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EFFECT OF DIETS WITH NON-GM SOYBEAN EXPELLER ON BODY WEIGHT, CARCASS QUALITY AND AMINO ACID DIGESTIBILITY IN BROILER CHICKENS*

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In a nutritional experiment carried out on 640 sexed Ross 308 chickens (experiment 1), the effect of commercial substitution of soybean meal in compound feed (control group) with extruded soybean expeller from non-genetically modified Merlin (Saatbau Linz) seed at 10, 18 and 39% of compound feed (experimental groups) was tested. The given levels of extruded expeller in experimental groups were 25%, 50% and 100% conversion of standard soybean meal protein. The tests were performed in a system of 4 groups (soybean feed), 2 sexes (male, female) in 8 replications, 10 chickens in a box. The apparent intestinal digestibility of the amino acids contained in the four feed mixtures was determined for 320 Ross 308 roosters, aged 2-4 weeks, fed with feed as in experiment 1 (experiment 2). The conversion of soybean feeds in diets significantly reduced chicken body mass (P<0.05), from 2609 g (control group) to 2488.3; 2461.8 and 2408.6 g/item in experimental groups. In relative terms, the weight loss was 4.5; 5.7 and 7.7% as compared to the control group. The mortality in the first experimental group was 2.5% and it was significantly lower than in the control group (P<0.05), and the remaining experimental groups did not differ from the control group. There were no significant differences in the intake and use of compound feed between the groups of broiler chickens. The feed consumption was 1.64 (control group) and 1.68; 1.72 and 1.73 kg/kg body weight (experimental groups). There were no significant differences in the slaughter performance of broilers. The conversion of commercial soybean meal into extruded soybean expeller in compound feed at all levels significantly diminished the mass of chicken breast muscles expressed in absolute and relative terms (P<0.05). Breast muscle mass was 564.9 g (control group) and 503.2; 496.4 and 457.4 g (experimental groups). The leg mass was significantly higher in the 1st and 2nd experimental group than the weight of the legs in the control group and the third experimental group (P<0.05). It amounted to 416.6; 434.6; 420.0 and 366.2 g/item, respectively. There were no significant differences between the broiler groups in the mass of the heart, stomach, liver and spare fat, in relative and absolute values. Carcass weight and male chicken muscles and the mass of spare fat at females were significantly higher (P<0.05). There were no significant differences in the chemical composition of breast muscles, whereas a significantly higher content of dry matter and crude fat was found in leg muscles, at 18 and 40.0% respectively of the content of expeller in compound feed (P<0.05). The content of raw fat in the breast muscles of the females was significantly higher as compared to the breast muscles of roosters (P<0.05). The complete replacement of both feeds in feed mixtures significantly reduced the content of glucose, triglycerides, protein and total cholesterol in chicken blood plasma (P<0.05). No differences were found in high-density lipoprotein (HDL) in the blood plasma of broiler chickens. The content of the expeller in the mix at the level of 39% reduced significantly the apparent intestinal digestibility of the general protein from 87 to 83% (P<0.05), with no significant differences between the

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broiler experimental groups. The introduction of extruded soybean expeller to mixes for broilers at the level of 10; 18% and 39% of compound feed reduced the intestinal digestibility of most exogenous and endogenous amino acids, including lysine from 94 to 92, 91 and 88%, respectively, and the observed differences as compared to broilers receiving soy meal were significant for the complete replacement of soy feed. Intestinal methionine digestibility was on average 93.5% and did not differ between the control group and the broiler experimental groups. The intestinal digestibility of histidine and threonine significantly decreased at 18% of extruded soybean expeller in the feed mixture (P<0.05). The replacement of commercial soybean meal to extruded soybean expeller at 39% significantly reduced the intestinal digestibility of most amino acids (P<0.05), with the exception of methionine, aspartic acid and proline.

Key words: rapeseed expeller, amino acid digestibility, broiler chickens

The growing consumption of poultry meat and dynamically growing meat exports increase the demand for high-protein feed materials, mainly extracted soybean meal. Research by Markowski and Korol (2006) showed that 95% of soybean meal found in the trade in Poland was genetically modified. According to Eurostat (2015), the amount of genetically modified soybean meal in the European Union feed market is now around 98%. The current Fodder Act (2006) assumes the ban on the use of GM feed in animal nutrition in Poland. One of the ways of providing the country with high-protein feed for animal feeding, but also with food production, is the domestic cultivation of leguminous plants, including non-GM soybean. The Central Research Centre for Plant Testing registered and authorised 6 varieties of non-GM soybean for cultivation in Poland, including the Polish Augusta variety. The studies on soybean varieties in Poland have shown yields of seeds in the range of 15 to 37 dt/ha. Yields at the Experimental Farms of the National Research Institute of Animal Production in Kołbacz, Pawłowice and Grodziec Śląski varied from 15.5 to 26.5 dt/ha in the total area of 30 ha, although the lowest yield was obtained in the extremely unfavourable year of cultivation in Pawłowice by Leszna (Śliwa et al., 2015). At the COBORU Głubczyce research station, the yields of 5 non-GM soybean varieties ranged from 26.7 to 37.4 dt/ha (SAC Głubczyce, 2012). The economic profitability of leguminous crops, including non-modified soybean, is improved by the area subsidy in the amount of 411 PLN/ha and the subsidy for certified seed introduced in 2010.

The harvest of soybean in Poland, with the 7-9 thousand hectares are estimated at around 20,000 tons, which is too small for the industrial production of post-extraction soybean meal in oleochemical plants. Full soybean seeds after heating are intended for feeding high-milk cows, and at the same time, other methods are sought for the treatment of non-genetically modified soybean for feeding mono-gastric animals, mainly poultry.

Soybean contains a significant amount of anti-nutritive substances, including urease, drug (haemaglutinin), oligosaccharides, lipase and lipoxidase, and the most potent trypsin inhibitor acting on monogastric animals (Buraczewska, 1991; Douglas et al., 1999; Parsons et al., 2000, Perez-Maldonado et al., 2003, Hsiao et al., 2006). These substances are mostly thermolabile, sensitive to high temperatures. The factor eliminating anti-nutritional substances of soybean is the interaction of high temperature (Qin et al., 1996, Machado et al., 2008). In the post-extraction process of soybean meal these substances are inactivated (Perez-Maldonado et al., 2003). The current research results indicate that the deactivating factor of the trypsin inhibitor of raw soybean in addition to heating the seeds is grain extrusion. In the process of extrusion, physical factors are high temperature and pressure, denaturation of trypsin inhibitor, feed enzymes with protein or peptide prosthetic group and native soybean proteins (Perilla et al., 1997). The effect of extruding whole soybeans on production effects was studied in chicken experiments (Subuh et al., 2002; Powell et al., 2011), looking for an alternative method for the production of post-extraction GM soybean meal. Mostly whole soybeans (Ruiz et al., 2004, Mirghelenj et al., 2013, Foltyn et al., 2013, Alsaftli et al., 2015) as well as soybean expeller (Powell et al., 2011) were extruded. In this study, it was assumed that due to insufficient soybean seeds for the production of extracted soybean meal from non-genetically modified seeds, the solution could be extruding soybean expeller, after removing a portion of soybean oil. Removing some oil will increase the protein and amino acid content in the soy milk, and its further extrusion will eliminate the trypsin inhibitor contained in the expeller.

The purpose of the study was to assess the impact of commercial substitution of soybean meal in feed mixtures for broiler chickens with extruded soybean expeller from non-GM soybean originating from domestic crops.

Materials and methods

Growth experiment (experiment 1) and efficiency tests (experiment 2) were performed. Growth experiment was carried out in a random block system, in a 2-factor system, on 640 sexed Ross 308 broilers. The factors of the experiment:

– the level of extruded soybean expeller as a commercial replacement of post-extraction soybean meal in compound feed for broilers;

– the sex of chickens.

Experimental design: 4 diets × 2 sexes × 8 repetitions × 10 chickens in repetition (tab. 1).

Table 1. Feeding scheme

Diet	Hugh-protein feed material	Control group	Experimental group		
			I	II	III
Starter	soybean meal	33,0	25,0	18,0	0,0
	soybean expeller	0,0	10,0	18,0	40,3
	fodder yeast	0,4	1,0	2,2	3,4
Grower	soybean meal	30,0	23,0	15,0	0,0
	soybean expeller	0,0	10,0	18,0	37,53
	fodder yeast	1,6	1,5	3,1	3,5

The compound feed of the control group contained post-extraction soybean meal as the main type of high-protein feed material with a small addition of fodder yeast. The broiler experimental groups (I, II and III) received blends that contained decreasing levels of post-extraction soybean meal and a growing amount of extruded soybean expeller from non-GM seeds from domestic cultivation of 10, 18 and 40% (on average for the starter and grower mix), corresponding to 25, 50 and 100% of the total protein contained in the extracted soybean meal. Starter mixes (for the first breeding period, 1-21 days) and grower type mixes (for the second breeding period, 22-42 days) were prepared. The content of fodder yeast in starter mixes ranged from 0.4 to 3.4%, and in grower type from 1.6 to 3.5%. For the sowing of feed mixtures of all food groups, soybean oil obtained from pressing out whole soybeans during the production of soybean expeller was used. The DL-methionine content was increased from 0.14 to 0.20% and L-lysine from 0.10 to 0.15% (starter) and DL-methionine from 0.20 to 0.26% and L-lysine from 0.16 to 0.21% (grower). Commercial DKA-Starter and DKA-Grower premixes were used at 0.5% containing Sincox coccidiostat. The recipes for feed mixtures were developed based on chemical analyses of high-protein feed materials and were determined using the Win-Pasze software. The nutritive value of the mixtures was assumed to be 12.5 MJ of metabolic energy, 220 g of total protein/kg (starter mixes) and 13.2 MJ of metabolic energy and 210 g of total protein (grower mixes). The chickens were kept in metal boxes on litter of deciduous tree shrubs and fed with water and feed mixtures fed at will. The body weight of 46 randomly selected 1-day-old chicks before the experiment was 40.0 ± 3.7 g. For the weight determination, all the chickens participating in the experiment were weighed on 21st and 42nd day of age, determining the final weight. The slaughter body weight was determined for 40 broilers selected randomly from experimental groups on the 43rd day of their life. The chickens were fed at will with loose feed mixtures with no pressure or thermal treatment. For the first 6 days, the feed was served on flat trays, from day 7 to the end of breeding in vertical self-feeding feeders. The water was fed centrally from the water supply system, through a system of pipes and droplets, with two water bottles in a pen. Compound feeds were made at the Feed Mixing Plant of the National Research Institute of Animal Production in Aleksandrowice, under the supervision of an engineering and technical employee, based on previously prepared recipes. Non-modified Merlin soybean from Saatbau Linz came from cultivated fields of the Experimental Department of the National Research Institute of Animal Production (PIB) in Grodziec Śląski, the Kostkowice farm, where the seeds were partly defatted. Full soybean seeds were pressed on the FL 200 model press from Farmet a.s. (Czech Republic) at a temperature of 70-80°C. From 1 ton of soybean, 867.3 kg of expeller and 132.7 kg of crude soybean oil was obtained. Soybean seeds after extrusion of a part of the oil, in the form of soybean expeller were subjected to extrusion at the Institute of Animal Production at the National Research Institute of PIB, at the Feed Mixing Plant in Aleksandrowice, after previous grinding. The soybean expeller was moistened before extrusion, using 150 ml of water/kg of expeller. The extrusion was carried out on the device of the Ukrainian company OLA--PPHW sp. z o.o. at 135°C, in the time of 8 seconds, cooled and ground again. Other cereal materials of feed mixtures, maize and wheat grains were ground and not extruded.

Growth experiment conditions

The nesting density of the chicks was 13-15 items/m^2 at the beginning of the experiment, which corresponded to the load of 33-35 kg body weight chickens/m^2 at the final rearing period.

Within the chicken disease prevention program, in both experiments a preventive program adopted for use in the Animal Nutrition and Feeding Department of the National Research Institute of Animal Production (PIB) was adopted. Chickens during the first 3 days received an anti-diarrhoea preparation in the form of a 10% solution of SCANOFLOX in the amount of 1 ml per 1^{-1} water. On day 7, an aqueous solution of the Gumboro vaccine, and on day 14 the vaccine against peptic fever (Bio-Vac ND-IB preparation) was administered. Furthermore, during the whole period of the experiment, the chickens received Vitazol vitamin preparation administered with water.

The premises for the chickens were disinfected and layered with fresh wood shavings. The room temperature was adjusted to 34°C within 3 days before settling, required by the nesting conditions and kept in accordance with the applicable standards for broiler chickens for 5 days, after which it was gradually reduced to 24°C. In the premises, constant incandescence lighting was maintained at the required level, with lighting within 24 hours, in accordance with the valid zootechnical requirements.

The daily amount of feed consumed by the broilers was determined by weighing the uneaten feed during the last day. The original body weight of the chickens was determined on 40 randomly chosen chickens. Growing broilers were weighed on 21 and 42 days of age. Prior to weighing, the chickens were starved for 12 hours.

Bird mortality analysis

During the experiments, the mortality of birds was controlled by removing dead chickens from the pens. Before calculating the significance of differences for mortality between groups of chickens, the obtained information was transformed according to the equation $y = log (x + 2)$ for percentage mortality rates. The transformed data was subjected to statistical analysis.

Feed consumption and use control

After the expiration of each day of the experiment, feed intake was calculated. At the end of the experiment, the intake of the mixture was corrected due to the mortality of chickens. After determining the weight of chickens on day 42 of the experiments, the feed consumption per 1 kg body weight gain was calculated.

Chicken slaughter and analysis of carcasses, tissue and blood sampling

On the 43rd day of the growth experiment, after the completion of rearing, 10 chickens of both sexes (5/5) were randomly selected from each group. Body mass was determined and slaughtered by stuttering with an electric impulse, decapitation and bleeding. During the slaughter blood samples were collected to obtain plasma for biochemical metabolic indices analysis. After the mechanical removal of the feathers and the head, chickens were eviscerated. The weight of the warm headless carcass, the mass of the stomach, liver, heart, fat around the stomach and spare fat and the skin was determined. Both types of fat were considered as spare fat.

Based on the slaughter and post-slaughter mass of headless chickens, slaughter yield was calculated. The carcasses were cooled for 24 hours in a cooling chamber at 5°C, and then separated into culinary elements. The dissection consisted of dissecting the right half of the carcass and weighing the breast muscles and the muscles of the leg and skin. The percentage share of carcase elements in the warm mass (liver, stomach, spare fat) and in chilled mass (breast muscles, leg muscles, skin) were calculated. The mass of edible carcass parts was calculated by adding up the mass of breast muscles, legs, heart, stomach, liver and skin. The dissection was performed according to the procedure of the Ministry of Agriculture and Rural Development described by Zgłobica and Róża (1972). Breast and leg samples were collected for chemical analyses, ground and frozen in plastic containers at -18ºC. The analyses were carried out after 30 days of sample storage.

Intestinal amino acids digestibility

The digestibility experiment was carried out randomly, on 320 sexed Ross 308 roosters, aged from 2 to 4 weeks, divided into 4 groups, each group in 8 replicates, 10 chickens in repetition. Chickens were fed with starter-grower granular compound feeder, as in the first experiment, administered at will. As the indicator of digestibility, chromium trioxide (Cr_2O_3) was used in an amount of 0.5% of the feed mixture. The experiment lasted for 21 days, including 14 days of the initial period and 7 days of the proper period. Before and after the experiment the samples of compound feedstuff were taken, combined, mixed and isolated for the entire experiment period with average analytical samples. After the end of the sampling, 10 chicken of each repetition were slaughtered with an injection of Marbital preparation (sodium pentobarbital). After cutting the abdominal wall, the intestines were removed. The final section of the small intestine (Intestinum ileum) was prepared from the Meckel's diverticulum to the point of 20 mm before the joint of the gut to the intestinal gut, while gently squeezing the food into the plastic container. The samples of intestinal contents were frozen at -18°C. After 20 days, the samples were thawed, lyophilised and subjected to chemical analysis. The feeding of broiler chickens, the procedure and preparation of samples for protein and amino acid analyses was in accordance with the procedures described by Kadim and Moughan (1997). The conditions for keeping the birds and experimental procedures were carried out with the consent of the Local Ethical Committee for Experimental Animals in Krakow.

Laboratory analyses

The content of dry matter, total protein, crude fat and crude fibre in feedstuff was determined in accordance with the methods quoted in the analytical standards according to AOAC (2007; procedures 976.05; 920.39), and the dry matter content in soybean and soy feedstuff was determined according to PN-EN ISO 665: 2004. The determination of calcium, magnesium, sodium and potassium in feedstuff was carried out by flame atomic absorption (AOAC, 2006) and phosphorus by spectrophotometric method according to PN-C-04288-16: 1989. The content of chromium trioxide in the broiler intestinal content was determined using the method described by Sahy and Gilbreath (1991). The content of the trypsin inhibitor was determined in accordance with the procedure described in the PN-EN ISO 14902 standard in the National Feed Laboratory of the Institute of Animal Production in Lublin, which has the status of a reference laboratory of the Ministry of Agriculture and Rural Development. The content of nutrients in compound feed was calculated from the content of nutrients in the materials of mixtures and their percentage share in compound feeds. The analysis of nutrients of fodder mixes components was performed at the Central Laboratory of the National Research Institute of Animal Production (PIB). The content of metabolic energy in feed materials of mixtures was calculated from their chemical composition, according to formulas and using the digestibility coefficients given in the European Tables of Caloric Value of Feed for Poultry (Smulikowska and Rutkowski, 2005).

In breast muscle samples, the content of dry matter, total protein, crude fat and crude ash was determined. The analyses of chicken feed and meat were made with the use of analytical methods, in accordance with the AOAC procedures (2009). Blood was collected into heparinised tubes during chicken slaughter and bleeding, followed by centrifugation to obtain plasma. In fresh plasma, the glucose level was determined and the remaining part was frozen for further analysis. The level of glucose in the blood plasma was determined using the enzymatic method using glucose oxidase. After 14 days, plasma was thawed and total protein, triglycerides, total cholesterol and high molecular weight lipoproteins (HDL) were determined. The analyses were carried out using the enzymatic-colorimetric method using diagnostic kits from Cormay Diagostock Polska.

The apparent intestinal digestibility coefficients of the protein and amino acids (AID) included in the individual compound feeds were calculated according to the following formula using anhydrous chromium trioxide (Cr_2O_3) as an indicator (Kadim and Moughan, 1997):

$$AID\ (\%) = 100 - [(Cr_d \times AA_{tj}) / (Cr_{tj} \times AA_d)] \times 100$$

where:

Cr_d and Cr_{tj} – the content of the indicator (Cr) in the dry mass of the diet and intestinal content

AA_{tj} *and* AA_d – the protein or amino acid content in the intestinal dry matter and diet, respectively.

Statistical data analysis

A two-factor analysis of variance was performed. Data on chick mortality were transformed according to the equation $x = log (x + 2)$ for percent mortality rates. The transformed data was subjected to statistical analysis. The significance of differences between groups for the growth experiment was calculated using the Tukey test for 5% probability. For the digestibility of amino acids, the analysis of variance was performed, identifying differences between groups by the Fisher test (NIR) for 5% probability. The calculations were performed using the SAS 9.3.TS Level 1 MO computer program.

Results

The soy oil pressing increased the total protein content from 316.7 g/kg in seeds to 399.6 g/kg in extruded oil expeller, which is an increase of 14.3% and reduced the crude fat content from 217.4 g/kg in seeds up to 84.7 g/kg in the expeller. The soybean oil pressing before extrusion increased the content of crude fibre as well as minerals in calcium expeller, including calcium, phosphorus, magnesium and potassium. The post-extraction soybean meal used in the control diets for broiler chickens contained 453.2 g/kg of total protein and 17.5 g/kg of crude fat. The level of metabolic energy in both feeds was respectively 9.0 MJ/kg in post-extraction soybean meal and 9.8 MJ/kg in extruded soybean expeller. Extruded soybean expeller comprised less lysine of 3.35 g/kg (12.3%), methionine by 1.36 g/kg (22.3%), threonine by 2.47 g/kg (14.1%), tryptophan by 2.21 g/kg (36.8%) and arginine by 6.08 g/kg (18.3%) as compared to commercial soybean extract meal. The nutritional value of fodder yeasts was similar to the information on the chemical composition and nutritional value of this fodder contained in the Food Dietary Tables in the Recommendations of Poultry Nutrition (Smulikowska and Rutkowski, 2005). The level of trypsin inhibitor in raw soybean, whole and peeled, was on average for the five analysed feeds, respectively 23, 24 and 22 mg/100 g. The removal of a part of the fat from the seeds by pressing oil increased the amount of trypsin inhibitor in soybean expeller to 26 mg/100 g in relative terms by 12.3% in comparison with whole soybeans. The process of soybean extrusion in this work reduced the content of the trypsin inhibitor to 2-3 mg/g of feed.

Table 2. Composition of the diet in the first feeding period (Starter, 1-21 days) of broilers (experiment 1)

Item	Control group	Experimental groups		
		I	II	III
Feed materials in the diet (%)				
ground maize	42,96	41,35	38,72	34,00
ground wheat	17,00	16,00	16,00	16,00
extracted soybean meal	33,00	25,00	18,00	-
soybean expeller	-	10,00	18,00	40,25
fodder yeast	0,40	1,00	2,20	3,40
soybean oil	1,40	1,80	2,00	2,50
ground limestone	0,40	0,40	1,00	0,60
dicalcium phosphate	3,80	3,40	3,00	2,10
fodder salt	0,30	0,30	0,30	0,30
DL-Methionine	0,14	0,14	0,15	0,20
L-Lysine HCl (78%)	0,10	0,11	0,13	0,15
L-arginine (99%) [1)]	0,20	0,20	0,20	0,20
premix DKA 0,5% [2)]	0,50	0,50	0,50	0,50
Dietary nutrients (g/kg)				
dry matter	897	896	895	893
metabolizable energy (MJ/kg)	12,5	12,5	12,5	12,5
crude protein	220	220	220	220
lysine	12,0	12,0	12,2	12,1
methionine	4,7	4,6	4,6	4,8
methionine+cystine	8,6	8,7	8,6	8,8
arginine	15,6	15,6	15,6	15,6
threonine	8,1	7,9	7,8	7,8
tryptophan	2,6	2,5	2,3	2,3
crude fat	34,8	36,9	37,1	37,8
crude fibre	27,7	29,8	31,1	36,0
starch	386	369	346	306
calcium	16,1	14,8	15,8	13,0
total phosphorus	6,7	6,6	6,6	6,5
digestible phosphorus	1,2	1,3	1,4	1,6

[1]Experiment 2 – with and without supplemental L-arginine.
[2]1 kg of Premix DKA Starter 0.5% contains: vit. A – 13 5000 IU; vit. D – 3 250 IU; vit. E – 40 mg; vit. B_1 –3.25 mg; vit. B_2 – 7.5 mg; vit. B_6 – 5 mg; B_{12} – 0.0323 mg; vit. K_3 – 6 mg; biotin – 0.15 mg; nicotinic acid – 45 mg; calcium pantothenate – 15 mg; folic acid – 1.5 mg; choline chloride – 100 mg; Mn –100 mg; Cu – 1.75 mg; Fe – 76.5 mg; Se – 0.275 mg; I – 1 mg; Zn – 75 mg; Co – 0.4 mg; Endox (antioxidant) – 125 mg; Sincox (coccidiostat) – 1 g; Ca – 0.679 g.

A moderate broiler growth rate was assumed at the level of 220/210 g of total protein and 12.5/13.2 MJ of metabolic energy per kilogram of feed mix (Tab. 2 and 3). The replacement of soybean meal with extruded soybean expeller in diets for the first period of broiler chicken rearing at the level of 10 and 18% of extruded soybean expeller in feed mix (first and second experimental group) reduced broiler body weight, and the differences were not statistically significant for all levels of expeller in compound feed (P<0.05, tab. 4). In relative terms, the reduction in the weight of broilers was 4.5; 5.7 and 7.7%, respectively. The body weight of the males was 8.8% higher than the weight of the females (P<0.05).

Table 3. Composition of the diet in the second feeding period (Grower-Finisher, 22–42 days) of broilers (experiment 2)

Item	Control group	Experimental groups		
		I	II	III
Feed materials in the diet (%)	42,96	41,35	38,71	34,00
ground maize	17,00	16,00	16,00	16,00
ground wheat	33,00	25,00	18,00	-
extracted soybean meal	-	10,0	18,00	40,25
soybean expeller	0,40	1,00	2,20	3,40
fodder yeast	1,40	1,80	2,00	2,50
soybean oil	0,40	0,40	1,00	0,60
ground limestone	3,80	3,40	3,00	2,10
dicalcium phosphate	0,30	0,30	0,30	0,30
fodder salt	0,14	0,14	0,15	0,20
DL-Methionine	0,10	0,11	0,13	0,15
L-Lysine HCl (78%)	0,20	0,20	0,20	0,20
L-arginine (99%)[1)]	0,50	0,50	0,50	0,50
premix DKA 0,5%[2)]	897	896	895	893
Dietary nutrients (g/kg)				
dry matter	12,5	12,5	12,5	12,5
metabolizable energy (MJ/kg)	220	220	220	220
crude protein	12,0	12,0	12,2	12,1
lysine	4,7	4,6	4,6	4,8
methionine	8,6	8,7	8,6	8,8
methionine+cysteine	15,6	15,6	15,6	15,6
arginine	8,1	7,9	7,8	7,8
threonine	2,6	2,5	2,3	2,3
tryptophan	34,8	36,9	37,1	37,8
crude fat	27,7	29,8	31,1	36,0
crude fibre	386	369	346	306
starch	16,1	14,8	15,8	13,0
calcium	6,7	6,6	6,6	6,5
total phosphorus	1,2	1,4	1,4	1,6
digestible phosphorus	1,2	1,3	1,4	1,6

[1)] Experiment 2 – with and without supplemental L-arginine.
[2)] 1 kg of Premix DKA Grower 0.5% contains: vit. A – 12 0000 IU; vit. D – 3 250 IU; vit. E – 40 mg; vit. B_1 – 2 mg; vit. B_2 – 7.25 mg; vit. B_6 – 4.25 mg; B_{12} – 0.03 mg; vit. K_3 – 2.25 mg; biotin – 0.1 mg; nicotinic acid – 40 mg; calcium pantothenate – 12 mg; folic acid – 1.0 mg; choline chloride – 450 mg; Mn –100 mg; Cu – 1.75 mg; Fe – 76.5 mg; Se – 0.275 mg; I – 1 mg; Zn – 75 mg; Co – 0.4 mg; Endox (antioxidant) – 125 mg; Sincox (coccidiostat) – 1 g; Ca – 0.790 g.

Tabela 4. Masa ciała, śmiertelność oraz spożycie i wykorzystanie paszy (doświadczenie 1)
Table 4. Body weight, mortality, and feed intake and conversion (experiment 1)

Wyszczególnienie Item	Grupa kontrolna Control group	Grupy doświadczalne Experimental groups			SEM	Płeć Sex		Wartość P P value		
		I	II	III		kogutki cockerels	kurki pullets	poziom makuchu expeller level	płeć sex	interakcja interaction
Masa ciała (g) Body weight (g)										
21. dzień 21 days	673,4 A	663,6 A	623,4 AB	601,9 B	8,5	664,8 A	616,4 B	0,004	0,0018	0,7198
42. dzień 42 days	2609,0 A	2488,3 B	2461,8 B	2408,6 B	21,6	2606,8 A	2376,9 B	<0,0001	<0,0001	0,4677
Śmiertelność Mortality										
1–21 dni (%) 1–21 days (%)	3,7 A	1,3 C	4,4 A	2,6 B	1,1	2,8	3,1	<0,0001	0,3251	0,5297
22–42 dni (%) 22–42 days (%)	2,6 A	1,3 B	2,7 A	2,6 A	1,0	2,3	2,3	0,0321	0,9999	0,4899
1–42 dni (%) 1–42 days (%)	6,1 A	2,5 B	6,8 A	5,0 A	2,3	4,9	5,3	<0,0001	0,8421	0,6205
Spożycie paszy (g/ptaka) Feed intake (g/bird)										
1–21 dni 1–21 days	1104,4	1119,4	1102,5	1117,5	45,0	1159,1 A	1062,8 B	0,985	0,0157	0,9844
22–42 dni 22–42 days	3388,8	3461,9	3221,9	3378,1	108,0	3534,7 A	3190,6 B	0,260	0,0002	0,7669
1–42 dni 1–42 days	4493,2	4581,3	4324,4	4495,6	119,4	4693,7 A	4253,5 B	0,304	0,0004	0,4279
Wykorzystanie paszy (g/g PMC) Feed conversion (g/g BWG)										
1–21 dni 1–1 days	1,69	1,69	1,79	1,78	0,27	1,72	1,76	0,092	0,3011	0,5633
22–42 dni 22–42 days	1,38	1,39	1,40	1,43	0,30 0,26	1,36	1,44	0,276	0,9086	0,9514
1–42 dni 1–42 days	1,64	1,68	1,72	1,73		1,67	1,71	0,234	0,7995	0,7477

A, B – wartości w wierszach oznaczone różnymi literami różnią się istotnie (P<0,05)
A, B – values in rows with different letters differ significantly (P<0.05)

Tabela 5. Masa ubojowa, wydajność rzeźna i elementy tuszek kurcząt brojlerów (doświadczenie 1)
Table 5. Slaughter weight, dressing percentage and carcass components of broiler chickens (experiment 1)

Wyszczególnienie Item	Grupa kontrolna Control group	Grupy doświadczalne Experimental groups			SEM	Płeć Sex		Wartość P P value		
		I	II	III		kogutki cockerels	kurki pullets	poziom makuchu expeller level	płeć sex	interakcja interaction
1	2	3	4	5	6	7	8	9	10	11
Masa i wydajność rzeźna tuszki Carcass weight and dressing percentage										
masa ubojowa ciała (g) slaughter weight (g)	2649,4 A	2636,3 A	2549,4 A	2404,4 B	24,4	2656,1 A	2463,6 B	<0,0001	<.0001	0,254
masa tuszki ciepłej (g) hot carcass weight (g)	2006,3 A	1986,9 A	1913,1 A	1778,8 B	18,5	1987,1 A	1855,5 B	<0,0001	<0.0001	0,380
masa tuszki schłodzonej (g) cold carcass weight (g)	1970,0 A	1950,6 A	1879,4 A	1746,9 B	20,3	1949,1 A	1824,4 B	<0,0001	0,0002	0,349
wydajność rzeźna (%) dressing percentage (%)	75,71	75,02	74,66	73,90	0,25	75,39	74,26	0,103	0,757	0,539
Wartości bezwzględne (g) Absolute values (g)										
mięśnie piersiowe breast muscles	564,9 A	503,2 B	496,4 B	457,4 B	8,4	520,6 A	490,3 B	<0,0001	0,035	0,575
mięśnie nóg leg muscles	416,6 A	434,6 B	420,9 B	366,2 B	7,8	442,1 A	377,0 B	0,001	<0,0001	0,150
serce heart	11,1	10,9	11,2	11,4	0,2	12,4	10,9	0,435	0,561	0,701
żołądek gizzard	21,0	21,6	24,4	23,9	0,04	22,9	22,5	0,117	0,227	0,295

wątroba liver	52,6	52,7	54,3	48.8	0,6	54,5	49,7	0,267	0,126	0,373
tłuszcz zapasowy abdominal fat	43,9	45,2	46,0	43,8	1,0	40,8 B	48,6 A	0,850	0,001	0,538
skóra skin	126.2 AB	119.7 AB	131,4 A	113,1 B	1,1	123,7	121.4	0,016	0.577	0,753
masa części jadalnych tuszki weight of edible carcass parts	1236,3 A	1187,9 AB	1184,6 B	1119,3 B	19,9	1205,0 A	1132,4 B	<0,0001	<0.0001	0,110
Wartości względne (%) Relative values (%)										
mięśnie piersiowe [1] breast muscles [1]	28,7 A	25,8 B	26,4 B	26,2 B	0,3	26,4 B	27,5 A	0,024	0,004	0,228
mięśnie nóg [1] leg muscles [1]	21,1 A	22,3 B	22.4 B	21,0 A	2,8	22,7 A	20,7 B	0,001	0,020	0,401
serce heart	0,6	0.6	0.6	0,7	0,03	0,6	0,6	9.479	0,411	0,466
żołądek [2] gizzard [2]	1,0	1,1	1,3	1,3	0,04	1,2	1,2	0.451	0,500	0.201
wątroba [2] liver [2]	2,6	2,7	2.8	2,7	0,1	2,7	2,7	0.461	0,806	0,173
tłuszcz zapasowy [2] abdominal fat [2]	2,2	2.3	2,4	2,5	0,1	2,1 B	2,6 A	0.167	<0,0001	0,619
skóra [1] skin [1]	6,3	6.0	6,9	6,4	0,1	6,3	6,5	0,496	0.091	0.612

A, B – wartości w wierszach oznaczone różnymi literami różnią się istotnie ($P<0,05$).
A, B – values in rows with different letters differ significantly ($P<0.05$).
[1] Oznaczone w tuszkach schłodzonych.
[1] Estimated in cooled carcasses.
[2] Oznaczone w tuszkach świeżych po uboju brojleów.
[2] Estimated in carcasses after broiler slaughtering.

Tabela 6. Skład chemiczny mięśni i parametry osocza krwi kurcząt brojlerów (dośw. 1)
Table 6. Chemical composition of muscles and blood plasma parameters in broiler chickens (experiment 1)

Wyszczególnienie Item	Grupa kontrolna Control group	Grupy doświadczalne Experimental groups			SEM	Płeć Sex		Wartość P P value		
		I	II	III		kogutki cockerels	kurki pullets	poziom makuchu expeller level	płeć sex	interakcja interaction
Składniki mięśni piersiowych (% s.m.) Components of breast muscles (% d.m.)										
sucha masa dry matter	23,88	24,15	24,40	24,18	0,21	24,36	23,95	0,375	0,051	0,141
białko ogólne crude protein	22,06	22,21	22,09	21,74	0,21	22,46	21,59	0,433	0,300	0,019
tłuszcz surowy crude fat	1,74	1.74	1,86	1,75	0,09	1,59 B	1.91 A	0,745	0,000	0,080
popiół surowy crude ash	1,16	1.17	1,18	1,19	1,18	1,19	1,16	0,259	0,410	0,039
Składniki mięśni nogi (% s.m) Components of leg muscles (% d.m.)										
sucha masa dry matter	26,18 B	26,42 B	27,20 AB	28,24A	0,28	26,90	27,12	<0,0001	0,459	0,506
białko ogólne crude protein	18,65	18.40	18,65	18,64	0,14	18,71	18,46	0,536	0,074	0,002
tłuszcz surowy crude fat	6,72 B	7.38 AB	7,76 A	8,20A	0,27	7,38	7,64	0,003	0,082	0,129
popiół surowy crude ash	1,07	1,06	1,06	1,05	0,01	1,06	1,06	0,708	0,514	0,043
Wskaźniki osocza krwi Blood plasma indicators										
glukoza (mg/dl) glucose (md/dl)	248,00 AB	256,52 A	239,83 AB	229,72 B	5,43	239,11	247,93	0,032	0,110	0,124
białko całkowite (g/dl) total protein (g/dl)	3,17 A	3,17 A	3,00 AB	2,85 B	0,08	3,25 A	2,86 B	0,014	<0.0001	0,582
trójglicerydy (mg/dl) triglycerides, mg/dl	50,11 AB	55,59 AB	59,25 A	44,53 B	3,14	51,99	52,75	0,010	0,8101	0,915
cholesterol całkowity (mg/dl) total cholesterol (mg/dl)	123,94 AB	131,84 A	122,26 AB	113,28 B	3,49	123,99	121,68	0,005	0,506	0,823
cholesterol HDL (mg/dl) HDL cholesterol (mg/dl)	94,50	97,60	88,55	86,18	3,14	93,95	89,47	0,068	0,159	0,767

A, B – wartości w wierszach oznaczone różnymi literami różnią się istotnie ($P<0,05$).
A, B – values in rows with different letters differ significantly ($P<0.05$).

Table 7. Coefficients of apparent ileal digestibility of crude protein and amino acids in the soybean expeller diet (experiment 2)

Item	Control group	Experimental groups			SEM	P value
		I	II	III		
Crude protein	87 A	85 AB	86 AB	83 B	3,5	0,041
Essential amino acids						
arginine	95 A	94 AB	93 AB	92 B	1,2	0,005
phenylalanine	92 A	90 AB	91 AB	89 B	1,9	0,058
histidine	88 A	86 AB	81 B	82 B	5,0	0,003
isoleucine	91 A	89 AB	88 AB	87 B	2,5	0,008
leucine	91 A	89 AB	89 AB	88 B	2,6	0,046
lysine	94 A	92 A	91 AB	88 B	2,2	0,003
methionine	89 A	86 AB	83 B	82 B	4,3	0,002
threonine	89 A	86 AB	83 B	82 B	4,3	0,002
valine	91 A	89 AB	88 AB	86 B	3,6	0,011
Non-essential amino acids						
alanine	90 A	88 AB	87 AB	85 B	0,8	0,016
aspartic acid	90	90	88	86	5,8	0,072
cystine	84 A	82 AB	83 AB	79 B	4,3	0,022
glycine	88 A	85 AB	83 B	83 B	1,5	0,018
glutamic acid	93 A	92 A	83 AB	91 A	0,8	0,028
proline	91	89	89	90	7,4	0,736
serine	90 A	88 AB	86 B	85 B	3,4	0,011
tyrosine	91 A	88 AB	85 B	85 B	2,1	0,001

A, B – values in rows with different letters differ significantly (P<0,05).

The mortality of chickens in the first breeding period was significantly higher than in the second period, with the exception of the first experimental group. The mortality in the first experimental group was significantly lower than in the control group ($P<0.05$), and the remaining experimental groups did not differ from the control group. There were no significant differences in male and female chicken mortality, nor a significant interaction of both experimental factors in influencing the mortality rate of chickens.

There were no significant differences in the intake of compound feed between groups of broiler chickens, while males consumed significantly more feed than females in both periods and throughout the rearing period ($P<0.05$, tab. 4). There were also no significant differences in the feed use rates, and their value slightly increased with the level of extruded soybean expeller in compound feed. There were no significant differences between the sexes of chickens as well as significant interaction for the analysed parameters.

The slaughter weight of 40 randomly selected broilers showed a significant reduction in the weight of chickens fed with mixtures containing extruded soybean expeller (tab. 4). Similar relations were found in the mass of warm and chilled carcasses. There were no significant differences in slaughter efficiency in chickens nor a significant interaction for this parameter. The replacement of commercial soybean meal with extruded soybean expeller in compound feed at all levels significantly diminished the mass of chicken breast muscles expressed in absolute and relative terms ($P<0.05$). There were no significant differences between the broiler groups in the mass of the heart, stomach, liver and spare fat, in relative and absolute values. The mass of breast muscles and the weight of the males' legs was significantly higher than in the females ($P<0.05$). The content of spare fat in the carcasses of the females was significantly higher as compared to the carcasses of males ($P<0.05$). No significant interaction was observed for the level of extruded soybean expeller in the diets and the number of chickens for all the parameters of the carcasses examined. There were no significant differences in the chemical composition of the breast muscles of broiler chickens (Tab. 5), except for the significantly higher fat content in the females as compared to males ($P<0.05$). Feeding broilers with fodder containing 20 and 39% of extruded soybean expeller significantly increased the content of dry matter and crude fat in the muscles of the broiler leg muscles as compared to the chickens in the control group ($P<0.05$).

There was a significant interaction between the level of extruded expeller in the feed mixtures and the sex of broiler chickens for total protein and crude ash content in breast muscles and leg muscles ($P<0.05$).

The complete replacement of both feeds in feed mixtures significantly reduced the content of glucose, triglycerides, protein and total cholesterol in chicken blood plasma ($P<0.05$; Tab. 6). There were no differences in the content of high density lipoproteins (HDL) in the plasma of broiler chickens nor a significant interaction of both experimental factors in the impact on the tested blood plasma parameters.

The complete replacement of soybean meal with extruded soybean expeller resulted in a significant reduction in the apparent intestinal digestibility of the general protein ($P<0.05$), in the absence of significant differences between the broiler experimental groups (Tab. 7). The introduction of extruded soybean expeller to blends for broilers at the level of 10 and 18% of the feed mixture lowered the intestinal digestibility of most exogenous and endogenous amino acids, including the lysine amino acid, although the differences observed as compared to soybean meal were negligible. The exception was the methionine amino acid, whose intestinal digestibility was similar and comparable in all the broiler groups. Intestinal digestibility of histidine and threonine significantly decreased at the 18% level of extruded soybean expeller in the feed mix ($P<0.05$). The replacement of commercial soybean meal with extruded soybean expeller significantly reduced the intestinal digestibility of most amino acids ($P<0.05$), with the exception of methionine, aspartic acid and proline.

Discussion of the results

The literature on the use of extruded soybean feeds in feeding broiler chickens is dominated by scientific work on full extruded soybeans (Zhaleh et al., 2012, Foltyn et al., 2012, Foltyn et al., 2013, Mirghelenj et al., 2013, Jahanian and Rasouli, 2016). Few publications discuss extruded post-extraction soybean meal (Johanian and Rasouli, 2016), and one of them concerns the use of extruded soybean expeller in broiler nutrition as compared to extruded post-extraction soybean meal (Powell et al., 2011).

Post-extraction soybean meal is the main source of protein in poultry diets (De Coca-Sinova et al., 2008) and constitutes over 50% of global feed protein (Kohlmeier, 1990). From over 2.1 million tonnes of extracted soybean meal imported to Poland, about 60% is intended for the production of feed mixtures for poultry feed, mainly broilers (Brzóska, 2009a, b).

Leeson and Atteh (1996) extruded whole and pelleted soybeans at 80°, 100°, 120° and 140°C and included in the amount of 30% of the diets for broiler chickens during a 3-week feeding experience. There were no effects of extrusion temperature on the body weight, feed use or chicken mortality. The effect of extruding whole and pelleted soybeans on feed intake, body weight and feed use and chicken mortality was also not found. The increase in extrusion temperature reduced the activity of trypsin inhibitors. There was no effect of the tested factors on N retention, fat, Ca, P and the metabolic energy level of the diet for chickens. In this work, soybean expeller was extruded at 130°C because higher temperature lowered the content of amino acids, including lysine, in extruded expeller (unpublished authors' results). The 130°C extrusion temperature reduced the inhibitor content from 22-23 mg/g to 2-3 mg/g of soybean fodder, adopted as an acceptable level in the diets for broiler chickens. Subuh et al. (2002) found that the partial or even total replacement of post-extraction soybean meal with extruded soybean in broiler diets does not increase chicken mortality if the level of trypsin inhibitor does not exceed the acceptable level of 2-3 mg/g of fodder.

Foltyn et al. (2013) in a study carried out on 260 Ross 308 broilers examined the effect of dietary intake of extruded soybean on the growth, gastrointestinal morphology, intestinal trypsin inhibitor activity and actual amino acids digestibility. The diets used 0, 40, 80, 120 and 160 g/kg of extruded soybean in feed mixtures, administered to chickens from 10 to 38 days of age. The level of 160 g/kg of extruded soybean significantly decreased the body weight to 2093 g (14.3%) as compared to 2443 g in the control group receiving post-extraction soybean meal. The levels of 40, 80, 120 g/kg of extruded soybean in feed mixes reduced the relative body mass by 6.0, 5.5 and 5.5%, respectively, as compared to the control group. Morphological examination of the gastrointestinal tract revealed a reduction in villi length and the depth of the intestinal epithelium crypts. The activity of the trypsin inhibitor in the intestinal content increased significantly by over 80% at 160 g/kg, with a significant increase in pancreas mass from 120 g/kg of extruded soybeans in absolute and relative terms.

The test results presented in this paper are largely consistent with the results described by Leeson and Athene (1996) regarding extruded whole soybean and with the results of studies of Foltyn et al. (2013). The use of 10% and 18% of extruded soybean expeller in the diets in this work, interchangeably with post-extraction soybean meal, lowered the chicken mass by 4.6% and 5.6%, respectively, with insignificant differences as compared to the group of broilers receiving soybean meal. The absolute differences in the weight of broilers amounted to about 121-147 g/item so that with a larger number of birds, the negative impact of extruded expeller on the weight of the broiler could be significant. The total replacement of commercial soybean meal in feed mixtures, with the average feed content 39% of the expeller in the starter and grower diets resulted in a significant reduction in chicken body weight by 7.7%. The above data indicate that the use of extruded soybean with reduced fat content to the level of 8-9% gives poorer broiler breeding results than the use of post-extraction soybean meal, and the optimal level in broiler feed mixes should not exceed 10%. The values for extruded whole soybean present their maximum share in mixes for broilers at the level of 18% of feed mixtures. The feeding of extruded whole soybean due to the lower content of protein and amino acids as compared to the extruded soybean expeller requires the use of larger amounts of other high protein materials in fodder mixes, e.g. fodder yeast, dried distillers or feed of animal origin in non-EU countries. In our work it was an addition of fodder yeast.

Powell et al. (2011) extruded soybean expeller from exfoliated soybean with the total protein content of 471.7 g/kg, achieving a protein content in the expeller at the level of 449.3 g/kg. The fat content in both feeds was similar to that in this study and was respectively 19.7 g/kg and 80.8 g/kg, and the caloric value was, respectively, 9.57 MJ ME_n/kg and 11.16 MJ ME_n/kg. Extruded soybean expeller contained less amino acids from extruded material in the following proportions: lysine by 30.6 vs 28.2 g/kg, methionine 7.0 vs. 5.8 g/kg and threonine 17.8 vs. 16.6 g/kg. Both feeds were used in a 49-day growth experiment in an amount of 34.51% and 37.66%, (starter); 30.93% and 33.76% (grower) and 29.05% and 31.71% (finisher), respectively. There were no significant differences in body weight of 49-day-old chicken (2.77 vs. 2.75 kg), daily weight gains (55.36 vs. 55.17 g), feed intake (100.39 vs 99.08 g/d), with a significantly worse use of feed in the group fed with a compound feed with an extruded soybean expeller. Despite insignificant differences in the chicken body weight, the authors showed a lower real intestinal digestibility of the amino acids of the diet containing the extruded soy expeller. The present study confirmed the results of those few studies so far proving that the full replacement of post-extraction soybean meal with extruded soybean expeller significantly reduces the production effect in broiler breeding. The body weight of males of broiler chickens, as expected, during the entire rearing period was about 10% higher than for the females, with significantly less feed intake by females, but with an even feed use and mortality of chickens of both sexes in the groups.

Feed consumption and use

In the paper by Clarke and Wiseman (2007), it was suggested that the depression of growth of broilers consuming feed with the addition of extruded soybean may be the result of increased endogenous amino acid losses and the decrease in intestinal proteolysis and the reduction of amino acid absorption. The negative effect of other thermostable anti-nutritive substances, which are not deactivating under the influence of temperature or partially deactivated in the extrusion process, also seems probable. Feed intake was also limited by the thermally stable saponins contained in soybean when the level of extruded seeds in mixtures was 15% (Jenkins and Atwal, 1994).

The phenomenon of craving and animal feed intake is closely related to the decreasing level of glucose in the blood. In our work, a significant effect of extruded soybean expeller on the reduction of blood glucose level was found although no significant differences in the feed intake were observed. In other studies, it was found that the trypsin inhibitor and urease activity in soybean correlated with body weight and feed use (Ruiz et al., 2004). The only method of getting rid of anti-nutritive factors and increasing the nutritional value of soybean feed so far is heating, including extrusion (Perilla et al., 1997, Qin et al., 1996, Macha-do et al., 2008). The opinions about the effect of extruded soybean and soybean expeller on the feed consumption by broiler chickens are divergent. It has been shown that the limiting factors are mainly inhibitors of pancreatic proteases which reduce the feed intake although the mechanism of inhibition of the feed intake has not been fully explained. Waldrup and Cotton (1974) concluded that the decrease in the intake of the mix containing the extruded soybean was due to the increase in the density of the ground fodder and recommended that the level of extruded soybean in the diets be limited to 25% if the mixes were served as powders. Leeson and Atteh (1996) showed that extrusion at 140°C significantly increased the feed intake as compared to other groups. Other results were presented by Marsman et al. (1997) and Nalle et al. (2011) stating that extruded soybean fodder, including soybean expeller (Powell et al., 2011), reduced the feed intake by broiler chickens but this impact was not statistically significant.

The production and economic factor of broiler feeding is the consumption of fodder per 1 kg of chicken body weight. Ruiz et al. (2004) found that partial and even total replacement of post-extraction soybean meal in broiler diets does not reduce the use of fodder. Foltyn et al. (2013), feeding the broilers with the feed mixes containing 0 to 160 g/kg of extruded soybean seeds showed deterioration in feed use after 38 days of breeding, and feed consumption rates were 1.69 and 1.90 kg/kg, respectively. Marsman et al. (1997) described different results. They found that extrusion significantly improved feed use and apparent digestibility of general protein and non-starchy carbohydrates. Nassiri-Fard et al. (2013), in research carried on Ross 308 roosters, receiving in diets 0, 5, 10, 15 and 20% of extruded soybean instead of post-extraction soybean meal from day 11 to 42 of breeding showed a significant reduction in the consumption and use of feed. The quoted results give a divergent picture, although most studies, also included in this paper, indicated that the conversion of post-extraction soybean meal into extruded soybean expeller worsened the feed use rate, with no significant differences between the broiler groups.

Quality of carcasses and chemical composition of breast muscles and leg muscles

In broiler production, the weight of breast muscles in relation to carcass weight is of economic importance (Renden et al., 1994). Breast muscles constitute 30% of the total meat of the edible carcass and 60% of the edible protein of the carcass (Summers and Leeson, 1985). The estimated lysine demand for chicken breast muscle growth up to 2 weeks is 1.32 ± 0.01% (NRC, 1994). Although the level of lysine in the feed mixtures was comparable, the reason for the worse results of broiler growth in the experimental groups could be the lower level of digestible lysine in the diets.

The slaughter efficiency and post-slaughter quality of broiler chickens is affected by many factors, both genetic and environmental, including the composition of the diet, its physical form, and the age of chicken slaughter. Amino acids that restrict the biological value of the diet for chickens are methionine and lysine. There was a significant increase in the muscle mass of broilers under the influence of lysine added to feed (Mushtag et al., 2007). The various conditions in which the broilers were fed make the results regarding the quality of the carcasses and their muscles divergent. Todorov et al. (1999) did not find any significant impact of 20% of extruded soybean in feed mix on the weight of the carcass, breast muscle mass and internal organs of broiler chickens. Sabuh et al. (2002) showed that the use of 34% of extruded whole soybean in the diet did not affect the weight of the broiler carcass while Kidd et al. (1998) found a decrease in breast muscle mass in the broiler breeding starter phase, with reduced feed intake. In other studies, it was found that extruded soybean expeller reduced the mass of breast muscles (Powell et al., 2011). Similar results were obtained in our own research. A negligible decrease in the share of breast muscles in broiler carcasses could result from the limited digestibility of amino acids necessary for the synthesis of proteins contained in the diet of chickens of experimental groups as compared to the diet of control chickens. Lysine has been shown to be the first amino acid restricting the growth of broiler muscles (Leeson and Summers, 2001). Limiting the availability of amino acids in the diet may result in poorer protein synthesis in the muscles and weakening of their growth. On the other hand, lowering the level of total protein and amino acids in the diet results in a significant increase in the content of spare fat.

The results of the analysis of the composition of chicken broiler carcasses fed diets containing extruded soybean indicate a decreasing content of spare fat in carcasses as compared to the effects obtained when feeding control diets. The level of crude fat in feed mixtures varied within a limited range while the amount of soybean oil added to the mixtures increased in the experimental groups. We do not know how the temperature and the process of extrusion affect the level and activity of lipase and lipoxidase enzymes, recognised as anti-nutritive substances in soybean, and which are present both in the extruded expeller and in the oil added to the compound feeds. The digestibility of crude fat has not been studied, hence the inference based on the available data is not justified. In birds, fatty acids are synthesised in the liver and transported via low-density lipoproteins (LDL) or chylomicrons to tissues that store spare fat as triglycerides (Hermier, 1997). Mirghelenj (2013) stated that the amount of spare fat in the percentage share of the birds' body weight decreased linearly along the increase of extruded whole soybean in the diets of chickens slaughtered at the age of 42 days, which was confirmed by the results obtained in our work. This is also confirmed by previous studies (Alleman et al., 2000; Ciftci and Ceylan, 2004). In the light of the above studies, the reduced absorption of fatty acids in experimental broiler diets seems possible, which could have influenced the reduced deposition of broiler fat as well as lower glucose and triglyceride levels in broiler blood plasma in the group with the highest share of extruded soybean expeller in compound feed discussed in this work.

The test results showed that the chemical composition of breast muscles was not influenced by the type of soybean fodder in diets or the sex of chickens, except for the significantly higher fat content in the breast muscles of females. The accumulation of fat by females in larger quantities resulted from a different hormonal system of females and to a lesser extent depended on dietary factors (Faud and El-Senousey, 2013). Significant influence of extruded soybean expeller contained in diets for chickens was found to increase the content of raw fat in leg muscles. The results of these studies are not confirmed in the literature on the influence of soybean feeds on the chemical composition of broiler carcass muscles.

Blood plasma indicators

Nassiri-Fard et al. (2013) showed that feeding Ross 308 roosters with diets containing extruded soybean significantly increased the level of high-density lipoproteins (HDL) and triglycerides in the blood serum. Hermier and Dillon (1992) in earlier studies found that the concentration of lipoproteins in the blood serum changed with the amount of dietary fat. In other studies, it was found that the fibre fractions contained in soybean are an important factor in lowering the serum cholesterol level (Uberoi et al., 1992). It is suggested that proteins of whole soybeans reduce cholesterol metabolism in the liver through increased removal of low-molecular-weight LDL cholesterol from the blood (Sirtori et al., 1995).

Cholesterol is a precursor to steroid hormones and bilious salts. Its level depends on the environmental conditions, nutrition and fat content of broilers (Itoh et al., 1998). The total cholesterol and serum triglyceride level in this work significantly increased at the level of 10% and 18% of extruded soybean expeller in the broiler diet, while at 39% it significantly decreased. Hermier and Dillon (1992) showed that the composition of serum lipoproteins can be altered by the type of fat chicken diet. Low-density lipoprotein (LDL) levels in chickens have been shown to lower the soybean oil contained in the diet, which contains a lot of unsaturated fatty acids, and the liver converts them to ketones instead of LDL low-density lipoproteins or triglycerides (Nitsan et al., 1997). Another theory is that soybean protein reduces cholesterol metabolism in the liver by removing LDL and total cholesterol from the birds' organisms (Sirtori et al., 1995).

The results of biochemical tests of blood plasma in this dissertation confirm earlier data (Nassiri-Fard et al., 2013, Anderson et al., 1995, Sirtori et al., 1995) although they are not unambiguous. The extruded soybean expeller significantly lowered all the tested parameters of blood plasma, including glucose, proteins, triglycerides and lipoproteins, especially at the highest content of extruded soybean expeller in diets. These results indicate that extruded soybean expeller, exceeding several times the content of crude fat in soybean meal, can significantly affect the metabolism of energy components of the broiler diet, including glucose, and especially lipids. It cannot be ruled out that the decreasing level of lipoproteins in the broiler chickens of experimental groups was the result of the presence of soybean oil added to the feed mixtures in these groups, which would confirm the results of other studies (Nitsan et al., 1997).

Intestinal protein and amino acids digestibility

The intestinal digestibility of feed materials in broiler chickens is influenced by many factors, including the age of chickens and the development of the gastrointestinal tract, physical structure of the diet, type of protein, type and level of fibre and the proportion of fibre to starch, the presence of non-starch polysaccharides in the diet, anti-nutritional factors, and processing temperature, endogenous excretion and interdependencies in the absorption of individual amino acids, as well as the use of an additive in the feed mixtures of crystalline lysine and methionine. It has been shown that a higher digestibility of amino acids in the diet affects the faster growth of birds. The high variability of digestibility coefficients for individual amino acids depends on the origin of soybean meal samples (Clark and Wiseman, 2007, De Coca-Sinova et al., 2010). Kim and Corzo (2012) have shown that the actual intestinal digestibility of amino acids in broilers depends on the line, age and sex of the chickens. The digestibility of soybean fodder is influenced by its geographical origin. De Coca-Sinova et al. (2008), comparing the apparent intestinal digestibility of the amino acids of post-extraction soybean meal derived from three different sources (USA, Brazil, Argentina) in broiler nutrition, showed that these values for lysine ranged from 77.8 to 85.1% and they were the highest for US feed. Research has not been conducted on the digestibility of whole soybean and extruded seeds from different geographic zones. Recommendations on poultry nutrition and feedstuffs diet tables (Smulikowska and Rutkowski, 2005) do not contain information on intestinal digestibility of the amino acids of extruded seeds and extruded soybean expeller. Frikha et al. (2012) found that the actual intestinal digestibility in chickens was determined for 22 commercial samples of post-extraction soybean meal from three countries, ranging from 89.1 to 94.0% (Thakur and Hurburgh, 2007; De Cova-Sinova et al., 2010). In the presented dissertation, apparent intestinal digestibility of general protein in the feed containing the extracted soybean meal was 87%. The replacement of soybean feed in diets with extruded soybean expeller lowered the digestibility to 85-86% in the first (10% of the expeller) and the second experimental group (18% of the expeller). The complete replacement of soybean feeds reduced the digestibility of the broiler diet protein in the third group to 83% (39% of the expeller). Based on the research, it was suggested that the differences in the content and digestibility of the general protein diet containing soybean feeds could result from the content of anti-nutritional substances (Opapeju et al., 2006; Gonzáles-Vega et al., 2011). It was found that the actual intestinal digestibility of amino acids (SID) determined for chickens for thermally processed feed, subjected to technological processes like toasting or drying, is lower than the amino acids of cereal grains (Szczurek, 2009), which would indicate that high temperature reduces the digestibility of amino acids, mainly due to the Maillard reaction.

In the studies of Foltyn et al. (2013) the replacement of post-extraction soybean meal with extruded soybean significantly decreased the actual intestinal digestibility of amino acids when the level of extruded seeds in diets reached 8, 12 and 16% of the feed mix. The decrease in lysine digestibility in relative terms was 6.8; 6.6 and 7.8%, respectively. The research of seven feed producing companies using soybean extrusion on an industrial scale, showed large differences in the amino acid composition and the nutritive value of feeds containing extruded seeds in diets for poultry (Karr-Lilienthal et al., 2006). This could be due to the many constructional solutions of feed extruders and the use of different extrusion temperatures. The actual degree of protein and amino acid digestion determined on shunted roosters turned out to be lower than the data presented in the NRC tables (1994), which was in line with earlier results of Zhang and Parsons (1993).

The actual digestibility of the amino acids of extruded soybean expeller in the tests carried out by Powell et al. (2011) determined on adult shunted roosters, was at the level of lysine - 86.6; methionine - 83.5; valine - 87.4; isoleucine - 85.5; leucine - 86.5% and was significantly lower than that of extruded post-extraction soybean meal. The results of the research presented in our work are confirmed by the data obtained by Powell et al. (2011). The values of the apparent intestinal digestibility ratios in our work were higher than in the quoted work although the trend of decreasing amino acid digestibility was found in all the experimental groups, and the level was significant at the highest level of extruded soybean expeller in compound feed. It has been demonstrated that the content of less than 10% of extruded soybean expeller in compound feed is the limit level due to the intestinal digestibility of the amino acids.

Apart from the results described above, different results were also obtained. The positive effect of soybean extrusion on the amino acid digestibility was confirmed in the studies of Ruiz et al. (2004). They showed that as the temperature of wet extrusion increased, the digestibility of amino acids increased, which indicated the progressive destruction of the trypsin inhibitor and other anti-nutritional factors that may limit the absorption of amino acids. Our own results are closer to those obtained by Zhang and Parsons (1993) for full extruded soybean stating that soybean meal substitutes for extruded soybean in compound feed for broiler chickens reduce the apparent intestinal digestibility of proteins and amino acids, which can result in a reduced broiler growth rate.

To sum up, it can be concluded that the replacement of commercial extracted soybean meal with extruded soybean expeller obtained from non-genetically modified soybean from domestic crops, with the content of 369.9 g/kg of total protein and 84.7 g/kg of crude fat/kg, used in quantities of 10, 18 and 40% of extracted soybean meal (which means a substitution of 25, 50 and 100% of feed protein) reduces the body weight of 42-day-old broilers significantly with the full replacement of both soybean meals in the diet. The replacement of soybean feed at the levels of 25% and 50% of dietary protein (10% and 18% of compound feed) also reduces the body weight of broilers, however at a negligible level. The lower weight of the broilers and carcasses corresponds to the lower mass of muscles and their share in carcasses. The negative impact of extruded soybean expeller on the intestinal digestibility of amino acids, including lysine, can be considered as the reason for the described effects of replacing soybean feeds in broiler diets.

References

Alleman F., Michel J., Chagneau A.M., Leclercq B. (2000). The effect of dietary protein independent of essential amino acids on growth and body composition in genetically lean and fat chickens. Br. Poultry Sci., 41: 214–218.

Alsaftli Z.A., Al-Saadi M.A., Subuh A.M. (2015). Effect of using extruded full-fat soybean on performance and carcass characteristics in female turkeys. Asian J. Anim. Sci., 9: 198–207.

Anderson J.W., Johnstone B.M., Cook-Newell M.E. (1995). Meta-analysis of the effects of soy protein intake on serum lipids. N. Engl. Med., 333: 276–282.

Brzóska F. (2009a). Czy istnieje możliwość substytucji białka GMO innymi surowcami białkowymi (Część I). Wiad. Zoot., 1: 3–9.

Brzóska F. (2009b). Czy istnieje możliwość substytucji białka GMO innymi surowcami białkowymi (Część II). Wiad. Zoot., 2, 1: 3–11.

Buraczewska L. (1991). Inhibitory enzymów, taniny, oligosacharydy i fityniany w nasionach roślin strączkowych – problemy przedstawione na seminarium w Holandii w 1988 roku. Post. Nauk. Roln., 3: 121–127.

Ciftci J., Ceylan I.R. (2004). Effects of dietary threonine and crude protein on growth performance, carcase and meat composition of broiler chickens. Br. Poultry Sci. 45: 280–289.

Clarke E., Wiseman J. (2007). Effect of extrusion condition on trypsin inhibitor activity of full fat soybeans and subsequent effect on their nutritional value for young broilers. Br. Poultry Sci., 48: 703–712.

De Coca-Sinova A., Valencia D.G., Jiménez-Moreno E., Lázaro R., Mateos G.G. (2008). Apparent ileal digestibility of energy, nitrogen, and amino acids of soybean meals of different origin in broilers. Poultry Sci., 87: 2613–2623.

De Coca-Sinova A., Jiménez-Moreno E., Gonzáles-Alvarado J.M., Frikha M., Lázaro R., Mateos G.G. (2010). Influence of source of soybean meal and lysine content of the diet on performance and total tract apparent retention of nutrients in broilers from 1 to 36 days age. Poultry Sci., 89: 1440–1450.

Douglas M.W., Parsons C.M., Hymovitz T. (1999). Nutritional evaluation of lectin-free soybeans for poultry. Poultry Sci., 78: 91–95.

Faud A.M., El-Senousey H.K. (2013). Nutritional factors affecting abdominal fat deposition in poultry: A review. Asian-Austral. J. Anim. Sci., 27 (7): 1057–1068.
Foltyn M., Rada V., Lichovniková M. (2012). The effect of graded level extruded full- fat soybean in diets for broiler on apparent ileal amino acids digestibility. Report of Mendel Net., pp. 248–253.
Foltyn M., Rada V., Lichovníková M., Šafařík I., Lohniský A., Hampel D. (2013). Effect of extruded full-fat soybeans on performance, amino acid digestibility, trypsin activity, and intestinal morphology in broilers. Czech. J. Anim. Sci., 58 (10): 47–478.
Frikha M., Serrano M.P., Valencia D.G., Rebollar P.G., Ficker J., Mateos G.G. (2012). Correlation between ileal digestibility of amino acids and chemical composition of soybean meals in broilers at 21 days of age. Anim. Feed Sci. Technol., 178: 103–114.
Gonzáles-Vega J.C., Kim B.G., Htoo J.K., Lemme A., Stein H.H. (2011). Amino acid digestibility in heated soybean meal fed to growing pigs. J. Anim. Sci., 89: 3617–3625.
Hermier D. (1997). Lipoprotein metabolism and fattening in poultry. J. Nutr. 127: 805–808.
Hermier D., Dillon J.C. (1992). Characterization of dietary-induced hypercholesterolemia in the chickens. Biochim. Biophys. Acta (BBA) Lipids Lipid Metab., 1124: 178–184.
Hsiao H.Y., Anderson D.M., Dale N.M. (2006). Levels of β-mannan in soybean meal. Poultry Sci., 85: 1430–1432.
Itoh N., Makita T., Koiwa M. (1998). Characteristics of blood chemical parameters in male and female quails. J. Vet. Med. Sci., 60: 1035–1037.
Jahanian R., Rasouli E. (2016). Effect of extrusion processing of soybean meal on ileal amino acid digestibility and growth performance of broiler chicks. Poultry Sci., 95: 2871–2878.
Jenkins K.J., Atwal A.A. (1994). Effects of dietary saponins on faecal bile acids and neutral sterols, and availability of vitamins A and E in the chicks. J. Nutr. Biochem., 5: 134–137.
Kadim I.T., Moughan P.J. (1997). Development of an ileal amino acid digestibility assay for the growing chicken – effects of time after feeding and site of sampling. Br. Poultry Sci., 38: 89−95.
Karr-Lilienthal I.K., Bauer L.L., Utterback P.L., Zinn K.E., Frazier R.L., Par - sons C.M., Fahej Jr. G.C. (2006). Chemical composition and nutritional quality of soybean meals prepared by extruded/expeller processing for use in poultry diets. J. Agric. Food Chem., 54: 8108–8114.
Kidd M.T., Ker B.J., Halpin K.M., Mc Ward G.W., Quarles C.L. (1998). Lysine levels in starter and grower-finisher diets affect broiler performance and carcass traits. J. Appl. Poultry Res., 7: 351–358.
Kim E.J., Corzo A. (2012). Interactive effects of age, sex, and strain on apparent ileal amino acid digestibility of soybean meal and an animal by-product blend in broilers. Poultry Sci., 91: 908–917.
Kohlmeier R.H. (1990). World production, storage and utilization various defatted animal and vegetable mid-high protein meals. Page 390 in World Conf. Edible Fats Oils Processing-Basic Principles and Modern Practices. Erickson D.R., ed. Am. Oil Chem. Soc., Champaign, Il, USA.
Leeson S., Atteh J.O. (1996). Response of broiler chicks to dietary full-fat soybeans extruded at different temperatures prior to or after grinding. Anim. Feed Sci. Technol., 57: 239–245.
Leeson S., Summers J.D. (2001). Naturally occurring toxins relevant to poultry nutrition. In: Scott's Nutrition of the Chicken, 4th ed. University Books, Guelph, Canada, pp. 544–586.
Machado F.P.P., Queiroz J.H., Oliveira M.G.A., Piovesan N.D., Peluzio M.C.G., Costa N.M.B., Moreira M.A. (2008). Effect of heating on protein quality of soybean flour devoid of Kunitz inhibitor and lectin. Food Chem., 107: 649–655.
Markowski J., Korol W. (2006). Informacje o wynikach badań GMO wykrywanych w KLP Szczecin w ramach Krajowego Planu Kontroli Pasz. Pasze Przemysłowe, 1: 25–30.
Marsman G.J.P, Gruppen H., der Poel A.F.B., Kwakkel R.P., Verstegen M.W.A., Voragen A.G.J. (1997). The effect of thermal processing and enzyme treatments of soybean meal on growth performance, ileal nutrient digestibilities, and chyme characteristics in broiler chicks. Poultry Sci., 76: 864–872.
Mirghelenj S.A., Golian A., Kermanshahi H., Raji A.R. (2013). Nutrition value of wet extruded full-fat soybean and its effects on broiler chicken performance. J. Appl. Poultry Res., 22: 410–422.
Mushtag T., Sarwar M., Ahmad G., Mirza M.A., Nawaz H., Mushtag H.M.M., Noreen

U. (2007). Influence of canola meal-based diets supplemented with exogenous enzyme and digestible lysine on performance, digestibility, carcass, and immunity responses of broiler chickens. Poultry Sci., 86: 2144–2151.

Nalle C.L., Ravindran G., Ravindran V. (2011). Extrusion of peas (*Pisum sativum* L.). Effects on the apparent metabolisable energy and ileal nutrient digestibility of broilers. Am. J. Anim. Vet. Sci., 6: 25–30.

Nassiri-Fard H., Shahryar H.A., Khani A.H. (2013). Effect of replacement of soybean meal with extruded full-fat soybean on performance and lipid serum in broiler. Adv. Biores., 4 (4): 121–124.

Nitsan Z., Dvorin A., Zoref Z., Mokady S. (1997). Effect of added soybean oil and dietary energy on metabolisable and net energy of broiler diets. Br. Poultry Sci., 38: 101–106.

Opapeju F.O., Golian A., Nyachoti C.M., Campbell L.D. (2006). Amino acid digestibility in dry extruded-expelled soybean meal fed to pigs and poultry. J. Anim. Sci., 84: 1130–1137.

Parsons C.M., Zhang Y., Araba M. (2000). Nutritional evaluation of soybean meals varying in oligosaccharide content. Poultry Sci., 79: 1127–1131.

Perez-Maldonado R.A., Mannion P.F., Farell D.J. (2003). Effect of heat treatment of the nutritive value of raw soybean selected for low trypsin inhibitor activity. Br. Poultry Sci., 44: 299–308.

Perilla N.S., Cruz M.P., De Belalcazar F., Diaz G.J. (1997). Effect of temperature of wet extrusion on the nutritional value of full-fat soybeans for broiler chickens. Br. Poultry Sci., 38: 412–416.

Powell S., Naranjo V.D., Lauzon D., Bidner T.D., Southern L.L., Parsons C.M. (2011). Evaluation of an expeller-extruded soybean meal for broiler. J. Appl. Poult. Res., 20: 353–360.

Qin G., Ter Elst E.R., Bosch M.W., van der Poel A.F.B. (1996). Thermal processing of whole soya beans: studies on the inactivation of antinutritional factors and effects on ileal digestibility in piglets. Anim. Feed Sci. Technol., 57: 313–324.

Rocha C., Duran J.F., Barrllli L.N.E., Dahlke F., Maiorka P., Maiorka A. (2014). The effect of raw and roasted soybeans on intestinal health, diet digestibility, and pancreas weight of broilers. J. Appl. Poultry Res., 23: 71–79.

Ruiz N., de Belalcázar F., Diaz G.J. (2004). Quality control parameters for commercial full- fat soybeans processed by two different methods and fed to broilers. J. Appl. Poultry Res., 13: 443–450.

Saha D.C., Gilbreath R.L. (1991). Analytical recovery of chromium from diet and feces determined by colorimetry and atomic absorption spectrophotometry. J. Sci. Food Agr., 55: 433–446.

Sirtori C.R., Lovati M.R., Manzoni C., Gianazza E., Biondioli A., Staels B., Auwers J. (1995). Reduction of serum cholesterol by soy proteins. Nutr. Metabol. Cardiovasc. Dis., 8: 334–340.

Smulikowska S., Rutkowski A. (2005). Zalecenia żywienia drobiu. Tabele wartości pokarmowej pasz. Wyd.: Instytut Fizjologii i Żywienia Zwierząt PAN. Jabłonna.

Subuh A.M.H., Motl M.A., Fritts C.A., Waldroup P.W. (2002). Use of various rations of un-extracted full fat soybean meal and dehulled solvent extracted soybean meal in broiler diets. Int. J. Poultry Sci., 1: 9–12.

Summers J.D., Leeson S. (1985). Poultry Nutrition Handbook. University of Guelph. Guelph, Ont.

Szczurek W. (2009). Standardized ileal digestibility of amino acids from several cereal grains and protein-rich feedstuffs in broiler chickens at the age of 30 days. J. Anim. Feed Sci., 18: 662–676.

Śliwa J., Zając T., Oleksy A., Klimek-Kopyra A., Lorenc-Kozik A., Kulig B. (2015). Comparison of the development and productivity of soybean (*Glycine max* (L.) MERR.) cultivated in western Poland. Acta Sci. Pol. Agricultura, 14 (4): 1–15.

Thakur M., Hurburgh C.R. (2007). Quality of US soybean meal compared to the quality of soybean meal from other origins. Am. Oil Chem. Soc., 84: 835–843.

Todorov N., Gieorgieva V., Mitev J., Djovinov D. (1999). Extruded full fat soybeans as an ingredient for dietary formulation for broiler chickens. Bulgarian J. Agric. Sci., 5: 443–448.

Uberoi S.K., Vadhera S., Soni G.L. (1992). Role of diet fiber from pulses and cereals as hypocholesterolemic and hypolipidemic agent. J. Food Sci. Technol., 29: 281–283.

Ustawa Paszowa (2006). Prawo paszowe. Ustawa z dnia 22 lipca 2006 r. (Dz. U. 2014, poz. 398).

Waldrup P.W., Cotton T.L. (1974). Maximum usage level of cooked full-fat soybean in all-mash broiler diets. Poultry Sci., 53: 677–680.

Z g ł o b i c a A., R ó ż y c k a B. (1972). Procedura analizy tuszek kurcząt. Wyd. Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa. V: 72–85.
Z h a l e h S., G o l i a n A., H a s s a n a b a d i A., M i r g h e l e n j S.A. (2012). Main and interaction effects of extrusion temperature and usage level of full fat soybean on performance and blood metabolites of broiler chickens. Afric. J. Biotechn., 11 (87): 15380–15386.
Z h a n g Y., P a r s o n s C.M. (1993). Effect of extrusion and expelling on the nutritional quality of conventional and Kunits trypsin inhibitor-free soybean. Poultry Sci., 72: 2299–3002.

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Effect of diets with non-GM soybean expeller on body weight, carcass quality and amino acid digestibility in broiler chickens

SUMMARY

A feeding trial with 640 sexed Ross 308 chickens (exp. 1) investigated the effect of replacing commercial soybean meal in the diets (control group) with non-GM soybean expeller (cv. Merlin, Saatbau Linz) at 10, 18 and 39% of the diet (experimental groups), which corresponded to 25%, 50% and 100% replacement of standard soybean meal. Apparent ileal amino acid digestibility of the four diets was deter- mined in 320 Ross 308 cockerels aged 2-4 weeks, which were fed same diets as in experiment 1 (exp. 2). Replacement of the soybean feed in the diets significantly ($P<0.05$) reduced the body weight of the chickens, from 2609 g (control group) to 2488.3, 2461.8 and 2408.6 g/bird in the experimental groups. Mortality in the first experimental group (2.5%) was significantly higher than in the control group ($P<0.05$), while the other experimental groups did not differ from the control group. No significant differences were observed in feed intake and feed conversion between the broiler groups. Feed conversion was 1.64 (control group) and 1.68, 1.72 and 1.73 kg/kg body weight in the experimental groups, respectively. There were no significant differences in dressing percentage between the broilers. The replacement of the commercial soybean meal with soybean expeller in the diets has significantly decreased the absolute and relative weights of breast muscles ($P<0.05$). No significant differences were found between the broiler groups in the absolute and relative weights of the heart, gizzard, liver and abdominal fat. Carcass weight and muscle weight were significantly higher in cockerels, and abdominal fat weight higher in pullets ($P<0.05$). No significant differences were observed in chemical composition of breast muscles, while significantly higher dry matter and crude fat content was noted in leg muscles when the diets contained 18 and 39.0% expeller, respectively ($P<0.05$). Crude fat content in breast muscles was significantly higher in pullets than in cockerels ($P<0.05$).

Complete replacement of both feeds in the diets significantly reduced the content of glucose, triglycerides, protein and total cholesterol in the plasma of chickens ($P<0.05$). There were no differences in the content of plasma high-density lipoproteins (HDL) in broilers.

The 39% expeller diet significantly reduced the apparent ileal digestibility of crude protein from 87 to 83% ($P<0.05$), with no significant differences between the experimental groups of the chickens. The addition of 10, 18 and 39% soybean expeller to the broiler diets reduced the ileal digestibility of most essential and non-essential amino acids, and in comparison with the broilers fed soybean meal, the differences were significant for the complete replacement of soybean diets. The ileal digestibility of methionine averaged 93.5% and did not differ between the control group and the experimental groups of broilers. The ileal digestibility of histidine and threonine decreased significantly when the diet contained 18% soybean expeller ($P<0.05$). The replacement of the commercial soybean meal with 39% soybean expeller significantly reduced the ileal digestibility of most amino acids ($P<0.05$) except for methionine, aspartic acid and proline.

Key words: soybean expeller, amino acid digestibility, broiler chickens