APARATURA
BADAWCZA I DYDAKTYCZNA

Effect of pig diet composition and type of packaging material on the chosen quality parameters of smoked bacon as related to storage time

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ABSTRACT:

In this work, the effect of packaging materials [polypropylene (PP), polypropylene/ethylene vinyl alcohol/polypropylene] on pH, color parameters, the intensity of the ongoing oxidative processes (TBA value) and instrumental texture indicators (hardness, shear force, elasticity) were investigated in bacon derived from two groups differ in the way of feeding (C – control group and E – group fed supplementation with rapeseed and linseed oils), both in the fresh condition and after storage at 4°C for up to 14 days. Smoked bacon stored in oxygen barrier packages (PP/EVOH/PP) showed lower TBA values and characterized by darker and more red color than that stored in packages more permeable to O_2 (PP). Therefore multilayer barrier sheet materials such as PP/EVOH/PP could be utilized successfully to extend commercial quality of smoked bacon during its fourteen day of refrigerated storage compared to polypropylene materials. Additionally supplementation of animal diet with 2% rapeseed oil and 2% linseed oil can allow to obtain pork bacon enriched in unsaturated fatty acids with no negative influence on its quality because there were no appreciable differences between samples taking into account most of the examined parameters. Although some differences for color parameters were reported in experimental group compared to control group, they are of little practical implication and would still provide satisfactory quality for consumer.

Wpływ sposobu żywienia świń oraz rodzaju materiału opakowaniowego na wybrane parametry jakościowe wędzonego boczku w czasie jego przechowywania

Słowa kluczowe: żywienie, materiały opakowaniowe, jakość, boczek wieprzowy

STRESZCZENIE:

W pracy określono wpływ rodzaju materiału opakowaniowego [polipropylen (PP), polipropylen/kopolimer etylenu i alkoholu winylowego/polipropylen (PP/EVOH/PP)] na pH, składowe barwy, intensywność zachodzących procesów oksydacyjnych (wskaźnik TBA) oraz wybrane wyróżniki tekstury (twardość, siła cięcia, elastyczność) przechowywanego przez 14 dni (4°C) wędzonego boczku wieprzowego, pozyskanego z dwóch grup doświadczalnych różniących się sposobem żywienia (C – grupa kontrolna, E – grupa doświadczalna, w której zastosowano suplementację paszy zwierząt olejem rzepakowym (2%) oraz lnianym (2%)). Na podstawie przeprowadzonych badań zaobserwowano, że boczek przechowywany w opakowaniach barierowych względem tlenu (PP/EVOH/PP) charakteryzował się niższymi wartościami TBA oraz bardziej intensywną czerwoną barwą w porównaniu do wędzonek przechowywanych w opakowaniach o wysokiej przepuszczalności O_2 (PP). W związku z powyższym w porównaniu do polipropylenu tworzywa wielowarstwowe, takie jak PP/EVOH/PP, mogą być z powodzeniem wykorzystywane do przedłużenia jakości handlowej wędzonego boczku w trakcie jego czternastodniowego przechowywania. Ponadto dodatek 2% oleju rzepakowego oraz 2% oleju lnianego do mieszanek paszowych nie wpłynął na większość badanych wyróżników jakości uzyskanych wędzonek, co może świadczyć o uzyskaniu produktów porównywalnej jakości jak w grupie kontrolnej i gwarantować wciąż zadowalającą jakość konsumenta.

1. INTRODUCTION

Quality of fat is an important aspect of processed pork products such as smoked bacon. Its quality rely on firm, saturated fat for desirable sensory, texture and storage characteristics. The proper choice of meat is of great importance, since subsequent technological processes rarely compensate for its low quality. Meat products with enhanced high nutritive value may differ in terms of quality from products made from pigs maintained in traditional grazing conditions. The supplementation of animal diet with oils rich in omega-3 acids into the mixture may change the physical and chemical properties of the obtained meat and, as a result, of the products made from it. External factors conditioned by the natural environment in which livestock is maintained throughout the whole process also play an important role in establishing the quality of the product. They include e.g. characteristics of the parameters within the technological process, control of temperature during storage and distribution, exposure of the product to daylight, and the type of packaging used [1, 2].

In modified atmosphere packaging (MAP), package barrier properties have a major effect on the overall quality of food by influencing the rate at which oxygen enters the package [3]. The present state of knowledge about the influence of packaging conditions on physical properties of meat products, and thereby on their final value, seems to be large [4], however, due to the ongoing implementation of new innovative technologies, it is still considered to be insufficient.

The heating process is supposed to destroy vegetative bacteria in the case of processed meat products, inactivate undesirable enzymes and stabilize the color of the final product. Due to the fact that the color of the meat is prone to oxidation, it is vital to ensure only trace amounts of oxygen in the package. In order to maximize the durability period, and reduce the development of microbes, it is suggested to use gas mixtures with CO_2 content ranging between 25% and 50% and N_2 content of 50% to 75% [4, 5]. Improper storage

conditions may lead to post cooking contamination by other bacteria on the surface of the product [6].

Meat products are generally low in omega-3 (n-3) fatty acids, which are beneficial to human health, and contain a large amounts of n-6 fatty acids [7]. Skiba et al. [8] showed that changes of feeding patterns may to some extent modify fatty acids profile of intramuscular fat even when diet is not supplemented with fat sources. In pigs grown according to the "normal" pattern an increased concentration of $C_{18:3n-3}$ was found. However the content of $C_{18:2n-6}$, and the ratio between these fatty acids decreased. The susceptibility of muscle tissue to lipid oxidation depends on the level of polyunsaturated fatty acids in the phospholipids present in cellular and subcellular membranes [9]. In pigs, the fatty acid composition of lipids deposited with rapeseed oil diet may alter the technological qualities of adipose tissues and that of meat as well as nutritional interest for humans [10]. The use of a diet rich in fish oil may lead to an increase in omega-3 advantageously affecting the lipid system, but at the same time deteriorate the quality of meat. Polyunsaturated fatty acids are in fact susceptible to oxidation leading to the formation and development of rancid [11].

Bacon is a cut of meat taken from the sides, belly, or back of a pig, and then cured, smoked, or both. It is often used for barding and larding roast fowl and game birds, served to eat as crackling or used as a base for cooking. However, despite this wide usage, there has been no detailed work done on its physical quality [12]. Moreover, bacon and its products are more susceptible to adverse changes during storage because of high concentrations of unsaturated fat. This can be due to belly having a higher overall fat content than the other primal cuts [13]. Diets high in unsaturated fatty acids can result in softer carcass fat of a pig and in faster lipid oxidation than in pork obtained from pigs fed with a control diet [14]. Thus, great care should be exercised in the development of product recipes as well as the packaging and storage methods for meat products like bacon. Parameters should be selected on an individual basis, taking their potential impact on products into account .

Most studies have focused on chemical and sensory characteristics of pork products with altered fat quality. Thus, the objectives of this study were to evaluate the effects of pig diet composition as well as type of packaging on pH, color stability and other selected texture indicators of smoked pork products like bacon kept in cold storage.

2. MATERIALS AND METHODS

Two groups of smoked bacon made in accordance with the general production process rules for products within the area of Mazowieckie Voivodeship were used as the research material. The research was carried out on 60 animals of the Polish Landrace breed assigned to two groups (30 animals in each one) with similar initial body mass. The raw material was obtained from 5 pork half-carcasses selected at random among sows from each research groups: the control group (C) was fed a non-supplemented diet and the supplemented group (E) was fed a mixture with 2% rapeseed oil and 2% linseed oil. The control and plantseed mixtures were isoenergetic (13.5 MJ), isoproteic (175 g/kg of the fodder), isolipidic (~ 40 g/kg of the fodder) and were also balanced in terms of exogenous amino acids Liz: Met + Cys : Tre : Tryp (0.9 : 0.65 : 0.6 : 0.2).

The smoked meat production process was carried out in industrial conditions. The weighed elements were subject to sodium chloride water injections: 82 kg water/ice pickling salt, 11 kg injection-specific substance, antioxidant E301, spice extracts. Sodium chloride water constituted 20% of all injected elements. The injected muscles were 5 hours in the meat tumbler in following intervals: 20 work (5 revolutions of the tumbler, with 90% vacuum) / 10 minutes rest (in atmospheric pressure conditions). The smoked meat was then placed to rest (6-24 h in storage rooms with temperatures below 7°C), and subsequently dried in the temperature of 60°C for ca. 3 hours, smoked in temp. of 60°C until proper color was attained, and steamed in 76-78°C until the temperature of 74°C within the inner part of the product was reached. After the products had been warmed in the temperature of 74°C for 10 min. it subsequently underwent cooling in temperatures below 8°C within the geometric center of the processed product.

The research material was packaged in modified atmosphere (MAP) under atmospheres of 70 N_2% and 30% CO_2 in two kinds of trays with an appropriately selected top films: polypropylene trays with oxygen permeability (23ºC; 0% RH) at 15.40 cc/package/24 hours (HP, Marcato Ltd, Poland) or polypropylene trays with ethylene vinyl alco-

hol (EVOH) layer in the 30 µm output film with oxygen permeability at 0.01 cc/package/24 hours (HB, Marcato Ltd, Poland). Sealpack packing machine, model M3 was used in this study. Samples were stored in temperatures 4°C throughout the period of 14 days with 36 W/76 light with the value lx = 1500 at the distance of 40 cm from the bottom of the package. Also, pH, texture constituents, and examination material color were measured on the packaging day 0 and on the 7th and 14th day of storage.

The pH measurement was performed in accordance with the norm PN-ISO 2917;2001 (Meat and meat products – Measurement of pH – Reference method). The instrumental measurement of the color parameters was specified in the L*a*b* system using a Minolta chromameter (CR-400, Konica Minolta Inc., Tokyo, Japan). The measuring head with a diameter of 8 mm, a D_{65} illuminant (color temperature – 6500 K) and a standard 2^{o} observer was used. Based on the obtained the L*, a* and b* values also determined a total color difference (ΔE) according to the following formula $\Delta E=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$. TBA analysis was carried out on bacon fat by using the method described byf Schmedes and Holmer (1989) [15]. The analysis of selected texture constituents was carried out using the Warner-Bratzler method using the Instron universal testing machine (Model 5965, Instron, Massachusetts, USA) with the width and knife edge angle 1.016 mm and 60° respectively. The test was conducted 6 times with a constant head speed of 200 mm x min^{-1} (cell capacity of 500 N) at 4 ± 1°C.

The analysis of results was carried out using STATISTICA 12.5 statistical package by StatSoft. The pH, color and texture distinguishers analysis results, was analyzed in three ways, as a whole, and each group specifically, in terms of distribution of pig diet composition, storage time for finished product and the applied type of packaging. Univariate variance analysis, as well as three-variate analysis were applied for the main effects, and moreover three-variate analysis including interactions. The interdependencies between pH and color parameters were analyzed with the estimation of Pearson linear correlation coefficient.

3. RESULTS AND DISCUSSION

Results in Table 1 are presented as mean values and standard deviations (SD) of pH, color properties parameters, TBA values and selected texture indicators (hardness, shear force, elasticity) depending on the group based on pig diet composition, storage time for the final product and the type of packaging used.

pH of the meat product is an important factor determining its shelf life and storage stability. The results (Tab. 2) revealed that treatments had no significant ($p\geq0.05$) effect on the pH of smoked bacon, while storage time and type of packaging affected the pH significantly ($p<0.001$) at the applied storage conditions. The pH value of smoked bacon ranged between 6.19 and 6.02 during the 14 days of storage (Tab. 1) and decreased in relation to the day of product packaging for control (C) as well as experimental group (E). The results of the present study are in close agreement with Jeun-Hornga et al. [16] who stated that the pH value of omega enriched frankfurters decreased during storage. Literature shows the decrease of pH value of meat products during the cold storage period to the degree determined by the type of the packaged product and the applied packaging method [17]. Larger pH decrease may be caused by the development of microorganisms such as lactic acid bacteria producing lactic acid which constitutes a major factor in lowering the pH of the product and affects its quality deterioration [18]. Carbon dioxide used during the packaging process in modified atmosphere may invade the solution if any water remains on the surface of the stored product. The dissolution of gas can cause the decrease of the pH level of the product. These correlations correspond to the results presented in Table 1. The storage of smoked bacon products for the period of 14 days in the form of final products in modified atmosphere packaging caused the decrease of the pH characteristic for cured processed meat subjected to heat treatment [19]. Moreover, it appears that in the case of pH a highly significant interaction ($p<0.001$) between the diet composition (DC), storage time (ST) and type of packaging exists (Tab. 2). On the 14th storage day the pH results for the control group (C) were similar than in the supplemented group (E) regardless of the type of packaging used.

Table 1 Comparison of the means for the pH, objective color parameters, TBA values and selected texture indicators (hardness, shear force, elasticity) depending on the group in terms of pig diet composition, storage time for the final product and the type of packaging used – multi-factor analysis

Item	Diet composition (DC)									
	C					E				
	Storage time (ST)									
	0	7		14		0	7		14	
	Type of package (TP)									
		HP	HB	HP	HB		HP	HB	HP	HB
pH	6.12^{d}±0.02	6.06^{bc}±0.01	6.07^{c}±0.02	6.03^{ab}±0.01	6.05^{bc}±0.02	6.19^{d}±0.06	6.08^{cd}±0.01	6.08^{cd}±0.01	6.02^{ab}±0.03	6.03^{ab}±0.01
L*	54.72^{a}±0.38	58.67^{c}±1.17	58.45^{c}±0.86	59.52^{c}±1.61	58.29^{bc}±0.95	55.27^{ab}±0.30	58.37^{bc}±0.30	59.52^{c}±0.56	60.04^{c}±1.38	59.76^{c}±1.28
a*	17.31±1.10	14.97±1.13	14.85±0.91	10.75±5.28	14.42±0.90	17.91±1.12	14.86±1.63	14.90±1.88	11.36±4.77	15.34±1.66
b*	7.30^{abcd}±0.29	7.41^{bcd}±0.17	6.95^{ab}±0.34	7.45^{b}±0.13	6.82^{a}±0.19	8.47^{e}±0.15	7.80^{d}±0.22	7.19^{abc}±0.17	7.70^{cd}±0.23	7.36^{b}±0.13
ΔE	-	4.77^{a} ±0.47	4.52^{a}±1.17	8.35^{b}±1.08	4.63^{a}±1.24	-	4.53^{a}±1.04	5.48^{a}±1.50	8.34^{b} ±1.51	5.35^{a}±1.90
TBA (mg MDA / kg fat)	1.25^{a}±0.02	1.40^{d}±0.01	1.36^{c}±0.01	1.76^{h}±0.01	1.68^{f}±0.01	1.32^{b}±0.01	1.44^{e}±0.01	1.40^{d}±0.01	1.82^{i}±0.01	1.71^{g}±0.01
Hardness (N)	60.64±5.36	52.18±5.63	64.80±14.12	52.13±5.63	64.04±13.99	58.76±7.02	55.62±7.85	58.96±11.60	57.20±9.63	60.43±11.89
Shear energy (J)	0.94±0.07	0.75±0.17	1.02±0.14	0.73±0.19	1.04±0.24	0.71±0.02	0.71±0.19	0.74±0.24	0.67±0.19	0.72±0.019
Elastisity (mm)	23.65±0.71	27.01±1.62	30.52±2.79	26.48±2.12	30.69±3.83	23.67±0.66	26.53±7.17	25.95±3.74	24.53±5.96	25.70±4.03

a, b, c, d, e, f, g – the mean values marked with various letters in rows show significant statistical differences (P<0.05); D – diet composition; C – control group; E – experimental group; ST – storage time; TP – type of package; HP – packages with high oxygen permeability; HB – packages with high oxygen barrier; L – lightness; a* – redness; b* – yellowness; C* – chroma; ΔE – total color difference

Table 2 Test probabilities for pH, objective color parameters, TBA values and selected texture indicators, generally and depending on the group based on pig diet composition, time of final product storage and the applied type of packaging – multi-aspect variance analysis including interactions

	Effect			Interactions			
	D	ST	TP	D x ST	D x TP	ST x TP	D x ST X TP
pH	ns	***	***	***	***	***	***
L*	ns	***	***	***	***	***	***
a*	ns	ns	ns	ns	ns	ns	ns
b*	**	*	***	***	***	***	***
ΔE	ns	***	***	**	**	***	**
TBA (mg MDA /kg fat)	ns	***	**	***	ns	***	***
Hardness (N)	ns	ns	ns	ns	ns	ns	ns
Shear energy (J)	**	ns	ns	ns	**	ns	ns
Elastisity (mm)	ns	ns	ns	ns	ns	ns	ns

DC – diet composition; C – control group; E – experimental group; ST – storage time; TP – type of package; HP – packages with high oxygen permeability; HB – packages with high oxygen barrier; * – P<0.05, ** – P<0.01, *** – P<0.001, ns – not significant; L* – lightness; a* – redness; b* – yellowness; C* – chroma; ΔE – total color difference

Smoked products already have extended shelf life because of prepackaging treatments, but the presence of oxygen in this kind of products can be deleterious for oxidation. In these cases, MAP may improve other quality aspects such as color stability [20]. In our study color parameters (L*, b* and ΔE) except a* values were influenced by interaction of three studied variables ($p<0.001$; Table 2). On the last day lightness (L*) values increased in all samples in relation to day of packaging (day 0) in both group (diet have no significant effect on this parameter – Table 2). Existing interactions contributed to the maintenance of L* parameter at similar levels on the last day of storage. It can be attributed to the fact that fodder might exert no influence on pH of meat [21, 22]. The results are in agreement with Sheard et al. [2000], who stated that there was no significant effect of diet composition on lightness changes of pork chops, sausages and bacon under simulated retail display conditions [23]. Results achieved in our study demonstrated also no effect of three analyzed variables on bacon redness (a* value). Regardless of which group was bacon obtained (C vs. E) it is visible downward trend in a* value along with extension of storage time. Although this trend is statistically insignificant, probably due to the addition of sodium chloride water injections, which perpetuates the red-pink color of processed meat products. However, in the case of yellowness (b*), a significant difference within the groups of individuals with various diet composition ($p<0.01$) and type of used packaging ($p<0.05$) was observed. On the last day samples from control group characterized by the lowest b* values in relation to experimental group (7.45 vs 7.70 for packaging of high permeability and 6.82 vs 7.36 for high barrier packaging). This may be due to limited oxidation process, although Irie and Sakimoto [1992] reported that fish oil did not create a yellow fat syndrome in bacon [24]. In relation to packaging lower values of b* on the last day of storage for HB group (6.82 vs 7.45 for control group and 7.36 vs 7.70 for experimental group) could be also explained by the slower rate of autoxidation of unsaturated fatty acids in samples packaging in oxygen barrier trays during 14 days of storage. Oxygen negatively affects meat products during prolonged storage periods. On the obtained results it can be assumed that good barrier properties against oxygen of PP/EVOH/PP packages are very important feature in order to ensure good quality of products such as bacon. The more that on the last day of storage, bacon packaged in a polypropylene packages (HP) was characterized by significantly higher values of ΔE than other samples, which give the impression of being different colors.

Additionally an attempt was made to study the correlations between pH and color parameters of smoked bacon. The resulting values of correlation indicators point out significant dependencies. A negative correlation ($p<0.05$) on a high level ($r = -0.75$) between pH and L* parameter was observed i.e. lower pH is related to the brightening of the product. Also correlation between pH and a* parameter is high ($p<0.05$), but positive ($r = 0.61$), i.e. lower pH is related to the decrease in the red color of product. In the case of relations between pH and b* color parameter, the estimated correlation ($p<0.05$) is rather low ($r = 0.35$). The data found in the literature indicates the existence of linear relation between the pH of meat and its color qualities. Decrease of pH causes meat to brighten and reduces the participation of yellow color in its entire spectrum [25, 26]. Similar qualities of meat products were observed in this study – relations between pH values of the stored smoked meat products and their color parameters exist. However to confirm the abovementioned relations, it is necessary to carry out further research in this field.

According to some studies extra amount of unsaturated acids added to animal fed results in products which are more susceptible to lipid oxidation, especially in the case of bacon [14, 27, 28]. In this study TBA value was not influenced by type of used diet composition ($p\geq0.05$). On the other hand type of packaging material and storage time had a significant effect ($p<0.001$) on its values. The interaction between three variables also affected the analysed parameter (Tab. 2). In each group (C vs. E) a fourteen-day storage time affects the increase of TBA values. If the storage period had been lengthened, a noticeable decline could have been detected for all samples, since, malonaldehyde is not stable for a longer period, and is oxidised to secondary oxidation products. Additionally the TBA numbers for samples packaged in high oxygen permeable packages (HP) reached higher values than samples packaged in barrier trays (HB) after as well as 7 and 14 days of storage (Tab. 1). This result could be explained by autoxidation which occur much faster in insuf-

ficiently protected from oxygen samples, and so, a higher amount of malonaldehyde accumulated and the TBA numbers reached higher values.
Also texture is an important tool to check the acceptability of meat product during its storage. Increased belly bacon firmness can be partly explained, by the increase in saturated to unsaturated fatty acid ratio as a result of pig diet [29, 30]. However, in this study the pigs were fed with a diet including various fat sources and it did not cause any significant statistical differences ($p \geq 0.05$) in the texture indicators such as hardness, shear energy and elastisity. The results are in contrary to other researchers who stated that the texture value varies significantly with storage time [31]. In our study examination of the texture parameters values pointed out its slight fluctuations with no clear downward or upward trend. It may be caused by prevailing influence of the technological process applied on the texture of the final product, since heating process determines the texture of meat products [32]. In Shahidi's et al. [1991] opinion, this could be also due to the nitrite in the bacon formulation acting as an antioxidant and causing significant reduction in lipid oxidation [33]. Moreover these samples were packaged without oxygen, which resulted in limited lipid oxidation.

4. CONCLUSIONS

In view of the effect of diet composition, packaging and time of storage reported in this work, it is likely that the applied type of packaging and the storage conditions significantly influence the stability of pH, color parameters and TBA values of smoked bacon throughout its storage in cold conditions. If the pork bacon has to be stored for fourteen days period, it should be packed in high oxygen barrier packages, because it will deteriorate in high oxygen permeable packages, regardless of the origin of raw material. What is more, supplementation of animal diet with 2% rapeseed oil and 2% linseed oil can allow to obtain high nutritive value smoked bacon with no negative influence on its quality during a two-week cold storage. Although further research, related to the quality of pork-bacon should be conducted in order to compare the results reported above.

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REFERENCES

[1] Brown H., Williams J., Food Packaging Technology, Oxford, England, Blackwell Publishing Ltd., 2003, 65-94.
[2] Morel P. C. H., Janz J. A. M., Zou M., Purchas R. W., Hendriks W. H., Wilkinson B. H. P., The influence of diets supplemented with CLA, selenium and vitamin E, with and without animal protein, on the composition of pork of female pigs, J. Anim. Sci., 86, (2008), 1145-1155.
[3] Ščetar M., Kurek M., Galić K., Trends in meat and meat products packaging – a review, Croatian J. Food Sci. and Technol., 2, (2010), 32-48.
[4] McMillin K. W., Where is MAP going? A review and future potential of modified atmosphere packaging for meat, Meat Sci., 80, (2008), 43-65.
[5] Mullan M., McDowell D., Food Packaging Technology, Oxford, England, Blackwell Publishing Ltd., 2003, 303-339.

[6] Vandendriessche F., Meat products in the past, today and in the future, Meat Sci., 78, (2008), 104-113.
[7] Lai L., Kang J. X., Li R., Wang J., Witt W. T., Young H. Y., Hao Y., Wax D. M., Murphy C. N., Rieke A., Samuel M., Linville M. L., Korte S. W., Evans R. V., Starzl T. E., Prather R. S., Dai Y., Generation of cloned transgenic pigs rich in omega-3 fatty acid, Nat. Biotechnol., 24, (2006), 435-436.
[8] Skiba G., Raj S., Poławska E., Pastuszewska B., Elminowska-Wend G., Bogucka J., Knecht D., Profile of fatty acid, muscle structure and shear force of musculus longissimus dorsi (*MLD*) in growing pigs as affected by energy and protein or protein restriction followed by realimentation, Meat Sci., 91, (2012), 339-346.
[9] Cava R., Ventanas J., Tejada J. F., Ruiz J., Antequera T., Effect of free-range rearing and α-tocopherol and copper supplementation on fatty acid profiles and susceptibility to lipid oxidation of fresh meat from Iberian pigs, Food Chem., 68, (2000), 51-59.
[10] Bourre J. M., Where to find omega-3 fatty acid and how feeding animals with diet enrich in omega-3 fatty acid to increase nutritional value of derived products for human: what is actually useful?, J. Nutr .Health Aging, 9, (2005), 232-242.
[11] Wood J. D., Richardson R. I., Nute G. R., Fisher A. V., Campo M. M., Kasapidou E., Sheard P. R., Enser M., Effects of fatty acid on meat quality: a review, Meat Sci., 66, (2003), 21-32.
[12] Purcărea C., Chis A., Timar A., Effect of storage condition on the chemical properties of pork bacon, Analele Universităţii din Oradea Fascicula. Ecotoxicologie. Zootehnie şi Tehnologii de Industrie Alimentară, (2009), 565-572.
[13] D'Souza D. N., Pethick D. W., Dunshea F. R., Suster D., Pluske J. R., Mullan B. P., The pattern of fat and lean muscle tissue deposition differs in the different pork primal cuts of female pigs during the finisher growth phase, Livestock Production Science, 91, (2006), 1.
[14] Rogers R. W., Etzler D. E., Effects of dietary fat supplementation of swine diets and subsequent packaging and storage conditions on rancidity development and sensory ratings of bacon, Prof. Anim. Sci., 16, (2000), 47-53.
[15] Schmedes A., Holmer G. A., New thiobarbituric acid (TBA) method for determination of free malonaldehyde (MDA) and hydroperoxides selectivity as a measure of lipid peroxidation, J. Am. Oil Chem. Soc., 66, (1989), 813-817.
[16] Jeun-Hornga L., Yuan-Huib L., Chun-Chinc K., Effect of dietary fish oil on fatty acid composition, lipid oxidation and sensory property of chicken frankfurters during storage, Meat Sci., 60, (2002), 161-167.
[17] Gajewska-Szczerbel H., Danyluk B., Sakowicz M., Dynamics of water activity changes in portioned meat products packed in multilayer foils, Acta Agrophysica, 4, (2004), 313-324.
[18] Bingol E. B., Ergun O., Effects of modified atmosphere packaging (MAP) on the microbiological quality and shelf life of ostrich meat, Meat Sci., 88, (2011), 774-785.
[19] Olszewski A., Measurement of pH as a measure of the quality of meat and meat products, Gosp. Mięsna, 9, (1999), 3-35.
[20] Conte A., Angiolillo L., Mastromatteo M., Del Nobile M. A., Food Industry, InTech., 355-379.
[21] Teye G. A., Wood J. D., Whittington F. M., Stewart A., Sheard P. R., Influence of dietary oils and protein level on pork quality. 2. Effects on properties of fat and processing characteristics of bacon and frankfurter-style sausages, Meat Sci., 73, (2006), 166-177.
[22] De Smet S., Fremaut K., Haak L., Raes K., Van Walleghem K., Fatty acid profile and oxidative stability of pork as influenced by duration and time of dietary linseed or fish oil supplementation, J. Anim. Sci., 86, (2008), 1418-1425.
[23] Sheard P. R., Enser M., Wood J. D., Nute G. R., Gill B. P., Richardson R. I., Shelf life and quality of pork and pork products with raised n-3 PUFA, Meat Sci., 55, (2000), 213-221.
[24] Irie M., Sakimoto M., Fat characteristics of pigs fed fish oil containing eicosapentaenoic and docosahexaenoic acids, J. Anim. Sci., 70, (1992), 470-477.
[25] Strzyżewski T., Bilska A., Krysztofiak K., The relationship between the pH of the meat and its color, Nauka Przyroda Technologie, 2, (2008), 1-9.

[26] Chmiel M., Słowiński S., Cal P., Application of computer image analysis for the detection of PSE defect of pork, Żywność. Nauka. Techn. Jakość, 6, (2011), 47-54.
[27] Kouba M., Enser M., Whittington F. M., Nute G. R., Woo J. D., Effect of a high-linolenic acid diet on lipogenic enzyme activities, fatty acid composition and meat quality in the growing pig, J. Anim. Sci., 81, (2003), 1967-1979.
[28] Elmore J. S., Cooper S. L., Enser M., Mottram D. S., Sinclair L. S., Wilkinson R. G., Dietary manipulation of fatty acid composition in lamb meat and its effect on volatile aroma compounds of grilled lamb, Meat Sci., 68, (2005), 233-242.
[29] Wiegand B. R., Sparks J. C., Parrish Jr. F. C., Zimmerman D. R., Duration of feeding conjugated linoleic acid influences growth performance, carcass traits, and meat quality of finishing barrows, J. Animal Sci., 80, (2002), 637-643.
[30] Lauridsen C., Mu H., Henckel P., Influence of dietary conjugated linoleic acid (CLA) and age at slaughtering on performance, slaughter and meat quality, lipoproteins, and tissue deposition of CLA in barrows, Meat Sci., 69, (2005), 393-399.
[31] Sohaib M., Anjum F. M., Khan M. I., Arshad M. S., Shahid M., Enhancement of lipid stability of broiler breast meat and meat products fed on alpha lipoic acid and alpha tocopherol acetate supplemented feed, J. Lipids Health Dis., 11, (2012), 1-10.
[32] Nikmaram P., Yarmand M. S., Emamjomeh Z., Darehabi H. K., The Effect of Cooking Methods on Textural and Microstructure Properties of Veal Muscle (*Longissimus dorsi*), Global Veterinaria, 6, (2011), 201-207.
[33] Shahidi F., Pegg R. B., Shansuzzaman K., Color and oxidative stability of nitrite-free cured meat after gamma irradiation, J. Food Sci., 5, (1991), 1450-1452.