosimetric detector and columns: HT 3 (500—30 000), HT 4 (5000—600 000) i PLgel 20 μm MIXED-A (2000—40 000 000) [7].

RESULTS AND DISCUSSION

The achieved average values of parameters characterizing the mechanical properties can be found in Tables 2 and 3. Based upon achieved results it may be stated that as a result of the exposure of studied films to different climate factors in the course of long-term (12-month) storage, the parameters characterizing the mechanical properties were changed in all the polyolefin packaging films. The results indicate that time is a factor reducing the average break load and elongation of all the tested packaging films. The greatest impact of time on the average break load and elongation can be noticed in the storage in the variant II (T = 40 °C and RH = 65 %) microclimate conditions. The differences in the values of the extension of the film samples stored at a higher temperature are distinctive and persist throughout the entire research period. The extension and break load along the length as well as along the width shows the lowest values in the variant II compared to the values of all other storage conditions variants.

When it comes to cooling conditions (variant IV) they actually have the smallest impact on the decrease of the break load and elongation for all studied films. After the

T a b l e 2. Changes of break load along the length *(KM,* expressed in N*)* of tested packaging films stored in different microclimate conditions variants*⁾

Kind of films	Variants of micro-climate conditions	Time of storage, months												
		0	1	2	3	4	5	6	7	8	9	10	11	12
BIAXFOL	I	20.67	21.00	20.57	20.56	20.54	20.53	20.45	20.43	20.40	20.38	20.36	20.36	20.35
	II	20.67	22.50	18.33	17.90	17.65	17.57	17.51	17.24	16.95	16.78	16.37	16.27	16.12
	III	20.67	21.44	20.55	20.39	20.28	20.28	20.27	20.26	20.25	20.23	20.21	20.12	20.11
	IV	20.67	21.07	22.91	23.39	23.17	23.08	22.92	21.79	21.75	21.44	21.12	20.90	20.66
	V	20.67	20.97	20.49	20.44	20.40	20.34	20.30	20.37	20.35	20.33	20.31	20.30	20.27
CRISTEL	I	19.09	21.30	19.69	19.46	19.14	18.80	18.25	18.02	17.91	17.73	17.70	17.57	17.53
	II	19.09	20.50	19.33	18.68	18.40	18.14	17.59	17.29	17.03	16.63	16.21	16.00	15.90
	III	19.09	21.53	19.53	19.28	19.03	18.66	18.20	17.92	17.77	17.49	17.46	17.14	17.11
	IV	19.09	20.23	20.06	19.50	19.37	19.15	18.93	18.81	18.80	18.71	18.60	18.49	18.49
	V	19.09	21.19	19.65	19.34	19.09	18.75	18.24	17.94	17.83	17.65	17.51	17.49	17.48
BG	I	31.87	32.94	32.20	31.05	30.39	30.26	28.53	28.13	28.07	28.03	28.00	28.00	27.96
	II	31.87	32.82	29.96	29.94	29.17	27.96	26.78	26.10	26.03	25.55	24.23	24.11	24.01
	III	31.87	32.75	32.13	30.34	29.10	28.48	28.40	28.10	28.00	27.77	27.41	27.37	27.36
	IV	31.87	32.09	32.01	31.95	31.91	31.43	30.09	30.08	29.02	28.86	28.86	28.83	28.74
	V	31.87	32.88	32.14	31.01	30.34	30.21	28.34	28.04	27.92	27.90	27.88	27.87	27.86
TB	I	20.16	21.44	20.11	19.95	19.86	19.68	19.49	19.48	19.43	19.40	19.36	19.31	19.28
	II	20.16	20.89	20.10	18.80	17.19	16.56	16.13	16.04	16.01	16.00	15.97	15.97	15.95
	III	20.16	21.20	19.88	19.39	19.77	19.54	19.42	19.35	19.35	19.34	19.31	19.28	19.27
	IV	20.16	21.28	21.66	21.11	20.81	20.80	20.64	20.47	20.37	20.23	20.19	20.16	20.16
	V	20.16	21.20	20.10	19.91	19.82	19.61	19.40	19.39	19.38	19.38	19.37	19.36	19.35
ECOR	I	13.13	13.75	13.10	12.48	12.76	13.75	13.87	13.46	13.27	13.26	13.13	13.12	13.11
	II	13.13	13.67	12.66	12.96	12.64	13.46	13.26	13.04	12.54	12.52	12.50	12.50	12.50
	III	13.13	13.54	12.14	12.12	12.93	13.41	13.51	13.27	13.11	12.92	12.90	12.83	12.83
	IV	13.13	13.71	13.20	12.81	13.16	13.30	14.62	14.19	13.82	13.45	13.33	13.18	13.13
	V	13.13	13.33	12.81	12.28	12.68	13.63	13.56	13.37	13.23	13.22	13.12	13.11	13.10

*⁾ Source: own research.

T a b l e 3. Changes of extension along the length (*KM*, expressed in %) of tested packaging films stored in different microclimate conditions variants[*)]

Kind of films	Variants of micro-climate conditions	Time of storage, months												
		0	1	2	3	4	5	6	7	8	9	10	11	12
BIAXFOL	I	25.32	27.91	27.65	26.35	25.99	25.66	24.63	24.02	23.99	23.88	23.66	23.51	23.50
	II	25.32	23.49	23.18	22.36	21.54	21.51	21.25	20.73	20.03	20.01	19.66	19.46	19.48
	III	25.32	26.78	26.47	26.04	25.47	25.18	24.07	23.85	23.82	23.70	23.38	23.21	23.15
	IV	25.32	24.98	23.17	30.53	31.81	31.68	31.51	28.52	26.43	26.00	25.68	25.22	25.20
	V	25.32	26.14	26.07	25.15	24.54	24.26	23.88	23.32	23.04	23.00	22.64	22.58	22.20
CRISTEL	I	40.91	42.74	42.57	41.66	41.28	41.27	41.16	40.91	40.63	40.42	40.38	40.35	40.26
	II	40.91	41.24	41.01	40.94	40.50	40.38	40.19	40.15	39.76	39.65	39.55	39.16	38.63
	III	40.91	42.03	42.00	41.57	41.21	41.15	41.09	40.60	40.55	40.37	40.33	40.31	40.20
	IV	40.91	44.68	43.02	42.42	42.30	42.12	42.11	42.09	42.05	42.00	41.99	41.96	41.95
	V	40.91	41.81	41.80	41.60	41.26	41.18	41.14	40.67	40.60	40.40	40.36	40.34	40.21
BG	I	14.78	15.49	14.75	14.11	13.17	12.93	11.02	10.26	10.23	10.21	10.19	10.14	10.12
	II	14.78	14.48	12.69	11.68	10.35	9.21	8.04	6.90	6.74	6.59	6.56	6.55	6.55
	III	14.78	15.27	14.50	13.87	13.00	12.74	10.54	9.61	8.15	8.03	8.01	7.94	7.92
	IV	14.78	15.73	15.12	15.08	14.93	14.90	14.78	14.76	14.52	14.50	14.45	14.31	14.20
	V	14.78	15.32	14.49	13.92	13.07	12.47	10.95	10.09	9.84	9.35	9.32	9.32	9.32
TB	I	35.55	40.95	39.89	36.70	36.50	36.29	36.07	36.01	35.04	34.60	34.52	34.44	34.40
	II	35.55	37.71	35.95	34.61	34.28	34.26	34.15	33.84	33.10	32.47	31.83	31.11	31.00
	III	35.55	39.63	37.03	36.63	36.06	35.84	35.43	34.69	34.14	34.02	33.97	33.20	33.17
	IV	35.55	35.61	35.59	35.59	35.49	35.46	35.24	35.22	35.18	35.12	35.09	35.01	35.00
	V	35.55	40.01	37.72	36.03	35.87	35.77	35.74	35.63	34.90	34.32	34.18	34.02	34.01
ECOR	I	139.38	115.52	138.67	135.02	130.11	127.81	123.81	120.14	99.85	98.53	98.48	98.02	97.97
	II	139.38	113.48	120.41	123.57	120.42	117.60	92.28	91.64	91.00	89.86	88.40	84.32	84.32
	III	139.38	114.20	134.38	131.36	129.65	126.61	121.45	119.69	98.10	97.84	96.94	94.62	94.08
	IV	139.38	112.28	126.09	127.49	127.04	126.37	121.21	119.53	111.24	107.17	106.18	105.58	104.28
	V	139.38	114.29	137.11	134.55	127.20	126.98	122.36	120.10	99.19	98.51	98.51	94.26	94.20

[*)] Source: own research.

initial dramatic growth, these parameters systematically decrease, however always reaching a much higher value than in the case of packaging films stored in all other microclimate conditions.

The average molecular weights of the tested polyolefin packaging films are presented in Table 4. The results of the investigation conducted by A. Sipinen, D. Rutherford [13], P. Gijsman, G. Meijers, G. Vitarelli [14] and A. Peacock [15] demonstrate that the rate of oxygenating degradation of polyolefin packaging films strongly depends on the temperature, while the thermal durability of polyolefin packaging films also increases with the increase of the average molecular weight.

The results of the critical characteristics changes as a function of time are served as a basis to create a model of functional value including the impact of the microclimate conditions on the film usage and storage.

Considering the panel character of the achieved data the designed model contains a linear impact of time and

T a b l e 4. Packaging film's molecular weight (expressed as average values of molecular weights) test results achieved in the course of storage under microclimate conditions variant I and II[*)]

Kind of films	Variants of microclimate conditions	Time of storage, months			
		0	4	8	12
BIAX-FOL	I	292 324	252 524	223 956	210 523
	II	292 324	242 394	213 562	196 454
CRIS-TEL	I	349 149	293 562	263 768	241 472
	II	349 149	264 935	248 734	215 891
BG	I	300 989	282 486	259 816	100 056
	II	300 989	216 304	88 716	68 589
TB	I	416 139	340 923	286 407	277 023
	II	416 139	285 777	277 763	247 615
ECOR	I	805 102	747 734	624 660	590 101
	II	805 102	716 163	617 770	553 666

[*)] Source: own research.

an additive impact of the type of packaging film as well as the variant of microclimate conditions in the course of the storage process [16]. As the type of packaging film and microclimate conditions are nominal variables, they were re-coded to so called artificial variables (zero-one) [1]. For this model, two variables were prepared (the type of packaging film and the variant of microclimate conditions in the course of storage).

The variable defined as the type of packaging film consists of 5 levels, with one of the tested packaging films (Biaxfol film) serving as a reference level. The artificial variables for the microclimate conditions variants in the course of storage were constructed in the same way. In the case of that variable, the reference level was set as I variant the microclimate conditions, which stands for normal atmospheric conditions (T = 20 °C, RH = 65 %). The created model was then fitted using the least-square method [8, 17].

In an attump to include the potential correlation effect of the observation in the subsequent periods of time as well as the heteroscedastic effect, a resistant covariance matrix estimator was applied [1]. In this way, a resistant evaluation of the average of errors of the estimated model parameters was achieved. On the basis of this data, the general model was created which can be described by the following equation:

$$\hat{Y}_t = a_0 + a_1 t + b_2 X_2 + ... + b_k X_k + c_2 Z_2 + ... + c_j Z_j \quad (1)$$

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;* 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;* 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.*

Due to the fact that the functional value of the polyolefin packaging films is analyzed from the point of view of the critical characteristics described by the parameters such as: break load, elongation (in both directions of the packaging film slitter) and molecular weight [18], the general shape of the model was modified, so that the created functional value models would include the impact of the microclimate conditions, based on which the analysis of the above mentioned parameters was conducted. As for the critical characteristics in the sense of mechanical properties, the application of following model is suggested:

$$\hat{Y}_t = a_0 + a_1 t + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + c_2 Z_2 + c_3 Z_3 + c_4 Z_4 + c_5 Z_5 \quad (2)$$

where: X_2 *— artificial variable, takes value 1, when the II-nd variant of microclimate conditions of the packaging films' storage is analyzed, in all other cases it takes value 0;* X_3 *— artificial variable, takes value 1, when the III-th variant of microclimate conditions of the packaging films' storage is analyzed, in all other cases it takes value 0;* X_4 *— artificial variable, takes value 1, when the IV-th variant of microclimate conditions of the packaging films' storage is analyzed, in all other cases it takes value 0;* X_5 *— artificial variable, takes value 1, when the V-th variant of microclimate conditions of the packaging films' storage is analyzed, in all other cases it takes value 0;* Z_2 *— artificial variable, takes value 1, when the CRISTEL film is analyzed, in all other cases it takes value 0;* Z_3 *— artificial variable, takes value 1, when the BG film is analyzed, in all other cases it takes value 0;* Z_4 *— artificial variable, takes value 1, when the TB film is analyzed, in all other cases it takes value 0;* Z_5 *— artificial variable, takes value 1, when the ECOR film is analyzed, in all other cases it takes value 0.*

The main goal of developing the model presented above was to measure the synthetic description of the functional value of polyolefin packaging films. The changes in the functional value of the analyzed packaging films, viewed as changes in the particular parameters characterizing the functional values and including the impact of the different variants of microclimate conditions in the course of storage were presented in Figs. 1, 2.

The realization of such a defined goal proceeded on the basis of the interpretation of the estimations of the model parameters, using the classic predictive validity test, Student's t-test, for each of the parameters of the linear model. The zero hypothesis was tested, which says that the value of any given parameter of regression equals 0. On the other hand, the alternative hypothesis says that the value of any given parameter of regression is different from 0. Therefore, the value of p lower than 0.05 indicates that the zero hypothesis should be rejected. The calculated values of parameters characterizing the mechanical properties of the model can be found in Table 5.

T a b l e 5. Estimated values of model parameters characterizing mechanical properties of tested polyolefin films[*)]

Variable name	Break load along *KM*		Elongation along the length *KM*	
	estimated parameter	*p*-value	estimated parameter	*p*-value
An absolute term	1.0503	0.0000	1.1698	0.0000
Time, month	-0.0095	0.0000	-0.0239	0.0000
Variant II	-0.0839	0.0000	-0.1423	0.0000
Variant III	-0.0122	0.1133	-0.0238	0.2006
Variant IV	0.0382	0.0000	0.0292	0.1165
Variant V	-0.0048	0.5346	-0.0083	0.6545
CRISTEL film	-0.0095	0.2193	0.0430	0.0210
BG film	-0.0642	0.0000	-0.1527	0.0000
TB film	-0.0158	0.0410	-0.0870	0.0000
ECOR film	0.0243	0.0017	-0.2361	0.0000
	R^2 = 0.67		R^2 = 0.67	

Source: own work.

Based on the results shown in Table 4, the statistical validity of the estimated model parameters can be con-

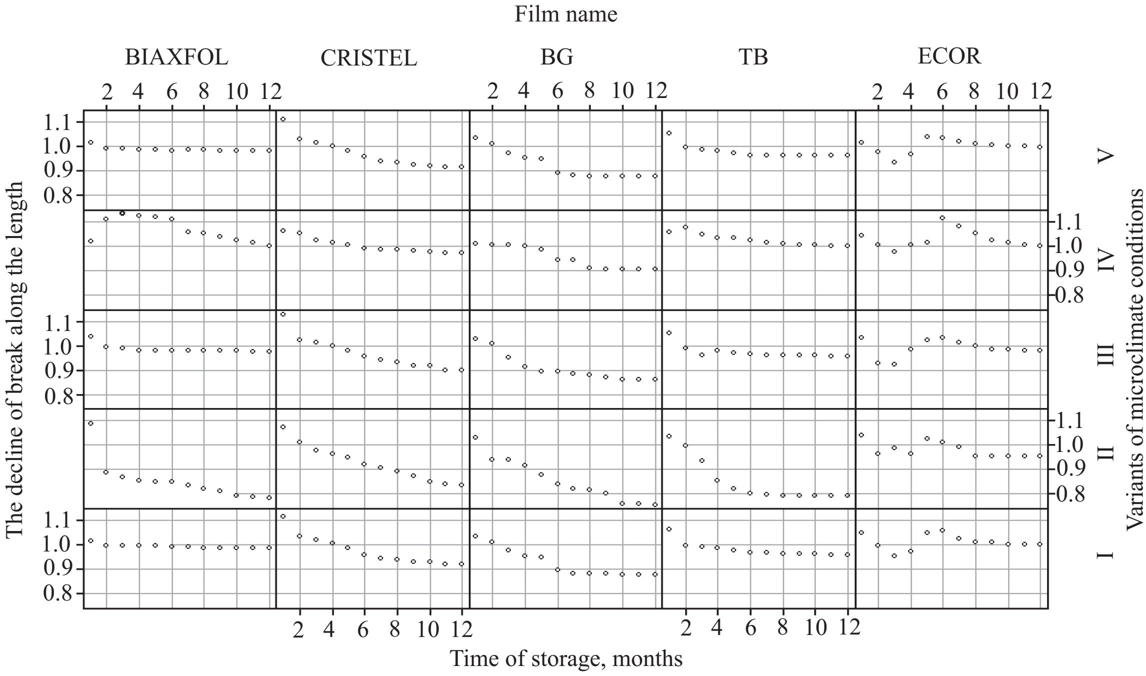

Fig. 1. Change of break load along the length of packaging films in the course of storage under different microclimate conditions variants

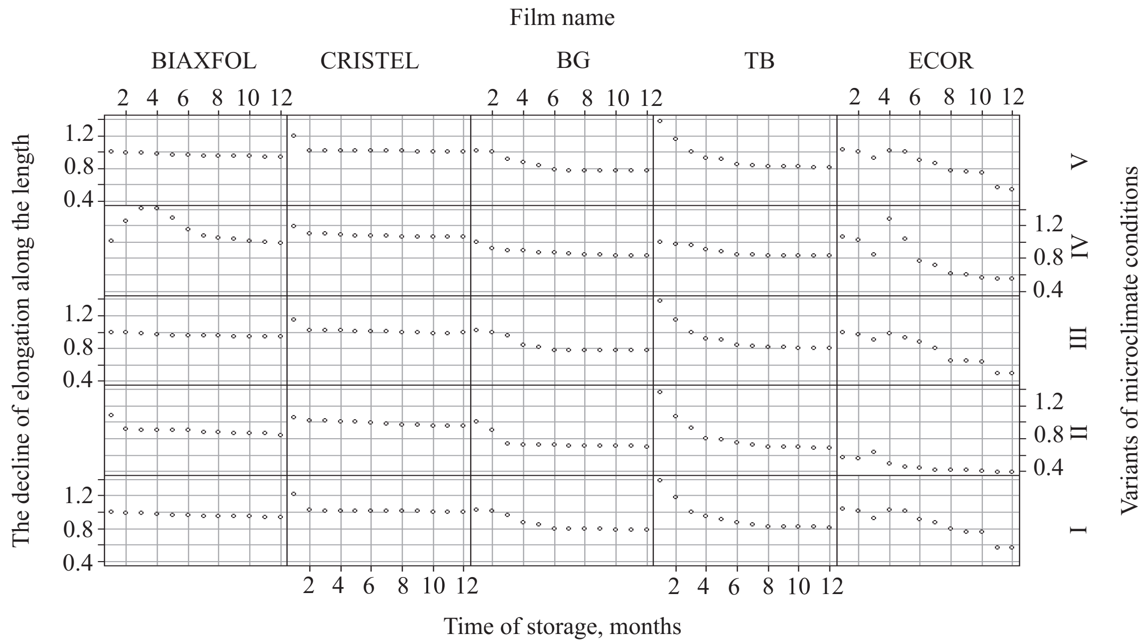

Fig. 2. Change of elongation along the length in the course of tested packaging films' storage under different microclimate conditions variants

firmed. Fitting the estimated models to the data was performed by the application of the determining factor (R^2). The precision of the estimated parameters was on the level of 67 %.

The analysis of the molecular weight as a parameter describing another critical characteristic, considering the included number of microclimatic variants in the course of the storage, for which this parameter was indicated, resulted in modification of the general model presented above. Therefore, another model was created:

$$\hat{Y}_t = a_0 + a_1 t + b_2 X_2 + c_2 Z_2 + c_3 Z_3 + c_4 Z_4 + c_5 Z_5 \quad (3)$$

The changes in the functional value of the analyzed packaging films as a change in the molecular weight characterizing structural changes including the impact of the different microclimate conditions in the course of the storage were presented in Fig. 3.

Analogically, similarly like in the case of the parameters characterizing mechanical properties, the model parameters were estimated, using the classic predictive

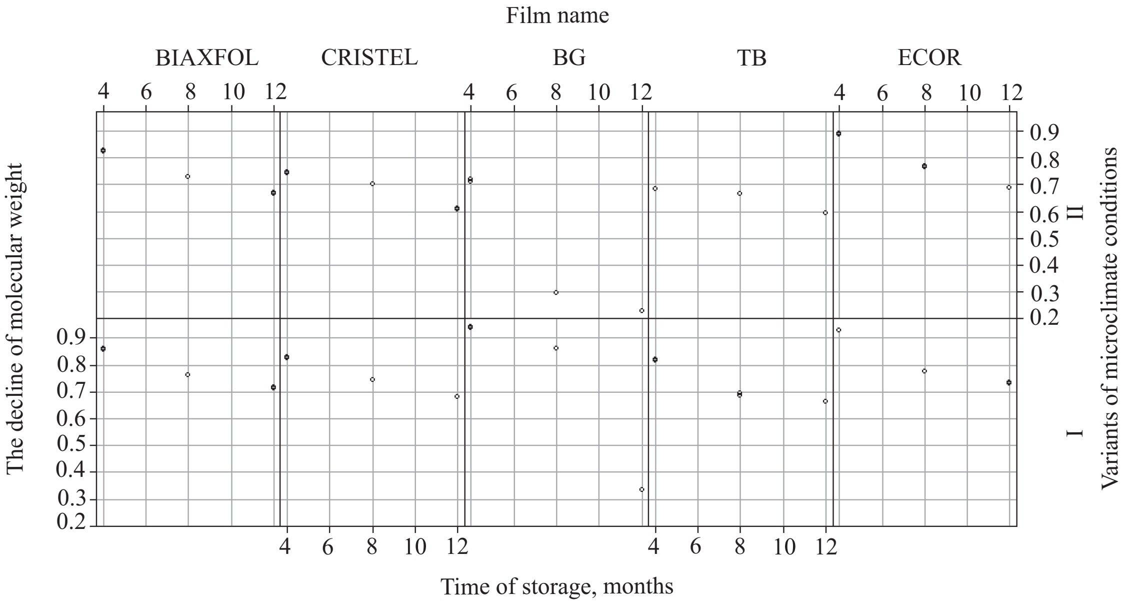

Fig. 3. Molecular weight changes of tested packaging films stored under different microclimate conditions variants

validity test, Student's t-test, which was presented in Table 5. Based on the data shown in Table 6, the statistical validity of the estimated model parameters was confirmed. The precision of the estimated parameters was on the level of 91 %, that indicates a very good fitting of the data to the model.

T a b l e 6. Estimated values of model parameters characterizing structural changes of tested polyolefin packaging film[*)]

Variable name	Estimated parameter	*p*-value
An absolute term	0.9394	0.0000
Time, month	-0.0192	0.0000
Variant II	-0.0527	0.0011
CRISTEL film	-0.0415	0.0585
BG film	0.3184	0.0000
TB film	-0.0730	0.0013
ECOR film	0.0377	0.0844
Time · BG film	-0.0491	0.0000
Variant II · BG film	-0.2464	0.0000
	R^2 = 0.91%	

*) Source: own work.

The developed general model enables the changes of critical parameters in the function of time based on the statistical validity of the estimated model parameters to be described. Additionally the detailed models help, on the basis of the parameter estimation, to designate the packaging film index and the variant of storage conditions. Based on the data from the created model, it is possible to determine the average monthly impact of the time on the changes of analyzed functional properties of the tested polyolefin packaging films. The information thus gathered enables to estimate the value of loss of the properties of the stored packaging films.

CONCLUSION

For plastic packaging materials, namely, polyolefin packaging films, a constant need of monitoring the properties characterizing the functionality of the materials to be in direct contact with the food in the course of the storage exists. Due to the fact that the scope of changes in the functional properties strongly depends on the climate factors in which these materials are exposed in the course of the storage and usage, there is a great need for creating a model which would include the impact of the said factors on the functional value level of the polyolefin packaging films. The problem of determining the functional value of these materials is extremely important from the needs of commercial practice point of view, for which it can become the basis of competitive prevalence on the market. The developed model predicting the changes in the functional properties of the polyolefin packaging films enables a synthetic description of the effect of the degression of critical parameters. Additionally, the model allows to estimate the loss of functional value of any given polyolefin packaging film and creates a possibility of predicting the reaching of critical time, which results in removing the packaging material from usage.

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