Nutritional value of white lupine cultivar Butan in diets for fattening pigs

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ABSTRACT: The aim of our study was to assess the nutritional value of whole and dehulled ground seeds of *Lupinus albus* L., cv. Butan by the determination of balance digestibility of nutrients in growing pigs at different levels of replacement of soy protein with lupine. The experiment was performed on 25 pigs of hybrid combination Pietrain × (Duroc × Large White × Landrace) with initial body weights of 30.7 ± 2.21 kg. The feed compound of the control group contained extracted soybean meal (ESM). In four experimental diets, 50% and 100% replacement of soy protein with the inclusion of whole (WL 50, WL 100) or dehulled (DL 50, DL 100) lupine was carried out. Nutrient and amino acid digestibility was determined using the indicator of insoluble ash in 4M HCl in pigs with a mean live body weight of 48.9 ± 3.51 kg . Higher digestibility of crude protein ($P < 0.01$), ether extract ($P < 0.01$), crude fibre ($P < 0.01$), NDF, ADF ($P < 0.05$), and cellulose ($P < 0.05$) was found for the diet WL 50 compared with the control group ESM. In the diet DL 50, higher digestibility of crude protein, ether extract, crude fibre, NDF, and cellulose ($P < 0.01$) was recorded compared with the control. Higher digestibility of lysine and threonine ($P < 0.01$) was found in the diet WL 50 in comparison with ESM; a lower digestibility of methionine ($P < 0.01$) was found in the diet DL 50. Lower digestibility of crude protein, NDF, ADF ($P < 0.01$), and cellulose ($P < 0.01$) was found at 100% supplementation of soy protein with whole seed lupine (WL 100) compared to the control. A 100% replacement of soy protein with dehulled lupine (DL 100) resulted in significantly higher digestibility of dry matter ($P < 0.01$), crude protein ($P < 0.05$), ether extract ($P < 0.01$), crude fibre ($P < 0.01$), N-FE ($P < 0.01$), organic matter ($P < 0.01$), NDF ($P < 0.01$), ADF, and cellulose ($P < 0.01$) compared with the control diet. In this case, digestibility of threonine ($P < 0.01$) and lysine was higher, that of methionine was lower. The highest concentration and daily output of diaminopimelic acid (DAPA) were observed in the diet WL 100. Daily gains in live body weight were nonsignificantly higher in all experimental animals compared with the controls, the most beneficial conversion being a 100% replacement of soy protein with dehulled lupine (DL 100).

Keywords: lupine; dehulled; nutrients; amino acids; digestibility; diaminopimelic acid; growth

Lupine is rated as being among eight potential sources of plant protein for the production of feeds and foods (Dijkstra et al., 2003). The seeds of sweet lupine cultivars (*Lupinus albus*, *L. angustifolius*, *L. luteus*) contain 28 to 48% crude protein in dry matter depending on lupine cultivar and climatic conditions (Sousa et al., 1996; Linnemann and Dijkstra, 2002). The amino acid profile is characterized by a lower level of sulphur containing amino acids and threonine in comparison with soybean (Simon and Jeroch, 1999); in contrast, arginine content is markedly higher (Suchy et al., 2005). The lipid content is 5 to 13%, high percentages (up to 80%) of unsaturated fatty acids are represented by linoleic and linolenic acids (Yanez et al., 1983) and the average levels of metabolized energy for pigs are slightly lower in comparison with soybean. In contrast to other leguminous plants, lupine seed contains more crude fibre; a proportion of which is viewed as dietetically beneficial (Johnson and Gray, 1993).

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The seed contains minute amounts of starch (5 to 12%), higher levels of soluble non-starch polysaccharides (NSP) and α-galactosides that cannot be digested by endogenous enzymes (Taverner et al., 1985); under such conditions, a decreased utilization of nutrients and energy, disturbed health status and low performance of pigs have been recorded (Batterham, 1992; Veldman et al., 1993; Gdala et al., 1997). The polysaccharide content of lupine cotyledon is predominantly constituted by galactan, and the hull is mainly comprised of cellulose or hemicellulose. The lupine hull makes up 25% of the grain and is low in lignin (Jean-Marc and Carre, 1989). The polysaccharide composition of lupine hull and cotyledons was reported by Mohamed and Rayas-Duarte (1995). Lupine cotyledons contained 21.5 and 2.2% insoluble and soluble fibre, respectively, the whole hull contained 86.2 and 1% insoluble and soluble fibre, respectively. The content of anti-nutrient substances, particularly quinolizidine alkaloids, is markedly decreased in new sweet lupine cultivars in comparison with bitter cultivars (Aniszewski et al., 2001). The content of other anti-nutrient substances (trypsin and chymotrypsin inhibitors, tanins, phenolic substances, lectins etc.) is relatively low and seeds of these cultivars do not require heat treatment and may be fed unprocessed to animals.

Current data concerning the use of lupine in the nutrition of pigs are controversial. Decreased growth and feed intake were observed in pigs fed a diet containing 150–430 g/kg *L. albus* seeds (Batterham, 1992; Roth-Maier and Kirchgessner, 1993; Zettl et al., 1995). Van Nevel et al. (2000) and King et al. (2000) described growth depression, decreased feed intake and reduced feed conversion rate (FCR) at 30% inclusion of white lupine to the feed compound. Moreover, King et al. (2000) failed to demonstrate a positive effect of seed dehulling and amino acid supplementation, and suggested a possible negative effect of anti-nutritional substances, e.g. alkaloids, α-galactosides or high content of manganese. In contrast, Gdala et al. (1996) did not find growth depression in pigs with *L. angustifolius* supplementation of 410 g/kg of diet compared with barley and soybean based diets. Beneficial effects of feeding yellow lupine, cv. Juno, were reported by Flis et al. (1996). Fernandez and Batterham (1995) studied the nutritional value of dehulled and whole lupine seeds for fattening pigs; the effect of dehulling on the digestive utilization of nutrients and energy and the digestible and metabolisable energy of *L. angustifolius* in fattening pigs and adult sows was investigated by Noblet et al. (1998); the ileal digestibility of nutrients and nitrogen balance in *L. albus* with the addition of α-galactosidase was studied by Froidmont et al. (2005).

The purpose of our study was to investigate the nutritional value of non-hulled and dehulled ground seeds of *L. albus*, cv. Butan as well as to determine the balance digestibility of nutrients in growing pigs at different levels of protein supplementation.

MATERIAL AND METHODS

Animals and diets

Twenty-five hybrid Pietrain × (Duroc × Large White × Landrace) barrows with an initial live body weight of 29.3 to 31.5 kg were used in the study. Whole (WL) and dehulled (DL) seeds of *L. albus* cv. Butan cultivated in the Czech Republic were used in the experiment. Five experimental feed compounds were based on cereals (barley, wheat) and feed supplements. The feed compound of the control group contained extracted soybean meal (ESM). In the four experimental diets, feed compounds with partial (50%) or total (100%) replacement of soy protein with whole (WL 50 and WL 100) or dehulled (DL 50 and DL 100) lupine were prepared (Table 1). Feed compounds were designed for the first stage of fattening of meat type pigs with a 56% proportion of musculature as isonitrogenous and isoenergetic (Simecek et al., 1993).

Experimental design

The animals were earmarked by tattooing and housed in pens of five animals each, under suitable hygienic conditions in accredited animal facilities at the Veterinary Research Institute, Brno (approved project of experiment No. 588 by the Ministry of Agriculture of the Czech Republic). Average surface space was 1.7 m^2 and the length of the feeding place was 0.3 m. Straw was used as bedding. Before initiation of the experiment, the animals were dewormed (Ivomec, inj., Agvet, USA). Mean live body weight of the animals was 30.7 ± 2.21 kg. Average ambient temperature and relative humidity were 19.5 ± 3.1°C and 57.3 ± 12.2%. After an adaptation period, the animals were divided into five groups based on live weight. In the course of the experiment the pigs were fed partly *ad libitum* twice a day at 7 a.m. and 4 p.m.; the diets were mixed with drinking water in a 1:1 ratio. Thirty minutes after the beginning of feeding, unconsumed food was weighed and taken into account in the calculations of feed consumption.

The animals were fed the experimental diets for 46 days. The live body weight of pigs was taken at weekly intervals (each time 2 h post feeding) and individual and group body weight gains (BWG) were calculated. FCR was determined from the feed consumption and BWG of the respective groups. Nutrient digestibility was determined using the indicator of insoluble ash in 4M HCl in pigs with an average body weight of 48.9 ± 3.51 kg that were placed in metabolic cages for five days. About 100 g of faeces were collected from individual animals twice a day, stabilized with 10% HCl and chloroform, and stored in the fridge until further use. After the termination of the balance period, the faeces were homogenized and the dry matter and crude protein contents were determined. For further analyses, the faeces were dried at 60°C and ground. Apparent digestibility of dry matter, crude fibre, amino acids, ether extract, neutral detergent fibre (NDF), acido detergent fibre (ADF), cellulose, ash, nitrogen-free extracts (N-FE), and organic matter were determined as well as the concentration and daily output of diaminopimelic acid (DAPA).

Chemical analysis

Ground samples of lupine seeds, feed compounds and faeces were analysed for their content of dry matter, crude protein (N × 6.25), ether extract, crude fibre and ash using AOAC methods (AOAC, 2001). The content of insoluble ash in 4M HCl (AOAC, 2001) was determined in the samples of experimental diets and faeces. Determination of NDF, ADF, and ADL was performed according to the technique described by Van Soest et al. (1991). Cellulose content was determined by deducting ADL from ADF. Before the analysis of amino acids and DAPA, the samples were processed with acid and oxidative analysis with 6M HCl. The samples were analysed (Official Journal L 206, 1978) using AAA 400 analyser (INGOS, Prague, Czech Republic). Mono- and disaccharides in lupine samples were detected by liquid chromatography (Dionex) on an anion exchanger with pulsed amperometric detection (HPAEC-PAD). Isocratic elution chromatography was used for the detection of monosaccharides, and a gradient mobile phase was employed for the detection of disaccharides (Erbas et al., 2005).

Statistical analysis

The results obtained were processed by statistical methods using the statistical and graphic software STAT Plus (Matouskova et al., 1992). Analysis of the obtained data was performed by one-way ANOVA, using the Tukey test.

RESULTS

Chemical composition of lupine seeds

The chemical composition of WL and DL seeds in comparison with ESM is shown in Table 2. In the samples of lupine seeds, the contents of crude protein were 384.8 and 435.7 g/kg while in ESM it was 510.0 g/kg. This corresponded with the levels of indispensable and dispensable amino acids which were higher in DL seeds compared with WL seeds, and the highest levels were in ESM. Lysine content was 21.0, 22.6 and 31.5 g/kg in WL, DL and ESM, respectively; methionine content was 4.3, 5.0 and 7.2 g/kg; threonine content was 14.3, 15.8 and 20.1 g/kg; and arginine content was 43.8, 51.0 and 37.5 g/kg. Ether extract in WL and DL seeds was 79.1 and 102.3 g/kg compared with 15.0 g/kg in ESM. Crude fibre content in WL and DL seeds was 152.6 and 37.7 g/kg, respectively; in ESM the content was 70.0 g/kg. The determination of saccharide contents revealed higher levels in DL seeds; the total content was 104.3 compared with 81.7 g/kg in the WL seed.

Digestibility of the diets

The apparent total nutrients digestibility coefficients are shown in Table 3. Significantly higher ($P < 0.01$; $P < 0.05$) or identical digestibility of the investigated indicators was found at 50% replacement of soy protein with WL and DL seed (WL 50, DL 50) compared with the control group ESM; the digestibility coefficient of ash was the only significantly lower ($P < 0.05$) indicator in the DL 50 diet. At 100% replacement of soy protein with

WL seeds (WL 100), lower digestibility coefficients were reported compared with the control, especially for crude protein, ADF ($P < 0.01$) and cellulose ($P < 0.01$). At 100% replacement of soy protein with dehulled lupine (DL 100), a significant increase in all digestibility coefficients under investigation (except for ash and ADF) compared with the control were calculated. Digestibility coefficients ranged as follows: dry matter from 81.9 (WL 100) to 85.7% (WL 50), crude protein from 77.3 (WL 100) to 81.0% (DL 100), ether extract from 43.3 (ESM) to 58.5% (DL 100), crude fibre from 37.9 (ESM) to 47.5% (DL 100), ash from 51.7 (DL 50) to 58.9% (WL 50), NDF from 53.5 (WL 100) to 62.0% (DL 100), ADF from 39.0 (WL 100) to 57.8% (WL 50), and cellulose from 36.8 (WL 100) to 63.1% (DL 100). The results clearly indicate that most beneficial digestibility coefficients were to be found in the WL 50 and DL 100 diets.

Amino acid digestibility

Data on the apparent amino acids digestibility coefficients are presented in Table 4. At 50% replacement of soy protein with WL seeds (WL 50), higher digestibility of both indispensable and dispensable amino acids 83.2 vs. 81.1% and 83.8 vs. 80.6%, respectively, were found compared with the control ESM. With regard to essential amino acids, higher digestibility was described for lysine 83.3% vs. 80.7% in ESM, and for threonine 81.2% vs. 76.5% ($P < 0.01$). Methionine digestibility did not increase; however, significantly lower ($P < 0.01$) methionine digestibility was found in the DL 50 diet compared with the control (80.4% vs. 84.4%). At 100% replacement of soy protein with WL seeds (WL 100), lower digestibility of both indispensable and dispensable amino acids compared with the control was observed (79.2% vs. 81.1% and 78.9% vs. 80.6%, respectively); methionine digestibility was significantly lower ($P < 0.01$) with this diet (80.2% vs. 84.4%). At 100% replacement of soy protein with DL seed (DL 100), significantly higher ($P < 0.01$; $P < 0.05$) digestibility was reported for indispensable (phenylalanine) and dispensable (cystine, glutamic acid, proline, serine and tyrosine) amino acids (with average values of 83.2% vs. 81.1% and 83.4% vs. 80.6%, respectively). Of the essential amino acids, higher digestibility ($P < 0.01$) was noted in the case threonine and lysine, whilst lower digestibility was seen for methionine (83.7% vs. 84.4%).

Diaminopimelic acid (DAPA)

At 50% replacement of soy protein with WL and DL seeds (WL 50, DL 50), non-significantly lower or identical DAPA concentrations were found in faeces compared with the control, and a significantly lower ($P < 0.01$) daily output of DAPA was observed. At 100% replacement of soy protein with WL, DAPA concentrations were non-significantly higher ($P < 0.01$), and the daily output of DAPA was significantly higher ($P < 0.05$) compared with the control and the WL 50 diet. At 100% replacement of soy protein with DL seeds (DL 100), DAPA concentrations and the daily output of DAPA were significantly lower ($P < 0.05$) compared with the control and the WL 100 diet (Table 5).

Growth performance of pigs

No marked difference was observed in the daily intake of feed compounds (2.03 to 2.10 kg/day) between the control and the experimental groups. Daily live weight gains were non-significantly higher in all experimental animals compared with the controls (Table 6). At 50% replacement of soy protein with WL seeds, live weight gains were higher by 3.8%, and at 100% replacement (DL 100) by 5.5%, compared with the control (ESM). This was in accordance with the coefficients of nutrient digestibility, amino acids (Table 3 and 4), and FCR. The non-significant lowest feed conversion (2.53 kg/kg) was observed at 100% replacement of soy protein with WL seeds (WL 100).

DISCUSSION

Genetically selected lupine cultivars with a low content of quinolizidine alkaloids represent an alternative source of protein that can replace soybean, especially in the diets of monogastric animals. The total content of alkaloids is generally low in lupine seed, and for the cv. in question, Butan, Ciesolka et al. (2005) described their values as ranging from 0.51 to 1.29 g/kg. The total content of saccharides in WL seeds (81.7 g/kg) and DL seeds (104.3 g/kg) used in the experiment (Table 2) was consistent with the values obtained by Ciesolka et al. (2005) and ranged from 64.0 to 105.4 g/kg. Dehulling of the used lupine seeds resulted in an increased content of nutrients and amino acids, and a decreased

Table 1. Composition and nutrient content in original dry matter of the diets

Item	Diet				
	ESM	WL 50	WL 100	DL 50	DL 100
Ingredient (%)					
Wheat	45.5	41.2	36.7	43.85	41.8
Barley	31.0	31.0	31.0	31.0	31.0
Corn	5.0	5.0	5.0	5.0	5.0
Extracted soybean meal 46% CP	14.0	7.0	–	7.0	–
Lupine	–	11.0	22.2	8.0	16.5
L-lysine HCl 40%	1.2	1.3	1.4	1.4	1.55
D,L-methionine 40%	0.2	0.3	0.35	0.3	0.4
L-tryptophan 10%	–	0.1	0.2	0.25	0.45
L-threonine 20%	0.7	0.75	0.8	0.85	0.95
Bolifor DCP-N	1.1	1.1	1.15	1.1	1.1
Feeding salt	0.4	0.4	0.4	0.4	0.4
Ground limestone	0.7	0.65	0.6	0.65	0.65
A1-CDP-HD 0.2%[1]	0.2	0.2	0.2	0.2	0.2
Nutrients (g/kg)					
Dry matter	888.7	890.0	889.0	890.0	888.7
Crude protein	181.9	182.5	180.1	179.6	182.0
Lysine	11.1	11.4	11.3	11.5	11.5
Methionine	4.5	4.6	4.3	4.6	4.3
Threonine	6.0	6.7	6.7	6.8	6.5
Fat	17.1	25.4	25.0	27.2	27.0
Fibre					
Crude	34.5	36.7	38.8	34.0	32.0
NDF	107.0	106.5	116.7	108.2	101.8
ADF	74.3	78.1	61.8	68.6	62.0
Cellulose	66.4	68.0	36.8	39.6	59.1
Ash	54.6	52.6	52.3	54.3	49.4
N-FE*	610.6	592.8	585.8	604.3	610.3
OM*	834.1	837.4	836.7	835.7	839.3
MEp (MJ/kg)*	12.9	12.9	12.8	13.0	13.1
Lysine/MEp (g/MJ)*	0.86	0.88	0.88	0.88	0.88

ESM = extracted soybean meal; WL = whole lupine; DL = dehulled lupine; N-FE = nitrogen-free extracts; OM = organic matter; MEp = metabolizable energy

[1] Commercial supplement containing the following per kg: 335 000 IU vitamin A, 45 000 IU vitamin D, 125 mg vitamin K, 2 665 mg vitamin E, 5.3 mg vitamin B_1, 165 mg vitamin B_2, 14 mg vitamin B_6, 1.10 mg vitamin B_{12}, 165 mg niacin, 250 mg pant. calcium, 1 000 mg cholinchlorid, 0.8 mg biotin, 6 600 mg vitamin C, 110 g L-lysine HCl, 33 g D,L-methionine, 55 g L-threonine, 15 mg Co, 65 mg I, 11 mg Se, 660 mg Cu, 1 585 mg Mn, 3 500 mg Zn, 2 080 mg Fe, 56 g Na, 12 g Mg, 80 g P, 205 g Ca, 833 mg Endox, 11 250 mg Bio-plus 2B, 2 900 mg Natuphos 5 000G, 665 mg Saccharin

*calculated

Table 2. Analyzed nutrient composition of the ingredients used in the experiment (in dry matter)

	Lupine seed meal		Extracted soybean meal
	whole	dehulled	
Nutrient (g/kg)			
Crude protein	384.8	435.7	510.0
Fat	79.1	102.3	15.0
Fibre			
Crude	152.6	37.7	70.0
NDF	216.0	86.3	183.9
ADF	174.6	54.5	108.0
Cellulose	150.3	54.2	102.3
Ash	41.1	42.7	70.0
N-FE	342.4	395.1	335.0
OM	958.9	957.3	930.0
Saccharides			
Galactose	0.10	0.19	–
Glucose	0.07	0.15	–
Fruktosa	0.32	0.39	–
Saccharose	24.9	26.3	–
Raffinose	7.02	7.92	–
Stachylose	43.4	59.1	–
Lactose	0.20	0	–
Verbascose	7.47	10.3	–
Total	83.5	104.3	–
Amino acids			
Indispensable			
Arginine	43.8	51.0	37.5
Histidine	11.9	12.8	13.5
Isoleucine	15.0	17.3	25.2
Leucine	24.1	26.9	39.5
Lysine	21.0	22.6	31.5
Methionine	4.3	5.0	7.2
Phenylalanine	13.6	13.6	25.6
Threonine	14.3	15.8	20.1
Valine	14.4	16.1	24.7
Total indispensable	162.4	181.1	224.8
Dispensable			
Alanine	12.3	13.8	20.5
Aspartic acid	40.7	45.9	54.1
Cystine	7.7	9.8	7.7
Glutamic acid	58.1	64.4	80.8
Glycine	14.6	16.4	20.5
Proline	16.1	18.3	28.9
Serine	19.5	22.3	26.2
Tyrosine	9.2	9.3	18.6
Total dispensable	178.2	200.2	257.3

content of fibre and its components. The detected values (Table 2) can be compared with the values reported for both WL and DL white lupine seeds (g/kg): crude protein 311 vs. 405, crude fat 46 vs. 76, crude fibre 172 vs. 51, NDF 313 vs. 110, lysine 16 vs. 20, methionine 1.6 vs. 2.1, threonine 12 vs. 15 (Fernandez and Batterham, 1995). In the studies of Brenes et al. (1993), dehulled sweet lupine seeds were found to contain 72% and 73% less ADF and NDF, respectively, than whole seeds.

Nutrient content in experimental diets was in agreement with the requirements for fattening of meat type pigs with a 56% proportion of musculature (Simecek et al., 1993). Inclusion of the tested lupine, at either 11.0% and 22.2% of WL seeds (diet WL 50 and WL 100) or 8.0% and 16.5% of DL seeds (diet DL 50 and DL 100) represented a 50% or 100% replacement of the protein in extracted soy meal. The lower biological value of lupine protein documented by the lower contents of essential amino acids lysine, methionine, threonine (Table 2) and tryptophan (Batterham, 1992; Fernandez and Batterham, 1995) was compensated by their supplementation. With regard to crude protein content and concentration of metabolisable energy, the diets were isonitrogenic and isoenergetic, with a balanced lysine to MEp ratio (Table 1).

Data from the literature has reported unbalanced values of nutrient digestibility in dehulled lupine compared with whole seeds at different proportions in a diet, and in comparison with soybean. Fernandez and Batterham (1995) found that lysine retention as a proportion of ileal digestible intake was, lupine seed meal 0.70, kernel (dehulled lupin-seed meal) 0.68, soybean meal 0.64, soybean meal plus hulls 0.69; moreover, their results suggest a mild decrease in the digestibility of dehulled lupine. The effect of dehulling on the nutritional value of white lupine seeds was investigated by Flis et al. (1997) who found higher contents of metabolisable energy (16.0 vs. 14.1) and digestible protein (371 vs. 295 g/kg) in dehulled seeds, but less crude fibre (42 vs. 129 g/kg) than in whole seeds. Noblet et al. (1998), in experiments with growing pigs, described digestibility coefficients of energy of 77, 81, and 40% in whole seeds, dehuled seeds, and hulls, respectively; corresponding digestible energy contents were 15.7, 16.8, and 7.3 MJ/kg of dry matter.

The results of this experiment describe a higher nutritional value of diets with lupine inclusion. The beneficial effects of lupine seed dehulling was demonstrated at 100% replacement of extracted soybean meal protein with lupine which resulted in improved parameters of nutrient and amino acid digestibility. A 50% replacement of soy protein (WL 50 and DL 50) and 100% replacement with DL seeds resulted in increased nutrient digestibility. Amino acid digestibility was higher in the WL 50 diet compared with the control, while in DL 50 digestibility was identical with the control or even lower; significantly lower digestibility was found

Table 3. Apparent nutrient digestibility coefficients (%) for growing pigs

Indices	ESM	WL 50	WL 100	DL 50	DL 100	SEM
Dry matter	83.5	85.7^{A}	81.9^{E}	83.7^{F}	85.6^{DIJ}	0.35
Crude protein	78.2	80.8^{A}	77.3^{E}	79.4^{F}	81.0^{dIJ}	1.06
Ether extract	43.3	57.0^{A}	56.9^{Be}	55.0^{FH}	58.5^{DJ}	3.80
Crude fibre	37.9	45.5^{A}	39.2^{E}	38.4^{F}	47.5^{DIJ}	2.92
NDF	55.9	60.2	53.5^{E}	57.8	62.0^{DI}	1.69
ADF	52.8	57.8^{a}	39.0^{BE}	50.0^{FH}	55.0^{Ij}	1.41
Cellulose	42.7	47.4^{a}	36.8^{BE}	51.7^{CfH}	63.1^{DGIJ}	2.46
Ash	55.2	58.9^{A}	52.1^{E}	51.7^{cF}	56.7^{IJ}	1.44
N-free extract	91.9	93.1^{A}	91.4^{E}	91.9^{F}	93.5^{DIJ}	0.41
Organic matter	85.9	87.9^{A}	84.2^{bE}	85.6^{F}	88.2^{DIJ}	0.76

Differences marked with capitals are significant $P < 0.01$; differences with small lletters are significant $P < 0.05$

^{A}ESM:WL 50; ^{B}ESM:WL 100; ^{C}ESM:DL 50; ^{D}ESM:DL 100; ^{E}WL 50:WL 100; ^{F}WL 50:DL 50; ^{G}WL 50:DL 100; ^{H}WL 100: DL 50; ^{I}WL 100:DL 100; ^{J}DL 50:DL 100

Table 4. Apparent amino acid digestibility coefficients (%) for growing pigs

Indices	ESM	WL 50	WL 100	DL 50	DL 100	SEM
Indispensable						
Arginine	91.2	92.2	90.8	91.6	92.7	0.53
Histidine	84.9	84.5	82.1	83.8	85.4	1.19
Isoleucine	76.0	79.1	73.1^{E}	75.2^{f}	79.0^{jI}	1.34
Leucine	80.8	83.0	81.3	80.3	83.0	1.11
Lysine	80.7	83.3	79.2^{E}	80.4	82.8^{i}	0.97
Methionine	84.4	84.4	80.2^{BE}	80.4^{CF}	83.7^{ij}	1.08
Phenylalanine	80.2	82.7^{a}	78.3^{E}	77.9^{cF}	83.1^{DIJ}	1.07
Threonine	76.5	81.2^{A}	75.7^{E}	78.1	82.0^{DIj}	1.37
Valine	75.2	78.0	71.9^{E}	73.8^{f}	77.2^{I}	1.33
Mean indispensable	81.1	83.2	79.2	80.2	83.2	1.01
Dispensable						
Alanine	69.3	71.8	64.0^{bE}	66.0^{f}	68.9	1.68
Aspartic acid	74.6	78.0	69.0^{BE}	72.9^{f}	76.2^{I}	1.66
Cystine	82.3	88.6^{A}	85.6^{BE}	86.5^{C}	89.2^{DjI}	1.22
Glutamic acid	88.5	91.0^{A}	87.7^{Eh}	89.8	91.1^{DI}	0.73
Glycine	76.3	79.6	73.6^{E}	75.8^{f}	78.9^{I}	1.27
Proline	89.3	91.0^{a}	88.7^{E}	89.9	91.4^{DI}	0.58
Serine	83.5	86.6^{a}	81.9	83.7^{Ef}	86.2^{dI}	0.99
Tyrosine	80.7	83.5^{A}	80.5^{E}	78.8^{CFh}	85.1^{DgIJ}	1.08
Mean dispensable	80.6	83.8	78.9	80.4	83.4	1.10

Differences marked with capitals are significant $P < 0.01$; differences with small lletters are significant $P < 0.05$
^{A}ESM:WL 50; ^{B}ESM:WL 100; ^{C}ESM:DL 50; ^{D}ESM:DL 100; ^{E}WL 50:WL 100; ^{F}WL 50:DL 50; ^{G}WL 50:DL 100; ^{H}WL 100: DL 50; ^{I}WL 100:DL 100; ^{J}DL 50:DL 100

in methionine. A 100% replacement of soy protein with WL seeds induced lower values of nutrient digestibility parameters, especially for crude protein and structured fibre NDF and ADF, cellulose, and amino acids (except for leucine and cystine); of the essential amino acids, lower digestibility was found for lysine, threonine and especially in methionine. These results were in accordance with the findings of Batterham (1992) who described a lower content and availability of methionine in the pig gastrointestinal tract. Zraly et al. (2007) confirmed the positive effect of lupine-containing diets on growth, feed intake and feed efficiency when supplemented with lysine, methionine and threonine. Schulze et al. (1995) investigated the effect of dietary fibre on the digestibility of protein and individual amino acids. In high-fibre diets digestion occurs predominantly in the large intestine where higher microbial activity can be found. Individual fibre components (NDF, ADF, ADL – hemicelluloses and/or lignin) induce an increase in production and a decrease in reabsorption of endogenous nitrogen (Rowan et al., 1994). This hypothesis is supported by our finding that the highest concentration and daily output of DAPA took place in the WL 100 diet.

The obtained results regarding growth performance and feed conversion in pigs are in accordance with the results of nutrient and amino acid digestibility. The highest BWG were obtained at 50% replacement of soy protein with WL seeds and 100% replacement with DL seeds, the most beneficial conversion being found in the DL 100

Table 5. Mean concentrations (dry matter) in the faeces and daily excretions of diaminopimelic acid (DAPA) of growing pigs

DAPA	ESM	WL 50	WL 100	DL 50	DL 100	SEM
Concentration (mg/g)	0.390	0.380	0.469^{e}	0.390	0.373^{i}	0.024
Daily output (mg/day)	143.7	90.5^{A}	158.4^{E}	107.4^{Ch}	87.8^{Di}	12.2

Differences marked with capitals are significant $P < 0.01$; differences with small lletters are significant $P < 0.05$
^{A}ESM:WL 50;^{C}ESM:DL 50;^{D}ESM:DL 100;^{E}WL 50:WL 100; ^{I}WL 100:DL 100

Table 6. Feed intake, body weight gain and feed efficiency of growing pigs

Indices	ESM	WL 50	WL 100	DL 50	DL 100	SEM
Initial BW (kg)	31.5	30.9	30.7	31.2	29.3	0.38
Final BW (kg)	68.8	69.6	68.9	69.6	68.6	1.23
Feed intake (kg/day)	2.03	2.06	2.10	2.07	2.05	0.01
BWG (g/day)	810	841	830	836	855	0.02
BWG (kg/kg)	2.50	2.45	2.53	2.47	2.40	–

diet. These positive results suggest a prospective use of dehulled and whole seeds of white lupine cultivar Butan as a replacement for soy protein in the nutrition of fattening pigs. Our results are consistent with the findings of Flis et al. (1996), using white lupine, cv. Juno, and those of Fernandez and Batterham (1995) who used *L. angustifolius*, cv. Gungurru. The latter reported the growth response of pigs fed the lupine seed meal diet to be greater than in the diets containing kernel or soy bean meal. Zraly et al. (2006, 2007) described a comparable production performance of white whole lupine, cv. Amiga compared with a control diet containing animal protein, and a higher production efficiency of the above lupine in compared with a control diet containing extracted soy meal, when the diet was balanced by supplementation with the limiting amino acids.

CONCLUSIONS

Generally, we can state that dehulled white lupine (*L. albus,* cv. Butan) can fully replace soy bean protein in diets for fattening pigs. Whole lupine seeds can replace 50% of soy protein, though performance characteristics at 100% soy protein replacement with whole lupine were comparable with those obtained in the control soy-based diet. A lower biological value of protein from the lupine cultivar used needs to be balanced by supplementation with limiting amino acids, predominantly methionine.

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