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FATTENING RESULTS OF FINISHING PIGS FED SECOND-STAGE DIETS WITH A HIGH CONTENT OF OAT BRAN AND SOYBEAN OIL

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K e y w o r d s: feeding, pigs 70–110 kg BW, oat bran, slaughter value, blood, liver.

A b s t r a c t

The experiment was performed on 48 crossbred (♀Polish Landrace x ♂Duroc) finishing pigs divided into three feeding groups: group I (control) – fed a cereal-soybean diet (diet 1), group II – fed a diet containing 15% oat bran and 3% soybean oil (diet 2), group III – fed a diet containing 30% oat bran and 5% soybean oil (diet 3). The pigs were kept in straw-litter pens (two animals, one gilt and one barrow, in each), and they were fed *ad libitum* from 70 to 110 kg live weight. A second-stage diet containing 30% oat bran and 5% soybean oil (group III) significantly decreased average daily weight gains and feed conversion efficiency, compared with control group I and group II. Different feeding had no significant effect on the lean meat and fat content of carcasses and the proximate chemical composition of meat. Diet supplementation with oat bran and soybean oil contributed to a significant increase in alpha-linolenic acid concentrations in the lipids extracted from *m. longissimus dorsi* (*m.l.d.*). The higher content of crude fiber and crude fat in diets resulted in a highly significant increase in HDL concentrations and a significant increase in triacylglycerol levels in the blood serum of pigs, yet it had no influence on total cholesterol levels in meat (*m.l.d.*) and liver samples.

WYNIKI TUCZU ŚWIŃ ŻYWIONYCH W DRUGIM OKRESIE TUCZU DIETAMI Z WYSOKĄ ZAWARTOŚCIĄ OTRĄB OWSIANYCH I OLEJU SOJOWEGO

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S ł o w a k l u c z o w e: żywienie, świnie 70–110 kg masy ciała, otręby owsiane, wartość rzeźna, krew, wątroba.

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Abstrakt

Do doświadczenia użyto 48 tuczników mieszańców (♀ polska biała zwisłoucha x ♂ duroc) podzielonych na 3 grupy żywieniowe: I (kontrolną) – żywioną mieszanką (1) zbożowo-sojową, II – żywioną mieszanką (2) z udziałem 15% otrąb owsianych i 3% oleju sojowego, III – żywioną mieszanką (3) z udziałem 30% otrąb owsianych i 5% oleju sojowego. Świnie utrzymywane były w kojcach ściołowych (po 2 szt., 1 loszka i 1 wieprzek), żywiono je do woli, a tucz obejmował przedział masy ciała 70–110 kg. Żywienie tuczników w drugim okresie tuczu mieszanką z udziałem 30% otrąb owsianych i 5% oleju sojowego (gr. III) wpłynęło na istotne obniżenie ich średnich dziennych przyrostów masy ciała oraz istotne pogorszenie wykorzystania paszy, w porównaniu z grupą kontrolną (I) i II. Zróżnicowane żywienie badanych tuczników nie wywarło jednak istotnego wpływu na mięsność i otłuszczenie pochodzących od nich tusz oraz na podstawowy skład chemiczny mięsa. Wprowadzenie otrąb owsianych i oleju sojowego do diet spowodowało istotne zwiększenie udziału kwasu linolenowego w tłuszczu mięśnia najdłuższego grzbietu (*m.l.d.*). Podwyższenie zawartości włókna surowego i tłuszczu surowego w mieszankach wpłynęło także na wysoko istotny wzrost koncentracji HDL i istotny wzrost poziomu triacylogliceroli w surowicy krwi badanych świń, jednak nie miało wpływu na poziom cholesterolu całkowitego w mięsie (*m. longissimus dorsi*) oraz wątrobie.

Introduction

Recent years have witnessed an increasing interest in food products of animal origin that satisfy human nutritional requirements and provide health benefits. Numerous research studies have been conducted with the aim to lower cholesterol levels and increase the concentrations of unsaturated fatty acids in meat. The enrichment of muscle tissue lipids with polyunsaturated fatty acids, particularly n-3 PUFAs, improves the nutritional quality of pork. The inclusion of vegetable oils in diets for growing-finishing pigs contributes to an increase in PUFA concentrations in tissues (BAROWICZ, PIESZKA 2001, DAZA et al. 2005, APPLE et al. 2009), and the observed changes are determined by the amount of vegetable oil added to feed (BAROWICZ et al. 2000, REALINI et al. 2010). Research results suggest that feeding unsaturated fatty acids to pigs may reduce the total cholesterol content of muscles, depot fat (BAROWICZ 2000, MIGDAŁ et al. 2005) and blood serum (BAROWICZ, PIETRAS 1998, RAMJIGANESH et al. 2002).

According to many authors, the quantity and quality of dietary fiber may affect the fatty acid composition of meat lipids and cholesterol metabolism (FERNANDEZ 1995, BAROWICZ et al. 1998). Short-chain fatty acids, produced during the microbial fermentation of fiber in the lower gastrointestinal tract, are almost entirely absorbed into the hepatic portal vein and transported to the liver. Due to their effect on the reduction of enzymes involved in cholesterol synthesis, short-chain fatty acids may affect lipid metabolism (CAMERON-SMITH et al. 1994, LEVRAT et al. 1994). KRITCHERSKY (1997) demonstrated that crude fiber, in particular its soluble fractions, is capable of binding bile acids,

thus limiting their absorption in the digestive system. DEMIGNE et al. (1995) studied isolated hepatic cells in rats and found that propionic acid inhibited cholesterol synthesis in the liver.

The objective of this study was to determine the effects of different inclusion levels of crude fiber and crude fat in complete diets for finishing pigs on production results, the fatty acid content of *m. longissimus dorsi*, and selected blood and liver lipids.

Materials and Methods

The experiment was conducted at the research laboratory of the Department of Pig Breeding, University of Warmia and Mazury in Olsztyn. The experimental materials comprised three second-stage complete diets for finishing pigs. Control diet 1 was composed of soybean meal, ground barley, ground wheat, mineral and vitamin supplements. Experimental diets 2 and 3 were supplemented with 15% and 30% oat bran, respectively, and their energy level was raised to reach the targeted level by the addition of 3% and 5% soybean oil, respectively. The diets were supplemented with synthetic amino acids (lysine, methionine), in accordance with the Pig Nutrient Requirements (1993). Diet composition is presented in Table 1.

Table 1

Composition of experimental diets [%]

Specification	Diets		
	1	2	3
Ground wheat	40.00	20.00	20.00
Ground barley	41.94	40.95	22.91
Soybean meal	13.50	16.50	17.50
Oat bran	–	15.00	30.00
Dicalcium phosphate	1.50	1.50	1.50
Limestone	1.00	1.00	1.00
Grower premix	1.50	1.50	1.50
NaCl	0.30	0.30	0.30
Soybean oil	–	3.00	5.00
L-lysine	0.24	0.21	0.23
DL-methionine	0.02	0.04	0.06

The experiment was performed on 48 crossbred (♀ Polish Landrace x ♂Duroc) finishing pigs with average initial body weight of 71.2 kg, selected from our own herd, divided into three feeding groups by the analogue method.

The pigs were kept in straw-litter pens (two animals, one gilt and one barrow, in each). Feed was provided *ad libitum*, in pelleted form, from automatic feeders. The animals had free access to water from automatic drinkers. Feed intake was monitored and registered daily. The pigs were weighed at two-week intervals. Blood samples were collected from the jugular vein before slaughter.

The animals were slaughtered at body weight of approximately 110 kg. Right half-carcass dissection was carried out as recommended by the Pig Testing Station. Samples of *m. longissimus dorsi* (*m.l.d.*) and liver were also collected. The proximate chemical composition of meat was determined, including the content of dry matter, total protein and ether extract, in accordance with the AOAC (1990). The fatty acid composition of lipids extracted from *m.l.d.* was determined using a PV-4600 gas chromatograph with a flame ionization detector (FID) and a capillary column (30 m x 0.32 mm i.o. x 0.25 fm film thickness), under the following conditions: detector temperature – 250°C, column temperature – 170°C, injection mode – 50:1 split ratio, carrier gas – helium. Total cholesterol levels were estimated in lipid extracts from *m.l.d.* and liver samples, as described by ARNETH and AL.-AHMAD (1995). The serum concentrations of total cholesterol, HDL and triacylgltcerols were determined by enzymatic methods, using Cormay diagnostic test kits. The chemical composition of feed was analyzed in accordance with AOAC guidelines (1990), using TECATOR analyzers. NDF and ADF fractions were determined by the method proposed by GOERING and SOEST VAN (1970), in the Fibertec System (Foss Tecator). The gross energy content of diets was determined in an adiabatic bomb calorimeter.

The results were verified statistically by a one-way analysis of variance and Duncan's test, using Statistica 6.0 software.

Results and Discussion

The addition of oat bran (chemical composition: dry matter – 93.87%, crude ash – 3.19%, crude protein – 8.45%, crude fat – 3.57%, crude fiber – 20.25%, N-free extracts – 58.41%) to experimental diets increased their crude fiber content. The level of this component amounted to 3.15%, 5.37% and 9.45%, respectively. The inclusion of soybean oil in experimental diets 2 and 3 increased their crude fat content (Table 2).

Production results are presented in Table 3. The initial body weight of pigs was similar in all groups, at 71.2 kg on average. The growth rate of pigs was high, and their daily gains reached 919 g, 973 g and 868 g in groups I, II and III, respectively. Group II animals, fed a diet containing 15% oat bran and 5.37% crude fiber, were characterized by the highest average daily gains.

Table 2

Chemical composition of experimental diets [%]

Specification	Diets		
	1	2	3
Dry matter	87.29	89.30	89.83
Crude ash	5.23	5.63	6.44
Organic matter	82.06	83.67	83.39
Crude protein	16.19	16.92	16.07
Crude fat	2.39	4.35	5.98
Crude fibre	3.15	5.37	9.45
N-free extractives	60.33	57.03	51.89
NDF	13.93	20.09	26.10
ADF	4.94	7.18	12.28
Hemicellulose	8.91	12.91	13.82
Gross energy MJ kg^{-1}	15.863	16.749	17.288

Table 3

Fattening performance of experimental pigs

Specification	Statistical measures	Group		
		I	II	III
Initial body weight [kg]	$\bar{x}$	71.10	71.30	71.31
	s	8.57	7.41	7.24
Final body weight [kg]	$\bar{x}$	109.6	109.8	106.5
	s	5.62	3.64	3.80
Daily gain [g]	$\bar{x}$	919^{A}	973^{A}	868^{B}
	s	61.4	62.8	68.5
Daily feed intake [kg]	$\bar{x}$	3.77	3.85	4.34
	s	0.25	0.34	0.66
Feed/gain ratio [kg kg^{-1}]	$\bar{x}$	4.12^{A}	3.97^{A}	5.00^{B}
	s	0.35	0.41	0.64

A,B – $P \leq 0.01$

The addition of 30% oat bran (group III) to diet 3 increased its crude fiber content to 9.45%, which significantly decreased ($P \leq 0.01$) average daily gains and feed conversion efficiency, compared with groups I and II (Table 3).

No significant changes were noted in the parameters of carcass quality (Table 4). Finishing pigs fed high-fiber diets (groups II and III) had insignificantly lower back fat thickness and an insignificantly higher carcass lean content. KREUZER et al. (2002) reported lower average daily gains (625 g vs. 566 g) in growing pigs fed diets whose crude fiber content was increased (from 5.5% to 8.3%) by adding sugar beet pulp, rye bran and citrus pulp. However,

the cited authors observed no differences in the body weight gains of pigs fed high-fiber diets whose crude fat content was increased to 7.9% by adding an oil blend. KENNELLY and AHERNE (1980) increased the crude fiber content of diets for pigs from 4.1% to 10.25% by adding 22% oat hulls and reported significantly lower body weight gains only at the first stage of fattening (22–63 kg). Lower daily gains and higher feed consumption per kg weight gain resulting from a higher crude fiber content of diets for fatteners were also observed by O'DOHERTY et al. (2002) and SHRIVER et al. (2003).

Table 4

Selected slaughter parameters of finishing pigs

Specification	Statistical measures	Group		
		I	II	III
Dressing percentage [%]	$\bar{x}$	78.92	79.02	78.32
	s	1.36	1.47	2.59
Carcass length [cm]	$\bar{x}$	80.50	80.90	79.7
	s	1.75	1.28	2.44
Carcass lean content [%]	$\bar{x}$	55.03	57.49	56.60
	s	3.01	2.47	3.01
Loin eye area [cm^2]	$\bar{x}$	58.20	58.19	59.74
	s	7.63	6.47	9.84
Back fat thickness mean of 5 measurements [mm]	$\bar{x}$	24.40	23.71	22.48
	s	2.91	2.76	4.12

There were no significant changes in the chemical composition of meat from the studied pigs (Table 5). The higher concentrations of crude fiber and crude fat in experimental diets caused an insignificant decrease in the crude fat content of *m.l.d.*, from 1.35% in the control group to 1.05% and 1.09% in groups II and III, respectively. The increase in the content of crude fiber and crude fat in diets affected the fatty acid composition of *m.l.d.* (Table 6). The concentrations of alpha-linolenic acid (18:3) increased significantly, from 0.42% in the control group to 0.60% and 0.81% in groups II and III, respectively. An increase was also noted in the linoleic acid (18:2) content of meat samples collected from experimental group pigs, but the differences were statistically non-significant. Total PUFA concentrations were also higher in experimental groups (9.20% in group II and 9.41% in group III) than in the control group (7.44%).

There were no significant differences in total cholesterol levels in *m.l.d.* between groups, but the cholesterol content of meat was somewhat lower in pigs fed diets with an increased content of crude fiber and crude fat (Table 7). The increase in the crude fiber and crude fat content of experimental diets

Table 5

Chemical and physico-chemical properties of meat

Specification	Statistical measures	Group		
		I	II	III
Dry matter [%]	$\bar{x}$	25.52	24.79	24.88
	s	1.39	0.63	0.57
Crude protein [%]	$\bar{x}$	22.47	22.31	22.29
	s	0.73	0.64	0.83
Crude fat [%]	$\bar{x}$	1.35	1.05	1.09
	s	0.52	0.40	0.30
Crude ash [%]	$\bar{x}$	1.11	1.14	1.15
	s	0.09	0.06	0.05
pH_{45}	$\bar{x}$	5.97	5.94	6.03
	s	0.25	0.23	0.23
pH_{24}	$\bar{x}$	5.21	5.25	5.30
	s	0.11	0.13	0.20

Table 6

Fatty acid composition of *m. longissimus dorsi* lipids [in % of total acids]

Fatty acids	Group			SEM
	I	II	III	
C 14:0	1.39	1.35	1.42	0.016
C 16:0	24.92	24.33	24.42	1.692
C 16:1	4.32	4.14	3.81	0.199
C 17:0	0.19	0.25	0.22	0.007
C 17:1	0.28	0.30	0.28	0.012
C 18:0	12.01	11.91	11.50	0.861
C 18:1	48.20	47.33	47.56	8.004
C 18:2	5.85	7.06	7.33	2.748
C 18:3	0.42^{B}	0.60^{b}	0.81^{Aa}	0.022
C 20:0	0.25	0.29	0.26	0.017
C 20:1	0.95	0.88	1.00	0.021
C 20:4	1.17	1.47	1.26	0.305
SFAs	38.78	38.14	37.80	–
PUFAs	7.44	9.20	9.41	–
MUFAs	53.76	52.65	52.85	–

a,b – $P \leq 0.05$
A,B – $P \leq 0.01$
SEM – standard error of the mean

caused a highly significant ($P \leq 0.01$) increase in the serum concentrations of HDL cholesterol (groups II and III), although the above feed ingredients had no effect on total serum cholesterol. The diet containing 9.45% crude fiber and 5.98% crude fat (group III) contributed to a significant increase ($P \leq 0.05$) in serum triacylglycerol levels. No significant changes were noted in cholesterol concentrations in fresh liver samples. Total cholesterol levels in the livers of finishing pigs reached 3.78 mg g^{-1}, 3.55 mg g^{-1} and 3.82 mg g^{-1}, respectively.

Table 7

Level of biochemical indices in blood serum, *m. longissimus dorsi* and in the liver

Specification	Statistical measures	Group		
		I	II	III
Blood serum:				
– total cholesterol [mg dl^{-1}]	$\bar{x}$	148.8	150.7	150.8
	s	15.1	20.5	15.4
– HDL [mg dl^{-1}]	$\bar{x}$	41.7^{B}	48.0^{A}	50.2^{A}
	s	4.7	4.8	4.8
– triacylglycerols [mg dl^{-1}]	$\bar{x}$	41.2^{a}	45.0^{a}	55.2^{b}
	s	10.9	11.6	18.2
M. longissimus dorsi:				
– total cholesterol [mg/g fresh tissue]	$\bar{x}$	0.59	0.48	0.50
	s	0.14	0.14	0.10
Liver:				
– total cholesterol [mg g^{-1} fresh tissue]	$\bar{x}$	3.78	3.55	3.82
	s	0.56	0.55	0.65

a,b – $P \leq 0.05$
A,B – $P \leq 0.01$

Research results indicate that that the type of fat added to pig diets affects the fatty acid composition of intramuscular fat. In a study by APPLE et al. (2009), a 5% addition of soybean oil to pig diets resulted in an increase in the alpha-linolenic acid (18:3n-3) content of intramuscular fat, from 0.65% (control group) to 1.94%. The most desirable n-6/n-3 fatty acid ratio was reported for fattening pigs fed a diet supplemented with linseed oil (REALINI et al. 2010). KOZERA et al. (2006) observed an increase in PUFA concentrations and a decrease in MUFA levels in fat samples extracted from the meat (*m.l.d.)* of pigs fed diets with an increased content of crude fiber (whose source was ground wheat straw) and crude fat (whose source was soybean oil). As reported by KREUZER et al. (2002), an increase in the crude fiber content of diets following the addition of sugar beet pulp significantly decreased the serum concentrations of total, LDL and HDL cholesterol in pigs. However, the crude

fiber content of the ration had no significant effect on total cholesterol concentrations in muscle tissue lipids. Serum cholesterol levels were not affected by the composition of crude fiber (cellulose, hemicellulose, pectins), either. Yet, an increase in the crude fiber and crude fat content of pig diets led to an increase in the serum concentrations of total cholesterol, HDL and triacylglycerols (KREUZER et al. 2002).

The dietary supply of fatty acids may affect lipid metabolism in the liver and blood cholesterol concentrations. FIEDOROWICZ et al. (2000) noted no significant differences in cholesterol levels in the liver and blood serum of pigs fed diets supplemented with 4% lard or linseed oil. MARTINEZ-FLORES et al. (2004) studied the effect of high-fiber diets containing oat hulls, and observed a significant decrease in total cholesterol and triacylglycerol levels in the livers of hamsters. The liver plays an important role in the control of cholesterol esterification and breakdown, and it is also involved in lipoprotein synthesis which affects serum cholesterol concentrations. Crude fiber contained in pig diets affects the populations of intestinal bacteria and the production of short-chain volatile fatty acids (FURGAŁ 2005), which may influence lipid metabolism in the liver (KREUZER 2002). As demonstrated by DEMIGNE et al. (1995), propionic acid lowered blood cholesterol concentrations by inhibiting cholesterol synthesis in the liver. Crude fiber, which is a source of volatile fatty acids, probably affects pancreatic insulin and glucagon secretion, thus influencing lipid metabolism in the liver and tissues (SILEIKIENE et al. 2005).

Conclusions

The second-stage diet containing 30% oat bran and 5% soybean oil (group III) significantly ($P \leq 0.01$) decreased average daily weight gains and feed conversion efficiency, compared with control group I and group II. Different feeding had no significant effect on the lean meat and fat content of carcasses and the proximate chemical composition of meat (*m.l.d.*). Diet supplementation with oat bran and soybean oil contributed to a significant increase in alpha-linolenic acid concentrations in the lipids extracted from *m. longissimus dorsi*. The higher content of crude fiber and crude fat in experimental diets resulted in a significant ($P \leq 0.01$) increase in HDL concentrations and increase ($P \leq 0.05$) in triacylglycerol levels in the blood serum of pigs, yet it had no influence on total cholesterol levels in meat (*m.l.d.*) and liver samples.

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