Journal of Animal and Feed Sciences, 13, 2004, 143−152

Effect of dietary fish and rapeseed oils on sensory and physicochemical characteristics of pig *M. longissimus dorsi* and fatty acid composition*

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(Received 22 April 2003; revised version 12 September 2003; accepted 14 January 2004)

ABSTRACT

The study evaluated the effect of fish and rapeseed oils in pig diets on the sensory and physicochemical characteristics of *M. longissimus dorsi* and its fatty acid composition. Both oils were added to a humus-mineral medium and blended with feed ingredients. Four groups of pigs, 54 per group, were fattened from 30 to 100 kg on diets that were either not supplemented (control, G I), or supplemented with oil (2%): G II-rapeseed, G III-fish, and G IV fish from 30 to 80 kg (growing) and rapeseed from 80 to 100 kg (finishing). Differences ($P \leq 0.01$) were found in the experimental groups (in comparison with G I) in meat juiciness and taste, pH, crude fat and total cholesterol, all in favour of the experimental diets. In relation to fatty acids, the differences ($P \leq 0.01$) concerned $C_{10:0}$, $C_{18:3}$ n-3, $C_{18:3}$ n-6, $C_{20:1}$ n-9, $C_{20:2}$ n-6, $C_{20:4}$ n-6, $C_{20:5}$ n-3 (EPA), $C_{22:5}$ n-3 (DPA), and $C_{22:6}$ n-3 (DHA). In the experimental groups, PUFA increased by 34-36%, the sum of n-3 increased 5-6.6 times, and the n-6/n-3 ratio decreased 4-5 times ($P \leq 0.01$). Colour, aroma, tenderness, dry matter, total protein, SFA, UFA, MUFA, DFA and OFA were similar in all of the groups. The best sensory results were found in pigs from G IV fed with two oils, fish (growing) and rapeseed (finishing).

KEY WORDS: pig, meat, fish oil, rapeseed oil, fatty acids, sensory, physicochemical evaluation

* Supported in part by the State Committee for Scientific Research, Grant No. PBZ-KBN-060/T09/2001/03

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INTRODUCTION

The nutritive and dietetic value of pork is determined by the feeding program during fattening, thus by the level of the ration and concentration of ingredients in the mixtures. Dietary fat type can influence the fatty acid composition of tissues, especially the long-chain n-3, EPA, DPA and DHA content of polyunsaturated fatty acids (PUFA) (Morgan, 1992; Migdał et al., 2000).

The results of many studies show that it is possible to obtain pork of high dietetic value with a low fat content, increased PUFA and low cholesterol content when pigs are fed various types of fatty acids of plant or animal origin (Leskanich et al., 1997; Lenartowicz and Kulisiewicz, 2000). Dietary fish oil increases the efficiency of transformation of long-chain fatty acids from the feed into pig muscle tissues (Sawosz et al., 2000). However, fish oil may worsen the sensory characteristics of meat, especially taste. This depends on the chemical composition of the feed mixture and type of dietary oil (Overland et al., 1996; Corino et al., 2002). Fish dietary supplements (oils, meals, concentrates) must be dosed carefully, since they contain sulphur and nitrogen compounds (mercaptans, 3-methylamine), all responsible for 'fishy taints' of meat (Urbańczyk et al., 2000; Brychni et al., 2001).

Fish oils manufactured in Poland have not been sufficiently investigated in terms of their usefulness in pig feeding and their effects on pork quality.

The purpose of the study was to determine of usefulness of dietary fish oil and rapeseed oil supplementation of feed mixtures for fattening pigs, with special focus on the effects of the two oils on the fatty acid composition of meat and its physicochemical and sensory characteristics.

MATERIAL AND METHODS

Fish oil was produced according to the technology developed by the Sea Fisheries Institute in Gdynia (Usydus and Bykowski, 1998; Dobrzański et al., 2002). Rapeseed oil was manufactured by Plant Oil Processing Ltd. in Brzeg Opolski. To obtain the experimental mixtures, both oils were added to a humus-mineral medium and blended with feed ingredients. Table 1 presents the composition of feed mixtures used in the study. There were no differences between mixtures for ME, crude protein, crude fibre, essential amino acids, macroelements and vitamins, but there was a difference in crude fat resulting from the enrichment of experimental rations with oils. Table 2 presents the fatty acid compositions of both oils, fish and rapeseed.

The experiment was carried out on 216 pigs (Polish Large White ♀ × Polish Landrace ♂) with a starting weight about 30 kg. The pigs were randomly assigned

TABLE 1

Composition of mixtures

Ingredient, %	Group[1]			
	I	II	III	IV
Ground wheat	20.0	20.0	20.0	20.0
Ground barley	59.0	51.2	51.2	51.2
Wheat bran	5.0			
Soyabean meal	4.0	7.0	7.0	7.0
Meat meal	5.0	5.0	5.0	5.0
Rapeseed meal	5.0	5.0	5.0	5.0
Humobentofet 'T'		8.0	8.0	8.0
Rapeseed oil		2.0		0.0/2.0
Fish oil			2.0	2.0/0.0
Chalk	1.0	0.8	0.8	0.8
Premix	1.0	1.0	1.0	1.0
Total	100	100	100	100
Per kg of feed				
metabolizable energy, MJ	12.5	12.1	12.1	12.1
crude protein	15.0	15.0	15.0	15.0
crude fibre	4.7	4.7	4.7	4.7
crude fat	2.5	4.7	4.7	4.7
Lys	0.81	0.84	0.84	0.84
Met	0.25	0.25	0.25	0.25
Met and Cys	0.57	0.55	0.55	0.55
Thr	0.55	0.55	0.55	0.55
Try	0.17	0.17	0.17	0.17
Ca	0.82	0.77	0.77	0.77
total P	0.62	0.60	0.60	0.60
Na	0.15	0.19	0.19	0.19
vitamin A, I.U	8000	8000	8000	8000
vitamin D, I.U	1500	1500	1500	1500
vitamin E, mg/kg	55	55	55	55

[1] I- control (30-100 kg of body weight); II-rapeseed oil (30-100 kg); III-fish oil (30-100 kg); IV-fish oil (30-80 kg) and rapeseed oil (80-100 kg)

to 4 groups (G), of 54 pigs each. The male/female ratio (36/18) was the same in each group. The males and females were kept separately in boxes of 18 pigs each. The following groups were established:

G I – fed a mixture without oils from 30 to 100 kg body weight (BW), control

G II – fed a mixture with 2% rapeseed oil from 30 to 100 kg BW

G III – fed a mixture with 2% fish oil from 30 to 100 kg BW

G IV – fed a mixture with 2% fish oil from 30 to 100 kg BW and 2% rapeseed oil from 80 to 100 kg BW.

TABLE 2

Fatty acid composition of dietary fish and rapeseed oils

Fatty acid, %	Fish oil	Rapeseed oil
$C_{10:0}$	0.03	
$C_{12:0}$	0.03	0.32
$C_{14:0}$	3.13	0.54
$C_{14:1}$	0.11	
$C_{15:0}$	0.20	
$C_{16:0}$	11.74	4.51
$C_{16:1}$(n-7)	2.14	0.33
$C_{17:0}$	0.33	
$C_{17:1}$	0.26	0.11
$C_{18:0}$	1.82	1.52
$C_{18:1}$(n-9)	41.03	59.80
$C_{18:1}$(n-7)	1.96	0.79
$C_{18:2}$(n-6)	17.74	20.61
$C_{18:3}$(n-9)	0.29	
$C_{18:3}$(n-3)	7.01	8.49
$C_{20:1}$	1.64	1.62
$C_{20:2}$	0.29	0.14
$C_{20:4}$(n-6)	0.14	0.43
$C_{20:5}$(n-3)	3.98	
$C_{22:4}$(n-6)	0.08	
$C_{22:5}$(n-3)	0.17	
$C_{22:6}$(n-3)	5.88	
$C_{22:1}$		0.56
$C_{24:1}$		0.23
SFA	17.28	6.89
UFA	82.72	93.11
MUFA	47.13	63.44
PUFA	35.59	29.67
PUFA/SFA	2.06	0.47
Sum of n-6	18.25	21.04
Sum of n-3	17.04	8.49
n-6/n-3 ratio	1.07	2.48

SFA-saturated; UFA-unsaturated; MUFA-monounsaturated; PUFA-polyunsaturated

Daily feed intake ranged from 2.11 to 2.18 kg per pig and feed conversion 3.15-3.52 kg per kg gain. Daily intake of oils averaged 42.9 g, and total oil intake 3.97 kg per pig (Korniewicz et al., 2002).

Eight pigs from each group (4♀ and 4♂) weighing about 100 kg were slaughtered and carcasses were chilled for 18 h at 2-4°C. *M. longissimus dorsi* samples were taken between the 13 and 14 rib for physicochemical analyses. The pH, dry matter, total protein, intramuscular fat and total cholesterol were determined us-

ing standard methods. After lipid extraction from the meat samples (Folch et al., 1957), the fatty acid composition was assessed with a gas chromatograph (Philips) equipped with a flame ionizing detector and Rtx-2330 column, 105 m long (the temperature of the injector chamber was 220°C, of the detector, 230°C). The carrier gas used in the study was helium, 70 psi (Shantha and Napolitano, 1992).

For sensory analyses the external layer of fat was removed from the *M. longissimus dorsi* and the meat was divided perpendicularly to the long axis into portions of 220 g each. The samples were roasted at 96°C, the meat pieces were heated until 75°C was reached in the geometrical centre of the sample. Sensory analyses included colour, taste, aroma, tenderness and juiciness of meat were carried out using a 5 point scale (Baryłko-Pikielna, 1997). The evaluation was performed by a panel of 10 trained judges.

Statistical analysis included one-way analysis of variance (ANOVA) using the Statgraphics ver. 5.0 procedure.

RESULTS

Sensory analyses. Differences in juiciness ($P \leq 0.01$) and taste ($P \leq 0.07$) of *M. longissimus dorsi* were found between control (G I) and experimental groups (G II, III, IV). The taste score was the highest in G III (4.16 points) and juiciness in G IV (3.95 points). The results obtained for colour, aroma tenderness were similar in all the groups (Table 3).

Physicochemical analyses. The value of pH increased ($P \leq 0.01$) in II, III and IV groups in comparison with G I, and the highest value was found in II group (5.84), the percentage of crude fat and the content of cholesterol decreased ($P \leq 0.01$), the

TABLE 3

Sensory evaluation of *M. longissimus dorsi*

Group	n	Colour	Taste	Aroma	Tenderness	Juiciness
		point scale (1-5)				
I	10	4.02	3.82^{a}	4.05	3.80	3.47^{B}
II	10	3.91	4.05	3.95	3.83	3.57^{B}
III	10	4.04	4.16^{b}	3.97	3.83	3.62^{B}
IV	10	4.03	4.01	4.11	3.89	3.95^{A}
Mean		4.01	4.01	4.02	3.84	3.65
SEM		0.04	0.03	0.05	0.04	0.04
Main effect	P≤	ns*	0.07	ns	ns	0.01

values in the same columns with different letters differ significantly: ^{a,b} $P \leq 0.05$; ^{A,B} $P \leq 0.01$
*ns - no significance

lowest value were in group IV (0.80% and 83.6 mg100 g^{-1}, respectively). Dry matter and crude protein content were similar in all of the groups (Table 4).

TABLE 4

Physicochemical analysis of *M. longissimus dorsi*

Group	n	pH	Dry matter	Crude fat	Total protein	Total cholesterol mg/100g
			%			
I	8	5.72^{A}	25.55	1.11^{BD}	22.43	97.2^{A}
II	8	5.84^{B}	26.06	1.10^{B}	22.86	97.0^{A}
III	8	5.75^{B}	26.14	1.00^{BC}	22.95	96.4^{A}
IV	8	5.79^{B}	25.44	0.80^{A}	22.96	83.6^{B}
Mean		5.77	25.79	1.00	22.80	93.55
SEM		0.01	0.14	0.01	0.11	0.21
Main effect	P≤	0.01	ns	0.01	ns	0.01

values in the same columns with different letters differ significantly ^{A,B} P≤0.01

Fatty acid analyses. Differences were found between experimental and control group (P≤0.01) in fatty acids content: $C_{10:0}$ (decanic), $C_{18:3}$ n-3 (ALNA), $C_{18:3}$ n-6 (GLNA), $C_{20:1}$ n-9 (eicosenoic), $C_{20:2}$ n-6 (eicosadienoic), $C_{20:4}$ n-6 (arachidonic), $C_{20:5}$ n-3 (EPA), $C_{22:5}$ n-3 (DPA) and $C_{22:6}$ n-3 (DHA). Between groups G II, G III and G IV the differences concerned $C_{20:1}$ n-9, $C_{20:2}$ n-6, $C_{20:4}$ n-6, $C_{20:5}$ n-3, $C_{22:5}$ n-3, $C_{22:6}$ n-3 (Table 5).

In comparison with G I, in G II, III and IV, PUFA increased by 34-36%, the sum of n-3 increased 5-6.6 times, the ratio of n-6/n-3 decreased 4-5 times (P ≤ 0.01). No significant differences were found between groups in SFA, UFA, MUFA, DFA and OFA (Table 6).

DISCUSSION

An important aspect of the study was the assessment of meat quality resulting from feeding pigs diets supplemented with rapeseed or fish oil.

The results of the study show that fish oil supplementation in the first stage of fattening followed by rapeseed oil supplementation in the second stage (G IV) decreased the content of intramuscular fat and cholesterol. Also the taste and juiciness of meat were better in this group than in the others. Other sensory parameters, such as flavour, tenderness and colour, and also dry matter, total protein, and pH determined for the experimental groups did not differ from the control group, which means that the diets did not influence the meat quality parameters. Similar results were obtained by Ishida et al. (1996) and Bakuła et al. (2000), although the latter author reported slightly reduced tenderness of the meat obtained from pigs

TABLE 5

Fatty acid composition of *M. longissimus dorsi*

Fatty acid %	Group				Mean	SEM	Main effect P≤
	I	II	III	IV			
n =	6	6	6	6			
$C_{8:0}$	0.053	0.053	0.057	0.052	0.053	0.001	ns
$C_{10:0}$	0.117^{A}	0.174^{B}	0.167^{B}	0.172^{B}	0.157	0.005	0.01
$C_{12:0}$	0.116	0.129	0.126	0.127	0.124	0.041	ns
$C_{14:0}$	1.589	1.513	1.450	1.490	1.510	0.040	ns
$C_{16:0}$	22.69	21.81	22.76	21.36	22.13	0.635	ns
$C_{16:1}$(n-7)	2.205^{a}	1.959	1.890^{b}	1.935	1.997	0.048	0.1
$C_{18:0}$	12.48	13.11	13.42	13.57	13.14	0.460	ns
$C_{18:1}$(n-9)	48.37	44.61	43.15	44.51	44.99	1.260	ns
$C_{18:2}$(n-6)	10.43^{a}	13.07	13.60^{b}	13.48^{b}	12.64	0.480	0.09
$C_{18:3}$(n-6)	0.888^{A}	0.920	0.966^{B}	1.030^{B}	0.946	0.036	0.01
$C_{18:3}$(n-3)	0.00^{A}	1.330^{B}	1.129^{B}	1.224^{B}	0.920	0.043	0.01
$C_{20:1}$(n-9)	0.208^{A}	0.298^{A}	0.437^{BC}	0.403^{BD}	0.336	0.012	0.01
$C_{20:2}$	0.267^{a}	0.237^{B}	0.345^{Ab}	0.235^{B}	0.271	0.009	0.01
$C_{20:4}$(n-6)	0.298^{b}	0.328^{Bb}	0.268^{A}	0.203^{Ba}	0.273	0.009	0.01
$C_{20:5}$(n-3) EPA	0.088^{A}	0.444^{BC}	0.148^{B}	0.129^{D}	0.202	0.006	0.01
$C_{22:5}$(n-3) DPA	0.186^{A}	0.018^{BC}	0.029^{B}	0.040^{BD}	0.068	0.002	0.01
$C_{22:6}$(n-3) DHA	0.00^{A}	0.00^{A}	0.052^{Ba}	0.039^{Bb}	0.023	0.001	0.01

values in the same rows with different letters differ significantly: ^{a,b} P≤0.05; ^{A,B,C,D} P≤0.01

TABLE 6

Fatty acids of different biological value in *M. longissimus dorsi*

Group	SFA	UFA	MUFA	PUFA	DFA	OFA	Sum of		Ratio n-6/n-3
							n-6	n-3	
I	37.05	62.95	50.79	12.16^{A}	75.43	24.28	11.62^{a}	0.27^{A}	43.3^{A}
II	36.79	63.21	46.87	16.34^{B}	76.32	23.32	14.32	1.79^{BC}	8.0^{B}
III	37.99	62.01	45.47	16.54^{B}	75.43	24.21	14.83^{b}	1.36^{BD}	10.9^{B}
IV	36.77	63.23	46.85	16.38^{B}	76.80	22.85	14.71^{b}	1.43^{BD}	11.7^{B}
Mean	37.15	62.85	47.50	15.36	76.00	23.67	13.87	1.21	11.5
SEM	0.70	1.21	1.25	0.47	1.25	0.63	0.47	0.043	1.01
P≤	ns	ns	ns	0.01	ns	ns	0.08	0.01	0.01

values in the same columns with different letters differ significantly: ^{a,b} P≤0.05; ^{A,B,C,D} P≤0.01
DFA-neutral-+hypocholesterolemic (desirable fatty acids); OFA-hypercholesterolemic (undesirable fatty acids)

fed diets supplemented with 3% fish oil. Also Urbańczyk et al. (2000) found that fish hydrolysate given in amounts > 0.5 kg per day per pig markedly worsened the taste and tenderness of cooked meat.

Our results show that oil supplementation did not increase the level of SFA, UFA and MUFA in *M. longissimus dorsi* and are in agreement with those reported by Sawosz et al. (2000) and Bryhni et al. (2002).

The meat from pigs in groups G III and G IV exhibited increased contents of PUFA, especially linolenic ($C_{18:2}$), eicosadienoic ($C_{20:2}$), EPA ($C_{20:5}$), DPA ($C_{22:5}$) and DHA ($C_{22:6}$) acids. Similarly, Overland et al. (1996) found a significant increase in EPA, DPA and DHA in the intramuscular fat of pigs fed mixtures supplemented with 3% fish oil. Ishida et al. (1996) documented the increase of EPA and DHA in pork lion after feeding a diet enriched with n-3 PUFA. Sawosz et al. (2000) studied the efficiency of transformation of fatty acids to *M. longissimus dorsi* from diets supplemented with 3 different oils (rapeseed, linseed, fish) in the amount 4%. In relation to rapeseed oil, linseed oil caused a significant increase of EPA and DPA, whereas fish oil resulted in the increase of EPA, DPA and DHA.

The pigs in group G II exhibited a more favourable fatty acid profile than in G I. Similar results were reported by Lenartowicz and Kulisiewicz (2000) who used vegetable oil for pig diets and found increased levels of linoleic and linolenic acids in intramuscular fat. Grela and Kondek (2000) reported a favourable effect of soyabean oil (8%) on the profile of fatty acids in the loin and ham.

A significant decrease in the ratio of n-6/n-3 (5-6.5 times) was stated in the groups G II, G-III and G IV, as compared with G I. The results are in agreement with those reported by Ishida et al. (1996) and Overland et al. (1996). In meat products, a high content of n-3 PUFA together with a low value of the n-6/n-3 ratio is known to have beneficial effects for human health, preventing coronary heart disease and related diseases due to their hypocholesteremic action (Fernandez and Venkatraman, 1993; Barowicz et al., 2000).

CONCLUSIONS

The results obtained in the study demonstrate that fish oil and/or rapeseed oil, added to the diet for fattening pigs (2%), significantly influences the fatty acid composition (mainly PUFA) and reduces the n-6/n-3 ratio in *M. longissimus dorsi*. Fish oil causes an increase in EPA and DHA and rapeseed oil an increase in EPA. Fish oil followed by rapeseed oil causes an increase in DHA and a decrease of crude fat and total cholesterol concentrations. Supplementation of feed mixtures with fish and rapeseed oils do not reduce the sensory quality of pork.

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STRESZCZENIE

Wpływ paszowego oleju rybnego i oleju rzepakowego na wskaźniki sensoryczne i fizykochemiczne mięśnia najdłuższego grzbietu (*M. longissimus dorsi)* tuczników oraz skład kwasów tłuszczowych

Celem badań była ocena wpływu dodatku oleju rybnego i rzepakowego do dawek dla świń na cechy sensoryczne, fizykochemiczne i skład kwasów tłuszczowych mięśnia najdłuższego grzbietu. Oleje były osadzone na nośniku humusowo-mineralnym i mieszane ze składnikami dawek pełnoporcjowych. Doświadczenie przeprowadzono na tucznikach o m.c. 30 do 100 kg, podzielonych na 4 grupy żywieniowe, po 54 osobniki w każdej. Grupę G I traktowano jako kontrolną, w 3 pozostałych grupach zastosowano 2% dodatek oleju, w następującym układzie: G-II olej rzepakowy, G-III olej rybny, G-IV olej rybny w 1 okresie tuczu (30-80 kg), a olej rzepakowy w 2 okresie tuczu (80-100 kg). Dodatek oleju w porównaniu z kontrolą, spowodował korzystne zmiany ($P \leq 0,01$) w soczystości i smakowitości mięsa, jak również pH, zawartości tłuszczu surowego i cholesterolu ogólnego. W składzie kwasów tłuszczowych stwierdzono różnice ($P \leq 0,01$): $C_{10:0}$, $C_{18:3}$ n-3, $C_{18:3}$ n-6, $C_{20:1}$ n-9, $C_{20:2}$ n-6, $C_{20:4}$ n-6, $C_{20:5}$ n-3 (EPA), $C_{22:5}$ n-3 (DPA) i $C_{22:6}$ n-3 (DHA). U świń z grup doświadczalnych zawartość PUFA wzrosła o 34-36%, suma n-3 zwiększyła się o 5-6,6 razy, stosunek n-6/n-3 obniżył się o 4-5 razy ($P \leq 0,01$). Kolor, zapach i kruchość mięsa, zawartość suchej masy, białka ogólnego i kwasów SFA, UFA, MUFA, DFA i OFA nie różniły się miedzy grupami. Najkorzystniejsze wyniki uzyskano u świń z grupy G IV, żywionych w pierwszym okresie tuczu paszą z dodatkiem oleju rybnego, w drugim okresie paszą z dodatkiem oleju rzepakowego.