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Effect of fat content in primal cuts of pigs fed diet enriched in n-3 polyunsaturated fatty acids on health-promoting properties of pork

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ABSTRACT. The effect of fat content in primal cuts of pigs fed diet enriched in the mixture of linseed (2%), rapeseed (0.5%) and fish (0.5%) oils on health-promoting properties of pork was investigated. Twenty-four crossbred (♂Duroc × ♀(Polish Large White × Danish Landrace)) pigs were fed an experimental diet restrictively from 60 to 105 kg of body weight. After slaughter the right-half carcass was dissected into neck, loin, ham, shoulder and belly. Based on the fat content in the *Longissimus thoracis et lumborum* muscle pigs were divided into two groups – with low intramuscular fat content (LMF; below 1.10%) and with high intramuscular fat content (HMF; above 1.10%). Meat from primal cuts was characterized with SFA (saturated fatty acids)/PUFA (polyunsaturated fatty acids) and n-6/n-3 PUFA ratios for meat with health-promoting properties according to WHO. Belly and neck of pigs from both groups, and loin and shoulder of HMF pigs met the European Union recommendations for human nutrition for products which are considered as either n-3 PUFA sources or products with high n-3 PUFA content. The particular fatty acids content is positively related with the fat content in primal cuts; however this effect is more pronounced in meat with a greater fat content.

Introduction

The nutritive value of pork depends mostly on the intra- and intermuscular fat and backfat content and fatty acid (FA) profile as well as proportion between particular groups of FA, as all these factors have an important impact on human health. Values of these parameters can be modulated by the amount and source of energy used in the diet, whereas the rate of the FA deposition depends on the type of a target tissue and primal cuts (Duran-Montgé et al., 2010). Also breed, understood as differences in the intramuscular and/or subcutaneous fat content, exert influence on the carcass fattening rate which is positively correlated with fat content in the body (Raj et al., 2010). Moreover Burkett (2009), Kapelański et al. (2010) and Raj et al. (2010) indicated that fatter pigs had higher intramuscular fat content with simultaneously higher saturated FA (SFA) and lower polyunsaturated FA (PUFA) contents when compared with leanest pigs. However, Pascual et al. (2007) claimed that both lean and fat pigs respond to fat supplementation in a similar way, thus the differences in FA profile result rather from carcass fatness and intramuscular fat content. Other authors pointed out a great diversity in intramuscular fat content in pigs even within the same genotype and similar backfat thickness (Huang et al., 2014).

Linoleic (C18:2 n-6, LA) and linolenic (C18:3 n-3, ALA) acids are precursors of long chain (LC) n-6 and n-3 PUFA, respectively; however both LA and ALA cannot be synthesised *de novo* by mammals, thus must be supplied with the diet. The LA/ALA and n-6/n-3 PUFA ratios in meat of pigs fed a commercial feed exceed the values recommended by WHO (2003) for meat with health-promoting properties. This resulted mainly from too high LA content (Raes et al., 2004). Therefore, to reduce (improve) these ratios feed for pigs should be enriched with ALA and LC n-3 PUFA. Literature data show that natural sources of n-3 PUFA include linseeds and linseed (ALA), fish (eicosapentaenoic (C20:5 n-3, EPA) and docosahexaenoic (C22:6 n-3, DHA) acids) and rapeseed (ALA but also LA) oils (Duran-Montgé et al., 2010). In our previous studies, it was found that feeding pigs with a mixture of linseed, rapeseed and fish oils resulted in the most efficient health-promoting properties of pigs tissues (Skiba et al., 2012) compared with a diet enriched in a single oil (Raj et al., 2010).

Most of the studies dealing with the FA composition of pork were carried out on a single tissue (muscle/fat) (e.g., Więcek et al., 2010), but there are only a few studies investigating the FA content in the primal cuts. Moreover these studies were mainly concentrated on FA content in primal cuts subcutaneous fat (Monziols et al., 2007) or in inter/outer fat layers (Hallenstvedt et al., 2012). In those experiments a standard diet or diets enriched in vegetable oils were often used; however the PUFA/SFA and n-6/n-3 PUFA ratios in primal cuts of pigs fed such diets did not meet WHO recommendations (2003). Thus, in the current study we determined the FA content in the meat of primal cuts of pigs fed diet enriched with the mixture of linseed, rapeseed and fish oils as a source of n-3 PUFA. Diet was composed on the basis of our previous study (Sobol et al., 2015) as these oils had the greatest impact on FA composition and allowed to obtain pork with health-promoting properties. Current study verifies the hypothesis that mixture of linseed, rapeseed and fish oils in the diet will impact FA composition in pig tissue as to achieve more nutritional benefits for people, however response will be different depending on the content of inter- and intramuscular fat as well as primal cuts of pig. Thus, the aim of the study was to investigate the changes in FA content in the primal cuts of crossbred (♂Duroc × ♀(Polish Large White × Danish Landrace)) pigs fed diet enriched with the mixture of linseed (2.0%), rapeseed (0.5%) and fish (0.5%) oils as a source of n-3 PUFA.

Material and methods

The experimental procedures used throughout this study were performed in accordance with national/local ethical guidelines and approved by the III Local Ethics Commission on Animal Experimentation of the Warsaw University of Life Sciences, Poland.

Animals and housing

The study was carried out on twenty four crossbred (♂Duroc × ♀(Polish Large White × Danish Landrace)) pigs of the similar body weight (BW). Such genotype was chosen, because it is the crossbred most commonly used in Polish pigs husbandry. Pigs were grown from 25 to 105 kg BW. Animals were kept individually on concrete floor without straw in pens (2.6 m^2) equipped with nipple drinker, in a thermally neutral environment. The environmental condition in the piggery: air temperature (18 – 20 °C), humidity (60 – 70%) and air flow (0.2 – 0.4 $m \cdot s^{-1}$), was regulated by a Fancom ventilation system (Fancom B.V., Panningen, The Netherlands) and was in the accordance with the Polish law (Regulation of the Minister of Agriculture and Rural Development, 2003).

Diets

During growth from 25 to 60 kg BW, the pigs were fed commercial grower diet (13.2 $MJ \cdot kg^{-1}$ metabolizable energy (ME) and 8.2 $g \cdot kg^{-1}$ standardized ileal digestible lysine; Table 1). Afterwards, during growth from 60 to 105 kg BW, the animals were fed restrictively (90% of assumed *ad libitum* intake) an experimental finisher diet twice a day. In the experimental diet, 9% of ME was provided by oils mixture (mixture of linseed, rapeseed and fish oils in proportion according to Table 1) enriching content of n-3 PUFA. Feed composition and nutritive value is presented in Table 1. Essential amino acids were balanced in comparison to lysine and the used proportion was 100:35:70:18 for lysine, methionine, threonine and tryptophan, respectively. The standardized ileal digestible lysine to ME ratio amounted 0.55 $g \cdot MJ^{-1}$. Diet supplementation with vitamin E (150 $mg \cdot kg^{-1}$ diet) protected PUFA against auto-oxidation.

Sample collection

At 105 kg BW, the pigs were slaughtered, after 16 h of starvation, using electrical stunning (STZ 3 apparatus, P.P.H. MASTER Sp. J., Solec Kujawski, Poland) at the experimental slaughterhouse of The

Table 1. Ingredients, chemical composition and nutritive value of diets

Indices	Commercial grower diet	Experimental finisher diet
Ingredients, g · kg^{-1}		
barley	305	365
wheat	300	360
maize	250	100
soyabean meal	80	80
rapeseed meal	40	40
linseed oil	–	20
rapeseed oil	–	5
fish oil	–	5
premix A[1]	25	–
premix B[2]	–	25
Analysed chemical composition, g · kg^{-1}		
dry matter	891	886
ash	38	41
organic matter	853	845
crude protein	158	165
ether extract	25	59
crude fibre	34	43
N-free extractives	674	606
Ca	4.58	4.50
Na	1.03	0.95
digestible protein	162	146
P, digestible	1.68	1.52
Calculated amino acid content, g · kg^{-1}		
lysine	8.17	7.41
methionine	2.83	2.64
threonine	5.59	5.02
tryptophan	1.46	1.31
Analysed metabolizable energy, MJ · kg^{-1}	13.24	13.40
Lysine / metabolizable energy, g · MJ^{-1}	0.62	0.55

[1]addition of 2.5% of premix A introduce to 1 kg of diet: IU: vit. A 1500, vit. D_3 300; mg: Fe 60, Zn 50, Cu 30, Mn 30, J 0.30, Se 0.20, vit. E 150, vit. K_3 2.0, vit. B_1 2.0, vit. B_2 2.5, vit. B_6 2.0, vit. B_{12} 0.02, biotin 0.11, folic acid 0.6, nicotinic acid 15, calcium-D pantothenate 10, choline chloride 500; g: Ca 3.6, P 0.33, and essential amino acids: g: lysine 3.46, methionine 0.77, threonine 1.50; [2]addition of 2.5% of premix B introduce to 1 kg of diet: IU: vit. A 1500, vit. D_3 300; mg: Fe 60, Zn 50, Cu 30, Mn 30, J 0.30, Se 0.20, vit. E 150, vit. K_3 2.0, vit. B_1 2.0, vit. B_2 2.5, vit. B_6 2.0, vit. B_{12} 0.02, biotin 0.11, folic acid 0.6, nicotinic acid 15, calcium-D pantothenate 10, choline chloride 500; g: Ca 2.8, P 0.07, and essential amino acids: g: lysine 2.63, methionine 0.68, threonine 0.98

Kielanowski Institute of Animal Physiology and Nutrition Polish Academy of Sciences in Jabłonna (Poland). After exsanguinations the carcass was divided into two half-carcasses, then weighed and chilled for 24 h at 4 °C. The entire *Longissimus thoracis et lumborum* (LTL) muscle was dissected from the left half-carcass, weighed and ground. Samples of approximately 500 g of the LTL muscle were taken, homogenized, packed into foil bag, frozen and kept at –20 °C until further analysis of fat (ether extract) content. Next the right half of each carcass was weighed and the backfat thickness was measured along the carcass dividing line between the last thoracic and the first lumbar vertebra. Each right half-carcass was dissected into primal cuts according to the standardized procedure used in Poland (Różycki, 1996). Then neck, shoulder, loin, ham and belly were separately weighted, next dissected into meat, subcutaneous fat, bones and skin. Meat from each primal cut was weighed, separately ground and a random sample (approximately 500 g) was taken, homogenized, packed into foil bag, frozen and kept at –20 °C until further analysis of fat (ether extract) content and FA composition.

Chemical analysis

Dry matter, ash, crude protein, crude fibre, simple sugar, starch and ether extract contents in the feed and carcass samples were determined according to AOAC International (2011) procedures No. 934.01, 942.05, 984.13, 978.10, 974.06, 920.40 and 920.39, respectively. Metabolizable energy and standardized ileal digestible amino acids of diet were calculated according to NRC (2012).

Lipids from the diet and primal cuts samples were extracted with chloroform-methanol (2:1) according to the method of Folch et al. (1957). After filtration through filter paper (FILTRAK 390; Spezialpapier FILTRAK GmbH, Niederschlag, Germany), 800 µl of filtrate was transferred to glass vials. Next, vials were evaporated to dryness under a gentle steam of nitrogen in a heating block at 50 °C. Samples were saponified with 1.5 ml of 0.5 M KOH in methanol in the heating block at 75 °C. After saponification, samples were esterified with 3.0 ml of 4% solution of $SOCl_2$ in methanol, then the methyl esters were extracted with 1.0 ml of n-heptane and salted out with NaCl to separate the organic layer. Afterwards, 300 µl portion of esters was transferred to 2.0 ml glass vials and 600 µl of n-heptane was added. The vials were stored at –80 °C and thawed before analysis of FA composition. Fatty acid methyl esters were analysed by gas chromatography (GC, model 2010AF), equipped with a BPX70 capillary column (length 60 m, internal diameter 0.25 mm, film thickness 0.25 µm; both from Shimadzu Europa GmbH, Duisburg, Germany) and a flame ionization detector. The operating conditions were as follows: carrier gas: helium; split ratio: 1:100; injector and detector temperature: 260 °C. The analysis started at a temperature of 140 °C and was held for 1 min, then was increased to 200 °C at a rate of 4 °C · min^{-1}, followed by an increase to 220 °C at a rate of 1 ° C · min^{-1}. Individual fatty acid peaks were identified by comparison with the Supelco 37 Component FAME Mix (SUPELCO, Bellefonte,

PA, USA) commercial standard. The total content of FA was calculated as 90% of ether extract (Kratz, 2003). The fatty acid concentrations were expressed in g per 100 g of tissue because this nutritionally reflects possible changes in the fatty acid profile better than the percentage content as it takes the fat content in 100 g of tissue into account.

Formation of experimental groups

After slaughtering, the fat content in the LTL muscle was measured. Based on the obtained results the pigs were divided into two groups – with low intramuscular fat content (LMF; below 1.10%) and with high intramuscular fat content (HMF; above 1.10%). This division was made on the basis of the intramuscular fat content in the LTL muscle because it is easily accessible after slaughter. It was assumed that with increasing intramuscular fat content in the LTL muscle, the fat content in the meat of other primal cuts increases.

Statistical analysis

Statistical analysis was performed using Statgraphics Centurion (version 16.1.18, 2011) software (StatPoint Technologies Inc., Warrenton, USA). The effect of fat content in the LTL muscle on the carcass characteristic of pigs was analysed using one-way analysis of variance (ANOVA). The effect of fat content in the LTL muscle and primal cuts on the FA content was analysed using two-way ANOVA with a model that included the fixed effects of fat content in the LTL muscle, primal cuts, and fat content in the LTL muscle × primal cuts interaction. The significance of differences between pairwise combinations of the least squares means was tested.

Results and discussion

Characteristic of the experimental diet

Through the used fat mixture rich in n-3 PUFA, the PUFA/SFA ratio increased and LA/ALA and n-6/n-3 PUFA ratios decreased compared with commercial diet used in the first period of growth (average 3.14, 2.30 and 2.07 vs 1.78, 14.70 and 14.58, respectively; Table 2). These ratios depend on the source of fat in the diet. Realini et al. (2010) found that dietary LA/ALA ratio amounted 0.56 or 58.17 when diets were supplemented with approximately 10% linseed or sunflower oil. Kloareg et al. (2005) reported that this ratio amounted 18 when pigs consumed basal diet without additional oils.

Table 2. Concentration (%) and profile of fatty acids in diets

Fatty acids	Commercial grower diet	Experimental finisher diet
SFA[1]	24.65	16.61
C16:0	20.98	12.36
C18:0	2.77	2.83
MUFA[2]	28.61	29.54
c9-C16:1	0.32	0.92
c9-C18:1	25.85	24.00
PUFA[3]	43.99	52.15
n-6 PUFA[4]	40.96	35.13
C18:2 n-6 (LA)	40.56	35.00
n-3 PUFA[5]	2.81	16.98
C18:3 n-3 (ALA)	2.76	15.20
C20:5 n-3 (EPA)	ND	0.69
C22:5 n-3 (DPA)	0.05	0.09
C22:6 n-3 (DHA)	ND	0.96
PUFA/SFA[6]	1.78	3.14
n-6/n-3 PUFA[7]	14.58	2.07
C18:2 n-6/C18:3 n-3 (LA/ALA)	14.70	2.30

[1]SFA – saturated fatty acids; [2]MUFA – monounsaturated fatty acids; [3]PUFA – polyunsaturated fatty acids; [4]n-6 PUFA – n-6 polyunsaturated fatty acids; [5]n-3 PUFA – n-3 polyunsaturated fatty acids; [6]PUFA/SFA – the ratio of total polyunsaturated fatty acids (PUFA) to total saturated fatty acids (SFA); [7]n-6/n-3 PUFA – the ratio of n-6 to n-3 polyunsaturated fatty acids; ND – not determined (value below 0.01)

Performance of pigs and carcass characteristic

Both groups of pigs consumed similar amount of feed per day; however LMF pigs had higher ($P = 0.092$) average daily gain and better ($P = 0.065$) feed conversion ratio compared with HMF pigs (Table 3). In this way LMF pigs stayed in the experiment 3 days shorter than HMF pigs ($P = 0.080$).

As we assumed (Table 4.) crossbred pigs differed in the fat content in the LTL muscle (average 1.77 and 0.63%, respectively, for HMF and LMF groups;

Table 3. Performance of pigs

Indices	Group[1]		SEM	Significance
	LMF	HMF		
ADG[2], g	1103	1052	23.117	0.092
Fattening period, days	40	43	1.737	0.080
FI[3], kg · day^{-1}	2.56	2.56	0.011	NS
FCR[4], kg feed · kg^{-1} gain	2.31	2.42	0.065	0.075

[1]LMF – pigs with low fat content in *Longissimus thoracis et lumborum* muscle, HMF – pigs with high fat content in *Longissimus thoracis et lumborum* muscle; [2]ADG – average daily gain of body weight (BW) during feeding period with experimental finisher diet; [3]FI – daily feed intake during feeding period with experimental finisher diet; [4]FCR – feed conversion ratio during feeding period with experimental finisher diet; NS – not significant

Table 4. Characteristic of pig carcass

Indices	Group[1]		SEM	Significance
	LMF	HMF		
Cold carcass weight, kg	80.6	79.3	1.444	NS
Carcass fat (extract ether), g · kg^{-1}	206	208	4.801	NS
Backfat thickness, mm	21.97	22.98	1.967	NS
Intramuscular fat[2], %	0.63	1.77	0.312	<0.01
Meat content in carcass, %	60.73	60.56	0.739	NS

[1]see Table 3; [2]intramuscular fat in *Longissimus thoracis et lumborum* muscle; NS – not significant

$P < 0.01$). Our data correspond with the results of Huang et al. (2014) who showed that even within breed/genotype pigs may have similar backfat thickness but different intramuscular fat content.

Fatty acid composition of primal cuts of pigs

The HMF pigs were characterized with higher fat (by 10%, $P < 0.01$), total FA (by 10%, $P < 0.01$), SFA (by 13%, $P < 0.001$), MUFA (by 4%, $P < 0.05$) and PUFA (by 23%, $P < 0.001$) contents than LMF pigs (Table 5). Similarly, contents of particular FA in the meat of HMF pigs were higher compared with those of LMF animals, except for C14:0, and c9-C18:1 n-9 FA. The results of our present study proved that not only composition of feed but also content of intra- and intermuscular fat in meat can influence the amount of FA deposited in the body. Similar findings were also presented by other authors (Burkett, 2009; Raj et al., 2010; Skiba et al., 2012).

The PUFA/SFA and n-6/n-3 PUFA ratios are important indicative parameters for the dietary value of pork fat (WHO, 2003). The PUFA/SFA ratio was higher in HMF than in LMF pigs (average 0.51 vs 0.46, respectively; $P < 0.001$); however difference in the fat content in the LTL muscle did not influence the LA/ALA and n-6/n-3 PUFA ratios in primal cuts (average 3.15 and 2.58, respectively). In both pigs groups the PUFA/SFA and n-6/n-3 PUFA ratios met WHO recommendations (2003) concerning meat with health-promoting properties (above 0.4 and below 5, respectively, for PUFA/SFA and n-6/n-3 PUFA ratios). Realini et al. (2010) also obtained values recommended by WHO for PUFA/SFA and n-6/n-3 PUFA ratios in carcass when pigs were fed diet supplemented with 10% of linseed oil or mixture of fish (4%) and linseed (6%) oils. However, when pigs were fed diet supplemented with a high amount of high-oleic sunflower or sunflower oil (rich in LA), pork of animals fed such diets did not meet WHO recommendations (Realini et al., 2010). Similar results concerned meat of animals fed diet not supplemented with additional fat source (Monziols et al., 2007; Realini et al., 2010).

In the present study the higher amounts of particular FA, expressed as g · 100 g^{-1} of tissue, were found in primal cuts that contained more fatty components (intra- and intermuscular fat) than in those having less fat. Thus, the content of FA in primal cuts took the following order: belly, neck, shoulder, loin and ham, as they contained respectively 18.90, 13.75, 8.97, 8.71 and 6.01% of fat.

Fat and FA content in the primal cuts allocated along the spine line was the greatest in the neck, smaller in the loin and the smallest in the ham (decreased from head to tail direction). In the contrary, in the lower part of the carcass fat and FA content was lower in the shoulder compared with the belly (increased from head to tail). Monziols et al. (2007) also found higher fat content in belly than in shoulder; however they found no significant difference between shoulder and ham or loin and between loin and ham. The observed discrepancies between obtained results may be due to use of different pig breed/genotype of different fat level in the diet (3 vs 2% fat content, respectively). Other reason may be the different carcass dissection. In the present study front part of the carcass was divided into neck and shoulder, while Monziols et al. (2007) whole front part of the carcass classified as shoulder, which resulted in the average fat content. It can be also suggested that the relationship between FA content and carcass cuts may be explained by the differences in the fat maturation, muscles types and muscles different functions.

The PUFA/SFA ratio ranged from 0.45 in belly to 0.52 in shoulder ($P < 0.001$). The LA/ALA ratio was higher in shoulder and ham than in neck, loin and belly (average 3.47 vs 2.93, respectively; $P < 0.001$). In the present study the PUFA/SFA and n-6/n-3 PUFA ratios in all primal cuts were in line with WHO recommendations (2003). On the other hand, Monziols et al. (2007) found that when pigs consumed standard diet (not supplemented with fat) the PUFA/SFA ratio in the intramuscular fat of the primal cuts was lower than recommended by WHO (2003) and ranged from 0.25 in belly to 0.35 in ham.

Fatty acids content in the meat of primal cuts compared with the European Union recommendations for human nutrition

In Central Europe culinary tradition pork plays a great role. It was calculated that the consumption of pork in Central Europe is on average 35 kg per person per year, placing it in the top of the list of the most consumed meat (Migdał, 2007). So it is important to improve the quality and health-promoting properties of pork. According to the European of Union recommendations (Commission Regulation,

Table 5. Content (g · 100 g^{-1} of tissue) of fat, total fatty acid, saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and particular fatty acids in meat of primal cuts (PC[1]) of crossbred (♂Duroc × ♀(Polish Large White × Danish Landrace)) pigs

Item	Group[2]	PC[1]						SEM	Significance		
		neck	shoulder	loin	ham	belly	mean		group	PC	group x PC
Weight	LMF	2.66	3.75	4.37	7.00	4.31	4.37	0.178	NS	<0.001	NS
	HMF	2.26	3.88	4.62	6.77	4.31	4.41				
	Mean	2.46 ^{A}	3.81 ^{B}	4.49 ^{C}	6.88 ^{D}	4.31 ^{C}	4.39				
Fat content	LMF	12.50	8.96	7.78	5.72	18.59	10.71 ^{A}	0.809	<0.01	<0.001	NS
	HMF	15.00	8.99	9.65	6.30	19.21	11.83 ^{B}				
	Mean	13.75 ^{C}	8.97 ^{B}	8.71 ^{B}	6.01 ^{A}	18.90 ^{D}	11.27				
Total fatty acid	LMF	11.25	8.06	7.00	5.15	16.73	9.63 ^{A}	0.728	<0.01	<0.001	NS
	HMF	13.51	8.09	8.68	5.67	17.29	10.65 ^{B}				
	Mean	12.38 ^{C}	8.08 ^{B}	7.84 ^{B}	5.40 ^{A}	17.01 ^{D}	10.14				
SFA[3]	LMF	4.35	2.94	2.69	1.89	6.48	3.67 ^{A}	0.259	<0.001	<0.001	NS
	HMF	5.35	2.97	3.44	2.11	6.90	4.15 ^{B}				
	Mean	4.84 ^{C}	2.95 ^{B}	3.07 ^{B}	2.00 ^{A}	6.69 ^{D}	3.91				
C14:0	LMF	0.130	0.088	0.083	0.061	0.194	0.111	0.007	NS	<0.001	NS
	HMF	0.144	0.081	0.091	0.057	0.183	0.111				
	Mean	0.137 ^{C}	0.085 ^{B}	0.087 ^{B}	0.059 ^{A}	0.188 ^{D}	0.111				
C16:0	LMF	2.50	1.74	1.57	1.11	3.81	2.14 ^{A}	0.143	<0.01	<0.001	NS
	HMF	3.03	1.73	1.99	1.24	3.93	2.38 ^{B}				
	Mean	2.76 ^{C}	1.74 ^{B}	1.78 ^{B}	1.17 ^{A}	3.87 ^{D}	2.26				
C18:0	LMF	1.61	1.04	0.970	0.647	2.37	1.33 ^{A}	0.106	<0.001	<0.001	NS
	HMF	2.10	1.12	1.32	0.795	2.69	1.60 ^{B}				
	Mean	1.85 ^{C}	1.08 ^{B}	1.15 ^{B}	0.721 ^{A}	2.53 ^{D}	1.47				
MUFA[3]	LMF	4.81	3.61	3.00	2.29	7.39	4.22 ^{a}	0.252	<0.05	<0.001	NS
	HMF	5.42	3.46	3.61	2.40	7.12	4.40 ^{b}				
	Mean	5.11 ^{C}	3.54 ^{B}	3.30 ^{B}	2.34 ^{A}	7.25 ^{D}	4.31				
c9-C16:1	LMF	0.246	0.189	0.165	0.130	0.362	0.218 ^{b}	0.013	<0.05	<0.001	NS
	HMF	0.243	0.164	0.167	0.115	0.308	0.199 ^{a}				
	Mean	0.244 ^{C}	0.176 ^{B}	0.165 ^{B}	0.122 ^{A}	0.335 ^{D}	0.209				
c9-C18:1	LMF	4.08	3.04	2.52	1.90	6.32	3.57	0.225	NS	<0.001	NS
	HMF	4.70	2.96	3.11	2.04	6.19	3.80				
	Mean	4.38 ^{C}	3.00 ^{B}	2.81 ^{B}	1.97 ^{A}	6.26 ^{D}	3.68				
c11-C20:1	LMF	0.112	0.074	0.071	0.048	0.176	0.088 ^{a}	0.003	<0.05	<0.001	NS
	HMF	0.108	0.065	0.075	0.045	0.149	0.096 ^{b}				
	Mean	0.109 ^{C}	0.070 ^{B}	0.073 ^{B}	0.046 ^{A}	0.163 ^{D}	0.092				
PUFA[3]	LMF	2.01	1.45	1.20	0.903	2.77	1.66 ^{A}	0.096	<0.001	<0.001	NS
	HMF	2.69	1.63	1.61	1.13	3.22	2.05 ^{B}				
	Mean	2.35 ^{C}	1.54 ^{B}	1.40 ^{B}	1.02 ^{A}	2.99 ^{D}	1.86				
C18:2 n-6 (LA)	LMF	1.30	0.954	0.749	0.595	1.79	1.08 ^{A}	0.069	<0.001	<0.001	NS
	HMF	1.80	1.080	1.05	0.757	2.11	1.36 ^{B}				
	Mean	1.55 ^{C}	1.02 ^{B}	0.899 ^{B}	0.676 ^{A}	1.95 ^{D}	1.22				
C18:3 n-3 (ALA)	LMF	0.444	0.293	0.260	0.154	0.642	0.362 ^{A}	0.035	<0.001	<0.001	NS
	HMF	0.593	0.316	0.364	0.217	0.751	0.448 ^{B}				
	Mean	0.518 ^{C}	0.305 ^{B}	0.312 ^{B}	0.193 ^{A}	0.697 ^{D}	0.405				
C20:4 n-6 (AA)	LMF	0.057	0.037	0.040	0.025	0.086	0.045 ^{a}	0.003	<0.05	<0.001	NS
	HMF	0.048	0.051	0.037	0.042	0.049	0.049 ^{b}				
	Mean	0.052 ^{C}	0.044 ^{B}	0.038 ^{A}	0.034 ^{A}	0.068 ^{D}	0.047				

continued on the next page

Table 5. continued

Item	Group[2]	PC[1]						SEM	Significance		
		neck	shoulder	loin	ham	belly	mean		group	PC	group x PC
C20:5 n-3 (EPA)	LMF	0.023	0.018	0.020	0.012	0.021	0.019 ^{a}	0.002	<0.05	<0.001	NS
	HMF	0.023	0.027	0.017	0.016	0.026	0.022 ^{b}				
	Mean	0.023 ^{C}	0.023 ^{C}	0.018 ^{B}	0.014 ^{A}	0.024 ^{C}	0.020				
C22:5 n-3 (DPA)	LMF	0.032	0.028	0.024	0.017	0.042	0.029 ^{A}	0.003	<0.001	<0.001	NS
	HMF	0.041	0.035	0.028	0.023	0.047	0.035 ^{B}				
	Mean	0.036 ^{C}	0.032 ^{C}	0.026 ^{B}	0.020 ^{A}	0.045 ^{D}	0.032				
C22:6 n-3 (DHA)	LMF	0.018	0.016	0.009	0.007	0.023	0.015 ^{A}	0.002	<0.001	<0.001	NS
	HMF	0.021	0.021	0.014	0.012	0.026	0.019 ^{B}				
	Mean	0.019 ^{B}	0.018 ^{B}	0.011 ^{A}	0.009 ^{A}	0.025 ^{C}	0.017				
C20:5 n-3 + C22:6 n-3 (EPA+DHA)	LMF	0.041	0.034	0.029	0.019	0.041	0.033 ^{A}	0.003	<0.001	<0.001	NS
	HMF	0.044	0.048	0.031	0.028	0.052	0.040 ^{B}				
	Mean	0.042 ^{C}	0.041 ^{C}	0.030 ^{B}	0.023 ^{A}	0.048 ^{D}	0.037				
PUFA/SFA[3]	LMF	0.46	0.49	0.45	0.48	0.42	0.46 ^{A}	0.016	<0.001	<0.001	NS
	HMF	0.51	0.56	0.48	0.54	0.47	0.51 ^{B}				
	Mean	0.49 ^{BC}	0.52 ^{D}	0.46 ^{AB}	0.51 ^{CD}	0.45 ^{A}	0.49				
C18:2 n-6/C18:3 n-3 (LA/ALA)	LMF	2.95	3.26	2.90	3.57	2.81	3.10	0.098	NS	<0.001	NS
	HMF	3.10	3.49	2.94	3.57	2.87	3.19				
	Mean	3.02 ^{A}	3.37 ^{B}	2.92 ^{A}	3.57 ^{B}	2.85 ^{A}	3.14				
n-6/n-3 PUFA[3]	LMF	2.53	2.56	2.37	2.63	2.55	2.53	0.033	NS	NS	NS
	HMF	2.61	2.73	2.46	2.85	2.43	2.61				
	Mean	2.57 ^{AB}	2.64 ^{AB}	2.41 ^{A}	2.74 ^{B}	2.49 ^{AB}	2.57				

[1] PC – meat of the primal cuts (without subcutaneous fat); [2]see Table 3; [3]see Table 2; ^{ABCD} and ^{abcd} – values with different superscripts differ significantly at ^{ABCD} $P < 0.01$ or ^{abcd} $P < 0.05$ in row (mean of both groups for each PC) or in column (mean of all PC for each group); ND – not determined; NS – not significant

No. 116/2010), when products contain at least 300 mg of ALA or at least 40 mg of EPA + DHA per 100 g of tissue, it can be considered as an n-3 PUFA source, whereas when it contains at least 600 mg of ALA or 80 mg of EPA + DHA per 100 g of tissue, then it can be considered as a product with a high n-3 PUFA content. Taking these needs into account, belly from both groups can be treated as a product with a high content of n-3 PUFA, whereas neck from both groups, and loin and shoulder of HMF pigs can be considered as a source of n-3 PUFA. Ham from both groups, shoulder and loin from LMF pigs did not meet these recommendations. Obtained results showed that meat from HMF pigs had higher nutritional value for the customers than meat from LMF pigs. In our previous study Skiba et al. (2012) found that despite using fat mixture containing a large amount of LC n-3 PUFA (or their precursors) the contents of ALA and EPA + DHA in the LTL muscle were not enough to obtain the values recommended for products that are considered to be a source of n-3 PUFA due to the low intramuscular fat content (average 3.3 g per 100 g of tissue).

The recommendations for the general adult population regarding daily EPA + DHA intake depend on the nationality, and range from 200 (Irish Heart Foundation, 2007) to 500 mg (National Heart Foundation of Australia, 2008). In Europe, daily oily fish or dietary LC n-3 PUFA supplements that provide 250 mg per day of EPA + DHA are recommended as sufficient for primal prevention in healthy subjects (EFSA, 2010). Taking this requirements and our results into consideration, daily consumption of 480 and 610 g of belly, 580 and 610 g of neck, 520 and 730 g of shoulder, 800 and 860 g of loin or 890 and 1310 g of ham (from HMF and LMF pigs, respectively) would be sufficient for daily needs. In our previous study (Sobol et al., 2015) it was found that daily consumption of 350 and 470 g of meat or 80 and 190 g of subcutaneous fat (respectively from pigs fed diets contained 3.5% fat mixture of linseed and rapeseed oils or linseed and fish oils) would be sufficient for daily human needs. Nevertheless, when the mixture of meat and subcutaneous fat is considered, daily consumption could be reduced to less than 200 g per day. The results

from the present study concurred with those of Rossi et al. (2010), who suggested that when pigs are fed diets with n-3 fatty acids, pork and pork products could be recognised as functional foods with new health-promoting properties.

Conclusions

Based on the obtained results it can be concluded that replacing part of energy in pig diet by mixture of linseed, rapeseed and fish oils improved the fatty acids (FA) content in pork. Primal cuts of pigs fed such diet meet WHO recommendations for PUFA/SFA and n-6/n-3 PUFA ratios, moreover most of them can be considered as a source of n-3 PUFA or as a product with a high n-3 PUFA content. The FA content ($g \cdot 100\ g^{-1}$) is positively related with the fat content of pork; however this effect is more visible in primal cuts with a greater meat fat content. The meat from pigs fed such diet gain health-promoting properties and could be recommended as a functional food in human nutrition.

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