Efficiency of lupine seed (*Lupinus angustifolium* and *Lupinus luteus*) in sow, piglet and fattener feeding

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The possibility to replace a part of soybean meal in sow, piglet and growing finishing pig feed by high and low alkaloid varieties of two species of lupines was examined in this study. 50 Polish Landrace sows and their progeny were allocated to 5 groups. Two varieties of *Lupinus angustifolius*: low (Graf) in group II and high alkaloid (Karo) in group III and *Lupinus luteus:* low- (Mister) in group IV and high alkaloid (Parys) in group V, partly replaced soybean meal (control). Apparent digestibility was evaluated using the same feeds on 30 barrows: around 40 kg (grower) and 80 kg (finisher). Litter weight of piglets from lupine groups was significantly lower than that from control group. Between 35th and 84 day piglet fed with low-alkaloid lupine (Graf) gained better than others and than soybean meal. Feed enzyme supplement has only limited effect on piglet and growing pig performance. During the whole fattening period there was no significant difference in weight gains except group fed high-alkaloid cv. Karo which was the worst. Meat of pigs fed with lupines was poorer in PUFA n-3 than control. Results suggest low alkaloid varieties of blue and yellow lupine, given in moderate amount, give similar results in growing pig feeding than soy-bean meal but meat quality is lower.

Key words: lupine seeds, sows, piglets, pig fattening, feed enzymes

Introduction

Soybean meal is currently the most important protein source in pig feeds. Other legumes cultivated in Europe, such as peas, field beans and lupines, are used on a smaller scale. About 98% of soybean meal present on the feed market is produced from genetically modified (GMO) plants (Sieradzki et al. 2006). According to earlier experi-ments, genetic modification did not influence the nutritive value of feedstuffs (Padgette et al. 1996, Aurlich et al. 2003) and had no effect on animal performance, carcass traits and meat quality (Flachowsky et al. 2005). Also, our experiments on feeding pigs with genetically modified soybean and maize proved that these feeds had no effect on animal performance and there was no transfer of transgenic DNA to animal tissues (Świątkiewicz et al. 2011). However, there is still strong public opposition in some countries against using GMO plants in human and farm animal feeding, thus it is possible that in some cases other protein sources will have to be used.

In European countries this could be legumes such as lupines, peas or field beans. Lupines contain high content of protein, depending on species 28–48% DM, rich in lysine and arginine, as well as they are also a good source of lipids, minerals and vitamins (Sobotka et al. 2016). The presence of antinutritive substances limits the nutritive value of legume seed protein, but the alkaloid content in 'sweet' varieties of lupines was lowered to 0.01% (Ruiz et al. 1977) so that they can be used as supplements, even in food for humans (Lee et al. 2006). In the experiment of Roth-Maier et al. (2004) replacing part of soybean meal by 20% of yellow or blue lupines seeds produced better results in fattener feeding than soybean meal used as a control. In the feeding of young animals, lupine must be used cautiously due to their not fully developed digestive system, but in the experiment of Prandini et al. (2005) white lupine, used at a level of 17%, gave similar results to 16% of soybean meal. Similar results were also obtained by Kim et al. (2008) in their experiment with yellow lupine. On the other hand, according to the earlier experiment of McNiven and Casteli (1995), the amount of lupine (white) in piglet feed should not exceed 10%. Also, Cherriére et al. (2003) recommended to limit the rate of inclusion of lupine to < 10% in weaned piglet diets.

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There is not much information available about using lupines in sow feeding and that cited by Casper et al. (1991) in their study was not good. Sows fed with lupine meal refused their feed and delivered small litters with a high percentage of stillborn foetuses. In this case, however, not native but dehulled and hexane extracted lupine meal was used.

The aim of this experiment was to examine the possibility of replacing a part of soybean meal in sow, piglet and growing finishing pig feed (i.e. during the whole production cycle) by high and low alkaloid varieties of two species of lupines.

Material and methods

All methods used in this experiment were accepted by the Local Ethics Commission for Experiments on Animals.

Animals and diets

50 sows of Polish Landrace were mated (second parity in all groups) with a Polish Landrace boar and kept and fed individually from mating to the end of 35 d lactation. After mating, the sows were allocated to 5 groups, with 10 animals in each. Group I (control) received standard feed mixture containing soybean meal as the main protein source. The remaining groups received standard feed mixture in which part of the soybean meal was replaced by blue lupine (*Lupinus angustifolius*) cv. Graf registered 2004, (Group II), blue lupine cv. Karo registered 2001 (Group III), yellow lupine (*Lupinus luteus*) cv. Mister registered 2003 (Group IV) and yellow lupine cv. Parys registered 1988 (Group V). The Karo and Parys varieties are high- and the Graf and Mister - are low alkaloid ones. All lupines were harvested in 2012. The composition of the diets for the pregnant and lactating sows is given in Table 1.

At 100 d of pregnancy the sows were moved to a farrowing house and also kept in individual pens until the weaning of the piglets. The sows received 2.5 kg of mixture per day from mating to 100 d of pregnancy and 3.5 kg from 100 d of pregnancy to farrowing. During lactation the administered amount of feed depended on the litter size: 1.80 kg per sow and 0.40 kg per piglet. Water was available *ad libitum.* The sows were weighed at mating, farrowing and weaning of the piglets.

The piglets were kept in group pens, each litter in a separate pen. They were weaned at 35d of life. Before weaning, from the 7 d of life they were fed *ad libitum* with the same, standard prestarter diet, whose composition is given in Table 2. After weaning the piglets received diets containing lupines corresponding to the feed for the sows. In each group half the animals (5 litters) received the fibrolitic enzyme RONOZYME VP (DSM Nutritional Products Ltd., Mszczonow, Poland) at 200 mg per kg of feed. RONOZYME VP i.e. carbohydrase complex is produced by a submerged fermentation of an *Aspergillus aculeatus* strain, which contains endo-1,3(4)-beta-glucanase (min. 50 FBG/g product) and various hemicellulase and pectic-substance hydrolysing activities. The diet's composition is also given in Table 2. The piglets were weighed at 35 (weaning), 56 and 84 d of life.

The piglets were raised to 84 d of life and then 20 animals (10 gilts and 10 barrows) from each group were randomly chosen for further fattening. They were fed with standard feed mixtures (Table 3) grower (to 60 ± 1.0 kg of body weight) and finisher (from 60 ± 1.0 to the end of the experiment, Table 3). In each group half the animals received the enzyme RONOZYME VP at 200 mg kg^{-1} feed. The fatteners were slaughtered at an average body mass 107 ± 2.0 kg. The quality of the carcasses was evaluated according to Tyra and Żak (2012). 24 h after slaughter the pH of the meat was measured and samples of the *longissimus* muscle, obtained from the area of the last thoracic and first lumbar vertebra, were taken for analysis.

Apparent digestibility was evaluated in parallel to the fattening experiment, using the same feeds, on 30 barrows weighing around 40 kg (grower) and 80 kg (finisher), not used in the fattening part of the experiment. The plan of the digestibility trial was the same as that of the fattening experiment, except for cv. Karo. Each group consisted of 6 fatterners. The animals were kept individually in balance cages and fed with the same feeds as in the fattening experiment. The preliminary period lasted 10 d and the samples collection lasted 5 d. Faeces from each animal were collected daily, weighed and frozen at –20 °C. At the end of the collection period, faeces samples from each animal were mixed and a representative sample was prepared.

Table 1. Composition and nutrient contents of the diets for experimental sows (g kg^{-1})

	Group I Control		Group II Blue lupine cv. Graf		Group III Blue lupine cv. Karo		Group IV Yellow lupine cv. Mister		Group V Yellow lupine cv. Parys	
	Pregnant	Lactating	Pregnant	Lactating	Pregnant	Lactating	Pregnant	Lactating	Pregnant	Lactating
Soybean meal	60	180	20	150	20	150	–	80	–	80
Blue lupine cv. Graf	–	–	70	60	–	–	–	–	–	–
Blue lupine cv. Karo	–	–	–	–	70	60	–	–	–	–
Yellow lupine cv. Mister	–	–	–	–	–	–	80	120	–	–
Yellow lupine cv. Parys	–	–	–	–	–	–	–	–	80	120
Wheat bran	100	50	100	50	100	50	100	50	100	50
Wheat, ground	300	300	300	300	300	300	300	300	300	300
Barley, ground	369	332.5	339	302	339	302	349	312	349	312
Beet pulp	150	100	150	100	150	100	150	100	150	100
Rapeseed oil	–	10	–	10	–	10	–	10	–	10
Dicalcium phosphate	5	7	5	7	5	7	5	5	5	5
Calcium carbonate	7	10	7	10	7	10	7	7	7	7
Premix 0.5% *	5	5	5	5	5	5	5	5	5	5
Salt	3.5	4.5	3.5	4.5	3.5	4.5	3.5	4.5	3.5	4.5
L-lysine	0.5	1	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5
Mixture contains (kg^{-1}, calculated):										
Metabolizable energy, MJ **	12.5	13.0	12.5	13.0	12.6	13.0	12.6	13.0	12.6	13.0
Crude protein, g	134	174	135	176	133	174	136	173	133	169
Ether exract, g	20	29	22	30	22	30	22	32	22	32
Lys, g	5.54	8.42	5.34	8.36	5.20	8.23	5.18	7.64	5.10	7.45
Met + Cys, g	4.66	5.63	4.47	5.24	4.49	5.26	4.63	5.23	4.56	5.13
Trp, g	1.68	2.27	1.55	2.18	1.53	2.16	1.50	1.95	1.48	1.93
Thr, g	4.55	6.17	4.38	6.08	4.30	6.01	4.26	5.58	4.22	5.53
Crude fibre, g	65	54	72	60	72	60	73	66	70	62

*** =** Vitamin-mineral premix for pregnant sows: vitamin: A - 200000 IU; D_3 – 2000 IU; E –10.0 g; K_3 – 0.4 g; B_2 – 0.8 g; B_6 – 0.4 g; B_{12} – 0.004 g; pantothenic acid – 2.0 g; choline cloride – 50 g; folic acid – 0.2 g; nicotinic acid – 4.0 g; biotine – 0.03 g; magnesium – 8.0 g; manganese – 5.0 g; iodine 0.08 g ; zinc – 15.0 g; iron – 18.0 g; copper – 4.0 g; cobalt – 0.08 g; selenium – 0.04 g.

*** =** Vitamin-mineral premix for lactating sows: vitamin: A – 240000 IU; D_3 –20000 IU; E –10.0 g; K_3 – 0.4 g; B_2 – 0.8 g; B_{12} – 0.004 g; pantothenic acid – 2.0 g; choline cloride – 50 g; folic acid – 0.4 g; nicotinic acid – 4.0 g; biotine – 0.04 g; magnesium – 8.0g; manganese – 10.0 g; iodine –0.2 g; zinc – 14.0 g; iron – 16.0 g; copper – 4.0 g; cobalt – 0.1 g; selenium – 0.04 g.

** = ME calculated using equation Hoffmann and Schiemann (1980)

Chemical and physical analyses

Gross composition of the feeds and faeces samples were analyzed according to AOAC (2005) methods.

Amino acids were analyzed using the AAA 400 INGOS automatic analyzer and that of alkaloids with the gas chromatographic method according to Carsten and Wink (1992).

Meat acidity was measured 24 h after slaughter with a pH meter equipped with a Metron OSH 12-00 electrode. Using the CIE (L*a* b*) system, the colour of the fresh meat was estimated with a Minolta colorimeter. On this basis, chroma C* was calculated according to MacDougall (2002): $C^* = (a^{*2} + b^{*2})^{1/2}$

The water-holding capacity of the meat was measured according to Grau and Hamm (1953).

The fatty acid profile was determined in samples after two weeks of freezing at –20 °C, immediately after thawing, using a CP-Wax 58 capillary column (Varian BV, Middelburg, The Netherlands) (25 m, 0.53 mm, df – 1µ, carrier gas – helium, 6 ml min^{-1}), with a column oven temperature programme from 90 to 200 °C, using a Varian 3400 gas chromatograph (Varian Associates Inc., Walnut Creek, USA) equipped with a Varian 8200 CX Autosampler (200 °C), FID detector (260 °C), and Star Chromatography Workstation software. All the analyses were performed in duplicate and the mean values are given.

Table 2. Composition and nutrient contents of the diets for piglets (g kg^{-1})

	7th – 35th day of age	35th – 84th day of age				
	All animals	Group I Control	Group II Blue lupine cv. Graf	Group III Blue lupine cv. Karo	Group IV Yellow lupine cv. Mister	Group V Yellow lupine cv. Parys
Soybean meal	250	200	170	170	120	120
Blue lupine cv. Graf	–	–	60	–	–	–
Blue lupine cv. Karo	–	–	–	60	–	–
Yellow lupine cv. Mister	–	–	–	–	100	–
Yellow lupine cv. Parys	–	–	–	–	–	100
Wheat, ground	414	300	300	300	300	300
Barley, ground	200	365.5	334.4	334.4	344.5	344.5
Milk powder	40	50	50	50	50	50
Dried whey	50	50	50	50	50	50
Rapeseed oil	10	–	–	–	–	–
Premix 0.5 *	5	5	5	5	5	5
Salt	3.5	3	2.5	2.5	2.5	2.5
Calcium carbonate	8	10	11	11	11	11
Dicalcium phosphate	12	9	9.5	9.5	9.0	9.0
L-lysine	1	2.5	2.6	2.6	3	3
DL methionine	1.5	–	–	–	–	–
Acidifier	5	5	5	5	5	5
Mixture contains kg^{-1}						
Metabolizable energy, MJ **	13.1	13.0	13.1	13.1	13.1	13.1
Crude protein, g	198	192	194	192	192	193
Ether extract, g	17	18	19	19	20	21
Lys, g	12.0	10.14	10.09	9.96	9.62	9.33
Met + Cys, g	8.00	6.24	6.12	6.13	6.16	6.07
Trp, g	2.40	2.56	2.47	2.15	2.31	2.28
Thr, g	7.30	7.08	6.98	6.92	6.64	6.58

* = Premix for nursing piglets: vitamin: A- 2700000 IU; D_3 – 400000 IU; E – 8.0 g; K_3 – 0.5 g ; B_1 – 0.5 g; B_2 – 0.8 g; B_6 – 0.8 g; B_{12} –0.008 g; pantothenic acid – 2.8 g; choline cloride – 70 g; folic acid – 0.2 g; nicotinic acid – 5.0; magnesium – 10 g; manganese – 12 g; iodine – 0.1 g; zinc – 30 g; iron – 20g; copper – 32 g; cobalt – 0.06 g; selenium – 0,04 g; limestone complete to 1000 g

* Premix for weaned piglets: A – 2400000 IU; D3 – 300000 IU; E – 14.0 g; K3 – 0.3 g ; B_1 – 0.3 g; B_2 –0.8 g; B_6 – 0.6 g; B_{12} – 0.005 g; pantothenic acid – 2.0 g; choline cloride – 80 g; folic acid – 0.2 g; nicotinic acid – 4.0 g; magnesium – 10 g; manganese – 8 g; iodine – 0.16 g ; zinc – 28 g; iron – 20 g; copper – 32 g; cobalt – 0.08 g; selenium – 0,04 g; complete limestone to 1000 g

** = ME calculated using equation Hoffmann and Schiemann (1980)

Sensory analysis

The sensory evaluation of meat after two weeks of freezing at –20 °C was made on a 5-point scale (1 = poorest, 5 = best)**.** Samples were thawed at +4 °C, cut in about 30 mm thick slices and boiled in 0.6% NaCl solution to an internal temperature +80 °C. After cooking, the meat was left for 2 min in order to level the temperature between its layers (Baryłko-Pikielna 1975). Then, the slices were cut into smaller pieces and presented to the panel. The evaluation board consisted of 6 trained persons. Odour, taste, tenderness and juiciness of the meat were evaluated.

Statistics

Statistical analysis of treatment effect was performed by one-way (sow reproductive rates), two-way (weaned piglets rearing indices and apparent digestibility coefficient) and three-way (fattening results) analysis of variance. Comparison of means was conducted with Duncan's multiple range test at $p \leq 0.05$ and $p \leq 0.01$ levels of significance. All the analyses were conducted using the STATISTICA 10 package (StatSoft 2011).

Table 3. Composition of diets for fatteners (g kg $^{-1}$)

	Group I		Group II		Group III		Group IV		Group V	
	Control		Blue lupine cv. Graf		Blue lupine cv. Karo		Yellow lupine cv. Mister		Yellow lupine cv. Parys	
	Grower	Finisher	Grower	Finisher	Grower	Finisher	Grower	Finisher	Grower	Finisher
Soybean meal	210	150	160	100	160	150	120	80	120	80
Blue lupine cv. Graf	–	–	80	80	–	–	–	–	–	–
Blue lupine cv. Karo	–	–	–	–	80	80	–	–	–	–
Yellow lupine cv. Mister	–	–	–	–	–	–	100	80	–	–
Yellow lupine cv. Parys	–	–	–	–	–	–	–	–	100	80
Wheat bran	50	60	50	60	50	60	50	60	50	60
Wheat, ground	300	250	300	250	300	250	300	250	300	250
Barley, ground	399.7	502	369.3	471.5	369.3	471.5	389.2	491.5	389.2	491.5
Rapeseed oil	15	15	15	15	15	15	15	15	15	15
Dicalcium phosphate	6	3	6	3	6	3	6	3	6	3
Calcium carbonate	10	11	10	11	10	11	10	11	10	11
Premix 0.5% *	5	5	5	5	5	5	5	5	5	5
Salt	2.8	2.5	2.8	2.5	2.8	2.5	2.8	2.5	2.8	2.5
L-lysine	1.5	1.5	1.7	2.0	1.7	2.0	2.0	2.0	2.0	2.0
Methionine	–	–	0.2	–	0.2	–	–	–	–	–
Mixture contains kg $^{-1}$										
Metabolizable energy, MJ **	13.1	13.0	13.2	13.1	13.2	13.1	13.2	13.1	13.2	13.1
Crude protein, g	185	164	185	164	182	161	182	162	178	160
Ether extract, g	35	35	37	38	37	38	38	37	36	36
Lys, g	9.01	7.56	8.70	7.27	8.53	7.10	8.24	7.05	8.16	7.00
Met + Cys, g	6.01	5.51	5.78	5.25	5.80	5.28	5.84	5.39	5.75	5.35
Thr, g	2.47	2.17	2.30	2.00	2.27	1.98	2.17	1.94	2.14	1.92
Trp, g	6.53	5.67	6.26	5.41	6.17	5.32	5.94	5.23	5.89	5.19

* = Premix grower: vitamin A – 1500000 IU; vitamin D3 – 300000 IU; vitamin E – 10.5 g; vitamin K3 – 0.22 g; vitamin B1 – 0.22 g; vitamin B2 – 0.6 g; vitamin B6 – 0.45 g; vitamin B12 – 0.004 g; pantothenic acid –1.5 g; choline chloride – 40 g; biotin – 0.015 g; folic acid – 0.3 g; nicotinic acid – 3.0 g; manganese – 6 g; iodine –0.12 g; zinc – 15 g; iron – 15 g; copper – 4 g; cobalt – 0.06 g; selenium – 0.03 g

* = Premix finisher: vitamin A – 1000000 IU; vitamin D3 – 200000 IU; vitamin E – 7.0 g; vitamin K3 – 0.15 g; vitamin B1 – 0.15 g; vitamin B2 – 0.4 g; vitamin B6 – 0.3 g; vitamin B12 – 0.002 g; pantothenic acid – 1.0 g; choline chloride – 20 g; biotin – 0.01 g; folic acid – 0.2 g; nicotinic acid – 2.0 g; manganese – 4 g; iodine – 0.08 g; zinc – 8 g; iron – 10 g; copper – 4 g; cobalt – 0.04 g; selenium – 0.02 g.

** = ME calculated using equation Hoffmann and Schiemann (1980)

Results

Both high alkaloid varieties (Karo and Parys) contained a lower amount of protein when compared to their low alkaloid equivalents within species (Table 4). All lupine seeds contained less protein and more fat and fiber than soybean meal. Lupine protein was relatively poor in methionine and tryptophan. Alkaloids content in the blue lupine was almost a hundred times higher in cv. Karo than in cv. Graf. The yellow lupine cv. Parys contained five times as many alkaloids as the cv. Mister.

At the beginning of the experiment the body mass of the sows was similar (Table 5), but at the farrowing body mass of the sows receiving *L. luteus* cv. Mister was significantly ($p < 0.01$) lower than those fed *L. luteus* cv. Parys.

Table 4. Chemical composition (g kg^{-1}) and amino acids content of seed protein (g 100 g^{-1} protein)

	Soybean meal	Blue lupine cv. Graf	Blue lupine cv. Karo	Yellow lupine cv. Mister	Yellow lupine cv. Parys
Dry matter	883.2	888.7	876.3	888.0	890.0
Crude protein	468.5	330.0	292.0	398.4	354.7
Ether extract	20.6	47.1	43.2	36.3	52.4
Crude ash	57.4	35.2	28.8	40.3	48.7
Crude fibre	35.7	148.7	149.6	140.5	105.0
Alkaloids % dm	–	0.01	0.99	0.03	0.15
Arg	7.2	8.9	12.6	8.5	12.3
His	2.6	2.3	3.0	2.3	2.7
Ile	4.4	3.2	4.2	3.1	3.7
Leu	7.6	5.5	7.0	6.2	7.4
Lys	6.2	4.0	5.2	4.1	5.1
Met	1.5	0.9	0.9	0.5	0.7
Phe	5.0	3.1	4.1	3.1	3.7
Thr	3.9	2.5	3.3	2.6	3.1
Trp	1.4	0.7	0.9	0.7	0.9
Val	4.4	3.0	3.9	2.9	3.4
Ala	4.2	2.6	3.4	2.7	3.3
Asp	10.9	7.5	10.0	7.8	9.1
Cys	1.3	1.2	1.3	1.8	2.1
Glu	17.0	17.1	22.2	18.9	22.1
Gly	4.1	3.3	4.3	3.2	3.9
Pro	4.6	2.8	3.6	3.2	3.3
Ser	4.8	3.6	4.8	3.8	4.4
Tyr	3.8	2.9	3.9	2.2	2.4

Table 5. Sow reproductive rates

	Experimental groups legumes					
	Group I Control	Group II Blue lupine cv. Graf	Group III Blue lupine cv. Karo	Group IV Yellow lupine cv. Mister	Group V Yellow lupine cv. Parys	SEM
Number of sows, head	10	10	10	10	10	–
Body weight at mating, kg	169.0	171.1	170.4	165.9	169.0	1.24
Body weight after farrowing, kg	178.0^{ABab}	182.6^{ABb}	177.4^{ABab}	173.1^{Aa}	186.4^{Bb}	1.41
Body weight at weaning, kg	139.6	142.4	135.2	133.7	148.6	2.27
Mean feed consumption during whole cycle, kg	486^{ABb}	490^{Bbc}	470^{Aa}	482^{ABab}	498^{Bc}	2.21
Number piglets born per litter, head	10.6^{b}	9.8^{ab}	9.6^{ab}	8.9^{a}	10.6^{b}	0.21
Litter weight, kg	17.38^{b}	12.25^{a}	10.56^{a}	12.37^{a}	13.54^{a}	0.63
Body weight of piglets at 1st day of age, kg	1.64^{Dc}	1.25^{BCb}	1.10^{Aa}	1.13^{ABa}	1.39^{Cb}	0.02
Body weight of piglets at 35th day of age, kg	9.85^{Bc}	9.71^{Bc}	8.81^{Ab}	8.42^{Aab}	8.22^{Aa}	0.09
Average daily weight gains1–35 day, g	241^{D}	248^{CD}	226^{BC}	214^{AB}	204^{A}	2.54
Piglet losses, head	5	2	7	7	6	–

a, b = mean values in the same row with different letters differ significantly at $p \leq 0.05$; A, B = mean values in the same row with different letters differ significantly at $p \leq 0.01$; SEM = standard error of the mean

The number of piglets born alive per litter was lower from the sows fed with cv. Mister. It was significantly ($p < 0.05$) lower than in control and Parys groups. The mean litter weight of the piglets from the lupine groups was significantly ($p < 0.05$) lower than that from the control group. The daily body weight gains before weaning were lower ($p < 0.01$) in both groups receiving yellow lupine than in the control and Graf groups. The highest body weight gains and lowest mortality of piglets were found in the group receiving blue lupine Graf.

In the second part of piglet experiment (Table 6) i.e. between 35 and 84 d of life, both low alkaloid varieties of lupines i.e. Graf and Mister gave significantly ($p < 0.01$) better body weight gains than the high alkalois varieties, and also better than the soybean meal. There was no difference in feed intake or feed utilization during the whole experiment i.e. between 35 and 84 d of life. In this part of the experiment the enzyme supplement significantly improved ($p < 0.05$) piglet body weight gains but during its further part (Table 7) the weight gains equaled. In the first half of the fattening period of the experiment i.e. between ca 23 kg and 60 kg of pig body weight, almost all the animals fed with lupine grew faster than the control ones (Table 7) but the differences were not significant. The exception was blue lupine Karo which produced growth rates significantly ($p < 0.01$) lower than all the other feeds. The results obtained during the whole fattening period (23–107kg) also showed the lowest body weight gains in pigs fed with blue lupine Karo ($p < 0.01$), but the best result appeared in control soybean meal group. Pigs fed with blue lupine Karo also characterized by the worst feed mixture utilization. The enzyme addition improved body weight gains (by 3.8%) only during the first fattening period (23–60kg), but the differences were not statistically significant. However, pigs receiving enzymes in the diet utilized feed better than controls ($p < 0.01$). It was observed that animal sex has not affected the fattening results.

Yellow lupine Parys produced the worst results in carcass evaluation (Table 7). All the important measurements (dressing yield, meat of ham, loin eye area, meat of primal cuts) were significantly ($p < 0.01$) lower in this group than those of the control. The best of the lupines was blue lupine Graf, which was comparable to the soybean meal. Carcasses of pigs fed with enzymes supplementation characterized of significantly higher loin eye area and thinner backfat ($p < 0.01$). The most beneficial carcass traits were observed in gilts – their carcasses contained more meat in primal cuts and less backfat.

Acidity of the meat 24h after slaughter (Table 8) ranged from pH 5.51 (control) to 5.66 (cv. Graf and Mister) and these differences, though not big, were statistically significant ($p < 0.01$). The biggest difference in water holding capacity index (i.e. 18.3 and 24.7; $p < 0.01$) was found within the species *L. luteus* between varieties Parys and Mister, respectively. The meat of pigs fed with both varieties of blue lupines was more saturated in redness than that of the control's ($p < 0.01$). In sensory evaluation, the highest values of all the traits were found in the control group and the lowest ones in the group fed with *L. luteus* cv. Parys. Evaluation of odour was lowered ($p < 0.05$) by the enzyme supplement. The sex hasn't influenced the meat quality, except some differences in the meat color.

Intramuscular fat (IMF) in the meat of pigs fed with lupines (except that of cv. Parys) contained more saturated fatty acids (SFA) than the control one, though this difference was significant only in the case of cv. Mister (Table 9). There was no significant difference between the groups in the content of monounsaturated (MUFA) or total content of polyunsaturated (PUFA) fatty acids. MUFAs dominated in the intramuscular fat of all the groups and SFAs were second. The meat of all the pigs fed with lupines contained a lower amount of PUFA n-3 acids ($p < 0.01$) than the control. Animals receiving yellow lupine Parys had the best athero- and thrombogenicity indexes and those fed with cv. Mister the worst. The enzyme addition in pig feed, as well as animals' sex, haven't changed the amount of saturated nor unsaturated fatty acids in IMF of meat.

The animals used in the digestibility tests did not come from the fattening experiment and they were not accustomed to the presence of lupine in feed. They refused consumption of the blue lupine Karo, therefore we could not obtain reliable results. There was no significant difference in protein or fat apparent digestibility of the grower mixtures (Table 10), but in the finisher mixtures the protein digestibility of the control mixture was higher ($p < 0.05$) than in all the other groups. Fat digestibility was the lowest ($p < 0.05$) in the finisher period in the mixture containing blue lupine Graf. Significant differences were also found in the fiber digestibility, which in the later part of the experiment was significantly ($p < 0.01$) higher in all the groups fed with lupines. The enzyme supplement had no significant effect on nutrients digestibility in the grower period, although higher coefficients were noticed in pigs obtaining this additive. Significantly improved apparent digestibility of protein ($p < 0.05$), fat ($p < 0.05$) and fiber ($p < 0.01$) were observed in the finisher period of the experiment, in pigs receiving the enzyme additive.

Table 6. Weaned piglets reading indices

	Experimental groups legumes (L)					Enzyme supplement (E)			
	Group I Control	Group II Blue lupine cv. Graf	Group III Blue lupine cv. Karo	Group IV Yellow lupine cv.Mister	Group V Yellow lupine cv.Parys	200 mg kg^{-1} feed	0	I^1	SEM
Number of piglets	101	96	89	82	100	213	255	–	–
Body weight of piglets, kg									
35th day of age	9.85^{Bc}	9.71^{Bc}	8.81^{Ab}	8.42^{Aab}	8.22^{Aa}	8.84	9.16	–	0.09
56th day of age	15.62^{Bc}	16.09^{Bc}	14.55^{Ab}	15.64^{Bc}	13.69^{Aa}	15.07	15.16	xx	0.12
84th day of age	24.15^{B}	25.59^{C}	23.11^{AB}	24.07^{B}	22.63^{A}	24.03	23.79	xx	0.17
Average daily gain in periods of life, g									
35th–56th day	274^{A}	304^{B}	273^{A}	343^{B}	260^{A}	296	285	xx	3.84
56th–84th day	305^{A}	339^{B}	306^{A}	301^{A}	319^{AB}	320	308	xx	3.91
35th–84th day	291^{A}	324^{B}	291^{A}	319^{B}	294^{A}	310^{b}	298^{a}	xx	2.86
Feed intake, g									
35th–56th day	343^{Aa}	368^{Aba}	342^{Aa}	409^{Bb}	333^{Aa}	368	351	NS	8.29
56th–84th day	786	835	801	798	792	794	811	NS	11.88
35th–84th day	592	629	604	629	594	605	606	NS	8.64
Feed conversion ratio in periods of life, kg kg^{-1}									
35th–56th day	1.25	1.21	1.25	1.19	1.28	1.23	1.24	NS	0.03
56th–84th day	2.58	2.46	2.62	2.65	2.48	2.48	2.62	NS	0.05
35th–84th day	2.03	1.94	2.07	1.97	2.02	1.96	2.02	NS	0.04

a, b = mean values in the same row with different letters differ significantly at $p \leq 0.05$; A, B = mean values in the same row with different letters differ significantly at $p \leq 0.01$; 1 = interaction; NS = not significant; SEM = standard error of the mean

Table 7. Fattening results

	Experimental groups legumes (L)					Enzyme supplement (E)		Sex (S)			
	Group I Control	Group II Blue lupine cv. Graf	Group III Blue lupine cv. Karo	Group IV Yellow lupine cv.Mister	Group V Yellow lupine cv.Parys	200 mg kg^{-1} of feed	0	gilts	barrows	I[1]	SEM
Number of pigs	20	20	20	20	20	50	50	50	50	–	–
Initial body mass, kg	23.5	24.7	23.3	22.7	22.9	22.6	24.3	23.6	23.6	LxE	0.28
Final body mass, kg	107.8	107.8	105.0	107.9	105.0	105.0	108.0	106	106	NS	0.66
Days of fattening	116.3	116.7	153.2	119.6	118.6	121.3	124.7	123.3	120.8	NS	1.65
Average daily weight gains, g											
23–60 kg	622^{B}	658^{B}	470^{A}	643^{B}	648^{B}	620	597	610	606	LxE	8.34
60–107 kg	848^{Cc}	764^{BCb}	611^{Aa}	793^{BCbc}	739^{Bb}	751	751	734	768	NS	12.95
23–107 kg	725^{B}	712^{B}	533^{A}	711^{B}	692^{B}	679	671	668	682	NS	8.03
Feed conversion ratio, kg											
23–60 kg	3.11^{A}	3.08^{A}	3.42^{B}	3.16^{A}	3.16^{A}	3.15	3.24	3.19	3.20	NS	0.02
60–107 kg	3.07	3.16	3.24	3.10	3.20	3.10^{a}	3.20b	3.21	3.11	NS	0.04
23–107 kg	3.09^{Aa}	3.12^{ABab}	3.32^{Bc}	3.13^{Aab}	3.18^{ABb}	3.12^{a}	3.22b	3.20	3.15	NS	0.05
Number of pigs	14	14	14	14	14	35	35	35	35	–	–
Cold dressing yield, %	79.1^{Bc}	79.9^{Bc}	74.6^{Aab}	76.5^{ABb}	73.9^{Aa}	76.7	76.8	77.0	76.6	NS	0.48
Meat of ham, %	78.4^{B}	79.5^{B}	79.9^{AB}	78.0^{AB}	76.6^{A}	78.8	78.1	78.9	78.0	ExS	0.37
Loin eye area, cm^2	51.04^{B}	51.00^{B}	47.86^{AB}	47.94^{AB}	45.11^{A}	50.07^{B}	47.12^{A}	49.71^{b}	47.48^{a}	NS	0.65
Meat of primal cuts, kg	22.09^{C}	22.65^{C}	20.36^{B}	20.71^{B}	17.52^{A}	20.38	20.95	21.34^{B}	20.00^{A}	LxE	0.29
Meatiness of carcass, %	52.26	53.36	53.04	51.44	51.05	52.72	52.00	53.05^{b}	51.67^{a}	LxExS	0.39
Backfat thickness of 5 measurements, cm	2.14^{Cb}	1.93^{Bb}	1.56^{Aa}	2.11^{Cb}	1.67^{ABa}	1.80^{a}	1.96^{b}	1.79^{A}	1.98^{B}	LxE	0.05
Backfat in point C, cm	0.96^{Bc}	0.91^{ABbc}	0.70^{Aa}	0.88^{ABabc}	0.75^{ABab}	078^{a}	0.90^{b}	0.76^{A}	0.92^{B}	LxE	0.04

a, b = mean values in the same row with different letters differ significantly at $p \leq 0.05$; A, B = mean values in the same row with different letters differ significantly at $p \leq 0.01$; 1 = interaction; NS = not significant; SEM = standard error of the mean

Table 8. Meat quality traits (*longissimus* muscle)

	Experimental groups legumes (L)					Enzyme supplement (E)		Sex (S)			
	Group I Control	Group II Blue lupine cv. Graf	Group III Blue lupine cv. Karo	Group IV Yellow lupine cv.Mister	Group V Yellow lupine cv.Parys	200 mg kg^{-1} feed	0	gilts	barrows	I[1]	SEM
Number	14	14	14	14	14	35	35	35	35	–	–
pH after 24 h cooling at +4 °C	5.51^{Aa}	5.66^{Bb}	5.62^{ABb}	5.66^{Bb}	5.57^{ABab}	5.60	5.60	5.61	5.60	LxS	0.02
Water holding capacity index, %	22.91^{Ab}	22.33^{Ab}	22.76^{Ab}	24.70^{Bc}	18.32^{Aa}	21.80	22.60	22.09	22.32	NS	0.35
Meat colour L*a*b											
lightness L*	50.77^{ab}	50.39^{ab}	49.75^{a}	51.50^{b}	51.13^{ab}	50.88	50.54	50.19^{a}	51.23^{b}	NS	0.21
redness a*	16.35^{Aa}	17.31^{Bb}	17.94^{Cc}	16.79^{ABab}	16.52^{ABa}	17.02	16.95	17.09	16.87	LxE	0.12
yellowness b*	2.45^{ABab}	2.28^{Aa}	3.01^{Bc}	2.84^{ABbc}	2.71^{ABabc}	2.70	2.62	2.39^{A}	2.92^{B}	NS	0.08
C*	16.54^{Aa}	17.47^{Bb}	18.21^{Cc}	17.05^{ABab}	16.75^{ABa}	17.24	17.17	17.27	17.14	LxE	0.12
Sensory evaluation of meat:											
odour	4.71^{Bb}	4.56^{Bb}	4.12^{Aa}	4.43^{ABb}	4.13^{Aa}	4.26^{a}	4.51^{b}	4.41	4.36	LxE	0.06
taste	4.67^{Bb}	4.58^{ABb}	4.28^{Aa}	4.17^{Aa}	4.15^{Aa}	4.30	4.44	4.40	4.34	LxE; LxExS	0.06
tenderness	4.66^{Cc}	4.33^{BCb}	4.15^{ABb}	4.20^{ABb}	3.82^{Aa}	4.23	4.24	4.28	4.18	LxE	0.07
juiciness	$4.70B^{c}$	4.35^{ABb}	4.26^{Ab}	4.31^{Ab}	3.97^{Aa}	4.27	4.36	4.35	4.29	LxE; LxExS	0.06

a, b = mean values in the same row with different letters differ significantly at $p \leq 0.05$; A, B = mean values in the same row with different letters differ significantly at $p \leq 0.01$; 1 = interaction; NS = not significant; SEM = standard error of the mean

Table 9. Fatty acid composition (g 100 g^{-1} detected fatty acids) and partial sums of fatty acids and related indices of *Longissimus thoracis* muscle of fattening pigs

	Experimental groups legumes (L)					Enzyme supplement (E)		Sex (S)			
	Group I Control	Group II Blue lupine cv. Graf	Group III Blue lupine cv. Karo	Group IV Yellow lupine cv.Mister	Group V Yellow lupine cv.Parys	200 mg kg^{-1} feed	0	gilts	barrows	I[1]	SEM
number	14	14	14	14	14	35	35	35	35	–	–
C10	0.00^{A}	0.04^{A}	0.00^{A}	0.00^{A}	0.34^{B}	0.07	0.08	0.08	0.07	LxE; LxS; LxExS	0.02
C12	0.28	0.19^{a}	0.27^{ab}	0.25^{ab}	0.44^{b}	0.28	0.29	0.27	0.31	NS	0.03
C14	1.71^{AB}	1.96^{B}	1.95^{B}	3.27^{C}	1.32^{A}	2.28^{B}	1.80^{A}	1.85^{A}	2.23^{B}	LxE; ExS; LxS; LxExS	0.12
C16	24.52^{Aba}	25.87^{Bb}	26.06^{BCbc}	27.16^{Cc}	23.39^{Aa}	25.46	25.34	25.64	25.17	LxExS	0.25
C16.1	3.26^{Aa}	3.66^{Ab}	3.56^{Ab}	4.23^{Bc}	3.43^{Aab}	3.73	3.52	3.77^{b}	3.49^{a}	LxS	0.07
C18	11.47^{Cc}	10.81^{Bb}	10.93^{Bb}	10.08^{Aa}	10.99^{BCb}	10.63^{A}	11.09^{B}	10.66^{A}	11.05^{B}	LxS; ExS	0.09
C18.1	39.82	39.88	39.21	40.54	42.19	39.71	40.99	40.53	40.17	NS	0.41
C18.2	1081	10.51	10.47	8.65	9.10	10.13	9.68	9.83	9.99	NS	0.33
C18.3γ	016^{Bb}	0.17^{Bb}	0.16^{Bb}	0.14^{Bab}	0.09^{Aa}	0.14	0.15	0.15	0.14	NS	0.01
C20	0.24^{B}	0.23^{B}	0.24^{B}	0.20^{B}	0.13^{A}	0.20	0.21	0.20	0.22	NS	0.01
C18.3	0.93^{Bb}	0.38^{Ab}	0.35^{Aab}	0.32^{Aab}	0.16^{Aa}	0.33^{A}	0.52^{B}	0.42	0.44	NS	0.04
C22	0.06	0.03	0.04	0.00	0.03	0.03	0.03	0.02	0.04	NS	0.01
C20.4	5.37^{AB}	4.93^{Ab}	5.30^{AB}	3.82^{A}	6.37^{B}	5.47	4.85	5.12	5.19	NS	0.26
C22.1	0.03^{b}	0.01^{a}	0.01^{a}	0.01^{a}	0.04^{b}	0.02	0.02	0.02	0.02	NS	0.01
epa	0.25^{b}	0.21^{ab}	0.16^{a}	0.16^{a}	0.026^{b}	0.22	0.20	0.21	0.21	NS	0.01
dha	0.27	0.24	0.23	0.20	0.22	0.25	0.21	0.22	0.24	NS	0.01
SFA	38.28^{ABb}	39.19^{Bb}	39.54^{BCb}	41.13^{Cc}	36.74^{Aa}	39.03	38.92	38.78	39.17	LxExS	0.28
UFA	60.91^{BCb}	59.99^{ABCb}	59.56^{ABb}	58.08^{Aa}	61.86^{Cc}	60.02	60.14	60.27	59.89	LxExS	0.26
MUFA	43.11	43.56	42.89	44.78	45.66	43.46	44.54	44.32	43.68	NS	0.44
PUFA	17.80	16.43	16.67	13.30	16.20	16.56	15.60	15.95	16.21	NS	0.60
PUFA.6	16.35	15.60	15.93	12.62	15.56	15.75	14.68	15.10	15.32	NS	0.57
PUFA.3	1.45^{B}	0.83^{A}	0.73^{A}	0.68^{A}	0.64^{A}	0.81	0.92	0.85	0.89	LxE	0.05
UFA/SFA	1.60^{BCb}	1.53^{Bb}	1.51^{ABb}	1.41^{Aa}	1.69^{Cc}	1.55	1.55	1.56	1.54	LxExS	0.02
PUFA6/3	13.41^{Aa}	18.64^{Bb}	21.63^{Bc}	18.52^{Bb}	25.63^{Cd}	19.80	19.34	19.59	19.55	NS	0.60

a, b = mean values in the same row with different letters differ significantly at $p \leq 0.05$; A, B = mean values in the same row with different letters differ significantly at $p \leq 0.01$; SFA = sum of saturated fatty acids; UFA = sum of unsaturated fatty acids; MUFA = sum of monounsaturated fatty acids; PUFA = sum of polyunsaturated fatty acids; 1 = interaction; NS = not significant; SEM = standard error of the mean

Table 10. Apparent digestibility coefficients of grower and finisher feed mixtures

	Experimental groups legumes (L)				Enzyme supplement (E)			
	Group I Control	Group II Blue lupine cv. Graf	Group IV Yellow lupine cv.Mister	Group V Yellow lupine cv.Parys	200 mg kg^{-1} feed	0	I[1]	SEM
Number of pigs	6	6	6	6	12	12	–	–
Grower mixtures								
Dry matter	85.3^{ABb}	85.7^{Bb}	85.2^{ABb}	82.7^{Aa}	85.1	84.6	NS	0.22
Crude protein	85.9	83.9	84.1	84.4	84.8	84.2	NS	0.43
Ether extract	56.8	58.4	48.3	55.6	56.0	53.8	NS	1.25
Crude fiber	29.7^{ab}	37.4^{b}	27.2^{a}	27.0^{a}	30.8	29.5	NS	1.10
N-free extractives	88.7^{a}	89.3^{ab}	89.7^{ab}	90.1^{b}	90.0	89.0	NS	0.23
Finisher mixtures								
Dry matter	84.3^{Bb}	83.7^{ABb}	83.0^{ABab}	82.1^{Aa}	83.6	82.9	NS	0.26
Crude protein	94.6^{Bb}	81.9^{ABa}	81.7^{ABa}	80.2^{Aa}	83.2^{b}	81.0^{a}	NS	0.48
Ether extract	63.5^{Bb}	51.0^{Aa}	59.7^{ABb}	62.4^{ABb}	62.5^{b}	55.8^{a}	NS	1.67
Crude fiber	22.8^{A}	30.0^{B}	30.7^{B}	32.4^{B}	32.8^{B}	25.1^{A}	LxE	1.22
N-free extractives	87.9^{B}	88.0^{B}	87.2^{B}	85.6^{A}	87.3	87.0	LxE	0.22

a, b = mean values in the same row with different letters differ significantly at $p \leq 0.05$; A, B = mean values in the same row with different letters differ significantly at $p \leq 0.01$; 1 = interaction; NS = not significant; SEM = standard error of the mean

Discussion

The low alkaloid varieties of both examined species of lupines (Graf and Mister) had a favourable composition when compared to the high alkaloid ones. They contained more protein and, of course, less alkaloids. Results obtained suggest that at the beginning of the experiment pigs at least partially became used to such a feed: piglet weight gains were similar to controls though were worse than those fed with sweet blue lupine. On the other hand, however, when older pigs in the digestibility trial first time received this lupine, they refused consumption. All the lupines contained less protein and amino acids than the soybean meal used as the control but the soybean was extracted (hence the relatively low fat content) and the lupines were unprocessed. This slightly increased the crude fat content in the experimental diets. The amino acid composition of the protein of the tested seeds was similar to that quoted by Schumacher et al. (2011). Differences in amino acid composition of protein of various varieties of legumes are generally small because yield, protein and antinutritive substances content are the main object of interests of plant breeders, and amino acids are of secondary importance (Wang et al. 2003).

There are not many experiments on feeding sows with lupine quoted in the literature. Early experiments performed in 1987 by pork producers using hexane-extracted dehulled lupine meal gave adverse results such as feed refusal, poor growth rate and constipation. Pregnant sows appeared to have an increased incidence of stillborn pigs and reduced litter sizes (Casper et al. 1991). As the lupine used was relatively low alkaloid (< 0.05%) it can be assumed that the poor results were due to the not removed hexane residue. If there was no further processing, hexane extraction alone could reduce the smell and nutritive value of the feed (Honig et al. 1976). In the present experiment reproduction rates of the sows receiving soybean were better than those fed with lupines taking in account the weight of the piglets born. Better results were obtained using lupines and other legumes in sow feeding in the previous experiment of Hanczakowska and Świątkiewicz (2013), in which sows fed *L. luteus* cv. Mister mixed with rapeseed press cake born heavier piglets than those fed with soybean.

In the experiment of McNiven and Casteli (1995) weaned (also at 35 d of life) piglets fed with white lupine grew as well as those fed with soybean if the amount of lupine in the feed was lower than 15%. Decreasing body weight gains with higher lupine level in the diet were probably due to lower feed intake. According to these authors the

results of all the groups also depended on the environmental conditions (different barn). Prandini et al. (2005), also using white lupine, found no significant difference in body weight gains of piglets between 1 and 42 d of life when compared to those fed with soybean. Extrusion did not improve animal growth. No improvement of protein digestibility of white lupine in piglets after supplementing feed (30% of lupine) with alpha-galactosidases was also found by Pires et al. (2007). Body weight gains cannot be taken into account because the piglets were submitted to an ileo-rectal anastomosis; as such, there was no significant difference in piglet body weight at the end of the experiment. The results of the present and quoted experiments suggest that lupine can be used in piglet diets at the level of 6–15%, and additional treatments such as extrusion at the beginning of the experiment do not improve its nutritive value. Also the supplements of fibrolitic enzymes has only limited effects.

In the first period of fattening i.e. from 23 to 60 kg of body weight the pigs receiving lupines grew slightly better than those fed with soybean but the differences were not significant. In the finisher period (60–107 kg) the control pigs grew faster. Similar results were obtained by Partanen et al. (2006) when blue lupine replaced rapeseed pressed cake at a level of 33%. In the earlier experiment of Hanczakowska and Świątkiewicz (2014) the mean daily body weight gains of fatteners fed with soybean meal (781 g) were intermediate between those of the pigs fed with blue (744 g) or yellow lupine (810 g) mixed with rapeseed press cake and these differences were not significant. In the present experiment the only exception were pigs fed with blue lupine cv. Karo, which grew significantly worse, probably due to its high alkaloid content given that pigs are particularly sensitive to the bitter taste of alkaloids (Godfrey et al. 1985). In this experiment the enzyme supplement had no positive effect on fattening results. The nutritive value of lupine seeds may be improved by dehulling or supplementing feed with fat but the results of different experiments are inconsistent. In any case such treatments complicate and increase the cost of feeding. The nutritive value of lupine for pigs was reviewed by Pisarikova and Zraly (2009) and there was no significant difference in the meatiness of the carcass. Generally low alkaloid varieties (Graf and Mister) gave better results than high alkaloid ones. No difference in carcass quality was found also by Sońta et al. (2015) and by Zraly et al. (2007), who used white lupine.

There are only a few publications on the quality of meat of lupine-fed pigs. In the experiment of Leikus et al. (2004), the replacing of soybean meal with white lupine had no effect on carcass and meat quality. This is inconsistent with the results of the presented experiment in which meat quality traits of fatteners fed with the varieties Karo and Parys were significantly lower than those of the control's. Also, the low alkaloid varieties were worse in some organoleptic traits such as taste (cv. Mister) or juiciness (cv. Graf) than the soybean control. These differences could be due to differences in the fatty acids contained in the meat. According to Wood et al. (2008) fatty acid compositions has profound effects on meat quality. In the case of cv. Parys poor odour could be due to the presence of capric acid (C10) which is known for its bad smell (Oprean et al. 2011). Differences in alkaloid content in the seeds seem to have no significant effect on meat taste.

According to Gatlin et al. (2002) the fatty acid profile of fat deposited in pigs is similar to that given in the diet, although according to Lopez-Bote and Rey (2001) this concerns mainly adipose tissue. Also, Froidmont et al. (2005) found big differences between the fatty acid pattern in the meat and backfat of pigs fed with a feed based on wheat and white lupine. In the present experiment there was no significant difference between the groups in the total content of MUFA and PUFA in fat of *longissimus thoracis*. The biggest difference in SFA content in meat was found between the two varieties of yellow lupine, but because fatty acid patterns of lupines' seeds lipids were not analyzed, it is hard to find reasons for these differences. Anyway, according to data quoted in literature long chain saturated fatty acids predominate in lupine seed fat (Zraly et al. 2007). Andrzejewska et al. (2016) analyzed fatty acid profile in seeds of different lupines, among them variety of blue lupine used also in this experiment (cv. Karo). They found that linoleic acid (C18:2) was most abundant and oleic acid (C18:1) was second. Generally, the fatty acid pattern of the meat found in this experiment (MUFA prevailing, SFA the second) was very similar to that found by Zraly et al. (2007). Despite this similarity PUFA n6/n3 ratio was high in our experiment due to a higher amount of PUFA n6 and a lower amount of PUFA n3 in the lupine groups. Such a ratio cannot be recommended from a health point of view (Kuhnt et al. 2012). According to recommended optimum this latter ratio should be 1/1 to 4/1 (Simopoulos 2004) though in European diets it ranges from 15/1 to about 17/1 (Fernandez et al. 2007). Thus in meat of animals from both experimental groups n6/n3 ratio is considerably above this limit.

There was no difference in the digestibility of the feed protein and fat in the first stage of the experiment. Similar results were obtained by Stanek et al. (2012) but they used older animals (BW about 80 kg), thus their results may be compared rather to the second stage in our experiment in which we found decreasing digestibility of protein and fat but improving digestibility of fiber. Stanek et al. (2012) found no differences in protein and fat digestibility of nutrients of the feed containing soybean meal or blue lupines except for one variety which was significantly

worse than the other ones. No difference in protein or fat digestibility in growing pigs was also found in the experiment of Flis et al. (1996) on yellow lupine. Also, Yang et al. (2007) found no improvement in the apparent digestibility of nutrients of feed containing blue lupine, though the apparent ileal digestibility of some amino acids (lysine, methionine and phenylalanine) was better in the expanded seeds. According to these authors this improvement was due to the effects of changes in non-starch poly- and oligosaccharides contained in the seeds.

Conclusions

The results obtained suggest that blue and yellow lupine seeds may be, in moderate amounts, good replacements of soybean meal in the weaned piglet and growing pig nutrition. Apparent differences were found between the high alkaloid and low alkaloid varieties in the seeds' chemical composition, especially in their protein and alkaloid content. Low alkaloid varieties of both blue and yellow lupine given at a level of 6 or 10% gave better results in piglet feeding than soybean meal. Feed enzyme supplement has only limited effect on piglet and growing pig performance. They also gave results comparable to soybean meal in growing pig feeding but the meat quality was lower, especially in the case of yellow lupines.

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