Replacement of soya in pig diets with white lupine cv. Butan

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ABSTRACT: The purpose of the present study was to evaluate the effect of soya replacement (50 or 100%) with whole (WL) or dehulled seeds (DL) of white lupine cv. Butan in the diets for market pigs. The experiment was performed on 50 pigs in equal numbers of barrows and gilts with the initial mean body weight (BW) of 18.3 ± 2.1 kg, fed isonitrogenous and isoenergetic diets for 100 days. In the experimental starter pigs (18 to 35 kg BW), the mean daily body weight gain (BWG) was 0.61 to 0.64 kg and was insignificantly lower by 1.5 to 6.2% in comparison with the pigs fed the control soya diet (SBM). The diet intake was also lower by 5.4 to 6.8% and could result from a higher content of crude fibre. In the grower and finisher diets, no side effect of high lupine levels on the feed intake was evident. The intake of DL diets was higher in comparison with the soya diet. The feed efficiency of the finisher diets was insignificantly higher ($P > 0.05$) for experimental diets (WL 50, WL 100, DL 100) in contrast to the control diet. The differences among diets containing WL or DL seeds were insignificant. During the experiment, no adverse effect of lupine on the health of pigs was observed and no significant differences in the parameters of market pig meat, nutrition quality of meat and sensory analysis were detected. The inclusion of lupine in diets resulted in a significantly lower n-6/n-3 ratio of polyunsaturated fatty acids ($P < 0.01$) in meat lipids (5.15 to 5.33) in comparison with soya (8.75). It follows from the obtained results that the tested lupine variety seeds are a source of high-quality protein that can be an alternative to soya in the diets for market pigs.

Keywords: *Lupinus albus*; whole seeds; dehulling; performance; pork; fatty acid profile; sensory properties

The current situation of pig nutrition can be characterized by a lack of animal protein, relatively high fish-meal prices, threatening crisis in the soya import to Europe and reduced nutripotential sources of indigenous raw materials for feeding animals in consequence of biofuel production. Due to the fact that cereal diets, primarily for monogastric animals, are being developed, new suitable sources of high-quality protein for supplementation of animal diets and mixtures have been investigated.

Lupine is classified as a leguminous plant, i.e. a crop with high content of crude protein (CP). Its use as an alternative source of protein in animal diets is gradually increasing. According to the significant recent studies, lupine is one of the eight promising vegetable protein sources for the pro-

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duction of feeds and foods (Dijkstra et al., 2003). If the yield between 30 and 50 q/ha is reached, the production of up to 2 000 kg/ha protein can be expected.

The seeds of sweet lupine (*Lupinus albus*, *L. angustifolius*, *L. luteus*) cultivars contain 28 to 48% of crude protein relative to the cultivar and climatic conditions (Linnemann and Dijkstra, 2002). In comparison with soya, the amino acid profile in lupine is characterized by a lower content of sulphur-containing amino acids and threonine (Simon and Jeroch, 1999) and by a much higher content of arginine (Suchý et al., 2005), which is often deficient in animal diets. Straková et al. (2006) found differences in the nutrient content among different cultivars; the content of crude protein in lupine is much higher in comparison with soya beans. In contrast to the sweet lupine seeds, the soya beans contain much less oil and crude fibre, namely acid detergent fibre (ADF). The oil content in sweet lupine seeds ranges between 5 and 13% (Yanez et al., 1983). The content of mono and polyunsaturated fatty acids is favourable; their content is up to 80%. The content of starch in cotyledons is only about 5 to 12%. On the other hand, the contents of surface soluble non-starch polysaccharides and α-galactosides are high and their digestion by endogenous enzymes is difficult (Van Barneveld, 1999). In comparison with the other leguminous plants, the content of crude fibre in lupine seeds is higher, which is beneficial from the aspect of the proportional composition of a diet (Johnson and Gray, 1993). The seeds of cultivated lupine species contain low levels of antinutritional substances such as alkaloids, tannins and trypsin inhibitors (Aniszewski et al., 2001) and they do not require heat treatment in comparison with soya. The content of non-starch polysaccharides and α-galactosides can result in a reduction of the nutrient and energy utilization and growth depression; these may affect the health condition as reported by Veldman et al. (1993) and Gdala et al. (1997).

Data concerning the utilization of lupine in pig nutrition is ambiguous. Feeding the diets containing 150 to 430 g/kg of *L. albus* seeds to pigs, Batterham (1992), Roth-Maier and Kirchgessner (1993) and Zettl et al. (1995) found out reduced live weight gains. Van Nevel et al. (2000) also documented decreased nutrient conversion and growth depression in pigs receiving diets containing 30% of white lupine. The supplementation of dehulled seeds and amino acids to pig diets failed to increase the efficiency of pigs (King et al., 2000). The authors reported adverse effects of antinutritional substances such as alkaloids, α-galactosides and high content of manganese. On the contrary, no growth depression was found by Gdala et al. (1996) in pigs fed a diet containing *L. angustifolius* (410 g/kg diet) versus a diet based on barley and soya. Flis et al. (1996) obtained positive results with yellow lupine cv. Juno. Fernández and Batterham (1995) investigated the nutritive value of dehulled and non-dehulled lupine in market pigs and failed to find any positive effect of dehulling the lupine seed. The effect of dehulling on the nutrient and energy utilization and metabolizable energy content in *L. angustifolius* on market pigs and gilts was investigated by Noblet et al. (1998). They documented higher digestibility of crude fibre for gilts in comparison with growing pigs. Investigating the adverse effect of non-starch polysaccharides on the utilization of dietary amino acids and energy, Van Barneveld (1999) obtained varying results.

The purpose of the present study was to assess the effect of diets in which different proportions of soya protein were replaced by whole or dehulled seeds of white lupine cv. Butan on the performance, health status, carcass characteristics and nutritional and sensory parameters of meat of market pigs.

MATERIAL AND METHODS

Animals and feeding

Fifty hybrid Pietrain × (Duroc × Large White × Landrace) pigs in equal numbers of barrows and gilts aged 8 weeks with the initial mean body weight of 18.3 ± 2.1 kg (V = 11.6%) were used in the study. The animals were housed in pens of 5 pigs each. Straw was used as bedding. Average surface space was 1.7 m^2 and the length of the feeding place was 0.3 m per pig. Average ambient temperature and relative humidity were 19 ± 2°C and 60 ± 10%, respectively. Before the beginning of the experiment, the animals were dewormed (Ivomec, inj., Agvet, USA) and allocated into five groups based on individual body weight and sex. In the course of the experiment (100 days) pigs were fed semi *ad libitum* twice a day at 7.00 and 16.00 h with receiving the diets mixed with drinking water 1:1. Thirty minutes after the beginning of feeding, the refusals were removed, weighed and taken into account in the calculations of feed consumption. Drinking water was available from nipple drinkers.

Body weight of pigs was taken in weekly intervals (each time 2 h after feeding). Individual and group body weight gains (BWG) were calculated. The feed conversion ratio (FCR) was calculated from feed consumption and BWG of the respective groups. The health status of animals was monitored daily by observation at regular intervals. At the end of the experiment, blood samples were drawn from the *v. cava cranialis* for biochemical analysis 3 h after feeding and all experimental animals were slaughtered using electrical stunning and exsanguination.

Diets

Five experimental diets were based on barley, wheat, maize and feed supplements. The control group diets contained soybean meal (SBM) with 46% of protein (CP). The soya protein was replaced in the diets for four experimental groups either partially (50%) or completely (100%) with non-dehulled (WL 50, WL 100) or dehulled lupine (DL 50, DL 100, Table 1). The seeds were mechanically abraded. The isonitrogenous and isocaloric diets (Tables 2 to 4) were formulated for the pre-fattening stage (starter – 9 to 12 weeks of age) and for the first and second stage (grower – 13 to 16 weeks of age, finisher – 17 to 22 weeks of age) of fattening of meat-type pigs with 56% proportion of lean musculature (Šimeček et al., 2000).

Chemical analysis

Dry matter (DM), crude protein (N × 6.25), crude fat, crude fibre and ash of lupine seeds and diets were analysed using AOAC (2001). Determination of neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) was per-

Table 1. The analyzed nutrient composition of white lupine seeds cv. Butan used in the experiment (in dry matter)

	White lupine seeds	
	whole	dehulled
Nutrient (g/kg)		
Dry matter (as fed)	922.7	930.2
Crude protein	363.2	435.7
Crude fat	92.2	102.3
Fibre		
Crude	152.6	37.7
NDF	216.0	86.3
ADF	174.6	54.5
Cellulose	150.3	54.2
Ash	41.1	42.7
N-FE	350.9	381.6
OM	958.9	957.3
Saccharides		
Galactose	0.10	0.19
Glucose	0.07	0.15
Fructose	0.32	0.39
Saccharose	24.9	26.3
Raffinose	7.02	7.92
Stachyose	41.6	59.1
Lactose	0.20	0
Verbascose	7.47	10.3
Total	81.7	104.3

	White lupine seeds	
	whole	dehulled
Amino acids		
Essential		
Arginine	43.8	51.0
Histidine	11.9	12.8
Isoleucine	15.0	17.3
Leucine	24.1	26.9
Lysine	21.0	22.6
Methionine	4.3	5.0
Phenylalanine	13.6	13.6
Threonine	14.3	15.8
Valine	14.4	16.1
Total indispensable	162.4	181.1
Non-essential		
Alanine	12.3	13.8
Aspartic acid	40.7	45.9
Cystine	7.7	9.8
Glutamic acid	58.1	64.4
Glycine	14.6	16.4
Proline	16.1	18.3
Serine	19.5	22.3
Tyrosine	9.2	9.3
Total dispensable	178.2	200.2

Table 2. The composition and nutrient content of starter diets

	Diet[1]				
	SBM	WL 50	WL 100	DL 50	DL 100
Ingredient (g/kg)					
Wheat	441.0	380.0	321.0	415.0	388.5
Barley	210.0	210.0	210.0	210.0	210.0
Maize	100.0	100.0	100.0	100.0	100.0
Extracted soybean meal 46% CP	200.0	100.0	–	100.0	–
Lupine	–	155.0	310.0	118.0	236.0
L-lysine HCl 40%	12.0	14.0	15.5	14.5	17.0
DL-methionine 40%	2.0	3.0	4.5	3.0	4.5
L-tryptophan 10%	–	2.0	3.5	3.5	6.5
L-threonine 20%	8.0	9.0	9.5	9.0	10.5
BOLIFOR DCP-N	13.0	13.0	13.5	13.0	13.5
Feeding salt	4.0	4.0	4.0	4.0	4.0
Ground limestone	7.5	7.5	6.0	7.5	7.0
A1-CDP-HD 0.2%[2]	2.5	2.5	2.5	2.5	2.5
Nutrients (g/kg)					
Dry matter	886.6	894.6	893.2	890.4	889.0
Crude protein	197.4	194.4	193.8	197.8	190.6
Crude fat	19.6	27.0	40.7	29.8	38.0
Crude fibre	35.9	38.1	47.0	32.5	33.4
Ash	59.8	59.0	57.0	55.6	50.1
N-FE[3]	573.9	576.1	554.7	574.7	576.9
Organic matter	826.8	835.6	836.2	834.8	833.6
MEp (MJ/kg)[4]	13.1	13.3	13.4	13.5	13.7
Lysine/MEp (g/MJ)	0.90	0.91	0.91	0.89	0.88

[1]SBM – soybean meal; WL 50, 100 – 50% or 100% replacement of SBM with whole lupine; DL 50, 100 – 50% or 100% replacement of SBM with dehulled lupine

[2]commercial supplement contained the following per kg: 4 000 000 IU vitamin A; 680 000 IU vitamin D_3; 600 mg vitamin K_3; 20 000 mg vitamin E; 600 mg vitamin B_1; 1 200 mg vitamin B_2; 800 mg vitamin B_6; 10 000 mg vitamin B_{12}; 6 000 mg niacinamide; 4 000 mg pant. calcium; 100 000 mg choline chloride; 20 mg biotin; 220 mg Co; 400 mg J; 150 mg Se; 7 200 mg Cu; 20 000 mg Mn; 46 000 mg Zn; 40 000 mg Fe; 50 000 mg betaine; 7 750 mg silicic acid (E 551a); 3 625 mg ethoxyquin (E 321); 625 mg citric acid (E 330); 500 mg propyl galate (E 310)

[3]N-FE – nitrogen-free extracts

[4]MEp – metabolizable energy

formed according to the technique described by Van Soest et al. (1991). Cellulose content was determined by deducting ADL from ADF. Metabolizable energy (MEp) was calculated by a regression equation according to Šimeček et al. (2000). Before the analysis of amino acids, the samples were processed with acid and oxidative hydrolysis using HCl (6 mol/l). The analysis of samples was performed in an AAA 400 analyser (INGOS Prague, Czech Republic).

Mono- and disaccharides in the whole or dehulled lupine seed meal were determined by high-performance anion-exchange chromatography with pulsed amperometric detection (HPAEC-PAD, Dionex, Sunnywale, USA). Isocratic elution chromatography was used for the detection of monosaccharides and gradient mobile phase was employed for the detection of disaccharides (Erbas et al., 2005).

Table 3. The composition and nutrient content of grower diets

	Diet[1]				
	SBM	WL 50	WL 100	DL 50	DL 100
Ingredient (g/kg)					
Wheat	455.0	412.0	367.0	438.5	418.0
Barley	310.0	310.0	310.0	310.0	310.0
Maize	50.0	50.0	50.0	50.0	50.0
Extracted soybean meal 46% CP	140.0	70.0	–	70.0	–
Lupine	–	110.0	222.0	80.0	165.0
L-lysine HCl 40%	12.0	13.0	14.0	14.0	15.5
DL-methionine 40%	2.0	3.0	3.5	3.0	4.0
L-tryptophan 10%	–	1.0	2.0	2.5	4.5
L-threonine 20%	7.0	7.5	8.0	8.5	9.5
BOLIFOR DCP-N	11.0	11.0	11.5	11.0	11.0
Feeding salt	4.0	4.0	4.0	4.0	4.0
Ground limestone	7.0	6.5	6.0	6.5	6.5
A1-CDP-HD 0.2%[2]	2.0	2.0	2.0	2.0	2.0
Nutrients (g/kg)					
Dry matter	887.7	890.6	889.0	890.0	888.7
Crude protein	174.1	178.0	178.6	177.6	175.0
Crude fat	17.1	24.2	32.0	23.3	26.6
Crude fibre	34.5	41.0	38.8	30.6	29.8
Ash	52.4	54.9	53.8	54.3	47.0
N-FE[3]	610.6	592.5	585.8	604.3	610.3
Organic matter	834.1	835.7	836.7	835.7	839.3
MEp (MJ/kg)[4]	13.1	13.0	13.3	13.3	13.5
Lysine/MEp (g/MJ)	0.80	0.80	0.80	0.80	0.80

[1,2,3,4]see Table 2

Total lipids in lupine seeds, diets and meat (*musculus longissimus lumborum et thoracis – MLLT*) were extracted with chloroform-methanol (2:1 v/v) according to the method of Folch et al. (1957). Derivatization of fatty acids was based on the base-catalysed reaction using KOH-methanol as reagent. Fatty acid methyl esters (FAMEs) were then extracted to hexane. FAMEs were analysed by gas-liquid chromatography using a SP-2560 fused silica capillary column (100 m × 0.25 mm i.d., 20 µm film thickness, Supelco, Bellefonte, USA) in a Hewlett-Packard 5890 gas chromatograph (Palo Alto, USA) equipped with flame ionizing detector (FID). The oven temperature was 175°C for 30 min, then it was increased by 1°C/min to 210°C and this temperature was maintained for 40 min. Detector and injection port temperatures were 220°C and the nitrogen carrier gas flow was 1 ml/min. For the identification of FAME, standard FAME mixtures were analysed. To confirm the identification of some FAME, GC/MS analysis was carried out in the GC/MSD system Agilent 5973 (Agilent, Palo Alto, USA) with the same column and temperature conditions as above, except for the helium flow, which was 0.6 ml/min and the detector temperature was 250°C.

Total protein, albumin, glucose, triacylglycerols, cholesterol, HDL and LDL lipoproteins, alkaline phosphatase (ALP), aspartate and alanine aminotransferase (AST, ALT), calcium and phosphorus blood plasma levels were determined spectrophotometrically using Bio-La-Tests (Pliva-Lachema Brno Ltd., Czech Republic).

Table 4. The composition and nutrient content of finisher diets

	Diet[1]				
	SBM	WL 50	WL 100	DL 50	DL 100
Ingredient (g/kg)					
Wheat	490.0	465.0	440.0	479.5	469.5
Barley	390.0	390.0	390.0	390.0	390.0
Extracted soybean meal 46% CP	80.0	40.0	–	40.0	–
Lupine	–	63.0	127.0	47.0	94.0
L-lysine HCl 40%	10.0	10.5	11.0	11.0	12.0
DL-methionine 40%	1.0	1.5	2.0	1.5	2.0
L-tryptophan 10%	–	1.0	1.0	1.5	2.5
L-threonine 20%	5.0	5.0	5.5	5.5	6.0
BOLIFOR DCP-N	11.0	11.0	11.0	11.0	11.0
Feeding salt	4.0	4.0	4.0	4.0	4.0
Ground limestone	7.0	7.0	6.5	7.0	7.0
A1-CDP-HD 0.2%[2]	2.0	2.0	2.0	2.0	2.0
Nutrients (g/kg)					
Dry matter	887.8	889.2	887.6	886.4	887.4
Crude protein	144.6	146.8	149.8	147.4	144.1
Crude fat	15.2	18.8	22.8	20.2	24.2
Crude fibre	38.7	48.6	49.8	41.1	40.5
Ash	47.0	45.9	48.3	49.2	48.9
N-FE[3]	642.3	629.1	616.9	628.5	629.7
Organic matter	840.8	843.3	839.3	837.2	838.5
MEp (MJ/kg)[4]	12.8	12.7	12.6	12.8	12.8
Lysine/ME (g/MJ)	0.65	0.65	0.65	0.65	0.65

[1,2,3,4]see Table 2

Carcass and meat quality measurement

At the end of the experiment, carcass quality was determined. The following criteria were used: dressing percentage, estimated lean yield in percent (ZP method, ČSN 46 61 60, 2000), backfat thickness and *MLLT* depth were measured with a slide gauge at the location of the last thoracic vertebra. At the same location of *MLLT*, pH values were measured 1 (pH_1) and 24 hours (pH_{24}) after slaughter using a WTW 720 pH meter (Inolab, Weilheim, Germany). Dry matter, crude protein (N × 6.25) and crude fat contents (petrol ether extraction in Soxhlet apparatus for 6 h) were determined in *MLLT* according to Czech Standard ČSN 570185 (1985).

Sensory evaluation

The samples (app. 500 g) of muscle tissue were collected from *MLLT* for analyses of sensory parameters. Evaluation was done by a group of 8 members meeting the requirements of ČSN ISO 8586-1 (2003) in a special room for the analysis of sensory parameters (according to ČSN ISO 8589, 1993). For the expression of sensory quality, a 10-cm unstructured seven-point graphic scale was used; the value could be read as both points and percentages. The following attributes (descriptors) of meat were assessed: colour, texture, juiciness, odour and taste.

Statistical analysis

The results were processed by statistical methods using statistical and graphic software STAT Plus (Matoušková et al., 1992). The analysis of the data was performed by one-way ANOVA, using Tukey's test and Kruskal-Wallis test.

RESULTS AND DISCUSSION

The chemical composition of whole and dehulled white lupines cv. Butan is shown in Table 1. The CP content was similar in the tested variety in comparison with the soya beans reported by Straková et al. (2006), i.e. 333.9 g/kg in the Vision variety of soya. The seed dehulling resulted in a marked increase in their nutritive value and the amino acid content was likewise elevated. The amino acid analysis revealed that lupine seeds are a good source of amino acids, except for methionine, in which they are deficient. The content of lysine in WL and DL was 21.0 and 22.6, methionine 4.3 and 5.0 and threonine 14.3 and 15.8 g/kg DM, respectively, which is in accordance with the findings of Ciesiolka et al. (2005). The lupine seed dehulling resulted in a beneficial reduction of NDF and ADF content (216.0 vs. 86.3; 174.6 vs. 54.5 g/kg DM). In the studies of Brenes et al. (1993), dehulled sweet lupine seeds contained less ADF and NDF by 72% and 73%, respectively, than the whole seeds. The total content of saccharides was higher in DL seeds compared to WL seeds (104.3 ± 0.03 vs. 81.7 ± 0.08 g/kg DM) and is comparable with the range of 105.4 to 64.0 g/kg reported by Ciesiolka et al. (2005). Of the α-galactosides of the raffinose series, the highest content was found for stachyose: 41.6 (WL) and 59.1 (DL) g/kg of DM. The lupine seeds are characterised by a relatively high crude fat content and favourable profile of fatty acids. In whole seeds, 14.7% of unsaturated fatty acids (SFA), 63.9% of monounsaturated fatty acids (MUFA) and 21.1% of polyunsaturated fatty acids (PUFA) were detected (not shown). The n-6/n-3

Table 5. Feed intake, body weight gain and feed efficiency

Parameter	Diet[1]					SEM
	SBM	WL 50	WL 100	DL 50	DL 100	
Starter						
BWG[2] (kg/day)	0.65	0.61	0.62	0.63	0.64	0.01
Feed intake (kg/day)	1.32	1.24	1.25	1.23	1.25	0.19
FCR[3] (kg/kg)	2.03	2.04	2.09	1.94	1.93	0.03
Grower						
BWG[2] (kg/day)	0.82	0.80	0.79	0.84	0.86	0.02
Feed intake (kg/day)	1.87	1.84	1.79	1.91	1.96	0.25
FCR[3] (kg/kg)	2.26	2.29	2.28	2.27	2.25	0.01
Finisher						
BWG[2] (kg/day)	1.02	1.07	1.05	0.94	1.05	0.02
Feed intake (kg/day)	2.99	2.90	2.87	2.91	3.03	0.23
FCR[3] (kg/kg)	$2.92^{a,b}$	2.72^{a}	2.77^{a}	3.10^{b}	$2.88^{a,b}$	0.03
Total test						
BWG[2] (kg/day)	0.84	0.85	0.84	0.82	0.86	0.01
Feed intake (kg/day)	2.15	2.09	2.06	2.11	2.17	0.35
FCR[3] (kg/kg)	2.53	2.45	2.47	2.58	2.48	0.02

[1]see Table 2; [2]body weight gain; [3]feed conversion ratio; $^{a,b}P < 0.05$

PUFA ratio was 1.79 and is comparable with the value reported by Erbas et al. (2005).

From an aspect of the CP content and the concentration of metabolizable energy, the diets intended for different growth stages (starter, grower, finisher – Tables 2 to 4) were isonitrogenic and isoenergetic and the lysine/MEp ratio was balanced. A lower biological value of the lupine protein documented by a lower content of lysine, methionine, threonine and tryptophan (Fernández and Batterham, 1995) was compensated. The n-6/n-3 PUFA ratio in control diet (SBM) was 9.52 and in experimental diets WL 50, WL 100, DL 50 and DL 100, the ratio was 6.36, 5.91, 5.65 and 5.09, respectively (not shown).

The effect of different diets on the feed consumption, BWG and FCR is shown in Table 5. In the starter diet, differences in the feed intake were insignificant among pigs, even though the feed intake was lower by 5.4 to 6.8% in all experimental groups compared with the control diet containing soya (SBM). The lower feed intake could be due to a higher content of crude fibre, especially in WL diets in contrast to the control soya diet. A decrease in the feed intake by 22% was documented by Donovan et al. (1993) in case that 75 or 100% of soya protein was replaced with dehydrated white lupine cv. Ultra. On the other hand, Barnett and Batterham (1981) found out that pigs with the body weight between 6 and 20 kg very well tolerated the diet with high crude fibre content in lupine combined with wheat, where the crude fibre content was low. BWG in our study was similar in experimental pigs (0.61 to 0.64 kg/day) to that in the control group (0.65 kg/day). In the diets containing DL, BWG was similar like in WL diets. The feed conversion was similar in all animal groups. The FCR for WL 100 diet (2.09) might be due to a higher content of crude fibre (47.0 g/kg) and lower CP content in the diet (Table 2).

The side effect of high levels of lupine in the starter diet was less apparent in the pigs with higher body weight, i.e. in subsequent stages of growth (35 to 60 kg or above 60 kg of body weight). The intake of almost all grower diets was comparable, except for WL 100 diet; the intake of the latter was lower by 4.3% in comparison with the control diet. The daily BWGs were comparable in all groups of animals fed grower diets. No adverse effect of either increased levels of lupine in diets or dehulling of lupine seeds on FCR was observed in comparison with the control diet (SBM).

The feed efficiency of finisher diets for experimental and control groups was significantly different (Table 5). The low BWG (0.94 kg) and impaired FCR in DL 50 group (Table 5) were due to inapparent pleuropneumonia of one barrow; the disease was detected after completing the experimental slaughter of the animals. The results obtained during the entire experimental period documented similar feed efficiency of diets containing white lupine,

Table 6. Selected biochemical characteristics of blood plasma

Parameter	Diet[1]					SEM
	SBM	WL 50	WL 100	DL 50	DL 100	
Total protein (g/l)	70.92	70.77	71.03	70.30	71.15	0.37
Albumin (g/l)	35.17	35.00	36.33	35.83	35.67	0.39
Glucose (mmol/l)	5.04	5.12	5.18	5.04	5.09	0.06
Triacylglycerols (mmol/l)	0.36	0.40	0.39	0.43	0.31	0.02
Cholesterol (mmol/l)	2.63[a]	2.63[a]	2.38[ab]	2.30[ab]	2.23[b]	0.05
HDL lipoproteins (mmol/l)	1.14[ab]	1.22[a]	1.11[ab]	1.00[b]	0.99[b]	0.03
LDL lipoproteins (mmol/l)	1.46	1.29	1.35	1.28	1.27	0.03
ALT (μkat/l)	0.86	0.90	0.89	0.84	0.88	0.03
AST (μkat/l)	0.59	0.52	0.45	0.51	0.52	0.02
ALP (μkat/l)	2.80	3.22	3.43	3.03	3.17	0.14
Ca (mmol/l)	2.64	2.60	2.65	2.60	2.72	0.03
P (mmol/l)	2.58	2.65	2.59	2.67	2.71	0.02

[1]see Table 2; [a,b]$P < 0.05$

Table 7. Fatty acid composition of *MLLT* lipids (% of total fatty acids)

Fatty acid	Diet[1]					
	SBM	WL 50	WL 100	DL 50	DL 100	SEM
Myristic C 14:0	1.66	1.70	1.49	1.33	1.35	0.12
Palmitic C 16:0	28.01	25.14	29.13	26.48	26.37	1.17
Stearic C 18:0	11.18[a]	13.28[ab]	15.00[b]	13.54[ab]	14.13[ab]	0.59
Palmitoleic C 16:1	3.52	2.89	2.97	3.39	3.00	0.15
Oleic C 18:1 n-9	36.72	39.61	35.56	38.59	38.19	0.01
Octadecenic C 18:1 *cis* isomeric	4.10	4.33	3.70	4.44	4.33	0.17
Linoleic C 18:2 n-6	8.69	6.42	6.42	6.67	6.76	0.49
Linolenic C 18:3 n-3	0.71	0.75	0.93	1.00	1.11	0.06
Eicosenoic C 20:1	0.26	0.29	0.20	0.18	0.11	0.03
Arachidonic C 20:4 n-6	1.55	1.08	1.27	1.17	1.29	0.13
Eicosapentaenoic C 20:5 n-3	0.19	0.11	0.14	0.20	0.12	0.02
Docosatetraenoic C 22:4 n-6	0.21	0.18	0.17	0.20	0.23	0.02
Docosapentaenoic C 22:5 n-3	0.21	0.20	0.26	0.22	0.25	0.02
Docosahexaenoic C 22:6 n-3	0.09	0.06	0.08	0.08	0.09	0.01
Others	2.90	3.96	2.68	2.51	2.67	0.23
Σ SFA[2]	40.86	40.11	45.65	41.34	41.85	1.66
Σ MUFA[3]	44.59	47.12	42.43	46.60	45.63	1.23
Σ PUFA[4]	11.66	8.81	9.28	9.55	9.84	0.70
PUFA n-6	10.45	7.68	7.87	8.04	8.28	0.63
PUFA n-3	1.20	1.13	1.41	1.51	1.56	0.09
n-6/n-3	8.75[a]	6.85[a,b]	5.22[b]	5.33[b]	5.15[b]	0.33

[1]see Table 2; [2]saturated fatty acids; [3]monounsaturated fatty acids; [4]polyunsaturated fatty acids; [a,b]$P < 0.05$

which is a source of high-quality protein. These diets may become a practical alternative to cereal diets containing soya, as a source of supplementary protein.

Our results are in accordance with Flis et al. (1996), who gave evidence of potential complete replacement of soya in the growing pig diets with non-dehulled yellow lupine, cv. Juno. Provided the essential amino acids are supplemented and the energetic value increased, 20% inclusion of the above-mentioned lupine can be used. On the other hand, King et al. (2000) and Van Nevel et al. (2000) observed growth depression, decreased feed intake and FCR reduction when 30% inclusion of white lupine was used in diets. Even though dehulling can result in a marked improvement of the nutritive value of lupine seeds, King et al. (2000) failed to find a beneficial effect of dehulling and supplementation with amino acids. They presumed an adverse effect of antinutritional substances such as alkaloids, α-galactosides etc. According to Schulze et al. (1995), the level of crude fibre affects digestibility of proteins and different amino acids and it is likely that due to this fact the feed efficiency of the starter diets containing 15.5 and 31% of non-dehulled lupine (WL 50, WL 100) could be influenced in the present study. The feed containing more crude fibre can be digested to a higher degree in the large intestine possessing a high microbial activity. Different components of the crude fibre enhanced the production and decreased endogenous nitrogen resorption (Rowan et al., 1994). In this case, barley should be replaced by raw materials with low crude fibre content such as maize or wheat, as documented by Barnett and Batterham (1981).

The resulting efficiency follows from the good health of pigs during the entire experiment. The effect of the diets on biochemical parameters of blood plasma of pigs is presented in Table 6. The

Table 8. Carcass characteristics and meat quality of pigs fed different diets

Indices	Diet[1]					SEM
	SBM	WL 50	WL 100	DL 50	DL 100	
BW[2] before slaughter (kg)	106.8	106.1	105.7	104.2	107.8	0.73
Dressing percentage (%)	79.4	79.1	79.3	79.3	79.2	0.08
Estimated lean yield (%)	58.2	59.2	58.2	59.7	56.8	0.44
Backfat thickness (mm)	21.5	18.6	22.0	19.5	20.0	0.54
MLLT[3] depth (mm)	68.6	66.5	66.2	67.0	67.4	0.56
pH_1	6.21	6.26	6.16	6.17	6.11	0.02
pH_{24}	5.34	5.33	5.29	5.31	5.29	0.01
Contents in *MLLT*[3]						
Dry matter (g/100 g)	25.62	25.91	25.72	25.90	25.63	0.05
Crude protein (g/100 g)	22.30	22.16	22.25	22.13	22.21	0.07
Intramuscular fat (g/100 g)	2.23	2.60	2.25	2.65	2.21	0.08
Sensory evaluation[4]						
Colour	71.90	75.94	70.89	71.50	73.86	0.64
Texture	69.98^{b}	76.91^{a}	68.21^{b}	71.33^{ab}	68.79^{b}	0.83
Juiciness	63.96	68.65	63.13	68.55	66.56	0.77
Odour	77.88	80.78	75.43	77.58	76.74	0.68
Taste	71.79	76.09	69.53	72.34	72.36	0.81

[1]see Table 2; [2]body weight; [3]*musculus longissimus lumborum et thoracis*; [4]for expression of sensory quality, a 10-cm unstructured seven-point graphic scale was used; the value could be read as both points and percentages; $^{a,b}P < 0.05$

analysed parameters of protein, glycide and mineral metabolism were mostly in the range of physiological values (Tlučhoř, 2001) and indicated well-balanced homeostasis of the organism. The cholesterol level was significantly lower ($P < 0.05$) in DL 100 group in comparison with the control group and WL 50 group. The levels of HDL lipoprotein were higher ($P < 0.05$) in WL 50 in comparison with groups DL 50 and DL 100. The good health status was documented by the fact that no symptoms of clinical disease were observed, except for inapparent, chronic respiratory problems in one barrow (DL 50). No digestive problems were noted and no gross lesions of internal organs were observed after slaughter.

The proportions of fatty acids in the *MLLT* muscle are presented in Table 7. A significantly higher ($P < 0.05$) proportion of stearic acid (C 18:0) was detected in WL 100 group in comparison with the control group. Due to the lupine inclusion in the diet, a beneficial, significantly lower ratio of n-6/n-3 PUFA ($P < 0.01$) was detected in experimental animals fed diets containing WL 100, DL 50 and DL 100. There is a paucity of information in the literature at present about the effect of lupine on the FA profile in the lipid component of pork (Van Nevel et al., 2000; Leiukus et al., 2004). The obtained results are comparable with the results reported by Mieczkowska and Smulikowska (2005), who tested the effect of white lupine, cv. Bardo. The PUFA concentrations and n-6/n-3 ratio in all tissues depend on their dietary intake because pigs cannot *de novo* synthesise fatty acids of n-6 and n-3 families (Wiseman et al., 2000).

The inclusion of whole or dehulled seeds of lupine in the diets for experimental pigs did not affect significantly the monitored carcass parameters in comparison with control animals (Table 8). The obtained results are comparable with data reported by Donovan et al. (1993) and Flis et al. (1996). A lower dressing percentage of animals receiving the highest amount of lupine seeds was observed by King et al. (2000) due to a larger gut fill caused by a higher crude fibre content in the diet. No significant effect of experimental diets on the CP and intramuscular fat content in *MLLT* was confirmed and the obtained data approached the requirements for the best quality of pork (Fernández et al., 1999).

Evaluating the results of sensory analysis from an aspect of the used diets, marked differences were observed only in texture (Table 8). Meat from pigs fed the diet containing non-dehulled lupine (WL 50) was characterized as most tender in comparison with SBM and DL 100 diets ($P < 0.05$) or WL diet 100 ($P < 0.01$). There is a paucity of data concerning the effect of lupine feeding on sensory characteristics of pork. Leikus et al. (2004) only detected a reduction in the colour intensity of meat in pigs fed a diet containing 15% of white lupine.

CONCLUSIONS

The present study indicates that white lupine cv. Butan can be used for the complete replacement of supplementary soya protein in the diet for market pigs. The prerequisite of the guarantee of a full-value diet is maintaining the balance of the essential amino acids, especially methionine. Dehulling of the lupine seeds increased the feed efficiency of the diets. Lupine supplemented into the pig diet significantly decreased the n-6/n-3 PUFA ratio in the lipid fraction of pork and can be highly involved in the production of functional food for consumers.

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