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THE EFFECT OF HYDROTHERMALLY PROCESSED SOYBEAN AND RAPESEED PRODUCTS ON NUTRIENT DIGESTIBILITY IN GROWING-FINISHING PIGS

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Abstract

The aim of this study was to determine nutrient digestibility, nitrogen retention, and calcium and phosphorus balance in growing-finishing pigs fed control complete diets containing soybean meal and soybean oil, and experimental complete diets where soybean meal and soybean oil were replaced with toasted full-fat soybeans, cold-pressed rapeseed cake and extruded rapeseed cake.

The experiment was performed on 28 crossbred pigs (Polish Large White x Polish Landrace sows) x (Hampshire x Pietrain boars) with average body weight of 55–60 kg. The animals were divided into 4 groups of 7 animals each, based on the percentage content of the following components in complete diets: soybean meal, toasted full-fat soybeans, cold-pressed rapeseed cake with increased oil content, extruded rapeseed cake with increased oil content.

The processes of extruding rapeseed cake and toasting soybeans had no significant effect on protein digestibility or nitrogen balance. The digestibility of calcium and phosphorus decreased insignificantly in pigs fed diets with rapeseed cake, compared with pigs fed diets with soybean meal and toasted soybeans. Extrusion of rapeseed cake increased the digestibility of ether extract.

Introduction

Soybean meal, which is one of the main sources of protein in animal feeds, has a high content of protein with an optimal amino acid composi-

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tion (JERZAK et al. 2012, STEIN et al. 2016). Soybean meal is characterized by a high content of essential amino acids, a low content of crude fiber and antinutritional factors and, consequently, high nutrient digestibility (BIEL 2011, KIM et al. 2012). Each year, Poland imports more than 2.0 million tons of soybean meal, but significant fluctuations in soybean prices and widespread concern regarding the use of transgenic plants and genetically modified soybeans in animal feed prompt the search for alternative, local sources of protein. In Poland, the by-products of rapeseed processing offer a viable option (FIEDOROWICZ and SOBOTKA 2013, HANCZAKOWSKA and ŚWIĄTKIEWICZ 2014, JUST and ŚMIGLAK-KRAJEWSKA 2015).

Rapeseed is one of the major industrial crops grown in Poland (KACZMAREK et al. 2016). Double-low varieties of rapeseed with a reduced content of glucosinolates and erucic acid, yellow-seeded varieties with low fiber content and the use of rapeseed as a biocomponent in the biofuel sector have increased the role and significance of rapeseed-based feeds (BRZÓSKA et al. 2010, STEIN et al. 2016). Rapeseed meal and oil cake, the by-products of rapeseed production, are used in the production of animal feeds (KALEMBASA and ADAMIAK 2010).

The chemical composition and nutritional value of rapeseed-based feeds are influenced by the production technology. Crude protein content ranges from 29% in rapeseed oil cake to 38% in rapeseed meal (BRZÓSKA et al. 2010, EKLUND et al. 2015). Rapeseed-based feeds are characterized by similar biological value of protein, and according to many authors (OCHODZKI et al. 1995, PASTUSZEWSKA et al. 1997, LIPIŃSKI 1998, STEIN et al. 2016), the biological value of rapeseed protein is comparable to that of soybean meal.

The ingredients used in the production of feeds for monogastric animals are hydrothermally processed to improve nutrient digestibility and reduce the content of antinutritional factors, including glucosinolates (EKLUND et al. 2015). Hydrothermal processing lowers the excretion of the undigested feed fraction, which delivers significant environmental benefits (SMULIKOWSKA and VAN NGUYEN 2003, LIPIŃSKI 2003, KORNIEWICZ et al. 2007b).

The aim of this study was to determine nutrient digestibility, nitrogen retention, and calcium and phosphorus balance in growing-finishing pigs fed control complete diets containing soybean meal and soybean oil, and experimental complete diets where soybean meal and soybean oil were replaced with toasted full-fat soybeans, cold-pressed rapeseed cake and extruded rapeseed cake.

Materials and Methods

Digestibility and balance trials were performed on 28 crossbred pigs (Polish Large White x Polish Landrace sows) x (Hampshire x Pietrain boars) with average body weight of 55–60 kg. The animals were divided into 4 groups of 7 animals each, based on the percentage content of the following components in complete diets: soybean meal, toasted full-fat soybeans, cold-pressed rapeseed cake with increased oil content, extruded rapeseed cake with increased oil content:

– group I – control, fed diets where soybean meal was the main protein source and soybean oil was the main energy source;

– group II – experimental, fed diets where toasted full-fat soybeans were the main source of protein and energy;

– group III – experimental, fed diets where cold-pressed rapeseed cake with increased oil content (21%) was the main source of protein and energy;

– group IV – experimental, fed diets where extruded rapeseed cake with increased oil content (21%) was the main source of protein and energy.

In each group, complete diets in mash form were offered and the amount of feed administered individually to pigs was recorded in successive stages of the fattening period. Pigs were feeding *ad libitum* from live weight 22 kg to 55–60 kg, then in digestibility trial 2 kg of feed daily, and in the end of experiment on 90 day *ad libitum*. Average daily gains, feed intake and feed consumption per kg of body weight gain were monitored on an individual basis on days 26, 60 and 90. During the digestibility and balance trial, the animals were fed complete diets in mash form. Chemical analyses of the ingredients of complete diets were performed by standard methods (AOAC 2005).

The results of the above analyses were used to determine the content of nutrients and minerals in complete diets. The energy value of diets was calculated based on own analyses of feed components, and nutrient digestibility coefficients and formulas given in the Polish edition of Pig Nutrient Requirements (2015) and CVB (2004). The percentage composition and nutritional value of diets are shown in Table 1. The glucosinolate content of rapeseeds and rapeseed cakes was determined by the glucose release method (Ciska and Waszczuk 1995). The results of chemical analyses were used to calculate nutrient digestibility coefficients, nitrogen balance and mineral balance (Jamroz 2004).

Pigs were placed in individual metabolism cages, and were fed completed diets at 2 kg daily. The feed was consumed in its entirety. A three-day adaptation period was followed by a 4-day collection period when feed

Table 1

Composition and nutritional value of experimental pig diets

Specification	Unit	Group			
		I soybean meal + soybean oil	II toasted full-fat soybeans	III rapesed cake	IV extruded rapeseed cake
Wheat	%	40.000	40.000	40.000	40.000
Barley	%	43.775	42.495	39.355	39.345
Soybean meal	%	11.500	4.000	4.000	4.000
Toasted full-fat soybeans	%	–	10.500	–	–
Cold-pressed rapeseed cake	%	–	–	14.000	–
Extruded rapeseed cake	%	–	–	–	14.000
Soybean oil	%	1.750	–	–	–
Limestone	%	0.730	0.730	0.750	0.750
Monocalcium phosphate	%	0.530	0.550	0.200	0.200
Acidifier (Lonacid Max)	%	0.300	0.300	0.300	0.300
Salt	%	0.450	0.450	0.450	0.450
L-lysine HCl	%	0.320	0.330	0.340	0.350
L-threonine	%	0.070	0.070	0.050	0.050
DL-methionine	%	0.050	0.050	0.030	0.030
L-tryptophan	%	0.010	0.010	0.010	0.010
Natuphos 5000G	%	0.010	0.010	0.010	0.010
Rovabio Excel	%	0.005	0.005	0.005	0.005
0.5% Grower Premix	%	0.500	0.500	0.500	0.500
Metabolizable energy	MJ	13.25	13.25	13.20	13.25
Crude protein	%	16.4	16.4	16.4	16.4
Crude fiber	%	3.1	3.3	4.1	4.1
Ether extract	%	3.2	3.5	4.2	4.2
Lysine	%	0.93	0.93	0.93	0.93
Methionine	%	0.29	0.29	0.29	0.29
Met+Cys	%	0.60	0.61	0.64	0.63
Threonine	%	0.59	0.59	0.59	0.59
Tryptophan	%	0.20	0.20	0.20	0.20
Calcium (Ca)	%	0.60	0.60	0.60	0.60
Available phosphorus (P av)	%	0.30	0.30	0.30	0.30
Sodium (Na)	%	0.19	0.19	0.19	0.19
Glucosinolates	mM kg^{-1}	–	–	2.37	1.96

Premix composition: 24.6% Ca, 2 000 000 IU vitamin A, 400 000 IU vitamin D_3, 14 000 mg vitamin E, 12 727 mg DL α-tocopherol, 300 mg vitamin K_3, 300 mg vitamin B_1, 800 mg vitamin B_2, 600 mg vitamin B_6, 5 mg vitamin B_{12}, 400 mg folic acid, 2 000 mg pantothenic acid, 4 000 mg niacin, 20 mg biotin, 60 000 mg choline chloride, 8 000 mg Mn, 20 000 mg Zn, 20 000 mg Fe, 4000 mg Cu, 120 mg Co, 240 mg J, 60 mg Se, 30 000 mg Herbiplant CS

intake and excretion of urine and feces were recorded daily. Urine was collected in plastic containers placed under the cages. Each day, 10 ml of 10% sulfuric acid was added to the containers to reduce ammonia emission. Feces were collected on a plastic mesh under the slatted floor of the pens. For four consecutive days, urine and feces were collected at the same time, and weighed. Samples accounting for approximately 20% of daily urine and feces collections were placed in jars sealed with cork stoppers (urine) and plastic bags (feces). The samples were stored in a refrigerator at a temperature of 3–4 ^{o}C. Urine and feces collected over four days were thoroughly mixed, and 1 kg feces and 1 l urine samples were taken. Wet feces samples were assayed for the content of dry matter and nitrogen. Dried fecal samples were assayed for the content of ether extract, crude fiber, crude ash, calcium and phosphorus. The content of nitrogen, calcium and phosphorus was determined in urine samples. All analyses were performed using standard procedures (AOAC 2005).

The results, including body weight gains, feed intake, feed conversion, nutrient digestibility and nitrogen balance, were processed statistically by one-way analysis of variance (ANOVA). The significance of differences between groups was estimated by Duncan's multiple range test using STATGRAPHICS v. 5.0 software. The results were expressed as arithmetic means and standard deviations.

Results and Discussion

Chemical composition of rapeseed cake and extruded rapeseed cake

The proximate chemical composition of rapeseed cake and extruded rapeseed cake is presented in Table 2. Extrusion contributed to an increase in dry matter content, from 92.16% to 94.31%. The analyzed rapeseed cake contained approximately 29% of crude protein (CP), 21% of ether extract (EE), 10% of crude fiber (CF), 5.7% of starch and 5.4% of crude ash. An analysis of detergent fiber revealed that neutral detergent fiber (NDF) and acid detergent fiber (ADF) accounted for approximately 20% and 16% of total dietary fiber, respectively. Extrusion had no significant effect on the mineral content of rapeseed cake.

Toasted full-fat soybeans (GMO) were finely ground in a mill to obtain a homogeneous product. Low moisture content (up to 9.5%) prevented mould growth. The major nutrients were crude protein (35%) and ether extract (21%). Crude fiber content was 5%, including 9.7% of NDF and 6%

Table 2

Nutrient content of soybean and rapeseed based feed materials

Specification	Unit	Soybean meal	Toasted full-fat soybeans	Rapeseed cake	Extruded rapeseed cake
Dry matter	%	89.98	90.68	92.16	94.31
Organic matter	%	84.08	85.98	86.81	88.77
Crude protein	%	46.40	35.32	28.57	29.39
Crude fiber	%	3.20	4.91	9.75	10.06
Ether extract	%	1.70	20.39	21.20	21.70
Crude ash	%	5.90	4.70	5.35	5.54
Starch	%	2.66	3.47	5.73	5.73
Sugars	%	8.22	6.81	8.26	8.31
N-free extractives	%	32.78	25.36	27.29	27.62
ADF *	%	5.10	6.00	15.85	16.85
NDF **	%	9.30	9.70	19.53	21.31
Calcium	%	0.29	0.22	0.67	0.67
Phosphorus	%	0.65	0.48	0.94	0.94
Sodium	%	0.03	0.01	0.01	0.01

*ADF – acid detergent fiber, **NDF – neutral detergent fiber

of ADF. Starch content was only 3.5%, sugar content was 6.8%, and ash content – 4.7%. The concentrations of mineral nutrients were similar as in soybean meal (Table 2).

Growth performance

The average daily gain of control group pigs fed diets containing soybean meal reached 942 g (Table 3). The average daily gain of group II pigs

Table 3

Growth performance of pigs

Specification	Group			
	I soybean meal + soybean oil	II toasted full-fat soybeans	III rapeseed cake	IV extruded rapeseed cake
Body weight [kg] – initial – final	 22.1 107.0	 21.9 111.6	 22.1 102.7	 22.3 107.6
Days of feeding trial	90	90	90	90
Average daily gain [g]	942 ± 16^{b}	998 ± 16^{c}	895 ± 17^{a}	947 ± 21^{b}
Daily feed intake [kg/animal]	2.44	2.51	2.45	2.47
Gain: Feed ratio [kg kg^{-1}]	2.59 ± 0.03^{a}	2.52 ± 0.03^{a}	2.74 ± 0.04^{b}	2.61 ± 0.04^{a}

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

fed diets where soybean meal and soybean oil were replaced with toasted full-fat soybeans was 5.9% higher. The average daily gain of group IV pigs receiving extruded rapeseed cake with increased oil content was comparable with that determined in the control group. Group III pigs fed diets containing cold-pressed rapeseed cake were characterized by lower average daily gain and higher feed intake per kg body weight gain (by 5%) compared with control group animals and group IV pigs receiving extruded rapeseed cake.

Nutrient digestibility and nitrogen balance

The results presented in Table 4 show that feed ingredients had no effect on dry matter digestibility, which was similar in all groups (83.3–83.9%). No significant differences in the digestibility coefficients of organic matter were found between the groups, either (84.9–85.7%). The digestibility of CP from diets based on soybean products and diets containing 14% of rapeseed cake was comparable (83.7–84.2%). The processes of toasting soybeans and extruding rapeseed cake had no significant influence on the digestibility of CP contained in complete diets. Ether extract digestibility was relatively high in all groups. In the control group, where soybean meal-based diets were supplemented with soybean oil, EE digestibility

Table 4

Apparent digestibility coefficients of nutrients [%]

Specification	Group			
	I soybean meal + soybean oil	II toasted full-fat soybeans	III rapeseed cake	IV extruded rapeseed cake
Dry matter	83.3 ± 1.71	83.9 ± 1.40	83.4 ± 0.83	83.4 ± 1.90
Organic matter	84.9 ± 1.80	85.7 ± 1.12	85.2 ± 0.90	85.0 ± 1.88
Crude protein	83.7 ± 2.14	84.2 ± 1.18	83.8 ± 1.21	84.0 ± 3.31
Ether extract	72.4^{a} ± 5.89	74.5^{A} ± 3.33	68.6^{B} ± 2.49	78.9^{Ab} ± 2.03
Crude fiber	25.7 ± 3.27	27.4 ± 1.75	25.4 ± 4.14	25.7 ± 3.61
Crude ash	53.0 ± 2.75	53.6 ± 2.34	53.1 ± 3.52	53.9 ± 3.37
N-free extractives	89.1 ± 1.71	89.6 ± 1.27	90.2 ± 1.34	90.0 ± 1.84

a, *b* – $p \leq 0.05$
A, *B* – $p \leq 0.01$

reached 72.4%. The digestibility coefficient of EE was somewhat higher in group II fed diets with toasted full-fat soybeans (74.5%). Pigs receiving diets with cold-pressed rapeseed cake with increased oil content were characterized by the lowest fat digestibility (68.6%).

The extrusion of rapeseed cake had a beneficial influence on fat utilization – the digestibility coefficient of EE was highest in group IV (78.9%). The difference in EE digestibility between group IV and group III fed diets containing cold-pressed rapeseed cake was statistically highly significant ($P \leq 0.01$). The extrusion of rapeseed cake with increased oil content contributed to a significant increase in EE digestibility, relative to the control group fed soybean meal-based diets supplemented with soybean oil ($P \leq 0.05$).

Crude fiber digestibility was at a similar level (25.7–25.4 %) in the control group and groups III and IV (fed diets containing rapeseed cake). An insignificantly higher digestibility coefficient of CF was noted in group II (fed toasted full-fat soybeans). The extrusion of rapeseed cake had no effect on CF digestibility. The digestibility coefficients of nitrogen-free extractives and crude ash were highly similar in all groups.

Similar values of nutrient digestibility coefficients were reported by Korniewicz et al. (1999) in pigs fed diets containing 18% of rapeseed cake or 11% of soybean meal. In the cited study, the digestibility coefficients of dry matter and organic matter reached 83.5% and 85.3%, respectively, whereas CP digestibility was lower (77.6%) than in our experiment (83.7%) where pigs were fed diets containing 14% of rapeseed cake. The above authors demonstrated that the digestibility of all nutrients was higher in control group animals receiving 11% of soybean meal than in pigs fed 18% of rapeseed cake.

Lipiński et al. (1994) found that rapeseed meal and rapeseed cake decreased organic matter digestibility in growing-finishing pigs, but had no effect on the digestibility coefficients of other nutrients. In a study by Kuśnierek et al. (2005), the extrusion of rapeseed meal at a temperature of 140°C and 160°C decreased the total and ileal digestibility of protein and amino acids. The total digestibility of CP was 86.9% in soybean meal-based diets and 78.2% in rapeseed meal-based diets. The increase in temperature from 140°C to 160°C led to a considerably decrease in protein digestibility, from 76.18% to 67.54%. Keady and O'Doherty (2000) investigated the effect of extrusion on the nutritive value of rapeseed meal as a protein supplement for growing-finishing pigs and found that the extrusion process had no influence on the digestibility coefficients of nitrogen and NDF. Pastuszewska and Ochtabińska (1998) evaluated the digestibility and biological value of protein contained in rapeseed and *Brassica*

rapa cake and meal. The protein digestibility of rapeseed cake and meal was 84.9% and 80.1%, respectively. An analysis of CF digestibility revealed even greater differences between rapeseed cake and meal (52.1% vs. 29.3%). KALDMÄE et al. (2010) compared the nutritional value of heat-treated and cold-pressed rapeseed cake and found that heat treatment improved CP digestibility (70.4% vs. 68.4%, $P \leq 0.05$).

PASTUSZEWSKA and RAJ (2003) demonstrated that CP digestibility is largely determined by technological processes which lead to the formation of indigestible complexes that resist enzyme action in the gastrointestinal tract of monogastric animals, and increase the amount of neutral detergent insoluble crude protein (ND-ICP), i.e. the amount of protein bound in the NDF fraction. According to SMULIKOWSKA and VAN NGUYEN (2003), part of rapeseed CP is strongly bound to dietary fiber fractions, which decreases its digestibility to 77–79%. BURACZEWSKA et al. (1998) determined the content of NDF, including protein and essential amino acids, in rapeseed cake and meal heated for 0, 20, 40, 60 and 80 minutes at a temperature of 130°C. In the cited study, prolonged heating increased the NDF content of rapeseed cake (from 21% to 34%) and rapeseed meal (26% to 38%). At the same time, protein concentration in the NDF fraction of rapeseed cake and meal increased from 10.5% to 24.0% and from 15.7% to 28.2%, respectively. The ileal digestibility of CP and amino acids determined in growing pigs decreased with increasing NDF content. The authors concluded that the NDF content of rapeseed meal exceeding 30% points to overheating in the processes of deoiling and toasting, and to a relatively low nutritional value of rapeseed meal, as confirmed by low ileal digestibility of CP (approx. 60%).

The results of the present study and the findings of other authors indicate that in finishing pigs over 50 kg of body weight, the utilization of protein contained in cold-pressed rapeseed cake with low glucosinolate content and soybean meal is equally efficient. In the current study, the extrusion of rapeseed cake with increased oil content did not improve protein utilization efficiency.

Nitrogen balance

Nitrogen intake was identical in all pigs, therefore nitrogen balance could be compared across dietary treatments (Table 5). Daily fecal nitrogen excretion was similar in all groups, at 8.3–8.5 g N. Relative to nitrogen intake, nitrogen excretion in feces accounted for 16% on average. Urinary nitrogen excretion was much higher, at approximately 40% of nitrogen intake. Control group pigs excreted 20.7 g of nitrogen in urine. Urinary

nitrogen excretion was at a similar level (20.9 g N) in group IV pigs fed diets with extruded rapeseed cake. Nitrogen excretion in urine was lowest in group II (19.5 g N), and the difference between group II and group III (fed cold-pressed rapeseed cake) was statistically significant ($P \leq 0.01$).

Table 5

Nitrogen balance

Specification	Group			
	I soybean meal + soybean oil	II toasted full-fat soybeans	III rapeseed cake	IV extruded rapeseed cake
N intake [g]	52.5	52.5	52.5	52.5
N excretion [g]:				
Fecal	8.5 ± 1.11	8.3 ± 0.71	8.4 ± 0.48	8.3 ± 0.63
urinary	20.7^{AB} ± 1.38	19.5^{A} ± 1.25	21.4^{B} ± 1.27	20.9^{AB} ± 0.64
N retention [g]	23.3^{AB} ± 1.43	24.6^{A} ± 1.22	22.6^{B} ± 1.21	23.3^{AB} ± 0.62
N retained as % of N intake	44.6^{ABab} ± 2.81	46.9^{Aa} ± 2.34	43.1^{B} ± 2.28	44.1^{b} ± 1.30
N retained as % of N digested	52.9 ± 2.90	55.8 ± 2.68	51.4 ± 2.72	52.7 ± 1.25

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

Nitrogen retention was highest in group II, at 24.6 g, i.e. 46.9% of nitrogen intake. Nitrogen retention in the control group and group IV (fed extruded rapeseed cake) was identical (23.3 g N). In group III pigs fed diets with cold-pressed rapeseed cake, nitrogen retention was lower (22.6 g N) than in the remaining groups. A highly significant difference ($P \leq 0.01$) was found between group III and group II (fed toasted full-fat soybeans).

Similar results were reported by McDonnell et al. (2010) who examined the effects of replacing soybean meal with rapeseed meal in diets for growing-finishing pigs. Urinary nitrogen excretion and nitrogen retention decreased with increasing levels of rapeseed meal in the ration. Lipiński et al. (1994) demonstrated that pigs fed rapeseed meal were characterized by lower nitrogen retention and utilization. In another study, Lipiński et al. (1997) found that rapeseed products (meal, cake, seeds) improved nitrogen retention and utilization efficiency.

Calcium and phosphorus balance

In the digestibility and balance trial, dietary calcium intake was 12 g and dietary phosphorus intake was 10 g; the Ca:P ratio was 1.2:1.0. The results presented in Table 6 show that the analyzed alternative sources of protein and energy had no significant effect on calcium balance. In all groups, pigs excreted from 7.10 to 7.24 g Ca in feces, which accounted for 59–60% of calcium intake. Urinary calcium excretion was low, at 0.25–0.33 g, i.e. 2% of calcium intake. Calcium retention was 4.44–4.61 g, i.e. 37.0–38.4% of calcium intake. The differences between groups were statistically not significant, but calcium retention and digestion was somewhat lower in groups III and IV fed diets with rapeseed cake.

Table 6

Calcium and phosphorus balance

Specification	Group			
	I soybean meal + soybean oil	II toasted full-fat soybeans	III rapeseed cake	IV extruded rapeseed cake
Calcium balance				
Ca intake [g]	12.00	12.00	12.00	12.00
Ca excretion [g]:				
Fecal	7.10 ± 0.33	7.10 ± 0.46	7.24 ± 0.28	7.23 ± 0.29
Urinary	0.32[a] ± 0.08	0.29[ab] ± 0.05	0.25[b] ± 0.03	0.33[a] ± 0.05
Ca retention [g]	4.58 ± 0.33	4.61 ± 0.49	4.51 ± 0.25	4.44 ± 0.32
Ca retained as % of Ca intake	38.1 ± 2.77	38.4 ± 4.06	37.6 ± 2.10	37.0 ± 2.64
Apparent total tract digestibility [%]	40.8 ± 2.76	40.8 ± 3.82	39.6 ± 2.33	39.8 ± 2.43
Phosphorus balance				
P intake [g]	10.00	10.00	10.00	10.00
P excretion [g]:				
Fecal	5.53 ± 0.25	5.57 ± 0.44	5.72 ± 0.20	5.76 ± 0.50
Urinary	0.09[a] ± 0.03	0.12[ab] ± 0.07	0.16[b] ± 0.04	0.15[b] ± 0.02
P retention [g]	4.37 ± 0.24	4.30 ± 0.42	4.12 ± 0.22	4.10 ± 0.49
P retained as % of P intake	43.7 ± 2.37	43.0 ± 4.16	41.2 ± 2.21	41.0 ± 4.90
Apparent total tract digestibility [%]	44.6 ± 2.45	44.3 ± 4.44	42.8 ± 1.98	42.4 ± 5.00

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

In all dietary treatments, phosphorus balance was more efficient than calcium balance. Pigs excreted from 5.53 to 5.76 g P in feces, which accounted for 55–57% of phosphorus intake. Urinary phosphorus excretion was low, at 0.09–0.16 g, i.e. 0.9–1.6% of phosphorus intake. Phosphorus retention was 4.10–4.37 g, i.e. 41.0–43.7% of phosphorus intake. A minor decrease in phosphorus retention and digestion was noted in pigs fed diets containing rapeseed cake (groups III and IV), but the observed differences were statistically not significant.

Similar utilization efficiency of calcium and phosphorus was reported by other authors (Fandrejewski 1997, Orda et al. 1998, Usydus et al. 2006, Korniewicz 2007a, Korniewicz 2007b).

Conclusions

It can be concluded that the processes of extruding rapeseed cake and toasting soybeans had no significant effect on crude protein digestibility or nitrogen balance. Rapeseed cake with increased oil content and extruded rapeseed cake had no adverse influence on the balance of phosphorus and calcium from complete diets. Extrusion of rapeseed cake increased the digestibility of ether extract. The nutrient digestibility coefficients determined in pigs indicate that extruded rapeseed cake with increased oil content can be a viable alternative to soybean meal in pig nutrition.

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