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PARTIAL REPLACEMENT OF SOYBEAN WITH LOW-TANNIN FABA BEAN VARIETIES (ALBUS OR AMULET): EFFECTS ON GROWTH TRAITS, SLAUGHTERING PARAMETERS AND MEAT QUALITY OF PUŁAWSKA PIGS*

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Abstract

The study was carried out involving 48 fattening pigs split into 3 groups of equal size: one control (I) and two experimental (II and III). The experimental factor was low-tannin faba bean seeds of the Albus variety (group II) or Amulet variety (group III) introduced to experimental feed mixtures as a partial replacement for soybean meal – the only protein-rich material in the control diet. It was noticed that the partial replacement of soybean meal with faba bean meal had no statistically significant effect on: the daily gains of pigs, feed conversion, meatiness and fattening grades and meat acidity (pH_1 and pH_{24}), water holding capacity and muscle colour parameters (L*a*b*). However, the drip loss from *longissimus* muscles of pigs fed with diets containing low-tannin faba bean was lower and the difference between the group receiving Albus faba bean and the control group was confirmed to be statistically significant (P≤0.05). In the analysed *longissimus lumborum* muscle, no differences were recorded between the groups in terms of the content of protein, fat, minerals, or saturated and unsaturated fatty acids, including monounsaturated fatty acids. However, it was determined that the muscles of the animals from groups II and III contained more essential unsaturated fatty acids and polyunsaturated fatty acids (P≤0.05 – between groups I and III). Albus faba bean seeds introduced to the feed mixture had a beneficial effect on the sensory characteristics of the evaluated muscle since, compared to the *longissimus lumborum* muscle from the control group, it was characterised by significantly (P≤0.05) improved juiciness, tenderness and palatability.

Key words: fattening pigs, low-tannin faba bean, growth parameters, meat quality

Nutrition is a significant element in pig breeding and the basal nutrients are grains supplemented with protein-rich materials. The most popular protein feed is soybean meal which is an imported, frequently genetically modified material (Sieradzki et al., 2006). It covers about 70% of the protein requirement in the feed mixtures made in

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Poland. Protein materials of domestic origin which could partially replace soybean meal are the seeds of leguminous plants such as faba bean, pea and lupin. Until recently the use of faba bean seeds in feed mixtures for monogastric animals was restricted mainly by tannins – substances decreasing the digestibility of nutrients, energy value and availability of mineral compounds (Jansman et al., 1995; Flis et al., 1999; Jezierny et al., 2010). The cultivation of faba bean has resulted in the production of low-tannin varieties; so far five such varieties have been entered into the National Register: Albus, Amulet, Kasztelan, Olga and Leo (Polish National List of Agricultural Plant Varieties, 2014). Thus, they can be used in mixtures fed to animals (Jamroz and Kubizna, 2008; Jezierny et al., 2010; Hanczakowska and Księżak, 2012; Giuliotti et al., 2014). However, as emphasized by Kasprowicz and Frankiewicz (2000), the use of seeds of leguminous plants in nutrition requires the selection of the most efficient varieties.

Also, it must be remembered that effective breeding of animals, and as a consequence the quality of the product, depends on the breed, genetic lineage or sex, completed by the interaction of all these factors (Osek and Milczarek, 2005; Czarniecka-Skubina et al. 2007; Babicz et al., 2009). Among pigs bred in Poland native breeds are predominant, including Puławska pigs. In comparison to typical meat-producing breeds, this breed is characterised by reduced fattening performance (lower daily weight gains, higher conversion of feed), reduced meatiness and slightly increased fattening grade, but has meat of better quality – lower natural drip loss, better water holding capacity, favourable intramuscular fat content and better sensory value (Piórkowska et al., 2010; Kasprzyk et al., 2013).

The study aimed to compare the effect of mixtures containing the seeds of low-tannin faba bean of Albus or Amulet variety, which partially replaced soybean meal, on the fattening results, slaughter value and physical and chemical as well as sensory properties of the *longissimus lumborum* muscle in Puławska pigs.

Material and methods

The experiment was carried out involving 48 Puławska fattening pigs split into three groups of equal size (I, II and III) which were further split into 4 subgroups of 4 barrows each.

The single-stage fattening of the pigs from the weight of 31 kg to about 117 kg lasted for 114 days. The animals were fed *ad libitum* with constant access to water. Pigs in the control group (I) were fed with a mixture based on barley, triticale, soybean meal, minerals and vitamins. The experimental factor was low-tannin faba bean meal which partially (about 28%) replaced the protein of soybean meal in mixtures fed to pigs from group II (Albus variety) and group III (Amulet variety). The nutritive value of the mixtures was calculated based on recommendations of the Polish Standards of Pig Nutrition (2014), using own analysis results and data included in the above-mentioned standards.

The content of basal nutrients in the feed raw material was determined according to AOAC (1990), while fibre fractions were determined according to the method proposed by Van Soest and Wine (1967). Mineral contents were determined after previous mineralisation of the sample and adding 10 cm^3 10% HCl per 50 cm^3 flask. In the resulting solutions the total content of respective elements was determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) using an Optima 3200RL apparatus made by Perkin Elmer. Amino acid content was determined at the National Feed Laboratory in Lublin. Tannins were determined by the colorimetric method in accordance with the BN-90/79160-62.

Prior to and after the experiment all the animals were individually weighed and the results were used as a reference for calculating daily weight gains. During fattening the intake of feed mixtures was controlled in order to calculate the feed conversion ratio (FCR). Only in the case of feed conversion ratio the experimental unit was the pen containing 4 pigs (N=12) and the individual results for others (N=48).

On the final day of the feeding experiment all fattening pigs were slaughtered using the technology used by meat processing plants, and the meatiness of the pigs was evaluated by means of an ULTRA-FOM 300 apparatus. The initial pH of the meat (pH_1) in the *longissimus* muscle between the last thoracic vertebra and the first lumbar vertebra was measured 45 minutes after the slaughter. The measurement was carried out by means of a portable pH-metre (Mettler Toledo) equipped with an insertion glass electrode. Afterwards, the carcasses were cooled for 24 hours at a temperature of 0–4ºC, and next they were weighed again and the acidity of meat was determined (pH_{24}). The length of the carcass was measured on the right-side half carcass, and backfat thickness was determined in 5 spots: above the shoulder, mid back (between the last thoracic vertebra and the first lumbar vertebra), and over the loin (at the level of sacral vertebrae: I, II III). The physical, chemical and sensory properties of the meat were evaluated based on samples of *musculus longissimus lumborum*. The following chemical properties were determined: the content of basal nutrients according to AOAC (1990), minerals (the same as in the faba bean seeds), and the fatty acids profile of the lipid fraction determined by gas chromatography of methyl esters in a Varian 450-GC fitted with a flame ionisation detector (air-hydrogen). The capillary column Select™ Biodiesel for FAME (30 m × 0.32 mm × 0.25 μm) with Select Biodiesel for FAME Fused Silica was used. The temperature of the injector was 250ºC, detector – 300ºC, and the column – 200ºC (initial) and 240ºC (final). The carrier gas was helium with a flow rate of 2.5 ml/minute. In addition, the drip loss was determined after 48 and 72 hours from the slaughter using methods practised by Prange et al. (1977), and the water holding capacity was measured using the Grau and Hamm's method (1953) as modified by Pohja and Ninivaara (1957). The instrumental colour evaluation was performed by means of a tristimulus colorimeter Minolta CR-310. The colour description model was L*a*b*. In the measuring system used, L* stands for lightness, which is a space vector. On the other hand, a* and b* are tri-chromatic coordinates, where a* as a positive value corresponds to red, as a negative value to green, positive b* to yellow, and negative b* to blue. Based on the results of the analysis of a*b* colour parameters, the chroma (C) and hue (H) of the colour were calculated from the following formulas:

$$C = \sqrt{(a^*)^2 + (b^*)^2};\quad H = \frac{b^*}{a^*}$$

(Mordenti et al., 2012).

The sensory evaluation of muscle samples was carried out according to methods practised by Baryłko-Pikielna (1975). The meat was cooked in a water solution of 0.8% NaCl (1:2 meat to water ratio) and evaluated by a group of 8 trained people. The following properties were evaluated in the muscle: smell, palatability, juiciness and tenderness according to a 5-point scale: from 1 (minimum) to 5 (maximum).

The results obtained were statistically analysed using one-way analysis of variance (ANOVA). The significance of differences between mean values was verified by means of Duncan's test at $P \leq 0.05$ and $P \leq 0.01$ levels of significance. All analyses were conducted using the Statistica 6 package (StatSoft, 2001).

Results

Table 1 presents the results of the chemical analysis of the experimental factor, that is, the seeds of two varieties of faba bean, Albus and Amulet. It indicates that the evaluated varieties did not significantly differ in terms of the total protein and minerals content. A little more crude fibre and respective fractions were recorded in the seeds of the Albus variety; however, these contained fewer (by 2.24 g·kg^{-1}) tannins.

Table 1. Chemical composition of low-tannin faba bean

Item	Albus	Amulet
1	2	3
Basal nutrients (%)		
dry matter	88.41	88.96
crude ash	3.30	3.17
crude protein	26.27	26.63
crude fat	0.84	0.76
crude fibre	7.94	7.20
ADF	10.32	9.87
NDF	19.50	18.80
ADL	1.80	1.56
CEL = ADF - ADL	8.52	8.31
HCEL= NDF - ADF	9.18	8.93
N-free extractives	50.06	51.20
Macroelements (g·kg^{-1})		
Ca	1.25	1.27
P	5.12	5.26
K	12.02	12.59
Na	0.17	0.15
Mg	1.26	1.21
S	0.78	0.74

Table 1 – contd.

1	2	3
Microelements (mg·kg^{-1})		
Fe	810	768
Cu	88	104
Zn	708	629
Mn	90	85
Mo	10	9
Co	3	3
Cr	4	3
Tannins (g·kg^{-1})	5.48	7.74

ADF – acid detergent fibre, NDF – neutral detergent fibre, ADL – acid detergent lignin, CEL – cellulose, HCEL – hemicellulose.

The composition and calculated nutritive value of the mixtures is presented in Table 2.

Table 2. Composition and nutritive value of feed mixtures

Item	Groups		
	I	II	III
Raw materials (%)			
barley	41.50	39.00	39.00
triticale	42.00	38.50	38.50
soybean meal	14.00	10.00	10.00
low-tannin faba bean*		10.00	10.00
premix**	2.50	2.50	2.50
Nutritive value per kg of mixtures:			
metabolizable energy (MJ)	12.74	12.71	12.71
crude protein (g)	163	163	163
crude fibre (g)	3.37	3.82	3.75
lys (g)	8.68	9.09	9.15
met + cys (g)	5.44	5.20	5.22
thr (g)	5.80	5.84	5.90
tryp (g)	1.79	1.73	1.74
Ca (g)	6.32	6.29	6.29
P (g)	4.20	4.27	4.28
P available (g)	2.65	2.68	2.68
Na (g)	1.46	1.46	1.46

* Group II – Albus variety, group III – Amulet variety.

** Premix contained: metabolizable energy – min. 1.25 MJ·kg^{-1}, crude protein – min. 90 g·kg^{-1}, lys – min. 65 g·kg^{-1}, met + cys – min. 7 g·kg^{-1}, thr – min. 12.5 g·kg^{-1},Ca – min. 220 g·kg^{-1}, P available – min. 43 g·kg^{-1}, Na – min. 53 g·kg^{-1}.

The replacement of about 28% of protein from soybean meal with protein from low-tannin faba bean in mixtures fed to Puławska pigs had no effect on the daily gain, feed conversion, dressing percentage or lean meat yield and fattening grades of the carcasses (Table 3).

Table 3. Fattening and post-slaughter results of pigs

Item	Groups			SEM
	I	II	III	
Body weight (kg)				
initial	31.5	31.0	31.0	1.05
after fattening	117.75	118.5	116.25	2.38
Daily gains (g)	760	768	749	9.85
FCR (kg feed·kg BWG^{-1})	3.53	3.53	3.58	0.19
Dressing percentage (%)	77.33	78.87	78.55	1.58
Meatiness (%)	52.08	52.43	52.50	1.91
Carcass length (cm)	87.25	86.25	87.00	1.07
Backfat thickness (mm)				
over the shoulder	29.20	27.75	30.75	3.73
mid back	44.20	40.70	43.50	3.85
sacrum I	37.40	32.25	34.80	2.98
sacrum II	26.50	23.25	26.35	2.75
sacrum III	36.00	31.25	35.75	3.05
Arithmetic averages from 5 measurements	34.65	31.05	34.25	3.89
Lard weight (kg)	2.60	2.75	2.78	0.21
Loin eye area (cm^2)	50.46	50.11	47.45	1.32

a, b – values in rows with different letters differ significantly (P≤0.05).

Table 4. Physical characteristics of *longissimus lumborum* muscles

Item	Groups			SEM
	I	II	III	
pH_1	6.15	6.14	6.14	0.05
pH_{24}	5.61	5.53	5.53	0.04
Water holding capacity (%)	20.72	19.85	20.25	0.55
Drip loss after 48h (%)	2.22 a	1.62 b	1.74 ab	0.20
Drip loss after 72h (%)	3.05 a	2.43 b	2.89 ab	0.27
Colour				
L*	53.43	52.74	51.48	1.06
a*	16.08	16.20	16.78	0.43
b*	1.94	1.75	1.78	0.22
$C = [(a^*)^2 + (b^*)^2]^{0.5}$	16.20	16.29	16.88	0.44
$H = b^*/a^*$	0.121	0.108	0.106	0.004

a, b – values in rows with different letters differ significantly (P≤0.05).

Similarly, no significant influence of the feeding method used was noted on the acidity of the meat measured 45 minutes and 24 hours after the slaughter, nor on the water holding capacity or the colour of the meat (Table 4). The lowest drip loss measured after 48 and 72 hours from the slaughter was found for muscle of pigs fed with a mixture containing faba bean of the Albus variety, which was a significant difference (P≤0.05) compared to the control group.

No effect of faba bean (regardless of the variety) was observed on the content of protein, fat and minerals of the evaluated muscle (Table 5).

Table 5. Chemical characteristics of *longissimus lumborum* muscles

Item	Groups			SEM
	I	II	III	
Basal nutrients (g·100 g^{-1})				
dry matter	27.30	27.26	27.25	0.14
crude protein	23.12	23.02	23.04	0.13
crude fat	3.02	3.05	3.00	0.15
Fatty acids profile (% of sum FA)				
EFA	2.30 b	2.63 ab	2.85 a	0.15
SFA	41.90	41.25	41.90	0.69
UFA	58.03	58.71	58.04	0.69
MUFA	55.65	55.98	55.09	0.73
PUFA	2.39 b	2.73 ab	2.95 a	0.17
DFA = MUFA + C18:0	70.48	70.78	70.53	0.33
OFA= C14:0 + C16:0	28.92	28.63	28.84	0.33
Crude ash (g·100g^{-1})	1.12	1.10	1.12	0.01
including minerals (mg·100 g^{-1})				
P	204	199.0	203	4.39
K	391	383	390	9.06
Ca	7.10	6.80	6.40	1.05
Mg	24.5	23.5	23.1	0.67
Na	46.5	45.7	43.7	1.04
Fe	1.018	1.024	0.812	0.09
Zn	1.761	1.299	1.274	0.19
Cu	0.088	0.112	0.121	0.02

a, b – values in rows with different letters differ significantly (P≤0.05).

EFA – essential fatty acids, SFA – saturated fatty acids, UFA – unsaturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, DFA – neutral and hypocholesterolemic fatty acids, OFA – hypercholesterolemic fatty acids.

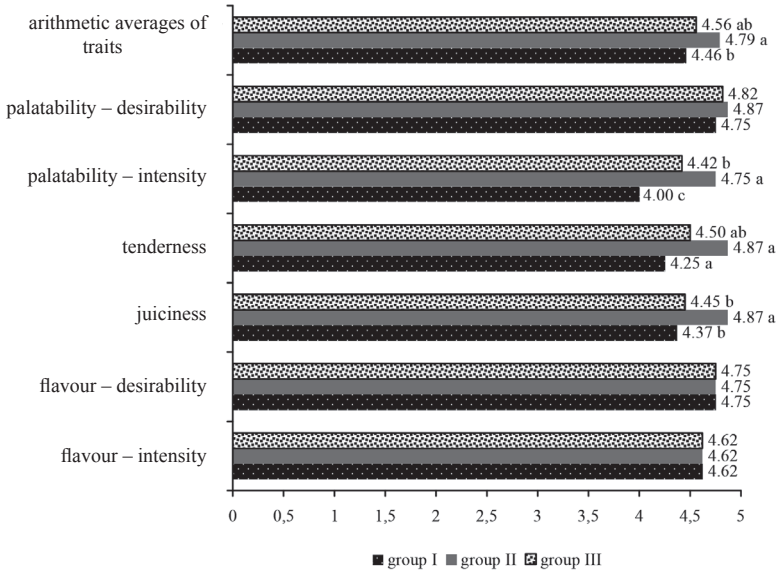

Figure 1. Results of sensory evaluation of *musculus longissimus* (points)

The study revealed no statistically significant differences in the total content of saturated fatty acids (SFA) and unsaturated fatty acids (UFA), including monounsaturated fatty acids (MUFA) as well as neutral and hypocholesterolemic (DFA) and hypercholesterolemic fatty acids (OFA). However, it was measured that the meat of pigs fed with a mixture containing faba bean contained more essential and polyunsaturated fatty acids (PUFA), and the statistical significance of the difference ($P \leq 0.05$) was confirmed between groups I and III.

The most highly evaluated in terms of all flavour traits was a muscle with the highest content of IMF (3.05%) – group II (Figure 1). A statistically significant difference ($P \leq 0.05$) was confirmed in the case of juiciness, tenderness, palatability and the average of four evaluated traits in comparison with the control group.

Discussion

The faba bean seeds of both varieties used in mixtures fed to fattening pigs had lower total protein content compared to the content determined in the Albus variety by Szpunar-Krok et al. (2009) but the figure was close to that reported by Hanczakowska and Świątkiewicz (2014). The content of protein also fell within the range (21.8–27.5%) determined by Zijlstra et al. (2008), similar to the crude fibre level that was close to levels reported by the above-mentioned authors (2008) and by Kiarie et al. (2013). Also, ADF and NDF levels fell within ranges indicated by Zijlstra et al. (2008) and by Woyengo and Nyachoti (2012), but were higher than those recorded in the studies by Beltranena et al. (2009), Kiarie et al. (2013), Hanczakowska and Świątkiewicz (2014). The evaluated varieties of faba bean had a slightly higher content of macroelements such as Ca, P and Na compared to values reported by the Polish Standards of Pig Nutrition (2014). Szpunar-Krok et al. (2009) found less Ca, Mg, K, Fe, and Zn in faba bean of the Albus variety. The determined content of tannins was different in the analysed faba bean varieties. Albus contained considerably fewer (5.48 $g \cdot kg^{-1}$) tannins than Amulet did (7.74 $g \cdot kg^{-1}$), but both values fell within the range from undetectable to 1% as reported by Jansman (1993), Jezierny et al. (2009), Woyengo and Nyachoti (2012), Kiarie et al. (2013), and by Hanczakowska and Świątkiewicz (2014). Perhaps such considerable differences in the content of tannins are due to the variety of methods used to determine their content, which was also suggested by Woyengo and Nyachoti (2012).

The results of the study support other researchers' findings (Zijlstra et al., 2008; Gatta et al., 2013) concerning the lack of any effect of faba bean meal (30% zero-tannin or 18% low-tannin faba bean) used in the diet of fattening pigs on daily gains (ADG) and the conversion of feed (FCR). In turn, Smith et al. (2013), evaluating the effect of mixtures with a different share of faba bean (7.5, 15, 22.5 and 30%), revealed an increase (compared to pigs from the control group) in daily gains (ADG) and feed intake (FI) in the first period of fattening, while in the second period of fattening the ratios tended to decrease.

Both the authors and Zijlstra et al. (2008), Smith et al. (2013) found that feeding diets containing (a different share of) faba bean to fattening pigs had no significant

effect on carcass fattening grade. Zijlstra et al. (2008), having introduced 30% of faba bean into the mixture, found that the dressing percentage and loin eye height were significantly ($P<0.05$) reduced, whereas Smith et al. (2013) did not record any effect of such feed (7.5, 15, 22.5 and 30%) either on the dressing percentage or the lean meat yield.

Higher dressing percentage (79.24%) and meatiness (55.47%) and thinner (16.9 mm) backfat in 5 measurements were found by Kasprzyk et al. (2013) in Puławska pigs slaughtered when they reached the weight of 100 kg. Similarly, Piórkowska et al. (2010) at the lowest slaughter weight of the animals noted that the backfat was thinner (19.4 mm) but the loin eye area was similar (48.3 cm^2).

The results of analyses indicating the lack of effect of low-tannin faba bean in mixtures fed to pigs on the pH, water holding capacity and colour of *m. longissimus* support the findings of Gatta et al. (2013). The pig feeding method used not only had no effect on pH_1 and pH_{24}, but it had no influence on the rate of *postmortem* glycolysis either. According to the classification proposed by Pospiech (2000), the measured values were characteristic of normal meat. Higher (6.25) pH_1 and lower (5.59) pH_{24} in the *longissimus* muscle of Puławska pigs are reported by Piórkowska et al. (2010). The results concerning drip loss were more favourable than the value (4.20%) reported by Kasprzyk et al. (2013) for Puławska pigs.

The nutritional value of meat is mainly determined by the content of basal nutrients, the most variable being the proportion of fat (Osek and Milczarek, 2005; Babicz et al., 2009; Piórkowska et al., 2010; Kasprzyk et al., 2013). The lack of effect of low-tannin faba bean used in the mixture fed to fattening pigs on the content of intramuscular fat (IMF) in *m. longissimus lumborum* supports the findings of Gatta et al. (2013) and Milczarek and Osek (2014). The amount of IMF determined in the muscle must be considered optimum in terms of meat quality, since studies (De Vol et al., 1988; Wajda et al., 2004; Daszkiewicz et al., 2005) reveal that in order to achieve the optimum flavour, tenderness and juiciness of meat, the required content of IMF is 2.5–3%. A lower (≤1%) content of intramuscular fat could negatively influence the flavour of the meat which, particularly after heat treatment, becomes dry and stringy (Schwörer et al., 2000); on the other hand, a higher content of IMF (above 3.5%) can contribute to lower evaluations of meat by consumers due to the visible fat deposits (Czarniecka-Skubina et al., 2007).

Likewise in the studies by Gatta et al. (2013) no significant effect of low-tannin faba bean on the total content of minerals in *m. longissimus lumborum* was recorded. A similar amount of P, Mg and Fe but less K, Na, Cu and more Ca was determined in raw pork joint by Kunachowicz et al. (2005).

The dietary value of meat is conditioned by proportion of fatty acids in the lipid fraction of the meat. Similarly, in an earlier study by Milczarek and Osek (2014), a greater proportion of PUFA ($P>0.05$) was noted in the meat of pigs fed with a mixture including low-tannin faba bean. Polyunsaturated fatty acids of the *n-3* and *n-6* groups cannot be synthesised by the human body and must be supplied by the diet. These fats play a role in a wide range of essential functions, including conditioning the proper functioning of cell tissues of the central nervous system and the retina (Achremowicz and Szary-Sworst, 2005).

Similarly Czarniecka-Skubina et al. (2007) and Kasprzyk et al. (2013) demonstrated that the highest scores were given to meat which contained the most intramuscular fat. Milczarek and Osek (2014) did not note any influence of the inclusion of low-tannin faba beans in mixtures fed to pigs on the taste characteristics of the *longissimus lumborum*.

The results of the study make it possible to suggest the use of Albus or Amulet variety faba beans as partial substitutes for soybean meal in mixtures fed to Puławska pigs since it generated fattening and slaughter analysis results comparable to the control group. In addition, both analysed varieties of faba bean improved the ability to maintain muscle juice and sensory values of the meat as well as not causing deterioration in the chemical properties of *m. longissimus lumborum*.

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