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STUDY ON THE THERMAL AND NON-THERMAL SHRINKAGE EFFECT OF TWO POLIMER FILMS AND ITS INFLUENCE ON SELECTED CHEMICAL AND COLOUR PARAMETERS DURING STORAGE OF PORK CHOPS IN VACUUM PACKAGING

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Abstract

Extension of the shelf life of meat on the market is one of the most important requirements that are placed in front of the meat industry because, in addition to safety and quality, contains and significant economic momentum. This paper presents a part of the examination of the project III 46009, funded by the Ministry of Education, Science and Technological Development of Republic of Serbia. The aim of the study was to observe the effect of thermal shrinkage on the differences in the sustainability of the application of these two packaging procedures.

In summer and winter cycle were conducted tests for sustainability of pork chops in a vacuum packaging of 7 and 9 layered foil. Samples were transported immediately after packing using the vehicle with Thermo King and stored in conditions of 1 - 3 ^{0}C. In the first cycle, the packaging is done with a thermal shrinkage, while in the second cycle subsequently thermal shrinkage after vacuuming was not done.

There were registered statistically significant differences in terms of TVB-N, pH and aw values between these two cycles ($p < 0.001$), and the values of color (L*, a* and b*; $p < 0.001$), measured using Konica-Minolta device, between the two types of films in both cycles. Looking at the days between these two cycles when the test was done, we registered a statistically significant difference ($p < 0.001$) between the acid value and the value determined by TBK test (Malon-aldehyde content).

The results indicate significantly prolonged sustainability of pork chops packed in vacuum packaging. Unpackaged pork chops were sustained up to 5 days. Under the conditions of our test, better results were obtained when, after vacuuming, is not done thermal shrinkage, because pork chops were sustained for 15 days, regardless of the type of film used, consistent with the sensory quality.

***Key words**: Sustainability, Pork chops, Vacuum packaging, Multilayer films, Thermal shrinkage.*

1. Introduction

Despite the development of new packaging technology, the Serbian meat industry has continued traditionally to dispatch fresh meat to supermarkets without excessive using the vacuum-packaging as a mechanism for increasing shelf-life during extended periods of storage.

Increasingly, red meat for retail display is being prepared and packaged centrally rather than at retail stores. Centralized packaging is growing in popularity because it requires less labor, equipment and space. It also reduces the chances of further cross-contamination [1].

Packing fresh meat is carried out to avoid contamination, delay spoilage, permit some enzymatic activity to improve tenderness, reduce weight loss, and where applicable to ensure an oxymyoglobin or cherry-red color in red meats at retail or consumer level [2].

Vacuum packing expands the shelf life of fresh pork even further than high-oxygen MAP. Vacuum packing eliminates the air surrounding the meat and consequently the meat color changes from the red oxymyoglobin color to the purple deoxymyoglobin color [3]. Here the product is placed in an air-tight pack, the air

sucked out and the package sealed. By removing air from around the product, the levels of oxygen in the packaging are reduced, impeding the ability of oxygen-breathing microorganisms to grow and spoil the product. The lack of oxygen also reduces the amount of spoilage due to oxidation – the process that causes apples and bananas to turn brown, for example. A certain amount of oxygen will remain, however, because it is not possible to create a total vacuum. Air contains around 21 per cent oxygen at normal atmospheric pressure – 1000 mb. As the air is withdrawn during the vacuum packaging process, the pressure inside the package is reduced. If, for example, the pressure is reduced to 100 mb, an equivalent of around 2.1 per cent oxygen will remain; if it is reduced to 10 mb, there will still be in effect 0.21 per cent oxygen present.

The color of meat is one of the most important parameter of quality and freshness, as well as first quality attributes determinating consumers in retail. Consumer acceptable color of pork is light pink, light red-pink or light red [4, 5, and 6]. Wide variations in color of meat, regardless of whether they are a consequence of differences in WHC (Water Holding Capacity), pH or chemical state of the pigments, make it sensory and technologically undesirable.

The purple color of meat and also the visible purge loss in the vacuum bag is thought to be unattractive to consumers, which is why vacuum packing is not frequently used for retail display in Serbia. Purge loss may be susceptible to bacterial growth and this could be a problem when it occurs in vacuum bags. However, there are some retailers that sell larger pieces and sub-primal cuts of beef and pork packed in vacuum at Serbian supermarkets.

Thus, it is well known, that multiple factors can affect the storage life of vacuum packaged cuts that individual processor controls, although specific differences among processors which use this technology have to be determined [7]. The present research explored the differences in shelf-life that may exist as a result of these that occur using different processor vacuum packaging procedures.

Air contains about 21 percent oxygen. Oxygen negatively affects unpackaged meat and meat products during prolonged storage cycles. It changes the red meat color to grey or green and causes oxidation and rancidity of fats resulting in an undesirable off-flavor.

The oxygen permeability of films used for the packaging of meat products varies. The lower the oxygen permeability the more efficient the protection of product quality. The best protection will be achieved using oxygen-proof packaging films together with vacuum packaging of the product. This ensures that practically no oxygen remains in the package and no oxygen will penetrate from the air into the packaged product. Practically all the other films used for meat packaging are designed as strong oxygen and water-vapor barriers. In order to fully achieve these requirements, films with good barrier properties for oxygen and water vapor respectively are combined.

Processed meat products in slices or as entire pieces are packed in small to medium-size vacuum bags. For larger sized products, bags made of shrinkable films can be used where, after vacuum-packaging, the product in its package of synthetic film is sprayed with or dipped into hot water (80 ^{0}C). The contact with the hot water causes the shrinkage of the thermoplastic film and results in tight impermeable wrapping of the goods. Shrink films may for example be composed as follows: PET (polyethilene-teraphalate)/PA (polyamide)/EVOH (ethilene-vinyl alcohol)/PE (polyethilene) [8].

It is known that during storage the oxidative processes that occur in both lipid and protein fractions of meat are one of the major causes for changes in its quality parameters. Lipid oxidation is often responsible for quality loss via formation of rancid flavor and is affected by the duration and temperature of storage of meat [9] as well as the presence of oxygen. During chilled and frozen storage lipid oxidation is usually slow, but does not stop since the reactive species are soluble in the lipid fraction and stable at low temperature [10]. Freshness indicators provide direct product quality information resulting from microbial growth or chemical changes within food product [11]. The quality of meat and meat products degrade as a result of digestive enzymes, microbial spoilage and fat oxidation. Proteins and lipids can break down resulting in the production of new compounds causing changes in meat flavor, tenderness, juiciness, odor and texture [12].

Lipid oxidation causes a rancid off-flavor and off-odor in meat and it is initiated in muscle systems at the membrane level in the intracellular phospholipids fractions. Many factors affect lipid oxidations: light, temperature, oxygen concentration, degree of non-saturation of the fatty acids and the presence of enzymes [13]. Among these factors, fatty acid structure of muscle is the most important because it affects the number and the proportion of the produced hydroperoxides [14]. According to Zhao *et al.* [15], lipid oxidation has slower increasing than microbial growth and discoloration and it is not considered to be a limiting factor for shelf life of aerobic packed meat. Increased lipid oxidation has been reported for meat stored at elevated oxygen concentrations [16]. Lipid oxidation does not only contribute to off-flavor, but it is also essential to the typical aroma for many meat products [17].

Among the many factors that influence the color of pork is the most important content of pigments at the time of animal death. The main carrier of color is sarkoplasmatic protein - pigment myoglobin (Mb), that gives a red color of muscle, reversibly binding oxygen [6].

The objective of this study was to determine the shelf-life of pork chops packaged in two kind of multilayered plastic bags, using two vacuum packaging procedures (with and without thermal shrinking of sealed bags) intended to distribution in Serbian supermarkets and public food services as well, through instrumental determination of color and chemical and physico-chemical analysis, to access the rate of lipid oxidation.

2. Materials and Methods

2.1 Procurement of samples and testing dynamics

The testing samples were packaged in the approved industrial meat processing facility including previous slaughtering, chilling and cutting operations.

Vacuum packaged wholesale pork-chops were received at the "Institute of Meat Hygiene and Technology" Laboratory for biotechnological development and food safety and quality control, Belgrade, Serbia at weeks of having been harvested and packaged. The sub-primal pork cuts (36 packages of pork chops) containing 3 chops in single pack per examination cycle, from the same processor, harvested seasonally in two period of year (winter and summer). The samples were stored under refrigeration (2 ^{0}C) and the experiment began on day after packaging and subsequently at day intervals (days 7, 10, 12, 13 and 15). The number of samples decreased in some days due to unacceptable sensory properties. The cuts, taken from 7 pork sides were about 0.5 - 1 cm thick, weighed 100 g.

2.2 Packaging equipment and materials

Packaging units were formed using industrial vacuuming device - Webomatic, with manual folding chamber for evacuation of air. Parameters during packaging were: for bags type HB-X:, for seal forming we used to (program 2; 98% vacuum); bags type HB-LX (welding - program 1.2; 98% vacuum), temperature baths for the sinking was set at 88 ^{0}C, sinking time was about two seconds, under the water level. The package of pork chops was carried out in vacuum shrink bags S-type, HB-X 200 x 300 mm - 7 layers (thickness 100 microns) and HB-LX 200 x 300 mm - 9 layer (thickness 50 microns). The packaging materials are produced by Spektar – Gornji Milanovac, Serbia (enterprise for production of multi-layer casings and barrier thermo-shrinkable films and bags).

Oxygen transmissibility for both types of bags was 8, expressed over OTR units (Oxygen Transmission Rate) measured according to ASTM D 3985-95, ASTM F 1297-98. The water vapor permeability were: for 7 layer foil - 6 expressed over WVTR units (Water Vapour Transmission Rate) while the 9 layer foil it was 12 WVTR units, measured according to ASTM E 96-00.

2.3 Chemical and physico-chemical examinations

During the meat storage, parameters that show hydrolytic and oxidative rancidity were determined. Acid number was determined by standard method EN ISO 660 [18], peroxide value by standard method EN ISO 3960 [19], and thiobarbituric acid reactive substances (TBARS) by method according to Tarladgis *et al.* [20] and Holland [21]. pH value of samples was measured by laboratory pH-meter, model Cyber Scan, pH 510 Meter, EUTECH Instruments, Netherlands, according to standard method ISO 2917 [22], and a_w value was measured by hygrometer (a_w meter FAst/1, GBX Scientific Instruments) according to standard ISO 21807 [23] method. TVBN (total volatile basic nitrogen) wad determined according to the method proposed in Official Journal of the European Union [24].

2.4 Color measurement

Color measurement was done using KONICA-MINOLTA device, with validated and accredited method. The every time the vacuum packages were opened (day 1, 7, 10, 12, 13 and 15), they were assessed for off-odor and liquid drip. After opening of packages, samples were leaved on ambient conditions for 10 minutes, standing on plastic plates to develop the surface color of packaged chops. The color measurement was done in 3 points of every single chop from particular packaging. Instrumental color parameters: lightness, redness and yellowness (L*, a*, b*) were analyzed.

2.5. Statistics

For statistical analysis we used the software package MINITAB INC. 16. Data are presented using descriptive statistics and expressed through: mean value, standard deviation, minimum value, maximum value, range interval- figure it out as the difference of maximum and minimum values. Determination of normality of the data was performed using Anderson-Darling test. One-way ANOVA was used to test the existence of statistical significant differences between the mean values of chemical and color parameters including different types of film through both cycles (periods). Determination of existing the significance of differences regarding the mean values of chemical and color parameters between pairs of the obtained values in the second step was performed using Tukey HSD test at a level of confidence of 95%.

3. Results and Discussion

In Table 1 are presented results of chemical and physico-chemical investigations. Presented values include all investigated parameters from whole investigation cycles and foil types. It must be mentioned that according sensory evaluation investigation, due to

unacceptable sensory properties, were lasted 12 days in the first cycle and 15 days in the second cycle.

Total volatile basic nitrogen (TVB-N) content (Figure 1) is an important reference index for evaluating meat freshness. In a vacuum packed (7 layered foil) meat, TVB-N were lower in the first (27.17 ± 2.88 mg/100g) and in the second cycle of examination (24.39 ± 2.37 mg/100g) in comparison with packed meat in 9 layered foil in the first cycle (28.98 ± 3.29 mg/100g). The least TVB-N value (19.20 ± 2.14 mg/100g) is obtained in the second cycle for meat packed in 9 layered foil. During the investigated study cycle (first 15 days of storage), TVB-N (min-max; mg/100g) in vacuum packed meat showed a permanent increase and were: The 7 layer; I cycle (24.85 - 31.36), II cycle (21.33 - 27.08); 9 layer, I cycle (24.98 - 32.35), II cycle (16.13 - 21.54).

Similarly to results of Sunki *et al.* [25], obtained results in our study showed that the increase of TVB-N was more rapid during the later part of storage, indicating that the rate of protein degradation was faster as storage time was prolonged (Figure 2).

Recently TVB-N limit values of cca. 20 and 30 mg N/100 g for beef and pork (corresponding to 8 and 10 days of refrigerated storage, respectively) have been proposed as indicators of meat freshness and shelf-life [26]. Total volatile basic nitrogen is a product of bacterial spoilage and often used as a chemical index to assess the quality and shelf-life of seafood products [27].

Because ammonia production increases due to the deamination of amino acids during spoilage, TVB-N has been proposed as an index of fresh meat quality and maximum acceptability limit values between of 20 and 30 mg N/100 g have been suggested for beef and pork, respectively [28]. But, in the same study it was suggested that stored meat (beef, pork) is not necessarily unpalatable until the TVB-N value reaches 30 mg N/100 g.

Table 1. Chemical parameters of vacuum packaged pork chops through examination cycles and foil types

Layer/ Cycle	Examined parameter	Total volatile basic nitrogen-TVB-N (mg/100g)	Peroxide value (mmol/kg)	Acid value (mg KOH/g)	TBARS value (mg MAL/kg)	pH value	Water activity (a)
7 I	Mean	27.17	0.00	1.955	0.093	5.71	0.963
	St. Dev.	2.88	0.00	0.876	0.040	0.14	0.005
	Min.	24.85	0.00	0.870	0.050	5.60	0.957
	Max.	31.36	0.00	2.900	0.140	5.91	0.967
	Range	6.51	0.00	2.030	0.090	0.31	0.010
9 I	Mean	28.98	0.00	1.615	0.107	5.65	0.965
	St. Dev.	3.29	0.00	0.615	0.063	0.01	0.009
	Min.	24.98	0.00	0.900	0.020	5.51	0.954
	Max.	32.35	0.00	2.370	0.180	5.74	0.981
	Range	7.56	0.00	1.470	0.160	0.23	0.027
7 II	Mean	24.39	0.00	1.420	0.063	5.94	0.976
	St. Dev.	2.37	0.00	0.534	0.028	0.15	0.001
	Min.	21.33	0.00	0.700	0.030	5.78	0.975
	Max.	27.08	0.34*	2.240	0.110	6.13	0.977
	Range	5.75	0.00	1.540	0.080	0.35	0.002
9 II	Mean	19.20	0.00	1.723	0.128	5.81	0.976
	St. Dev.	2.14	0.00	0.765	0.056	0.13	0.002
	Min.	16.13	0.00	0.890	0.030	5.64	0.972
	Max.	21.54	2.55*	2.830	0.190	5.96	0.979
	Range	5.41	0.00	1.940	0.160	0.32	0.007

*Only one value registered; 7I – 7 layered bags from I cycle; 9 I – 9 layered bags from I cycle;
7 II – 7 layered bags from II cycle; 9 II – 9 layered bags from II cycle;

Statistically significant differences were registered in regard to TVB-N as between different types of films within the cycle (II) or the same types of films between the ran cycles ($p < 0.001$). Thus, statistically significant differences for this parameter, between 9 layer film in the first cycle, registered in comparison to the 9 layer in the second, and also the lack of statistical differences between different types of film (7 and 9) within the first cycle.

Higher TVB mean values are recorded in both foil types in the I cycle (with no thermal shrinking of bags) in comparison to II (with thermal shrinking). Looking at different type of foils deployed within the same cycle, significant differences in regard to TVB N value were registered in the II cycle ($p < 0.001$), while in the I cycle those differences were not significant ($p > 0.05$).

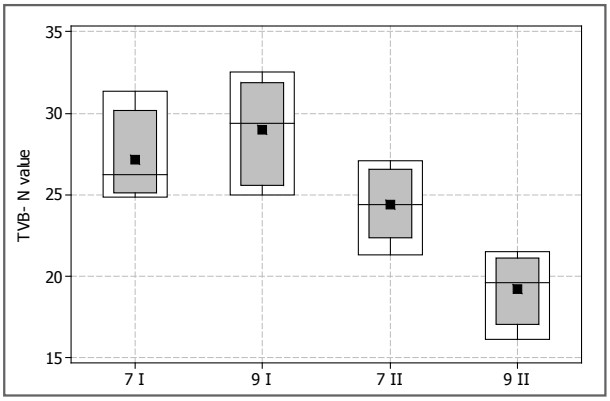

Figure 1. Box-plot of TVB-N value by cycles and foil type

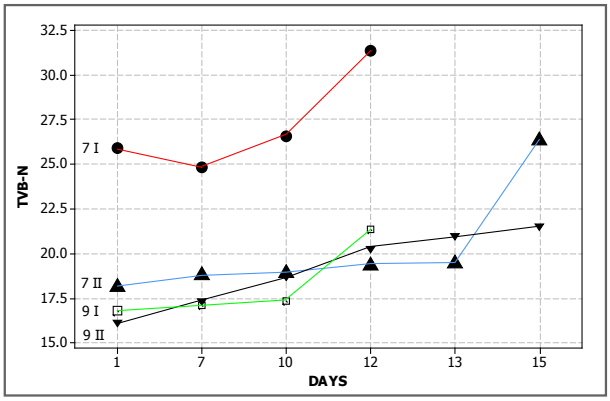

Figure 2. TVB N value trends in various types of foils between the packaging cycles by the storage days

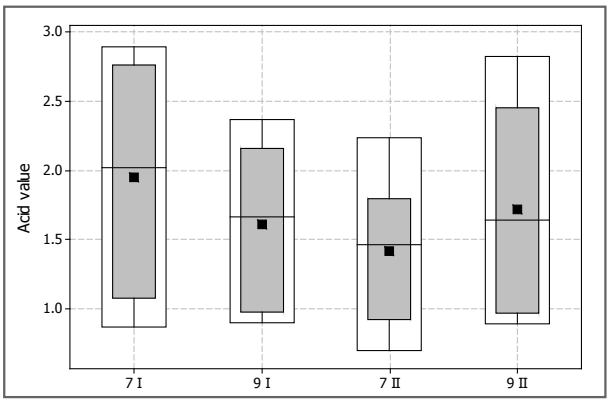

Figure 3. Box-plot of acid number values by cycles and foil type

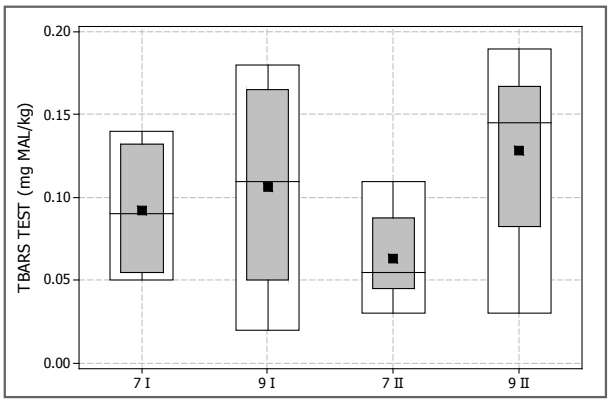

Figure 4. Box-plot of TBARS values by cycles and and foil type

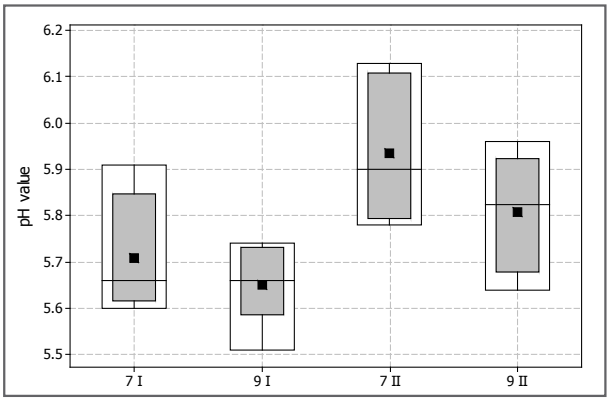

Figure 5. Box-plot of pH value by cycles and foil type

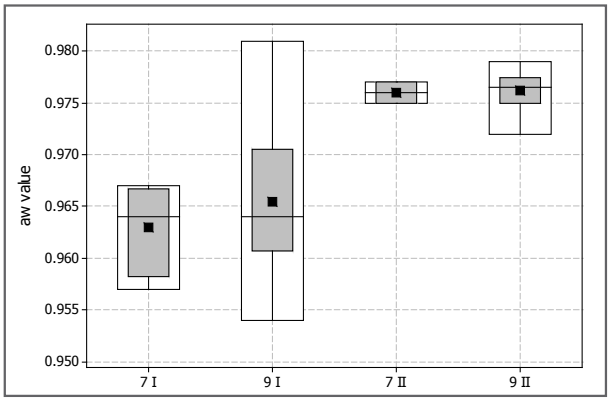

Figure 6. Box-plot of aw values by cycles and foil type

Within the same foil type, in regard to TVB N, the 7 layer foil from I cycle didn't differ significantly from the 7 layer foil from II cycle ($p > 0.05$), while in the case of the 9 layer foil used for packing in the I and the II cycle, statistically significant difference was registered ($p < 0.001$).

Taking into account the nature of the above mentioned statistical differences, it can be stated that the chops packaged in the 9 layer foil from both of the packaging cycles (with or without thermo shrinking after vacuuming process) generally show a slightly rising trend of TVB N values in comparison to the 7 layer bags (Figure 2).

Through both of the cycles, the peroxide value didn't change, looking at both of the foil types (Table 1). There were only two extreme values registered at the end of day 15 in both foil types from II cycle (0.34 mmol/kg and 2.55 mmol/kg, 7 and 9 layer foil, respectively), when the examination ended due to unacceptable sensoric changes. Peroxide value is connected mostly with pH value of meat. If pH value is closer to neutral point, it is favorable conditions for oxidation [29]. According to Khaksar *et al.* [30], the amount of hydro peroxide increased more rapidly at pH = 6.8 than pH = 3.

Observing the obtained values in regard to acid number (Figure 3), there is an increase in mean values registered in the I cycle, summer period-without thermo shrinking (1.95 ± 0.88 mg KOH/g and 1.62 ± 0.62 mg KOH/g, 7 and 9 layer foil, respectively), while lower average values are registered in the II cycle, winter period – with thermo shrinking (1.42 ± 0.53 mg KOH/g and 1.72 ± 0.76 mg KOH/g, 7 and 9 layer foil, respectively). There were no statistically significant differences registered between the same or different foil types within the same cycle, and also between ran cycles ($p > 0.05$). Acid number is the parameter that shows the first step in degradation of meat lipids and sign hydrolytic changes of lipids. It can not be used as only one indicator for meat rancidity and its increasing during the storage is common appearance. Value of acid number is linked with the moisture content in meat which contributes to biolysis reactions [31].

The thiobarbituric acid reactive substances (TBARS) test (Figure 4) is a common method to measure lipid oxidation in meat which determines malondyaldehide (MDA) content [32]. The degree of oxidation of meat is generally assessed by measuring the content of secondary degradation products that arise from oxidation of polyunsaturated fatty acids. These secondary products can cause loss of color and nutritive value [33] and are directly related to carcinogenic and mutagenic processes [34]. A higher TBARS value indicates a greater degree of oxidation of meat. Oxidation of lipids in meat depends on several factors: the level of the antioxidant vitamin E and pro-oxidants such as the free iron presence in muscles. TBARS values were rising in both of cycles, looking at the days when the packages were opened and investigated. In the 7 layer foil packed meat, TBARS were from 0.05 mg MAL/kg to 0.14mg MAL/kg (I cycle), and from 0.03 mg MAL/kg to 0.11 mg MAL/kg (II cycle); in the 9 layer foil packed meat, TBARS were also permanently increasing and ranged from 0.02 mg MAL/kg up to 0.18 mg MAL/kg (I cycle) and from 0.03 mg MAL/kg up to 0.19 mg MAL/kg (II cycle), (Table 1). Looking at the changes of mean values of TBK, during the examination period in the same foil types used for packaging, there were no statistically significant differences across different foil types within the same cycle, and also between ran cycles ($p > 0.05$). TBARS is one of the products derived from peroxide decomposition and has the potential for reaction with other components [35]. Changes of TBARS are related to peroxide value. Simultaneous increase of TBARS and peroxide value at 15th day (II cycle, the 7 layer and the 9 layer foil packed meat) was probably due to the partial decomposition of peroxide beside its formation, which resulted in an increase in TBARS and that is in accordance to results showed in the study of Khaksar *et al.* [30]. Similar, the maximum values of TBARS in I cycle (0.14 MAL/kg and 0.18 MAL/kg, respectively) are probably caused with an intensive degradation of peroxide occurring simultaneously (peroxide value was 0 mmol/kg in both cases). According to Wong *et al.* [36], the amounts of 3 mg MAL/kg is the critical value at which rancidity is detected.

In regard to pH values (Figure 5), there were differences of pH values registered in certain foil types between cycles ($p < 0.001$). Within this particular cycle, significant differences in pH values, between different foil types (7 layers and 9 layers) are not registered ($p > 0.05$). There were differences registered regarding the pH values of chops packaged in the 7 layer foils between packaging cycles ($p < 0.001$). Looking at different types of foils, there was a statistical difference registered between pH values measured in the 9 layer foil from II cycle to the 7 layer foil from I cycle ($p < 0.001$).

According to Russel *et al.* [37], the growth of spoilage bacteria in meat occurs at pH values from 5.5 to 7.0. Measured values in regard to pH in our study observing both of cycles and foil types (the 7 layer and the 9 layer) were in range (min - max) 5.51 - 6.13. According Khaksar *et al.* [30], the contents of the hydroperoxide as a measure of lipid oxidative degradation increases significantly at pH=6.8 in comparison to pH = 3, thus resulting a higher content of malondialdehyde (pH = 6.8). However, the formation of lactic acid as consequnece of lactic bacteria growth decreases pH. Vacuum packaging favorize arrival of anaerobic bacterial microflora, together with lactic bacteria, *Enterobacteriaceae* and *Brochothrix thermosphacta* [38]. The content of the package is increased in CO_2, lactate and other acidic products, thus lowering the pH value, whereby, there is involved not only microorganisms , but also the meat enzymes [39].

Microbiological safety of food is directly influenced by water activity (a_w). Most fresh meats have a water activity more than 0.85 and require refrigeration or another barrier to control the growth of pathogens [40]. Micro-organisms generally grow best between a_w values of 0.980 - 0.995 [41]. Obtained results in present study shown similar mean values of chops packaged in the first cycle in regard to both of used foil types : the 7 layer: 0.963 ± 0.005 and the 9 layer: 0.965 ± 0.009. Also mean values regarding aw registered in both of foil types were similar in the second cycle: the 7 layer: 0.976 ± 0.001; the 9 layer: 0.976 ± 0.002; (Table 1; Figure 6).

Observing a_w values, there were significant differences registered between ran cycles. This parameter differs statistically between both cycles, including the same and different foil types. There were no statistically significant differences registered between the different foil types within the same cycles ($p > 0.05$).

This can be explained by taking into account different film adhesion rate on the meat surface and also physical influence of film provoking liquid separation from meat pieces during to I cycle. Thus the amount of free liquid retained in micro space between the surface of the meat and film wrinkles due to uneven geometrical shape gave, as a consequence, higher a_w values in II cycle. But occasionally this phenomenon didn't affect the sensory properties. On contrary to the commonly established facts, the sensory quality was better in the case when thermal shrinking the vacuuming process and consequent thermal shrinking which is done in II cycle in comparison was not done. Considering the crossed, significant statistical differences ($p < 0.001$) (the values range shown in Figure 6) were registered between a_w values from II cycle in comparison to I, there can be stated that film adhesion and liquid retention between film surface and meat pieces have significant influence on the overall sensory quality. For example, the shelf life of pork chops packaged in vacuum bags (including both types of used foils) in II cycle was prolonged in comparison to I (when thermal shrinking was not done). The chops packaged in the 7 layer film in I cycle shown shorter shelf life (10 days – when unacceptable sensory changes were registered) in comparison to chops packaged in the same type of foil in II cycle (15 days).

Results of color parameters measuring are presented in Table 2 and Figures 7 and 8. Taking into account the presented results it could be argued that there are significant differences ($p < 0.001$) between the average L* values of pork chops packaged in the first cycle, 9-layer film (58.65 ± 5.59) in comparison to chops packed in the 7-layer foil (I cycle: 51.94 ± 5.44) and the 7-layer and the 9-layer film (II cycle: 50.47 ± 3.81 and 50.56 ± 5.48), respectively.

Table 2. Color parameters by cycle and foil types

Layer/ Cycle	Examined parameter	L*	a*	b*
7 I	Mean	51.94	5.74	4.23
	St. Dev.	5.44	1.12	0.89
	Min	42.56	3.79	2.36
	Max	59.61	7.38	5.42
	Range	17.05	3.59	3.06
9 I	Mean	58.65	8.11	7.01
	St. Dev.	5.59	1.50	1.55
	Min	47.39	5.82	4.21
	Max	66.42	12.15	10.31
	Range	19.03	6.33	6.10
7 II	Mean	50.47	9.14	6.56
	St. Dev.	3.81	1.86	1.44
	Min	42.42	5.67	4.04
	Max	56.84	13.51	9.50
	Range	14.42	7.84	5.46
9 II	Mean	50.56	8.04	6.26
	St. Dev.	5.48	1.34	1.26
	Min	39.86	4.97	4.06
	Max	59.86	11.68	8.96
	Range	20.00	6.71	4.90

Regarding the parameter a* (redness), there were statistically significant differences ($p < 0.001$) registered between the chops packaged in the 7 layer foil without thermo shrinking (I cycle; 5.74 ±1 12) to all other packaging types (I cycle, the 9 layer: 8.11± 1.50; II cycle, the 7 layer: 9.14 ± 1.86; II cycle, the 9 layer: 8.04 ± 1.34). Other differences, looking at the foil type, within the same or between the ran-cycles were not registered ($p > 0.05$).

The striking difference was registered in regard to parameter b* (yellowness) of chops packaged in the 7 layer foil in the first cycle: 4.23 ± 0.89 to all other packaging types and foil structure (I cycle, the 9 layer: 7.01 ± 1.55; II cycle, the 7 layer: 6.56 ± 1.44; II cycle, the 9 layer: 8.04 ± 1.34) as within the particular cycle as across ran cycles ($p < 0.001$). Other differences, including all pair wise comparisons, under the established methodology of comparisons were not registered ($p > 0.05$).

The results indicate greater variation in L*, a*, b* values of chops packed in the first cycle (the summer period). Also, the obtained L*, a*, b* values observed by day trials can be concluded that in the first cycle the chops color were paler, with a smaller proportion of red and yellow.

However, in addition to the content of myoglobin and other proteins (hemoglobin and cytochrome C), the color of the meat affects a number of other pre -mortem factors (breed, housing conditions, nutrition,

age, season, pre-slaughter handling of animals, type of muscle) and post-mortem factors [6, 42]. It is well known that pigs as a species are particularly sensitive to high temperature [43, 44], and heat stress before slaughtering increases incidence of PSE meat [45, 46] and affects the color of the meat by causing a drop in pH, reduction of the WHC and the L* values increase.

Color lightness (L* value) are usually measured 24 hours post mortem, in combination with other parameters (pH, water holding capacity), and used to as an indicator of the quality of meat [47, 48].

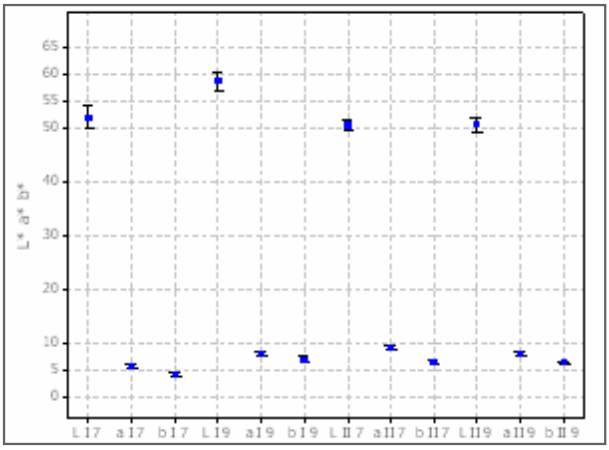

Figure 7. Measured color parameters (L*, a*, b*) by cycles and foil types

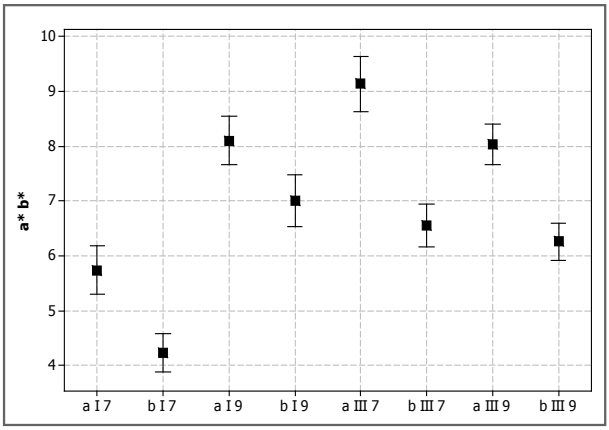

Figure 8. Measured color parameters (a*, b*) by cycles and foil types

If we adopt the lightness (L*) as cutoff value 55 [49] that separates the muscles with acceptable color defined as "normal" from those dedicated as PSE meat (Pale Soft Exudative) the results of our study indicate that the incidence of PSE meat, as well as color variations in muscles were more distinctive in the first packaging cycle (summer period of the year) in comparison to second (winter period). The obtained results are in line with findings of Warris [50]. He found that a higher lightness and a higher water loss in the *m. longissimus dorsi* carcasses of pigs slaughtered at temperature higher than 18 ^{0}C in comparison to those slaughtered at a temperature bellow 18 ^{0}C. Krzecio *et al.* [51] examined the impact of slaughter season to pork quality and they found a higher incidence of PSE meat in the period spring-summer compared to autumn-winter period.

4. Conclusions

- The results of this study show differences between packaging (with and without thermal shrinking) in different kinds of foil types. However, chops from II cycle (without thermal shrinking) had lower purge loss which might be more appealing to the consumers in retail display.

- Acid number, peroxide value and TBARS, as well as TVB-N, pH value and a_w value are important factors that influence meat shelf life and their highest values shows the moment when fresh meat in the both of applied packaging procedures and used packaging materials loses appropriate chemical and physico-chemical quality.

- It can be noted that remarkable differences in regard to a_w value between ran packaging cycles could be matter of vacuum conditions achieved in the case where thermo shrinking was done.

- Statistically significant differences are registered regarding the color parameter (L*) of chops packaged in the 9 layer foil in comparison to those in the 7 layer foil within the first cycle, as in comparison to the chops packaged in the both of foil types (the 7 layer and the 9 layer) used for packaging within the second cycle. The color parameters (a* and b*) of chops packaged in the 7 layer foil in the first packaging cycle were statistically significant ($p < 0.001$) in comparison to the 9 layer foil within the first cycle as in comparison to these values obtained measuring color of chops packaged in both foil types within the second packaging cycle ($p < 0.001$).

- From color measurements it can be pointed that the seasonal variations (various slaughter periods during the year) when packaging is done, have certain influence on color acceptability from consumer point of view.

- The chops packaged in the 9 layer foil had generally prolonged shelf life thorough examination cycles in comparison to 7 layer foil. It is issue probably about barrier properties and different layer structure if we consider influence of packaging material.

- The obtained gain in prolonged shelf life regarding this type of packaging material was about 3 days looking within particular cycles. Taking into account retail conditions and market requests it would be considered as satisfactory.

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