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EFFECTS OF DIETARY MODIFIED FISH MEAL (MFM) ON PHYSICOCHEMICAL AND SENSORY PROPERTIES OF PIG LOIN*

Roman Kołacz[1], Adolf Korniewicz[2], Zbigniew Dobrzański[1], Daniel Korniewicz[3], Zygmunt Usydus[4]
[1] *Department of Animal Hygiene and Ichthyology, Agricultural University of Wroclaw, Poland*
[2] *Department of Animal Nutrition and Feed Quality, Agricultural University of Wroclaw, Poland*
[3] *Lower Silesian Feed Company "Dolpasz" S.A., Wrocław, Poland*
[4] *Sea Fisheries Institute, Gdynia, Poland*

ABSTRACT

Modified fish meal (MFM) produced from liquid wastes obtained during commercial fish processing (with the addition of wheat bran) contains 25% of total protein and 24.5% of crude fat. The fattening pigs were fed MFM (10% of the content of mixture) from 30 kg to ca. 80 kg body weight, and next in the fattening phase from 80 to 100 kg, MFM was substituted for meat meal (group II) or extracted soybean meal (group III). The control group (I) was fed a mixture containing 5% of meat meal. The pigs when they reached about 100 kg were slaughtered and dissected (8 fatteners from each group). The samples of loin (*muscle longissimus)* were taken for sensory and physicochemical assessment, including the analysis of dry matter, protein, fat and cholesterol content and also of fatty acids profile. The results show that MFM in groups II and III did neither reduce physicochemical properties nor sensory characteristics of loin pork as compared with group I. However, the MFM groups exhibited an increased level of polyunsaturated fatty acids (PUFA), including omega-3 family, along with 2-4-fold decreasing of omega-6/ omega-3 acids ratio.

Key words: pig, dietary fish meal, meat quality.

INTRODUCTION

Protein present in grain does not satisfy the needs of intensively growing pigs and, therefore, it requires supplementation. Animal meals were found to be a good source of protein [24].

When the import of meat and bone-meat meals from EU countries was banned due to the protection against BSE, an increased interest in fish products as a source of bioavailable protein (including exogenous amino acids) and fats (including polyunsaturated fatty acids) was observed. One of such products is meal obtained from technological wastes obtained during commercial deep-sea fish processing with appropriate organic carrier. The product obtained was different from typical fish meal and was called modified fish meal (MFM) [10].

Usefulness of MFM for feeding of broiler chickens was described by Dobrzański et al. [9]. Similar products (plant-fish concentrates) used in feeding of laying hens were described by Koreleski et al. [19]. The fat present in fish, rich in polyunsaturated fatty acids (PUFA), particularly of omega-3 family, can improve the dietetic value of chicken meat and egg yolk. Urbańczyk et al. [29] found that plant-fish concentrates improved the productive results of pigs. Similar results were reported by Korniewicz et al. [20], who studied the effects of fish fat-mineral concentrates in feeding of pigs.

Although the feeding value of fish meals is unquestionable, their use in animal feeding cannot remain uncontrolled because of their unfavourable effects (fishy taints) on meat, fats and eggs. They results from the presence of some nitrogen compounds (trimethylamine), sulfur (mercaptans) or other odour-forming substances [23, 28]. For this reason, the amount of any fish meal or oil cannot be too high, and in the final phase of fattening, totally eliminated from animal diet.

The aim of the present researches was to find the effects of modified fish meal (MFM) added to feed mixtures for fattening pigs on physicochemical properties and sensory characteristics of meat.

MATERIALS AND METHODS

Modified fish meal [MFM] was produced from wastes from consumptive fish processing, according to the technology elaborated at Sea Fisheries Institute in Gdynia [30,31]. In the processes of coagulation and flotation fat-protein coagulate is formed, that undergoes hydrothermal processing, and afterwards is mixed with wheat brans, dried and milled. The product in the final form [MFM] contains 92.5% dry matter, 25% protein, 24.5% fat, 11.5% ash and 1.6% fiber. The energetic value was 14.9 MJ of metabolisable energy. Protein contains many exogenous amino acids, such as: leucine (16.23 g kg^{-1}), lysine (14.37), arginine (10.42), as well as methionine and tryptophan (below 5 $g.kg^{-1}$). Detailed amino acid content of protein from this meal, the content of mineral components and some contamination, such as toxic metals, chlorinorganic pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons were shown previously [10]. The percentage contribution of fatty acids in the fat from this meal was shown in Table 1.

The studied material consisted from 162 pigs (Polish LargeWhite♀ × Polish Landrace♂) fattened from 30 to ca. 100 kg body weight (b.w.) in the pigs farm Agro-Eko in Frączków. The fatteners were randomly assigned to 3 feeding groups, 54 heads in each group (G). The male/female ratio (36/18) was the same in each group. The division into 3 feeding groups resulted from the contribution of animal meals or soybean meal and the period of fattening.

Due to the possibility of fishy taints of the obtained pork, modified fish meal (MFM) was used only until 80 kg b.w. was studied, and in the fattening period from 80 to 100 kg b.w. was substituted meat meal (MM) or extracted soybean meal (ESM), according to the experimental procedure:

G I – control, the pigs fed mixture containing of 5% MM for the whole period of fattening, from 30 to 100 kg b.w.;
G II – the pigs fed mixture containing of 10% of MFM from 30 to 80 kg b.w. and from 80 to 100 kg b.w. - containing MM (as the group I);
G III – the pigs fed mixture containing of 10% MFM from 30 to 80 kg b.w., and from 80 to 100 kg b.w. - containing ESM (elimination of MFM).

The mixtures were produced from the same components, according to the same recipe in the regional feed mixing station in Agro-Eko Farm. The composition of the diets is shown in Table 2. The components used in the production of mixtures underwent chemical analysis in the State Veterinary Hygiene Laboratory in Wrocław,

with the use standardized methods [2]. On this basis, the content of the basic nutritive components was assessed in the mixtures studies. Energetic value of the mixtures (metabolisable energy) was calculated on the basis of the analyses of the components and digestibility coefficients, as well as according to Pigs Feeding Standards [24]. The pigs were fed the mixtures *ad libitum* from self-feeders. Indicators of performance (weight gains and feed intake) were controlled. The experiment was concluded with slaughtering, dissection and carcass analysis 8 fatteners from each group. The production results and postslaughter carcass evaluation are shown in the separate work [21].

From each carcass dissected, the samples of the loin were taken on the height of 13^{th} and 14^{th} rib *(muscle longissimus)* for sensory and chemical analyses. The content of pH, dry matter, protein and cholesterol was determined. For the evaluation of the content of fatty acids in intramuscular fat, lipids extraction was carried out with the use of Folch et al. method [11]. In these samples of loins, the content of fatty acids was determined with gas chromatography [27]. The analyses were performed with gas chromatography from Philips equipped with flame-ionic detector. The columns used were Rtx-2330, 105 m length, temperature of injection chamber was 220 °C and of detector 230 °C. Helium (70 psi) was used as the carrier gas. Similarly, analysis of fatty acids in fat extracted from MFM was performed.

Sensory analysis of meat (loin) was carried out in 5-points scale. Color, aroma, flavor, tenderness and juiciness of meat were evaluated according to the procedure described by Baryłko-Pikielna [6] and polish norm PN-ISO 6564. The *m. longissimus* was divided of the external layer of fat, cut perpendicularly to the long axis into the parts (220 g). The samples of loins were baked at ca. 96 °C (396.3 K). All the meat parts were heated until the moment of reaching the temperature 75 °C (348.3 K) in the geometrical center. Sensory evaluation was carried out by trained 10-people team at Department of Animal Products Technology, Agricultural University of Wrocław.

The results were analysed statistically with analysis of variance and significant differences between the means were estimated using Duncan's multiple range test, with the use of Statgraphics v. 5.0 software.

RESULTS

Evaluation of feeds

Table 1 shows that the percentages of fat present in fish meal (MFM) accounted for 36.1% of saturated (SFA), 63.9% of unsaturated fatty acids (UFA) and 16.0 % of polyunsaturated fatty acids (PUFA). Besides, high percentages of MUFA (47.9%) and linoleic acid (11.24%) were found. The content of omega-3 fatty acids was not as high as in typical fish oils [22], but they are mainly connected with long-chain acids (EPA, DPA and DHA), which do not occur in plant oils [3, 4]. These acids are deposited in products of animal origin, and their presence is desired in human diets for the prevention of civilization diseases [17,23].

Table 1. Fatty acid composition in fat of modified fish meal – MRM (in % of total fatty acids)

Fatty acid	Amount
Octanic $C_{8:O}$	0.02
Decanic $C_{10:O}$	0.03
Lauric $C_{12:O}$	0.04
Myristic $C_{14:O}$	5.68
Miristoleic $C_{14:1}$	0.32
Pantadecanoic $C_{15:O}$	0.61
Palmitic $C_{16:O}$	25.17
Palmitoleic $C_{16:1}$ [n7]	4.05
Heptadecanoic $C_{17:O}$	0.65
Stearic $C_{18:O}$	3.86
Oleic $C_{18:1}$ [n9]	39.00
Vaccenic $C_{18:1}$ [n7]	2.53
Linoleic $C_{18:2}$ [n6] LA	11.24
γ -linolenic $C_{18:3}$ [n6] GLNA	0.07
α -linolenic $C_{18:3}$ [n3] ALNA	2.20
Eicosenoic $C_{20:1}$	2.02

Table 1. cont.

Eicosadienoic $C_{20:2}$	0.11
Arachidonic $C_{20:4}$ [n6]	0.08
Eicosapentaenoic $C_{20:5}$ [n3] EPA	1.03
Docosatetraenoic $C_{22:4}$ [n6]	0.07
Docosapentaenoic $C_{22:5}$ [n3] DPA	0.13
Docosahexaenoic $C_{22:6}$ [n3] DHA	1.09
Total	100.00
Saturated [SFA]	36.06
Unsaturated [UFA]	63.94
Monounsaturated [MUFA]	47.92
Polyunsaturated [PUFA]	16.02
Total fatty acids	100.00
PUFA/SFA	0.44
Sum of omega- 6	11.46
Sum of omega- 3	4.45
Omega -6/omega-3	2.58

Feed mixtures for all the groups (Table 2) contained 14.4-15.0% of total protein and 0.81-0.85% of lysine. The level of the remaining balanced amino acids and mineral components was in agreement with the requirements of Pigs Nutrition Standards [24]. The control mixture (G I) contained only 2.5% crude fat, while G II and G III contained 4.4% of fat. This means that about 2% of the fat present in the mixtures fed to pigs until they reached 80 kg l.w. was fish fat. In the final period of fattening (80-100 kg b.w.), the content of fat in the experimental mixtures with no fish meal was similar to that in the control group.

Table 2. Composition of the diets for fattening pigs

Ingredient	Group I	Group II		Group III	
	30-100	30-80	80-100	30-80	80-100
Ground wheat (%)	20.0	20.0	20.0	20.0	20.0
Ground barley (%)	59.0	53.0	59.0	53.0	56.8
Wheat bran (%)	5.0	5.0	5.0	5.0	5.0
Extracted soybean meal (%)	4.0	5.0	4.0	5.0	11.0
Rapeseed meal (%)	5.0	5.0	5.0	5.0	5.0
Meat meal (%)	5.0	-	5.0	-	-
Modified fish meal (%)	-	10.0	-	10.0	-
Fodder chalk (%)	1.0	1.0	1.0	1.0	1.2
Vitamin-aminoacid-mineral premix (%)	1.0	1.0	1.0	1.0	1.0
Total	100.00	100.0	100.0	100.0	100.0
In 1 kg feed:					
Metabolisable energy (MJ· kg $^{-1}$)	12.5	12.6	12.5	12.6	12.3
Crude protein (%)	15.0	14.4	15.0	1.4	14.9
Crude fibre (%)	4.7	4.6	4.7	4.6	4.9
Crude fat (%)	2.5	4.4	2.5	4.4	2.0
Crude ash (%)	3.3	3.5	3.3	3.5	2.8
Lysine (%)	0.81	0.81	0.81	0.81	0.85
Methionine (%)	0.25	0.25	0.25	0.25	0.25
Methionine and cystine (%)	0.57	0.55	0.57	0.55	0.57
Threonine (%)	0.55	0.51	0.55	0.51	0.55
Tryptophan (%)	0.17	0.17	0.17	0.17	0.18
Calcium total (%)	0.82	0.66	0.82	0.66	0.67
Phosphorus total (%)	0.62	0.59	0.62	0.59	0.53
Sodium total (%)	0.15	0.13	0.15	0.13	0.12
Vitamin A (IU· kg $^{-1}$)	8000	8000	8000	8000	8000
Vitamin D_3 (IU·kg $^{-1}$)	1500	1500	1500	1500	1500
Vitamin E (mg·kg $^{-1}$)	57	56	57	56	56

Evaluation of meat quality

Table 3 shows the results of sensory analysis of meat samples collected from the loins (*m. longissimus*). The mean values of colour, taste, flavour, tenderness and juiciness of pork were similar in all the groups. The differences found between the groups were not significant.

Table 3. Results of sensory evaluation of the loin *(m.longissimus)* of pigs fed diets containing MM (group I), MFM + MM (II) and MFM +ESM (III) ($\bar{x} \pm s$)

Indices / Group	Color	Flavor	Aroma	Tenderness	Juiciness
I	4.02 ±0.33	3.82 ±0.25	4.05 ±0.37	3.80 ±0.39	3.47 ±0.41
II	4.08 ±0.27	3.60 ±0.51	3.72 ±0.38	3.51 ±0.26	3.37 ±0.42
III	3.93 ±0.40	3.68 ±0.28	3.75 ±0.36	3.57 ±0.41	3.43 ±0.29

Table 4 shows the results of physicochemical analysis of the loins. No significant differences between the groups were observed in the pH, dry matter, total protein and total cholesterol contents. However, significant differences ($p<0.05$) were found in the content of crude fat, the lowest percentage (2.45%) was found in G II.

Table 4. Results of physicochemical analyses of the loin *(m.longissimus)* of pigs fed diets containing MM (group I), MFM + MM (II) and MFM +ESM (III) ($\bar{x} \pm s$)

Parameter / Group	pH	Dry matter (%)	Crude fat (%)	Total protein (%)	Total cholesterol (mg·100g)
I	5.72 ±0.51	25.55 ±1.49	$2.72^{a,d}$ ±0.09	21.43 ±2.37	96.4 ±8.16
II	5.74 ±0.99	25.37 ±3.89	$2.45^{a,c}$ ±0.25	22.16 ±3.17	95.75 ±7.45
III	5.77 ±0.72	25.98 ±3.13	3.20^{b} ±0.35	21.89 ±3.87	97.6 ±8.80

a,b and c,d - $p<0.05$.

Table 5 shows a significant ($p<0.05$) increase in the level of linoleic and eicosenoic acids in G III and α-linoleic acid in G II and G III as compared to G I. However, the percentage of monounsaturated fatty acids (MUFA) decreased. In experimental groups an increased content of PUFA was observed (9.9 and 20.8%, respectively) as compared to the control group. No significant increase in long-chain acids (EPA and DHA) was found in G II and G III, although the tendencies were increasing. Worth mentioning is an increase in the level of fatty acids of omega-3 family. The ratio of omega-6/omega-3 acids in pork from G II and G III was 2-4-fold time lower than that observed in G I. No significant differences in the sum of the content of neutral, hypocholesterolemic (DFA), or hypercholesterolemic (OFA) acids were found.

Table 5. Fatty acid composition of total lipid of the loin *(m. longissimus)* of pigs fed diets containing MM (group I), MFM + MM (II), and MFM +ESM (III)

Fatty acid (%)	Group		
	I	II	III
Octanic $C_{8:0}$	0.05	0.03	0.05
Decanic $C_{10:0}$	0.12	0.13	0.16
Lauric $C_{12:0}$	0.13	0.11	0.13
Myristic $C_{14:0}$	1.58	1.59	1.56
Palmitic $C_{16:0}$	22.70	23.32	22.10
Palmitoleic $C_{16:1}$ [n7]	2.21	2.46	2.28
Stearic $C_{18:0}$	12.47	11.88	13.15
Oleic $C_{18:1}$ [n9]	48.32^{a}	46.82	45.27^{b}
Linoleic $C_{18:2}$ [n6]	10.40^{a}	11.18	12.26^{b}
γ -linolenic $C_{18:3}$ [n6]	0.89^{b}	0.88^{b}	0.11^{a}
α-linolenic $C_{18:3}$ [n3]	0.05^{a}	$0.62^{b,c}$	$1.24^{b,d}$
Eicosenoic $C_{20:1}$	0.21^{a}	0.24^{a}	0.55^{b}
Eicosadienoic $C_{20:2}$	0.25	0.15	0.29
Arachidonic $C_{20:4}$ [n6]	0.29	0.33	0.34
Eicosapentaenoic $C_{20:5}$ [n3]	0.09	0.05	0.06
Docosatetraenoic $C_{22:4}$ [n6]	0.03	0.08	0.04
Docosapentaenoic $C_{22:5}$ [n3]	0.19^{a}	0.08^{b}	0.07^{b}
Docosahexaenoic $C_{22:6}$ [n3]	0.02	0.05	0.06
Saturated (SFA)	37.05	37.06	37.15
Unsaturated (UFA)	62.95	62.94	62.85
Monounsaturated (MUFA)	50.74	49.52	48.10
Polyunsaturated (PUFA)	12.21	13.42	14.47
Neutral and hypocholesterolemic (DFA)	75.42	74.82	76.00
Hipercholesterolemic (OFA)	24.28	24.91	23.66
Sum of omega-6	11.61	12.47	12.75
Sum of omega-3	0.35	0.80	1.43
Omega-6/omega-3	34.17	15.59	8.92

a,b and c,d - $p < 0.05$.
DFA=UFA+$C_{18:0}$ OFA=$C_{14:0}$ + $C_{16:0}$

DISCUSSION

The nutritive value of modified fish meal (MFM) proved to be high, which was in agreement with earlier reports by Dobrzański et al. [9]. The fat present in MFM met the standards required for animal feed, although the content of polyunsaturated fatty acids (PUFA) was lower than that of typical fish oil [22]. The results show that modified fish meal (MFM) used instead of meat meal (MM) did not have a deteriorating effect on body weight gain and feed intake of the fattening pigs. Carcass evaluation using a EUROP system even showed a better meatiness, which was likely due to the favourable effect of protein and fat present in the MFM [21].

The mostly significant aim of this work was to assess the quality of pigs' meat fed with mixture supplemented with MFM. Awareness of negative influence of feeding with meal on sensory quality of this meat was not confirmed. The obtained results proved that meal applied did not have a negative influence on organoleptic characteristics, such as color, aroma, flavor, tenderness and juiciness of meat. However Hertman et al. [13], after the application of higher than 3% substitution of fish meal for fatteners, found deterioration of sensory characteristics of meat, after preliminary 4-6-month frozen storage. Also, higher doses of fish oil, than $30g \cdot kg^{-1}$ aused disadvantageous change in taste and flavor of pig meat [25]. In our studies, the experimental mixtures contained only ca. 2% fat from fish meal, and moreover it was eliminated in the final stage of fattening. Therefore no disadvantageous influence on parameters of sensory evaluation was found.

The fat present in MFM did not have a significant impact on total cholesterol in the pork loins. Barowicz and Pietras [4] found a decrease in total cholesterol content of serum, but no influence on cholesterol level in *m.*

longissimus, when fattening pigs were fed diet with 8% linseed oil. Busboom et al. [7] found no influence of plant oils on total cholesterol content of this pork muscle.

An increase in the content of polyunsaturated fatty acids (PUFA), especially α-linolenic acid and increasing tendencies in EPA and DHA of pork was found in the experimental groups fed MFM. Similar results were also reported by other authors [1,14,25]. Sawosz et al. [26] studied the efficiency of fatty acids transformation in feed - muscular tissues interactions and observed that the highest efficiency of PUFA was obtained with 4% supplemented of diet fish oil. Linseed oil was found to be the richest source of omega-3 acids, but efficiency coefficient of transforming these acids in feed-tissue interactions proved to be the lowest. Similar results were reported by Ishida et al. [15].

The content of fatty acids in the loin did not indicate any hypocholesterolemic activity, which was confirmed by total cholesterol content of the fat present in this muscle of pigs in all the feeding groups under investigation. However, some hypocholesterolemic effect was reported by Barowicz et al. [5], who supplemented pig feed with calcium salts of linseed oil and blended fat. Generally, pig and poultry breeders can hardly achieve a reduced cholesterol content of the muscle tissues of animals [5, 9,12,23].

The results obtained in the present study are in agreement with those reported by other authors [1,3,8,16,18] and confirm that it is possible to improve the dietetic value of pork using special diets containing various composites of fatty acids in animal feed, especially fish meals and plant oils, which can reduce the fat content of the muscle tissue and increase the content of PUFA.

CONCLUSIONS

Ten percent of modified fish meal (MFM) applied in growing pig diet during fattening from 30 to 80 kg body weight, followed by diet supplemented with meat meal or extracted soybean meal introduced in the final phase of fattening (i.e. until 100 kg b.w.) did not negatively affect the physicochemical and sensory quality of loin *(m. longissimus)*, however significantly increased the content of PUFA, along with 2–4 fold decreasing of omega-6/omega-3 acids ratio.

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Zbigniew Dobrzański, Roman Kołacz
Department of Animal Hygiene and Ichthyology
Agricultural University of Wroclaw
Chełmońskiego 38 C, 51-630 Wrocław, Poland
phone (+4871) 348-41-42,
e-mail: khz@ozi.ar.wroc.pl
Adolf Korniewicz
Department of Animal Nutrition and Feed Quality
Agricultural University of Wrocław
Chełmońskiego 38 C, 51-630 Wrocław, Poland
phone (+4871) 320-58-39
Daniel Korniewicz
Lower Silesian Feed Company "Dolpasz" S.A.
Legnicka 52, 54-204 Wrocław, Poland
phone (+4871) 358-26-31

Zygmunt Usydus
Sea Fisheries Institute
Kołłątaja 1, 81-322 Gdynia, Poland
phone (+4858) 620-17-28
