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Effect of extrusion-cooking of some grain species on piglet performance and blood lipid profile

Wpływ ekstruzji ziarna zbóż na wyniki odchowu prosiąt i profil lipidowy krwi

Summary. The objective of the research was to determine the effect of extruded grain of wheat, barley, rice and naked oats on piglet performance till 56 day of age as well as the parameters of blood lipid profile. The study involved 400 piglets from 40 hybrid PIC line gilts mated to P-76 boars. The experiment comprised 4 treatment groups, each consisting of 100 weaned piglets penned in groups of 10 animals. Piglets from group I received diet with extruded wheat, group II – with barley, group III – with rice and group IV – naked oats. The grains were extruded at 14% moisture, temperature profile 120/160,180^{o}C and screw rotation speed 80 rpm. During the study, the production effects on the basis of individual body weight of animals on 4, 28 day of life (weaning) and 56 day as well as the feed intake for each litter were evaluated. The digestibility studies by indicator method were performed on 6 barrows from each group. Blood for analyses was collected twice from 10 piglets from a group on 28 and 56 days of age. According to the research results, extruded rice and oats proved to be more palatable components of diets for piglets than barley or wheat. Their dietary inclusion significantly increased the feed intake and assured a high health status of piglets at the rearing period. Dietary supplement of extruded rice significantly improved piglet performance manifested by higher daily weight gains and better feed conversion ratio. The piglets fed naked oats-based diet showed a significantly lower content of total cholesterol and triacyloglycerols as well as an elevated HDL cholesterol fraction in blood serum as compared to the animals receiving a wheat, barley or rice supplemented diet.

Key words: piglets, barley, naked oat, wheat, rice, blood, lipids

INTRODUCTION

Productive efficiency of piglet rearing depends on a wide range of factors, especially nutritive value of a diet at both, supplementary feeding and post weaning time. Properly formulated piglet diets can enhance the development of gastrointestinal tract, nutrient

digestibility and animal health status. The key ingredient of swine diet is cereal grain that can contain anti-nutritive factors such as, non-starch polysaccharides, tannins, alkyloresorcinols, protease inhibitors [Hanczakowski *et al.* 2001]. However, thermal processing of cereal grains may contribute to anti-nutritive compound reduction as well as improved nutritive value of the feedstuffs [Parera *et al.* 2010, Serrano 1997].

The objective of the present research was to determine the effect of extruded grains of wheat, barley, rice and naked oats on piglet performance till 56 day of age and blood lipid profile indices.

MATERIAL AND METHODS

The study involved 400 piglets from 40 hybrid PIC line sows mated to P-76 boars. The experiment comprised 4 treatment groups consisting of 100 weaned piglets penned in groups of 10 animals. The research assessed the effectiveness of extruded wheat, barley, rice and naked oats in piglet diets. The process conditions of the extrusion cooking included a Schaaf single screw cooking extruder, 14% moisture level, 120/160/180^{o}C temperature profile, screw rotation speed 80 rpm and 100 MPa pressure. The diet ingredients were mixed up and granulated. The piglets from I group received a diet with extruded wheat, group II with barley, group III with rice and group IV with naked oats. The diet composition is presented in Table 1. Nutrient contents in the mixtures fed to all the treatment groups were in accordance with the swine feeding standards [Grela *et al.* 2009]. Granulated complete diets for piglets were provided *ad libitum*, with full access to water. During the study, there were evaluated the productive effects on the basis of individual body weight on 4, 28 day of life (weaning) and 56 day as well as feed intake rate for each litter (pre-weaning) or for a pen (post-weaning).

Besides, animal physical body condition and health were monitored throughout the study period. Feed samples were collected twice to examine the basic chemical composition, amino acids and calcium, phosphorus and sodium in conformity with AOAC methods [2000]. The digestibility studies were conducted on 6 barrows from each group. The animals under investigation were kept individually in the metabolism cages allowing measurement of feed intake and faeces sampling. The digestibility evaluation with the indicator method with Cr_2O_3 use (3 g/kg feed) was carried out for 6 days, between 50 and 56 day of life. The fecal samples collected daily were placed into containers and a couple of sulphuric acid drops were added. The samples from three consecutive days were mixed and the average sample of ca.0.5 kg taken for laboratory analysis. The feed and fecal samples were examined for Cr_2O_3 content in accordance to the Kimura and Miller protocol [1957] as well as basic components [AOAC 2000]. The energy value of diets was calculated with Kirchgessner and Roth equation [1983].

Blood for analyses was collected twice from 10 piglets from a group on 28 and 56 day of age. It was taken from the jugular vein into the 10 ml heparinized tubes under veterinary supervision. In blood serum, colorimetric methods were used with Cormay monotests to determine a level of triacyloglycerols (TG), total cholesterol (CHOL) as well as lipoprotein fraction of high density cholesterol (HDL). While lipoprotein fraction of low density cholesterol(LDL) was estimated from the Friedewald formula [1970].

Table 1. Composition (%) and nutritional value of piglet diets
Tabela 1. Skład (%) i wartość pokarmowa mieszanek dla prosiąt

Wyszczególnienie Item	Grupy żywieniowe Feeding groups			
	I	II	III	IV
Extruded wheat – Pszenica ekstrudowana	67.88	-	-	-
Extruded barley – Jęczmień ekstrudowany	-	64.69	-	-
Extruded rice – Ryż ekstrudowany	-	-	58.77	-
Extruded naked oat – Owies nagi ekstrudowany	-	-	-	68.03
Whey powder – Serwatka w proszku	10.00	10.00	10.00	10.00
Toasting of whole soybeans – Pełnotłuste nasiona soi toastowane	8.40	11.50	18.70	10.60
Blood plasma – Plazma krwi	7.50	7.50	7.50	7.50
Plant oil – Olej roślinny	2.22	2.37	1.15	-
Calcium formate – Mrówczan wapnia	1.38	1.42	1.17	1.39
Monocalcium phosphate – Fosforan jednowapniowy	0.95	0.98	1.32	0.97
Mieszanina kwasów organicznych Mixture of organic acids	0.50	0.50	0.50	0.50
Lysine HCl – L – lizyna	0.50	0.40	0.31	0.38
DL methionine – metionina	0.19	0.18	0.15	0.19
L treonine – treonina	0.15	0.12	0.09	0.09
DL tryptofane – tryptofan	0.02	0.03	0.03	0.03
Mineral-vitamins premix – Premiks mineralno-witaminowy*	0.25	0.25	0.25	0.25
Choline chloride 65% – Chlorek choliny 65%	0.04	0.04	0.04	0.04
Cr_2O_3	0.03	0.03	0.03	0.03
Total – Razem	100.00	100.00	100.00	100.00
1 kg mieszanki zawiera: – 1 kg mixture contained:				
E M, MJ kg^{-1}	13.96	13.98	14.02	14.01
Total protein – Białko ogólne , g	191.0	193.0	189.0	201.0
Crude fibre – Włókno surowe, g	24.8	36.4	12.7	22.8
Lysine – Lizyna, %	1.41	1.40	1.41	1.42
Met. + cyst., %	0.85	0.84	0.84	0.85
Treonine – Treonina, %	0.90	0.91	0.91	0.90
Tryptofan – Tryptophan, %	0.28	0.29	0.28	0.28
Ca, %	0.76	0.75	0.75	0.76
P, %	0.61	0.59	0.60	0.60
Na, %	0.26	0.26	0.27	0.27

*Zawartość witamin i składników mineralnych w 1 kg mieszanki paszowej: witamina A 15 000 j.m., witamina D_3 2000 j.m., witamina E 150 mg, witamina K_3 4,5 mg, witamina B_1 3 mg, witamina B_2 6 mg, witamina B_6 4 mg, witamina B_{12} 30 µg, biotyna 150 µg, pantotenian wapnia 15 mg, kwas nikotynowy 30 mg, kwas foliowy 2 mg, żelazo 120 mg, mangan 50 mg, miedź 150 mg, cynk 120 mg, jod 0,8 mg, kobalt 0,4 mg, selen 0,40 mg.

*Content of minerals and vitamins in 1 kg mixtures: vitamin A 15 000 i.u., vitamin D_3 2000 i.u, vitamin E 150 mg, vitamin K_3 4,5 mg, vitamin B_1 3 mg, vitamin B_2 6 mg, vitamin B_6 4 mg, vitamin B_{12} 30 µg, biotin 150 µg, Ca panthotenate 15 mg, nicotine acid 30 mg, folic acid 2 mg, Fe 120 mg, Mn 50 mg, Cu 150 mg, Zn 120 mg, J 0,8 mg, Co 0,4 mg, Se 0,40 mg.

$$\text{LDL (mmol } 1^{-1}) = \text{total cholesterol} - \text{HDL} - \text{triacylglycerols}/2.2$$

The obtained numerical data was analyzed statistically using Statistica ver. 7.1, the single-factor analysis of variance ANOVA at 0.05 significance level.

RESULTS AND DISCUSSION

The nutritional value of diets for piglets at each group was similar, in compliance with the swine feeding standards [Grela *et al.* 2009]. Solely in the diet intended for II group (barley), a crude fiber content was higher. Extrusion-cooking of cereal grains contributed to differentiated production effects (Tab. 2). The piglets fed the extruded rice based-diet had higher body weight and daily gains as compared to other groups. These results agree with

Table 2. Productive results of piglets
Tabela 2. Wyniki produkcyjne prosiąt

Item – Wskaźnik	Day of life Dzień życia	Feeding groups – Grupy żywieniowe			
		I	II	III	IV
Body weight, kg Masa ciała, kg	4	2.11 ±0.45	2.24 ±0.42	2.27 ±0.41	2.13 ±0.34
	28	8.19 ±1.17	7.87 ±0.98	8.49 ±1.15	7.91 ±1.13
	56	19.81^{a} ±3.21	20.7^{a} ±3.12	23.08^{b} ±3.17	21.24^{ab} ±3.39
Daily gains from 4 to 28 day of life, g Przyrosty dobowe od 4 do 28 dnia życia, g		264^{ab} ±37	245^{a} ±38	270^{b} ±39	251^{a} ±43
Daily gains from 28 to 56 day of life, g Przyrosty od 28 do 56 dnia życia, g		415^{a} ±82	458^{b} ±94	521^{c} ±74	476^{b} ±85
Feed intake from 28 to 56 day of life, g Dzienne pobranie paszy przez prosię, od 28 do 56 dnia życia, g		569^{a} ±18	582^{a} ±29	693^{c} ±24	643^{b} ±16
Feed conversion ratio from 28 to 56 day of life, kg/kg Wykorzystanie paszy od 28 do 56 dnia życia, kg/kg		$1,37^{b}$ ±0.021	1.27^{a} ±0.024	1.33^{ab} ±0.023	1.35^{ab} ±0.025
Falls of piglets after weaning, % Padnięcia prosiąt po odsadzeniu, %		3.0	3.0	2.0	2.0

[a, b, c] values in the same rows with different letters differ significantly at $p \leq 0.05$
[a, b, c] wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

the studies of Parera *et al.* [2010]. Kim *et al.* [2008] reported higher body weight of piglets fed a diet with extruded wheat supplement, while Serrano [1997] with extruded barley and maize feed additive. Importantly, dietary inclusion of extruded rice and naked oats has significantly increased feed intake on 28–56 days of piglet life. It was caused by higher palatability of these cereals, especially after extrusion-cooking processing, as confirmed by the studies of Solá-Oriol *et al.* [2009]. Daily intake of these cereals based-feeds proved significantly higher than in the case of wheat and barley additives. Good feed conversion ratio was determined in the piglets fed the diet with barley supplement (1.27 kg kg^{-1}) and rice (1.33 kg kg^{-1}). It is likely to be linked to a higher barley dietary fiber content along with beta-glucans that improve the morphological structure of intestinal villi, promote the activity of digestive enzymes and nutrient absorption [Hedemann *et al.* 2006]. Vicente *et al.* [2008] reported the highest effectiveness of the thermal processing of barley and rice included to growing pig diets. The studies showed a low mortality percentage of weaned piglets at each group (2.0–3.0%).

Slightly higher digestibility of crude protein and ether extract was established for the mixtures with extruded rice and naked oats (Tab. 3). The data are consistent with the research results by Parera *et al.* [2010]. Dietary incorporation of barley in group II has increased crude

fiber digestibility. The highest digestibility of nitrogen-free extracts was determined for the extruded rice based – mixture. Vicente *et al.* [2008] found higher digestibility of organic matter and gross energy for the rice supplemented mixture in comparison to the maize one.

Table 3. Apparent faecal digestibility coefficients (%) of nutrients in 56 days old piglets
Tabela 3. Współczynniki pozornej strawności kałowej (%) składników pokarmowych u prosiąt w 56 dniu życia

Components – Składnik	Feeding groups – Grupy żywieniowe			
	I	II	III	IV
Crude protein – Białko ogólne	79.2 ±2.43	78.2 ±2.11	80.7 ±2.27	81.5 ±1.98
Ether extract – Tłuszcz surowy	41.7 ±1.98	39.4 ±2.09	42.6 ±2.18	42.3 ±2.26
Crude fibre – Włókno surowe	13.6^{a} ±2.11	17.8^{b} ±1.96	13.1^{a} ±1.13	14.5^{a} ±1.29
Nitrogen-free extract – Bez N związki wyciągowe	89.6^{a} ±1.67	89.5^{a} ±2.03	91.8^{b} ±1.24	89.8^{a} ±1.32

[a, b] values in the same rows with different letters differ significantly at $p \leq 0.05$
[a, b] wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

The blood lipid profile indices were shown to be prone to a type of dietary cereal used. Emphasis should be placed on the naked oats additive (group IV) that decreased the total cholesterol level and LDL-cholesterol but increased HDL-cholesterol fraction (Tab. 4). That clearly indicates a dietetic character of oats which has played preventive and therapeutic roles in human cardiovascular diseases. Kerckhoffs *et al.* [2003] highlight health benefits of β-glucans contained in oats manifested by significant reductions in total and LDL-cholesterol in blood serum.

Table 4. Lipid parameters in piglets' plasma
Tabela 4. Wskaźniki lipidowe osocza krwi prosiąt

Item Wskaźnik	Feeding groups – Grupy żywieniowe				
	Day of life Dzień życia	I	II	III	IV
CHOL mmol l^{-1}	28	4.43^{c} ±0.27	4.05^{b} ±0.35	4.08^{b} ±0.32	3.49^{a} ±0.26
	56	2.01^{b} ±0.20	1.94^{ab} ±0.16	2.36^{c} ±0.21	1.72^{a} ±0.22
	$\bar{x}$	3.22^{c} ±0.24	3.00^{b} ±0.31	3.22^{c} ±0.29	2.61^{a} ±0.20
TG mmol l^{-1}	28	0.99^{b} ±0.10	0.65^{a} ±0.14	0.71^{a} ±0.10	1.06^{b} ±0.09
	56	0.46^{b} ±0.06	0.42^{ab} ±0.04	0.34^{a} ±0.05	0.41^{ab} ±0.08
	$\bar{x}$	0.73^{b} ±0.13	0.54^{a} ±0.08	0.53^{a} ±0.08	0.74^{b} ±0.06
LDL mmol l^{-1}	28	2.60^{c} ±0.23	2.22^{b} ±0.26	2.45^{bc} ±0.48	1.32^{a} ±0.56
	56	0.93^{b} ±0.19	0.91^{b} ±0.24	1.53^{c} ±0.32	0.71^{a} ±0.25
	$\bar{x}$	1.77^{bc} ±0.21	1.57^{b} ±0.60	1.99^{c} ±0.40	1.02^{a} ±0.42
HDL mmol l^{-1}	28	1.38^{a} ±0.13	1.53^{ab} ±0.14	1.31^{a} ±0.10	1.69^{b} ±0.11
	56	0.87^{b} ±0.08	0.84^{b} ±0.09	0.68^{a} ±0.09	0.82^{b} ±0.09
	$\bar{x}$	1.13^{ab} ±0.09	1.19^{ab} ±0.11	1.00^{a} ±0.09	1.26^{b} ±0.10
HDL %	28	31.15^{a} ±3.12	37.78^{b} ±2.49	32.11^{a} ±2.16	48.42^{c} ±4.03
	56	43.28^{b} ±4.18	43.29^{b} ±2.58	28.81^{a} ±2.49	47.67^{b} ±3.91
	$\bar{x}$	37.22^{b} ±3.54	40.54^{b} ±2.74	30.46^{a} ±2.37	48.05^{c} ±3.42

[a, b, c] values in the same rows with different letters differ significantly at $p \leq 0.05$
[a, b, c] wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

Special attention should be paid to a notable difference between the concentration of total cholesterol and its fractions determined on 28 day (piglets suckling mother's milk) and on 56 day of age. A total cholesterol level on 28 day exceeded the upper limit of the reference range reported by Winnicka [2008], Friendship and Henry [1996]. Average LDL-cholesterol fraction after the 4-week feeding period with the mixtures has declined from 2.15 mmol l^{-1} to 1.02 mmol l^{-1}. According to Larson *et al.* [1996], a recommended HDL-cholesterol level should reach 40% of total cholesterol. The piglets aged 28 days and receiving the extruded wheat based-diet (group I) and with rice (group III) had a HDL-cholesterol percentage in blood serum significantly lower as compared to the animals from group IV. Alike, the piglets on 56 day of life from group IV showed the highest HDL-cholesterol concentration. Elevation of the HDL-cholesterol level along with reduced total cholesterol amount is quite possible to achieve through the supply of non-digestible oligosaccharides found in large amounts in oats grain. The lowest TG concentration was noted in the group fed mixtures with rice and barley additive (Tab .4).

CONCLUSIONS

The research results from the studies on piglets fed diets based on extruded wheat, barley, rice or naked oats allowed to form the following conclusions:

1. Extruded rice and oats have proven to be more palatable components for piglets than barley and wheat, their dietary inclusion significantly increased feed intake.
2. Extruded rice supplement has significantly improved piglet performance demonstrated by higher daily weight gains, slightly better nutrient digestibility and feed conversion ratio.
3. The piglets fed the naked oats based – diet had a significantly lower level of total cholesterol and triacyloglycerols but elevated HDL-cholesterol concentration in blood serum as compared to the animals receiving the mixture with extruded wheat, barley or rice additive.

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Streszczenie. Celem pracy było określenie wpływu zastosowania ekstrudowanego ziarna pszenicy, jęczmienia, ryżu i owsa nagoziarnistego na wyniki odchowu prosiąt do 56 dnia życia oraz wskaźniki profilu lipidowego krwi. Doświadczenie przeprowadzono na 400 prosiętach pochodzących od 40 loch linii hybrydowej PIC i knurów P76, podzielonych na 4 grupy. W każdej grupie po odsadzeniu znajdowało się po sto prosiąt, umieszczonych w kojcach po 10 sztuk. Prosięta z grupy pierwszej otrzymywały w mieszance paszowej pszenicę, drugiej – jęczmień, trzeciej – ryż, a czwartej – owies nagoziarnisty. Zboża poddano ekstruzji przy wilgotności 14%, profil temperatur 120/160/180^{o}C, prędkość obrotu ślimaka 80 obr./min. W trakcie doświadczenia oceniano wyniki produkcyjne na podstawie indywidualnego ważenia w 4, 28 dniu (odsadzenie) i 56 dniu życia oraz spożycia paszy dla poszczególnych miotów. Badania strawnościowe metodą wskaźnikową przeprowadzono na 6 wieprzkach z każdej grupy. Krew do analiz pobrano dwukrotnie od 10 prosiąt z grupy w 28 i 56 dniu życia. Wyniki wskazały, że ekstrudowany ryż i owies są smaczniejszymi komponentami mieszanek dla prosiąt niż jęczmień i pszenica. Zastosowanie ich istotnie zwiększyło pobranie paszy oraz zapewniło utrzymanie wysokiego statusu zdrowotnego prosiąt w okresie odchowu. Dodatek ekstrudowanego ryżu wpłynął na istotną poprawę wyników odchowu prosiąt, które cechowały się wyższymi przyrostami dziennymi oraz lepszym współczynnikiem wykorzystania paszy. U prosiąt żywionych mieszankami opartymi na ekstrudowanym owsie nagoziarnistym stwierdzono istotnie mniejszą zawartość cholesterolu ogólnego i triacylogliceroli, a zwiększony udział frakcji HDL-cholesterolu w osoczu krwi niż u zwierząt otrzymujących mieszankę z udziałem pszenicy, jęczmienia lub ryżu.

Słowa kluczowe: prosięta, pszenica, owies nagoziarnisty, ryż, jęczmień, krew, wskaźniki lipidowe