QUALITY CHARACTERISTICS OF CHICKEN BURGERS ENRICHED WITH VEGETABLE OILS, INULIN AND WHEAT FIBER

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ABSTRACT

The aim of the study was to modify the composition of chicken burgers in terms of nutritional value by substitution of 20% of pork jowl with a mixture of rapeseed oil and linseed oil, and addition of inulin (1%) or wheat fiber (3%). Substitution of pork jowl with vegetable oils resulted in significant increase in polyunsaturated fatty acids, and rosemary extract retarded the oxidation process of lipids. Addition of wheat fiber was helpful in maintaining the thermal processing yield and texture of burgers. Microbiological quality of vacuum packed burgers subjected to 21-day storage at +4°C±1 and -20°C±1 was satisfactory.

- Keywords: chicken burger, inulin, quality, vegetable oil, wheat fiber -

INTRODUCTION

Despite the constant dissemination of knowledge in the field of proper nutrition, consumers do not always consider it when choosing foods. Results of research over a composition of a daily diet of the average Polish consumer indicated, among others, that the consumption structure of fatty acids and the level of intake of fiber were not consistent with nutritional recommendations (DYBKOWSKA *et al.*, 2004; RADZYMIŃSKA *et al.*, 2005). Therefore, in recent years scientists and manufacturers have taken actions towards reformulation of various food products aimed at improving their nutritional value (WASZKOWIAK *et. al.*, 2001; KOWALSKI and PYRCZ, 2009).

Since meat products provide considerable amounts of fat to the diet (GIVENS *et al.*, 2006), practical strategies of modifying their nutritional value include enrichment with polyunsaturated fatty acids (PUFA) (JIMÉNEZ-COLMENERO, 2007; PYRCZ *et al.*, 2007; VALENCIA *et al.* 2006; ÖZVURAL and VURAL, 2008). Fatty acid (FA) composition of meat products may be changed by introducing of vegetable or fish oil into the composition of formula or by replacing some animal fatty raw material with vegetable oil. However, the substitution of the animal fatty raw material with vegetable oil may have negative effect on the technological quality and sensory desirability of the product, among others, the increase of thermal loss, the acceleration of fatty acid oxidation process (NITSCH, 2007; ANDRÉS *et al.*, 2009; DECKER and PARK, 2010). In order to prevent adverse changes in quality of meat products prepared with vegetable oil, addition of other ingredients of natural origin may be applied. Potential deterioration of structure or sensory attributes of such products could be avoided by using both vegetable oil and fiber preparation (VURAL *et al.*, 2004; JAVIDIPOUR *et al.*, 2005). The effective method for retardation of the FA oxidation of meat products enriched with unsaturated fatty acids is the addition of antioxidants of natural origin, such as plant extracts (GEORGANTELIS *et al.*, 2007; FORELL *et al.*, 2010).

Recently, ready-to-eat meat products have grown in popularity with Polish consumers (STANGIERSKI and KIJOWSKI, 2002; GÓRSKA-WARSEWICZ, 2007). Therefore, the main objective of the present study was to develop a popular in Poland ready-to-eat meat product, which is chicken burger, with improved nutritional value. Launching such a product into market would facilitate composing a quotidian diet without necessity of changing eating habits or giving up favourite meals. This work includes determination of the effect of 20% substitution of pork jowl with a mixture of vegetable oils (rapeseed oil and linseed oil in mass ratio 7 to 3) and addition of inulin (1%) or wheat fiber (3%) on physical, chemical, and microbiological of chicken burgers.

MATERIALS AND METHODS

Materials

Raw materials: chilled chicken thigh meat and pork jowl, were collected from the local meat processing plant (Karczew near Warsaw, Poland). Pork jowl (about 10 kg) was purchased once, then coarse ground in a laboratory grinder Mesko WN60 (Mesko, Skarżysko-Kamienna, Poland) equipped with a plate with three kidney-shaped orifices. The ground jowl was divided into four lots, which were vacuum packed and stored at -20°C±1 until further use. Chicken meat (about 4 kg) was purchased prior to the each replication of experiment.

Fiber preparations were obtained from the manufacturers: inulin Orafti® HPX from Beneo-Orafti Ltd. (Tienen, Belgium) and wheat fiber Vitacel WF400® from J. Rettenmeier & Söhne GmbH + Co. (Rosenberg, Germany). Cold pressed unrefined vegetable oils: rapeseed oil and linseed oil, and spices were obtained from the local supermarket.

About 24 h prior to the production of chicken burgers, inulin gel was prepared: 1 part of inulin powder was dissolved in 3 parts of water using an electric blender Braun Multiquick 7 (Braun GmbH, Kronberg, Germany). The solution was heated to boiling. Heating was continued until a clear solution was obtained. The inulin solution was chilled at the room temperature for 60 min, then placed in a laboratory refrigerator (4°C±1).

A mixture of vegetable oils was used in the production process of burgers in the form of an emulsion with soy protein. The emulsion was prepared directly before the onset of production of burgers. Rapeseed oil and linseed oil were used in a mass ratio 7 to 3, to prepare the mixture of oils. Soy protein isolate SPI 733 (Solae ™, St. Louis, MO, USA) was rehydrated (1 part of dry preparation: 4 parts of water) using water provided in the composition of formula. To obtain the emulsion the mixture of oils was mixed with hydrated soy protein using the electric blender (Braun Multiquick 7) at low speed. The mass ratio of oils, rapeseed and linseed oil, was adopted on the basis of literature data on the nutritional properties of oils and the applicability of them as ingredients in meat preparations, as well as own calculation (KUNACHOWICZ *et al.*, 2005; MIŃKOWSKI *et al.*, 2010). The calculation suggested that the content of polyunsaturated fatty acids (PUFA) in chicken burgers, as a result of modification of the recipe composition, should not be less than 1.5 g per 100 g of product.

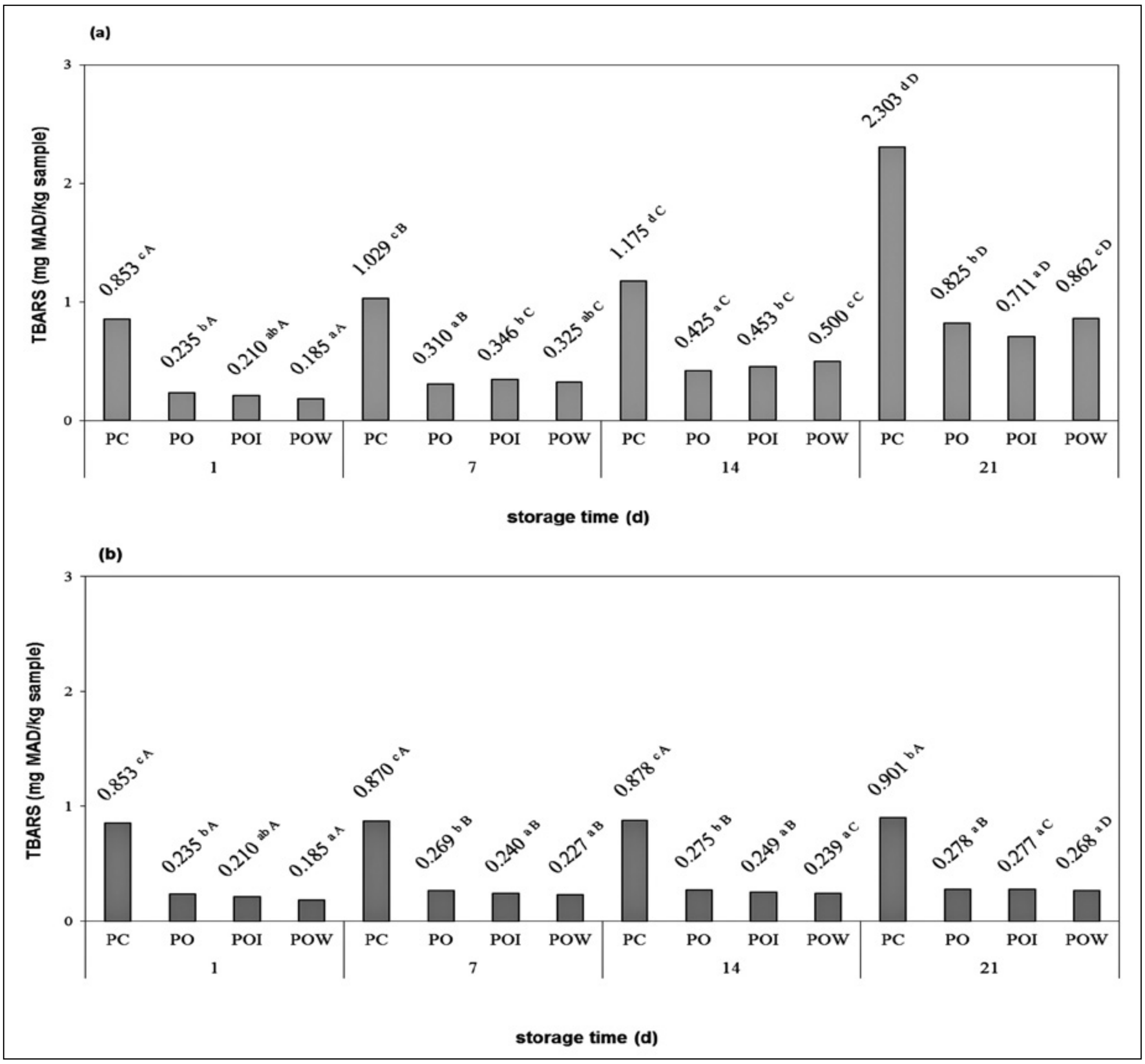

Fig. 1 - Thiobarbituric acid reactive substances (TBARS) values of chicken burgers formulated with different combinations of pork jowl, vegetable oils and dietary fiber preparations, during 21 days of storage at +4°C±1 (a) and at -20°C±1 (b).
For product description see Table 1.
[a-c]Means in the same figure (a, b) without a common lowercase letter differ significantly ($p < 0.05$) – influence of recipe composition of burgers (product formula) on TBARS value of burgers stored in different periods.
[A-D]Means in the same figure (a, b) without a common lowercase letter differ significantly ($p < 0.05$) – influence of storage time on TBARS value of burgers of each formula.

Table 1 - Composition of chicken burgers containing different combinations of pork jowl, vegetable oils, and dietary fiber preparation.

Ingredient	Product formula[a]			
	PC	PO	POI	POW
Chicken thigh meat (%)	85.0	85.0	85.0	85.0
Pork jowl (%)	15.0	12.0	12.0	12.0
Mixture of rapeseed and linseed oil (%)	-	3.0	3.0	3.0
Total raw materials (%)	100.0	100.0	100.0	100.0
Water[b] (%)	10.0	10.0	10.0	10.0
Sodium chloride[c] (%)	1.8	1.8	1.8	1.8
Soy protein isolate[c] (%)	1.5	1.5	1.5	1.5
Black pepper[c] (%)	0.3	0.3	0.3	0.3
Rosemary extract[c] (%)	-	0.03	0.03	0.03
Inulin[c] (%)	-	-	1.0	-
Wheat fiber[c] (%)	-	-	-	3.0

[a]Product formula: PC - control burgers; PO, - burgers formulated with substitution of 20% of pork jowl by mixture of vegetable oils; POI - burgers formulated with substitution of 20% of pork jowl by mixture of vegetable oils, and added inulin; POW - burgers formulated with substitution of 20% of pork jowl by mixture of vegetable oils, and added wheat fiber. [b]In relation to the mass of chicken meat and pork jowl (total raw materials). [c]In relation to the mass of chicken meat, pork jowl and water.

Chicken burger preparation

Four formulas of chicken burgers with different combinations of pork jowl, vegetable oils, and dietary fiber preparation (PC, PO, POI, POW) were prepared (Table 1). The level of substitution of pork jowl with the mixture of vegetable oils and the addition level of inulin or wheat fiber were adopted on the basis of previous studies results (CEGIEŁKA and PĘCZKOWSKA, 2008; CEGIEŁKA, 2011).

Before the production of burgers, pork jowl was thawed (4°C±1, 12 h). Chicken meat and pork jowl were ground using a laboratory grinder Mesko WN60 equipped with a plate having 5 mm diameter orifices. Meat batters were prepared in laboratory mixers Kenwood KM 070 (Kenwood Ltd., Havant, England). After mixing of chicken meat with NaCl (about 5 min) fatty raw materials were added: pork jowl only (PC) or pork jowl and emulsion of oils with soy protein isolate (PO, POI, POW). Rosemary extract Flavour Guard P GIN:601331 (Chr. Hansen A/S, Hørsholm, Denmark) was added to batters containing oils. After the next 5 min, other ingredients were added: black pepper, hydrated soy protein isolate (PC), and – depending on the product formula – inulin gel (POI) or wheat fiber (POW). Mixing was continued until a homogenous distribution of all the ingredients was obtained (about 10 min).

Burgers (100 g±1) were formed using a hamburger mould (about 10.0 cm diameter and 1.0 cm high) and placed in laboratory refrigerator (-28°C±2) for 30 min, in order to maintain the shape. Burgers were cooked in a commercial electric grill (Unox S.p.A., Vigodarzere-Padova, Italy) preheated to reach the temperature of 200°C. Cooking was continued until the internal temperature of burger reached 72°C. The temperature of burgers was monitored using a portable skewer digital thermometer HI 98804 (Hanna Instruments, Woonsocket, RI, USA). The burgers were then cooled at room temperature (about 30 min) over absorbent paper.

After cooling, chicken burgers of each formula were divided into two lots: the first one was left in the refrigerator at 4°C±1 until next day (about 24 h), and the second one was devoted to storage research.

The procedure was replicated four times.

Storage conditions

Before the storage chicken burgers of each formula were vacuum packed in bags in lots of four and then stored at +4°C±1 and -20°C±1 for a maximum of 21 days.

Yield after thermal processing

Yield after thermal processing of chicken burgers was determined by weight, after cooking and chilling the products to about 4°C, in relation to the weight of raw burgers.

Chemical analysis

Chemical analyzes were carried out on cooked and chilled (4°C±1, 24 h) chicken burgers.

Content of moisture, protein, total fat, salt, and ash was determined using analytical techniques according to AOAC (1990). All analyzes were done in 2 replications.

Analysis of texture

Measurements of texture were conducted on cooked and chilled (4°C±1, 24 h) chicken burgers. The measurements were taken using the universal testing machine Zwicki 1120 (Zwick GmbH & Co., Ulm, Germany) equipped with the Warner-Bratzler blade. Shear force (N), the maximum value of the force registered during movement of the blade through the sample, was estimated at the speed of cross-head of 50 mm/min. Burger samples were prepared by cutting the products into cuboid-shaped pieces (9 mm high, 30 mm wide and 90 mm long). Five replicates were measured from five burger samples of each formula.

Fatty acid composition

Fatty acid (FA) composition was determined in cooked and chilled (4°C±1, 24 h) chicken burgers and in chicken burgers stored at +4°C±1 and -20°C±1 for 21 days.

To determine the contents of FA the lipid extracts of the burgers were analyzed by gas chromatography. Procedure proposed by FOLCH *et al.* (1957) was used for lipid extraction from the sample. Fatty acid methyl esters (FAME) were obtained according to method of MORRISON and SMITH (1964). Chromatographic analyzes of FAME were performed using an Agilent 7890A GC System gas chromatograph (Agilent Technologies, Santa Clara, CA, USA) equipped with a split-spiltless injector and a flame ionization detector, using a fused silica capillary column Rt®-2330 (0.25 mm internal diameter and 105 m long; Restek Corp., Bellefonte, PA, USA). The mobile phase consisted of helium at a flow of 1.2 mL/min. The FAMEs were identified by comparing their retention times with FAMEs of the reference standards (Supleco 37 Component Fame Mix; Sigma-Aldrich, St. Louis, MO, USA). Quantification of FA was done by determining the surface areas of their peaks. All analyzes were done in 2 duplicates.

Lipid oxidation

Lipid oxidation was assessed in cooked and chilled (4°C±1, 24 h) chicken burgers and in chicken burgers stored at +4°C±1 and -20°C±1 for 7, 14 and 21 days. The 2-thiobarbituric acid (TBA) test was carried out in each sample in duplicate. Thiobarbituric acid reactive substances (TBARS) values were determined by an extraction method according to the procedure of SHAHIDI (1990). A constant coefficient of 2.34 was employed for converting the absorbance units to TBARS values, which were expressed as mg malondialdehyde/kg sample (mg MAD/kg).

Microbiological analysis

Microbiological analyzes were carried out in cooked and chilled (4°C±1, 24 h) chicken burgers and in chicken burgers stored at +4°C±1 and -20°C±1 for 7, 14 and 21 days.

The analyzes were conducted in Analytical Center of Warsaw University of Life Sciences - SGGW (Warsaw, Poland) in conditions accordant to requirements of PN-EN ISO 7218:2008 standard (PCS, 2008). The microbiological culture media were prepared according to PKN-CEN ISO/TS 11133-1:2009 standard (PCS, 2009). The preparation of test samples for microbiological analyzes, initial suspension and decimal dilutions was carried out according to PN-EN ISO 6887-2:2005 (PCS, 2005b). For quantitative analyzes, 10 g of the sample from central part of burger was collected. Next, the first decimal dilution was performed by dosing physiological solution with peptone according to PN-EN ISO 6887-1:2000 (PCS, 2000). Determination of total bacteria count (TBC) was conducted according to PN-EN ISO 4833:2004+Ap1:2005 standard (PCS, 2005a) using PCA culture medium (Plate Count Agar) of Bio-Rad company (Bio-Rad Laboratories, Inc., Herkules, CA, USA). Determination of coliform bacteria was conducted according to PN-ISO 8432:2007 standard (PCS, 2007) using VRBL medium (Violet Red Bile Lactose Agar; Bio-Rad) and BGBBL (Bile Green Brilliant Lactose Broth; Bio-Rad). The presence of *Salmonella ssp.* in 25 g of product was determined according to PN-EN ISO 6579:2003 standard (PCS, 2003) using MKTTn selective media (Müller-Kauffman's medium with tetrathionate and novobiocin), RVS (medium acc. to Rappaport-Vassilliads with soya), XLD (xylose lysine deoxycholate) and Hektoen of Bio-Rad Company. The colonies typical for *Salmonella ssp.* and suspicious colonies were confirmed using API 20E biochemical tests of bioMérieux Company (bioMérieux Sp. z o.o., Warsaw, Poland).

Statistical analyses

Microbiological data was analyzed using Statistica 6.0 (StatSoft Inc., Tulsa, Okla., U.S.A.). All the other data was analyzed using Statgraphics Plus 4.1. (STSC Inc., Rocville, MD, U.S.A.) by means of the one-way ANOVA test. Differences between burger formulas were tested by the Tukey HSD test. Pearson's correlation coefficients (r) were calculated to determine the linear correlation between chosen quality attributes of chicken burgers.

RESULTS AND DISCUSSION

Yield after thermal processing, chemical composition and texture

Yield after thermal processing of chicken burgers ranged from 82.0 to 88.4% and was not affected ($p > 0.05$) by applied modifications of the composition of formula (Table 2).

The results obtained in this study are in agreement with those obtained by ANDRÉS *et al.* (2009) who showed that an introduction of squid oil into the composition of formula of frankfurters instead of beef tallow did not affect thermal loss of the product. PYRCZ *et al.* (2007), LÓPEZ-LÓPEZ *et al.* (2009), and YOUSSEF and BARBUT (2011) proved, in turn, that thermal loss of scalded sausages increased as the result of replacement of some animal fat with vegetable oil. Decrease in processing yield of meat products enriched with

Table 2 - Processing yield, chemical composition, and shear force of chicken burgers formulated with different combinations of pork jowl, vegetable oils, and dietary fiber preparation.

Characteristic	Product formula[1]			
	PC	PO	POI	POW
Processing yield (%)	88.4±3.9[a]	84.5±3.6[a]	82.0±2.8[a]	87.7±4.6[a]
Moisture (%)	62.3±0.2[a]	62.8±0.7[a]	62.3±0.1[a]	62.6±0.6[a]
Protein (%)	18.0±0.5[a]	18.4±0.6[a]	18.7±0.1[a]	18.3±0.1[a]
Fat (%)	14.5±0.6[a]	13.3±1.7[a]	13.0±1.3[a]	13.7±0.8[a]
Chlorides (%)	2.3±0.1[a]	2.3±0.1[a]	2.2±0.1[a]	2.3±0.1[a]
Ash (%)	2.7±0.1[a]	2.7±0.2[a]	2.7±0.2[a]	2.8±0.2[a]
Shear force (N)	31.1±2.6[b]	23.7±1.6[a]	21.9±2.5[a]	29.9±1.1[b]

[1]Product formula: see Table 1.
[a, b]Means within a raw without a common lowercase letter differ significantly ($p < 0.05$).

oil may be counteracted - like in this study - by an application of oil in form of an emulsion with hydrated vegetable protein (YOUSSEF and BARBUT, 2011) or combined addition of oil and fiber preparation (VURAL *et al.*, 2004; JAVIDIPOUR *et al.*, 2005).

Chemical composition of chicken burgers formulated with different combinations of pork jowl, vegetable oils, and dietary fiber preparation is shown in Table 2. The content of any of the analyzed chemical component of burgers was not differentiated significantly ($p > 0.05$) by the applied modifications the composition of formula. Slightly lower fat content in burgers prepared with a contribution of vegetable oils (PO, POI, POW), when compared to control product (PC), could have been caused by poorer oil maintenance in protein matrix of the product, and as a consequence its loss during thermal treatment.

The results obtained in this study are in agreement with those presented by KAYAARDI and GÖK (2003), MUGUERZA *et al.* (2003), PELSER *et al.* (2007) and CÁCERES *et al.* (2008) who also showed that replacement of some animal fatty raw material with oil did not exert any influence on the chemical composition of scalded sausages and raw fermented sausages. In contrast, GARMIENE *et al.* (2007), and LÓPEZ-LÓPEZ *et al.* (2009) found in studies on frankfurters and scalded sausages, respectively, that substitution of some animal fatty raw material with oil resulted in a significant increase in water content and decrease in protein content in these meat products.

Enrichment of ready-to-eat meat products with wheat fiber: beef burgers (CEGIEŁKA and BONDERSKI, 2010) and poultry burgers (CEGIEŁKA and PĘCZKOWSKA, 2008), did not differentiate the chemical composition of these products when compared to their counterparts prepared without the fiber. It was also shown that the application of inulin did not affect the chemical composition of turkey meat balls (ERGÖNÜL *et al.*, 2009).

Mean values of shear force measured in chicken burgers ranged from 21.9 N to 31.1 N (Table 2). Measurements of shear force of chicken burgers revealed that the texture of products was impacted ($p < 0.05$) by the applied modifications the composition of formula (Table 2). It was found that substitution of 20% of pork jowl with vegetable oils (PO) or application of both oils and inulin (POI) resulted in a significant ($p < 0.05$) decrease of shear force when compared to the control product (PC). The product enriched with oils and wheat fiber (POW) was characterized by a comparable ($p > 0.05$) shear force to the control product (PC).

In contrast to the results of this study, instrumental measurements of texture of scalded sausages showed that substitution of some animal fat with vegetable oil significantly decreased hardness of these products (AMBROSIADIS *et al.*, 1996; PYRCZ *et al.*, 2007; ÖZVURAL and VURAL, 2008). However, in studies on raw sausages it was reported that the deterioration of texture of sausages prepared with oil could be counteracted by addition of dietary fiber preparation (VURAL *et al.*, 2004; JAVIDIPOUR *et al.*, 2005).

Some literature findings suggest that dietary fiber preparations could help to obtain the desired texture of ready-to-eat meat products. It was found that the addition of wheat fiber increased the shear force of poultry burgers (CEGIEŁKA and PĘCZKOWSKA, 2008) and beef burgers (CEGIEŁKA and BONDERSKI, 2010). In other studies ERGÖNÜL *et al.* (2009) showed that inulin addition did not affect significantly the instrumental hardness of turkey meat balls. The above mentioned products, however, did not contain vegetable oil in the composition of formula.

Fatty acid composition

The share of main FA in the overall FA pool of chicken burgers is shown in Tables 3, 4 and 5. The results obtained showed that substitution of 20% of pork jowl with a mixture of vegetable oils did not totally changed fatty acid profile of chicken burgers, but improved nutritional value of them in terms of the share of saturated and polyunsaturated fatty acids (SFA and PUFA).

Products enriched with vegetable oils, irrespectively of an addition of fiber preparation (PO, POI, POW), contained significantly ($p < 0.05$) less saturated fatty acids (SFA) than the control product (PC; Table 3). In burgers of all the formulas, palmitic acid (C16:0) and stearic acid (C18:0) were present in the highest amounts among SFA, and their contents were significantly ($p < 0.05$) higher in the PC product when compared to burgers prepared with vegetable oils. Introduction of a mixture of vegetable oils into the composition of formula of chicken burgers did not significantly ($p > 0.05$) increase the share of monounsaturated fatty acids (MUFA) in the overall FA pool (Table 4), but PO, POI, and POW products contained significantly ($p < 0.05$) more PUFA, including nutritionally valuable PUFA *n-3*, when compared to the PC product (Table 5). Among MUFA, oleic acid (C18:1 *n-9*) was predominant is the products of all the formulas. In burgers prepared with oils, significantly lower ($p < 0.05$) amounts of myristoleic (C14:1) and elaidic acid (C18:1*t*) were found when compared to the PC product.

The content of polyunsaturated fatty acids (PUFA) in chicken burgers with oils (PO, POI, POW) was higher than 2.5 g per 100 g of product. Irrespectively of the burger formula, the highest share in PUFA pool had linoleic acid (LA; C18:2 *n-6*). The LA content in burgers was not significantly ($p > 0.05$) differentiated by application of vegetable oils. Chicken burgers of all the formulas contained relatively high amounts of linolenic (C18:3 *n-3*), arachidonic (C20:4 *n-6*)

Table 3 - SFA of chicken burgers (g/100 g total FA) formulated with different combinations of pork jowl, vegetable oils, and dietary fiber preparations, with different storage conditions, during 21 days of storage.

FA/FA group	Storage conditions	Product formula[1]			
		PC	PO	POI	POW
Capric C10:0	+4°C±1, 24 h	0.081^{aA}	0.070^{aA}	0.046^{aA}	0.062^{aA}
	+4°C±1, 21 d	0.083^{aA}	0.073^{aA}	0.044^{aA}	0.060^{aA}
	-20°C±1, 21d	0.079^{aA}	0.066^{aA}	0.041^{aA}	0.076^{aA}
Lauric C12:0	+4°C±1, 24 h	0.648^{aA}	0.562^{aA}	0.522^{aA}	0.512^{aA}
	+4°C±1, 21 d	0.643^{aA}	0.545^{aA}	0.512^{aA}	0.511^{aA}
	-20°C±1, 21d	0.643^{aA}	0.531^{aA}	0.476^{aA}	0.516^{aA}
Myristic C14:0	+4°C±1, 24 h	1.466^{bA}	1.212^{aA}	1.185^{aA}	1.152^{aA}
	+4°C±1, 21 d	1.367^{abA}	1.218^{abA}	1.188^{aA}	1.154^{aA}
	-20°C±1, 21d	1.469^{bA}	1.206^{abA}	1.163^{aA}	1.158^{aA}
Palmitic C16:0	+4°C±1, 24 h	21.576^{bA}	18.350^{aA}	18.114^{aA}	17.638^{aA}
	+4°C±1, 21 d	21.740^{bA}	18.550^{aA}	18.244^{aA}	17.868^{aA}
	-20°C±1, 21d	21.733^{bA}	18.579^{aA}	18.392^{aA}	17.915^{aA}
Stearic C18:0	+4°C±1, 24 h	8.633^{bA}	7.352^{aA}	7.351^{aA}	7.023^{aA}
	+4°C±1, 21 d	8.672^{bA}	7.395^{aA}	7.334^{aA}	7.112^{aA}
	-20°C±1, 21d	8.656^{bA}	7.537^{aA}	7.604^{aA}	7.256^{aA}
Arachidic C20:0	+4°C±1, 24 h	0.130^{aA}	0.179^{bA}	0.179^{bA}	0.193^{bA}
	+4°C±1, 21 d	0.129^{aA}	0.180^{bA}	0.177^{bA}	0.184^{bA}
	-20°C±1, 21d	0.129^{aA}	0.181^{bA}	0.182^{bA}	0.195^{bA}
Behenic C22:0	+4°C±1, 24 h	ND[2]	0.073^{aA}	0.076^{aA}	0.085^{aA}
	+4°C±1, 21 d	ND[2]	0.069^{aA}	0.076^{aA}	0.081^{aA}
	-20°C±1, 21d	ND[2]	0.073^{aA}	0.079^{aA}	0.085^{aA}
SFA	+4°C±1, 24 h	32.944^{bA}	28.142^{aA}	27.827^{aA}	27.007^{aA}
	+4°C±1, 21 d	33.128^{bA}	28.378^{aA}	27.930^{aA}	27.315^{aA}
	-20°C±1, 21d	33.120^{bA}	28.518^{aA}	28.294^{aA}	27.533^{aA}

[1]Product formula: see Table 1. [2]ND - not detected (the content of the FA was lower than 0.05 g/100 g of total FA). [abc]Means within a row without a common lowercase letter differ significantly ($p < 0.05$) – influence of product formula on FA content in burgers stored in different conditions. [A]Means within a column with a common uppercase letter do not differ significantly ($p < 0.05$) – influence of storage conditions on FA content in burgers of different formula.

Table 4 - MUFA of chicken burgers (g/100 g total FA) formulated with different combinations of pork jowl, vegetable oils, and dietary fiber preparations, with different storage conditions, during 21 days of storage.

FA/FA group	Storage conditions	Product formula[1]			
		PC	PO	POI	POW
Myrictoleic C14:1	+4°C±1, 24 h	0.133^{bA}	0.114^{aA}	0.113^{aA}	0.115^{aA}
	+4°C±1, 21 d	0.132^{bA}	0.108^{aA}	0.112^{aA}	0.114^{aA}
	-20°C±1, 21d	0.135^{bA}	0.108^{aA}	0.112^{aA}	0.113^{aA}
Palmitoleic C16:1	+4°C±1, 24 h	3.456^{aA}	2.874^{aA}	2.824^{aA}	2.876^{aA}
	+4°C±1, 21 d	4.438^{bcA}	2.860^{aA}	2.800^{aA}	2.853^{aA}
	-20°C±1, 21d	3.446^{cA}	2.821^{aA}	2.870^{abA}	2.847^{aA}
Elaidic C18:1t	+4°C±1, 24 h	0.372^{bA}	0.282^{abA}	0.288^{abA}	0.271^{aA}
	+4°C±1, 21 d	0.542^{bA}	0.311^{aA}	0.325^{aA}	0.305^{aA}
	-20°C±1, 21d	0.455^{abA}	0.306^{aA}	0.317^{aA}	0.306^{aA}
Oleic C18:1 (*n-9*)	+4°C±1, 24 h	40.237^{abA}	40.837^{abA}	39.712^{aA}	42.830^{bA}
	+4°C±1, 21 d	40.429^{aA}	41.096^{aA}	39.810^{aA}	40.911^{aA}
	-20°C±1, 21d	40.313^{aA}	40.953^{aA}	39.499^{aA}	40.779^{aA}
Eicosanoic C20:1	+4°C±1, 24 h	0.734^{aA}	0.770^{aA}	0.744^{aA}	0.773^{aA}
	+4°C±1, 21 d	0.731^{aA}	0.774^{aA}	0.741^{aA}	0.779^{aA}
	-20°C±1, 21d	0.731^{aA}	0.778^{aA}	0.747^{aA}	0.767^{aA}
Eruic C22:1	+4°C±1, 24 h	0.054^{aA}	0.084^{aA}	0.055^{aA}	0.061^{aA}
	+4°C±1, 21 d	0.045^{bA}	0.018^{aA}	0.017^{aA}	0.017^{aA}
	-20°C±1, 21d	0.038^{bA}	0.019^{aA}	0.039^{bA}	0.019^{aA}
MUFA	+4°C±1, 24 h	45.959^{aA}	45.960^{aA}	44.720^{aA}	47.926^{aA}
	+4°C±1, 21 d	48.297^{aA}	48.234^{aA}	46.749^{aA}	48.066^{aA}
	-20°C±1, 21d	48.143^{aA}	48.113^{aA}	46.544^{aA}	47.705^{aA}

[1]Product formula: see Table 1. [2]ND - not detected (the content of the FA was lower than 0.05 g/100 g of total FA). [abc]Means within a row without a common lowercase letter differ significantly ($p < 0.05$) – influence of product formula on FA content in burgers stored in different conditions. [A]Means within a column with a common uppercase letter do not differ significantly ($p < 0.05$) – influence of storage conditions on FA content in burgers of different formula.

Table 5 - PUFA of chicken burgers (g/100 g total FA) formulated with different combinations of pork jowl, vegetable oils, and dietary fiber preparations, with different storage conditions, during 21 days of storage.

FA/FA group	Storage conditions	Product formula[1]			
		PC	PO	POI	POW
Linoleic C18:2 *(n-6)*	+4°C±1, 24 h	13.341[aA]	14.939[aA]	15.508[aA]	15.555[aA]
	+4°C±1, 21 d	13.054[aA]	14.730[aA]	15.433[aA]	15.400[aA]
	-20°C±1, 21d	13.274[aA]	14.700[aA]	15.403[aA]	15.515[aA]
γ- Linolenic C18:3 *(n-6)*	+4°C±1, 24 h	0.081[aA]	0.072[aA]	0.072[aA]	0.068[aA]
	+4°C±1, 21 d	0.077[aA]	0.071[aA]	0.072[aA]	0.068[aA]
	-20°C±1, 21d	0.080[aA]	0.070[aA]	0.069[aA]	0.071[aA]
Linolenic C18:3 *(n-3)*	+4°C±1, 24 h	1.631[aA]	5.353[bA]	6.410[bA]	6.092[bA]
	+4°C±1, 21 d	1.599[aA]	5.248[bA]	6.480[bA]	6.932[bA]
	-20°C±1, 21d	1.587[aA]	5.211[bA]	6.362[bA]	6.015[bA]
Eicosadienoic C20:2 *(n-6)*	+4°C±1, 24 h	0.327[aA]	0.291[aA]	0.275[aA]	0.280[aA]
	+4°C±1, 21 d	0.324[aA]	0.290[aA]	0.271[aA]	0.280[aA]
	-20°C±1, 21d	0.324[aA]	0.296[aA]	0.289[aA]	0.285[aA]
Eicosatrienoic C20:3 *(n-6)*	+4°C±1, 24 h	0.110[aA]	0.103[aA]	0.101[aA]	0.098[aA]
	+4°C±1, 21 d	0.112[aA]	0.099[aA]	0.096[aA]	0.098[aA]
	-20°C±1, 21d	0.114[aA]	0.104[aA]	0.104[aA]	0.101[aA]
Eicosatrienoic C20:3 *(n-3)*	+4°C±1, 24 h	0.158[aA]	0.155[aA]	0.134[aA]	0.140[aA]
	+4°C±1, 21 d	0.140[aA]	0.115[aA]	0.107[aA]	0.110[aA]
	-20°C±1, 21d	0.124[aA]	0.115[aA]	0.106[aA]	0.107[aA]
Arachidonic C20:4 *(n-6)*	+4°C±1, 24 h	0.198[aA]	0.212[aA]	0.202[aA]	0.195[aA]
	+4°C±1, 21 d	0.196[aA]	0.173[aA]	0.179[aA]	0.172[aA]
	-20°C±1, 21d	0.216[aA]	0.226[aA]	0.218[aA]	0.179[aA]
Eicosapentaenoic (EPA) C20:5 *(n-3)*	+4°C±1, 24 h	ND[2]	ND[2]	ND[2]	ND[2]
	+4°C±1, 21 d	ND[2]	ND[2]	ND[2]	ND[2]
	-20°C±1, 21d	ND[2]	ND[2]	ND[2]	ND[2]
Docosahexaenoic (DHA) C22:6 *(n-3)*	+4°C±1, 24 h	ND[2]	ND[2]	ND[2]	ND[2]
	+4°C±1, 21 d	ND[2]	ND[2]	ND[2]	ND[2]
	-20°C±1, 21d	ND[2]	ND[2]	ND[2]	ND[2]
PUFAs	+4°C±1, 24 h	15.862[aA]	21.125[bA]	22.701[bA]	22.427[bA]
	+4°C±1, 21 d	15.501[aA]	20.726[bcA]	22.639[cA]	22.058[cA]
	-20°C±1, 21d	15.720[aA]	20.722[bcA]	22.569[cA]	22.271[cA]

[1]Product formula: see Table 1. [2]ND - not detected (the content of the FA was lower than 0.05 g/100 g of total FA). [abc]Means within a row without a common lowercase letter differ significantly ($p < 0.05$) – influence of product formula on FA content in burgers stored in different conditions. [A]Means within a column with a common uppercase letter do not differ significantly ($p < 0.05$) – influence of storage conditions on FA content in burgers of different formula.

and eicosatrienoic acid (C20:3 *n-3*). The significant ($p < 0.05$) increase in the share of PUFA in overall FA pool in PO, POI, and POW products - when compared to PC product - was mainly determined by an increased content of linolenic acid. The presence of valuable nutritionally long-chain PUFA *n-3* acids: eicosapentaenoic (EPA) and docosahexaenoic acid (DHA), was not observed in the products prepared with oils. This was possibly due to the fact that the share of vegetable oils in the recipe composition of burgers was relatively low.

The ratio of PUFA to SFA and the ratio of PUFA *n-6* to PUFA *n-3* are often used in nutritional characteristics of lipids in food. The values of these ratios for control burgers (PC) were 0.48 and 7.91, respectively (Table 6). The introduction of mixture of vegetable oils into the formula composition of burgers resulted in significant ($p < 0.05$) changes in the value of both ratios. For the PO, POI, and POW burgers the ratios of PUFA to SFA ranged from 0.75 to 0.83, and the ratios of PUFA *n-6* to PUFA *n-3* varied between 2.47 and 2.84. The significant ($p < 0.05$) increase in the PUFA to SFA ratio, and decrease in the PUFA *n-6* to PUFA *n-3* ratio in burgers formulated with oils - when compared to the control product - was the positive effect indicating improvement of the nutritional value of fat in these products.

Regardless of the temperature of 21-day storage no significant ($p > 0.05$) changes in the content of any FA were found in any of the burgers.

The results obtained confirm the thesis put forward by JIMÉNEZ-COLMENERO (2007), who - based on the literature data - reported that substitution of some animal fatty raw material with oil was an effective method of improvement of FA composition in a wide range of meat products. Usefulness of linseed oil and rapeseed oil in improvement to nutritional value of lipids in meat products, expressed by increased contribution of UFA and PUFA *n-3,* was confirmed by GARMIENE *et al.* (2007), MAKAŁA and JERZEWSKA (2008) in scalded sausages, and by PELSER *et al.* (2007) in fermented sausages. It has been also found that the FA composition of meat products may be modified by the application of olive oil (KAYAARDI and GÖK, 2003), soybean oil (MUGUERZA *et al.*, 2001), or mixture of vegetable oils (ÖZVURAL and VURAL, 2008; LOPÉZ-LOPÉZ *et al.*, 2009). Mixture of oils was also used for an improvement in nutritional value of lipids in ready-to-eat meat products: beef burgers (FORELL *et al.*, 2010) and pork patties (LEE *et al.*, 2006).

Lipid oxidation

Changes in TBARS value in chicken burgers subjected to storage at the temperature of +4°C±1 and -20°C±1 are presented in Figs. 1a and 2b, respectively. The highest TBARS values were observed in control burgers (PC), irrespectively of the storage temperature and time. Significantly lower ($p < 0.05$) TBARS values were observed in burgers prepared with vegetable oils (PO, POI, POW), which meant inhibition of the oxidation process of lipids when compared to the PC product. It should be noted that enrichment of burgers with oils was accompanied by addition of rosemary extract, which was intended to protect FA against oxidation.

The results obtained confirmed that, irrespectively of product formula, freezing was better method of storage than refrigerating. Although lowering the temperature of the storage from +4 to -20 degrees did not stop completely the oxidation process of FA in burgers, it was inhibited significantly.

When compared to the results presented by other authors (FERNÁNDEZ-LÓPEZ *et al.*, 2005; PIETRZAK and MYRON, 2008; FORELL *et al.*, 2010), the TBARS values in chicken burgers were relatively low, both after manufacturing (24 h) and 21 days of storage.

Incorporation of oil into the formula composition of meat product may influence the oxidative stability of lipids in the product. According to KAYAARDI and GÖK (2003), the adverse changes of lipids in beef sausage were caused by the partial replacement of beef tallow with olive oil. In turn, MUGUERZA *et al.* (2003), and PELSER *et al.* (2007) reported that replacement of some animal fatty raw material with vegetable oil in fermented sausages did not intensify the adverse changes in lipids, such as oxidation and hydrolysis. MAKAŁA and JERZEWSKA (2008) also found that the quality of frankfurters enriched with linseed oil, in terms of lipids oxidative changes, was satisfactory even after 8-week of refrigerating storage.

In order to extend the storage stability of chicken burgers with enriched oils, an anti-

Table 6 - Proportions of PUFA : SFA and PUFA *n-6* : PUFA *n-3* in chicken burgers formulated with different combinations of pork jowl, vegetable oils, and dietary fiber preparations, with different storage conditions, during 21 days of storage.

FA group	Storage conditions	Product formula[1]			
		PC	PO	POI	POW
PUFA *n-6*	+4°C±1, 24 h	14.056^{aA}	15.617^{aA}	16.157^{aA}	16.196^{aA}
	+4°C±1, 21 d	13.762^{aA}	15.363^{aA}	16.052^{aA}	16.018^{aA}
	-20°C±1, 21 d	14.010^{aA}	15.397^{aA}	16.082^{aA}	16.160^{aA}
PUFA *n-3*	+4°C±1, 24 h	1.806^{aA}	5.508^{bA}	6.544^{bA}	6.231^{bA}
	+4°C±1, 21 d	1.739^{aA}	5.364^{bA}	6.587^{bA}	6.041^{bA}
	-20°C±1, 21 d	1.711^{aA}	5.362^{bA}	6.487^{bA}	6.122^{bA}
PUFA : SFA	+4°C±1, 24 h	0.48^{aA}	0.75^{bA}	0.82^{bA}	0.83^{bA}
	+4°C±1, 21 d	0.47^{aA}	0.73^{bcA}	0.81^{cA}	0.81^{cA}
	-20°C±1, 21 d	0.48^{abA}	0.73^{bcA}	0.80^{cA}	0.81^{cA}
PUFA *n-6* : PUFA *n-3*	+4°C±1, 24 h	7.91^{bA}	2.84^{aA}	2.47^{47aA}	2.60^{aA}
	+4°C±1, 21 d	7.91^{bA}	2.86^{aA}	2.44^{aA}	2.65^{aA}
	-20°C±1, 21 d	8.19^{bA}	2.89^{aA}	2.48^{aA}	2.64^{aA}

[1]Product formula: see Table 1. [abc]Means within a row without a common lowercase letter differ significantly ($p < 0.05$) – influence of product formula on FA content in burgers stored in different conditions. [A]Means within a column with a common uppercase letter do not differ significantly ($p < 0.05$) – influence of storage conditions on FA content in burgers of different formula.

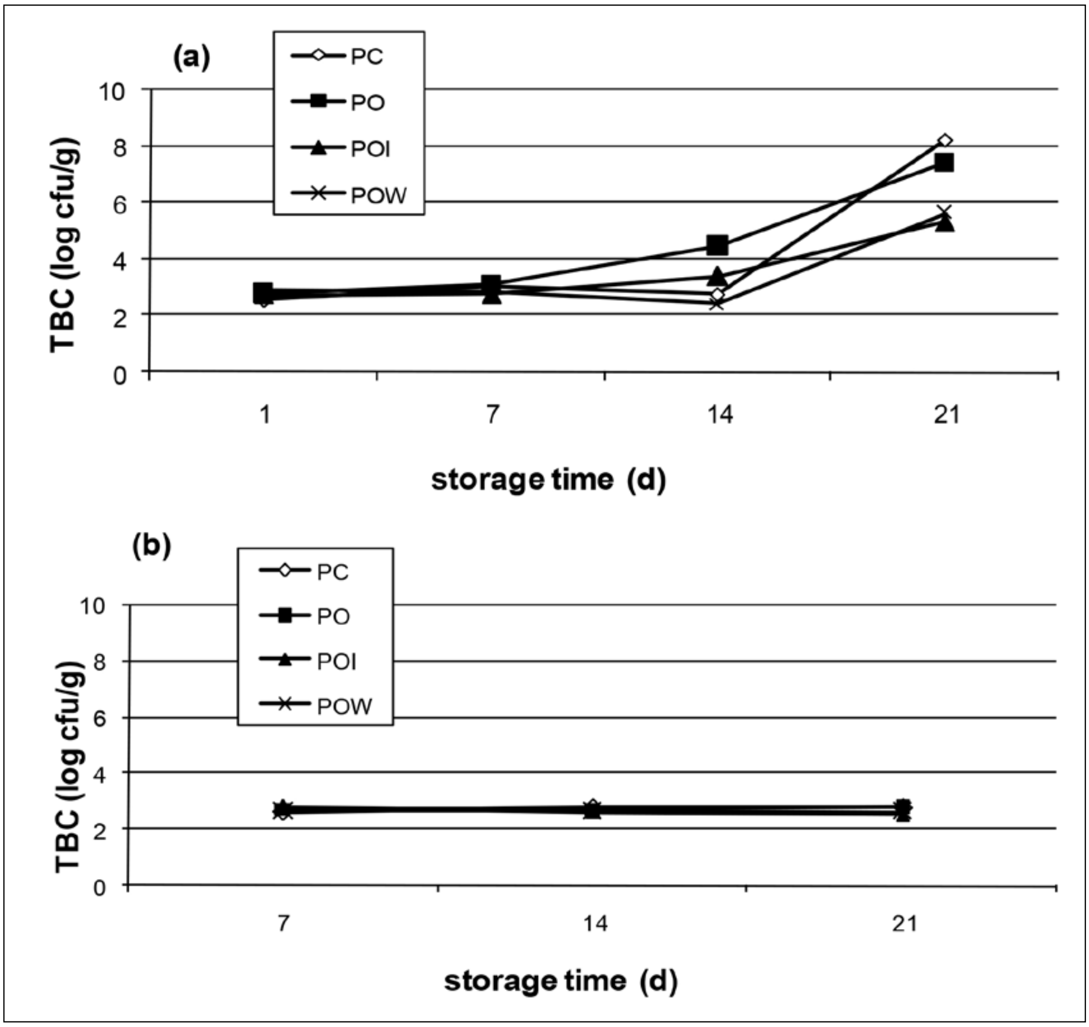

Fig. 2 - Total bacteria count of chicken burgers formulated with different combinations of pork jowl, vegetable oils and dietary fiber preparations, during 21 days of storage in refrigerator (a) or freezer (b).
For product description see Table 1.

oxidant additive of natural origin, which was rosemary extract, was used. The effectiveness of this component in the inhibition of lipid oxidation had already been confirmed in studies on ready-to-eat meat products (NISSEN *et al.*, 2004; FERNÁNDEZ-LÓPEZ *et al.*, 2005; GEORGANTELIS *et al.*, 2007; FORELL *et al.*, 2010; KONG *et al.*, 2010).

Microbiological analysis

The changes in TBC in chicken burgers stored at the temperature of +4°C±1 and -20°C±1 are shown in Figs. 2a and 2b, respectively. It was found that 24 h after preparing, TBC in burgers was as follows: 2.54 log cfu/g for PC product, 2.73 log cfu/g for POI product, 2.78 log cfu/g for PO product, and 2.88 log cfu/g for POW product, and was not significantly ($p < 0.05$) differentiated by the applied modifications of the composition of formula.

After the 21-day storage at +4°C±1, the TBC increased to the level of: 5.32 log cfu/g for POI product, 5.61 log cfu/g for POW product, 7.40 log cfu/g for PO product, and 8.21 log cfu/g for PC product. The increase of TBC during the whole period of storage was statistically significant ($p < 0.05$) only in the PC and PO product.

After the 21-day storage at -20°C±1 the TBC increased to the level of: 2.54 log cfu/g for POI product, 2.65 log cfu/g for POW product, 2.79 log cfu/g for PO product, and 2.80 log cfu/g for PC product. The TBC of any of the frozen products was not significantly ($p < 0.05$) differentiated during the whole period of storage. For chicken burgers of each formula the TBC was significantly ($p < 0.05$) higher in the refrigerated product than in the frozen one after 21 days of storage (results not showed).

The presence of *Salmonella ssp.* was not found in chicken burgers, and the number of coliform bacteria was lower than 10 cfu/g during the whole storage period, regardless of the product formula and storage conditions (temperature and time).

The results obtained proved that the microbiological quality of chicken burgers of all the four formulas fulfilled the requirements mentioned in EC REGULATION (2007) with respect to *Salmonella ssp.* Despite the fact that the regulation does not require determination of coliform bacteria nor total bacteria count in ready-to-eat meat products from poultry meat, it should be noticed that they may influence both health safety and shelf-life of these products.

The results obtained are in agreement with these obtained ANDRÉS *et al.* (2009) who showed that microbiological quality of poultry frankfurters containing squid oil instead of beef tallow was not significantly differentiated when compared to the control product. Similarly, LOPÉZ-LOPÉZ *et al.* (2009), on the basis of determination of total bacteria count and lactic bacteria count, found that microbiological quality of pork frankfurters enriched with olive or algae oil did not differ significantly during storage. TBC in frankfurters after manufacturing ranged - depending on product formula - from 2.64 to 4.18 log cfu/g, and was comparable to the results obtained in the present study.

CONCLUSIONS

After summarizing the results of this study it was found that 20% substitution of pork jowl with a mixture of vegetable oils in the composition of formula of chicken burgers resulted in an improvement in nutritional quality in terms of FA composition. Chicken burgers enriched with oils contained significantly less SFA and more PUFA, including nutritionally valuable PUFA *n-3*, than the control product, what means the improvement in nutritional value of lipids in these products. The oxidation process of lipids in products containing vegetable oils could be retarded significantly by the addition of 0.03% of rosemary extract. The results of measurements of the shear force of burgers indicated that addition of 3% of wheat fiber to product prepared with the mixture of vegetable oils as the 20% substitute of pork jowl counteracted the changes in texture. Microbiological quality of vacuum-packed burgers subjected to 21-day storage at the temperature of +4°C±1 and -20°C±1 was satisfactory.

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