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Effect of variety and dehulling on nutritional value of white lupin seeds for growing pigs*

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ABSTRACT

The nutritional value of three Polish varieties of white lupin: whole seeds of an older variety, Wat, a newer variety, Hetman, as well as whole or dehulled seeds of the newest variety, Bardo, was determined in a 36-day growth experiment (Experiment 1) on 25 barrows (30-56 kg BW). Twenty per cent whole seeds or 16.5% dehulled seeds were added to the diet at the expense of the soyabean oilmeal which was decreased from 19% in the control diet to 6-9% in the experimental diets.

In comparison with the control group, daily weight gains and feed utilization were significantly poorer in the pigs fed the diet containing Wat seeds (0.106% alkaloids in DM), while performance of pigs fed Hetman or Bardo lupin (0.035% and 0.052% alkaloids, respectively) was only insignificantly worse. In pigs fed dehulled seeds, fattening performance was the same as in the control group.

In the second experiment (2), nutrients digestibility of the three lupin varieties and dehulled Bardo lupin seeds was determined by difference method. No significant differences in the digestibility of crude protein, crude fibre or N-free extractives were found among the evaluated varieties. Digestibility of energy was the greatest in Hetman seeds. Dehulling the seeds increased digestibility of energy from 80.8 to 86.4% ($P < 0.01$). Dehulled seeds contained more metabolizable energy (16.0 vs. 14.1 MJ/kg) and digestible protein (371 vs. 295 g/kg), while less crude fibre (42 vs. 129 g/kg) than whole seeds.

KEY WORDS : white lupin, dehulling, digestibility, performance, pigs

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INTRODUCTION

The nutritional value of lupin for pigs is determined mainly by its alkaloid content. The studies of Buraczewska et al. (1993) have shown that the dietary alkaloid level tolerated by young pigs depends on the species and variety of lupin and ranges from 90 to 455 mg per kg of diet. These authors also found that pigs are more sensitive to the alkaloids of white lupin than those of narrow-leafed and yellow lupin. It is recommended to use only up to 10-15% of low-alkaloid varieties of white lupin in the diet so as not to decrease the palatability of diet, daily weight gains and feed utilization in fattening pigs (Bourdon et al. 1980; King, 1981; Brand et al., 1995; Zettl et al., 1995).

In Poland, less white lupin is cultivated than other species. For many years only one low-alkaloid variety, Wat, was grown. It has an alkaloid content of about 0.1-0.13% and a low nutritional value for pigs (Fuchs et al., 1983; Flis et al., 1989). Newer varieties (Hetman, Bardo) have lower alkaloid contents – about 0.04-0.08% (Buraczewska et al., 1993; Zduńczyk et al., 1996) and are more suitable for use in pig feeding. The nutritional value of the Hetman variety for young barrows as assessed by Gdala et al. (1996) was only slightly (and insignificantly) less than that of yellow and narrow-leafed lupin.

Another component of lupin seeds affecting their nutritional value for pigs, particularly young ones, is their substantial fibre content (Eggum et al., 1993). For this reason, dehulling may be a good method of decreasing the amount of components with low nutritional value for pigs.

The objective of this study was to determine the nutritional value of three Polish varieties of white lupin (Wat, Hetman, Bardo) and dehulled lupin seeds (Bardo) in pig nutrition.

MATERIAL AND METHODS

The nutritional value of three varieties of lupin and dehulled seeds was assessed in two experiments on the basis of : daily body weight gain, feed utilization and nutrient digestibility in pigs fed diets containing the studied varieties and forms of seeds (Experiment 1); nutrient digestibility of whole and dehulled seeds, determined by a difference method, and digestible energy (DE), metabolizable energy (ME) and digestible crude protein (DCP) contents in seeds (Experiment 2).

The seeds were dehulled using a method developed at the Institute of Agricultural and Machinery and Equipment, Olsztyn University of Agriculture and Technology. Dehulling efficiency was 70%.

Animals and diets

Experiment 1 was conducted on 24 barrows (from Polish Large White sows and Duroc boars), 5 per group, housed individually in metabolic cages. Isonitrogenous diets balanced, according to the Nutrient Requirements of Pigs (1993), were used (Table 1). The protein component of the control group diet was soyabean oilmeal (group C).

TABLE 1

Composition and nutritive value of diets (Experiment 1)

Indices	Groups[1]				
	C	W	H	B	dB
Ingredients, %					
barley	42.41	32.21	34.67	34.20	38.68
wheat	35.0	35.0	35.0	35.0	35.0
soyabean meal (SBM)	19.0	9.0	6.5	7.0	6.0
lupin	–	20.0	20.0	20.0	16.5
minerals[2]	2.4	2.5	2.5	2.5	2.5
mineral-witamin premix	1.0	1.0	1.0	1.0	1.0
L-lysine HCL	0.13	0.20	0.23	0.21	0.23
DL-methionine	0.06	0.09	0.10	0.09	0.09
Chemical composition, %					
dry matter	87.44	87.60	87.59	87.45	87.60
crude protein	17.56	17.45	17.63	17.56	17.94
ether extract	2.94	4.43	4.41	4.20	4.19
crude fibre	4.47	6.15	5.70	5.89	3.88
alkaloids[3]	–	0.019	0.006	0.009	nd
gross energy, MJ/kg	16.39	16.64	16.82	16.56	16.65
Nutrient contents, g/kg					
digestible crude protein	146.3	136.3	143.7	140.3	146.7
lysine[3]	9.02	9.44	9.36	9.30	9.43
methionine[3]	3.09	3.16	3.14	3.12	3.12
threonine[3]	6.23	6.42	6.33	6.23	6.19
Ca	7.6	7.7	7.6	7.6	7.6
P digestible	2.9	3.1	3.1	3.1	3.1
metabolizable energy, MJ/kg	12.87	12.50	12.90	12.70	13.05
SBM crude protein substitution by lupin protein, %	0	67	77	75	76

[1] main protein concentrate in the diet: soyabean meal (S) or lupin seeds v. Wat (W), v. Hetman (H), v. (Bardo (B), dehulled seeds v. Bardo (dB)

[2] dicalcium phosphate 1.2%, limestone 0.9-1.0%, salt 0.3%

[3] calculated from values measured in the feed ingredients (Table 3)

In the experimental diets, 66-77% of the soyabean protein was replaced by lupin: Wat (group W), Hetman (H), and Bardo (B) in amounts of 20% of the diet, and by dehulled Bardo seeds (dB) in an amount of 16.5%. The adaptation period to the experimental diets after switching from the control feed lasted 13 days. The growth experiments were conducted for the subsequent 36 days and ended by determining the nutrients digestibility and nitrogen balance.

Experiment 2 was carried out on the same barrows after completion of Experiment 1. Nutrients and energy digestibility of Wat, Hetman, Bardo and dehulled Bardo seeds were determined by a difference method. The basic diet (Table 2) was fed to one group, three groups were fed diets containing the basic diet (80%) and the studied lupin variety (20%): Wat, Hetman, Bardo; the last group received dehulled Bardo seeds (16.5%) and the basic diet (83.5%). The adaptation period lasted 9 days. The weight of the animals at the beginning of the actual experimental period was about 61 kg (in group W, about 50 kg).

The lupin seeds and cereals used in both experiments were from the same lots. The animals were fed according to Polish standards (1993), twice a day at 7 and 15 h, in moistened form (feed : water as 1:1).

Faeces (Experiments 1, and 2) and urine (Experiment 1) collections were conducted over 5-day periods. Two average samples of about 10% were taken from the daily faeces collection. One preserved with sulphuric acid was used for N determination, the other was dried and used for nutrients and energy

TABLE 2

Composition of basal diet (BD) (Experiment 2)

Indices	
Ingredients, %	
barley	69.3
wheat	20.0
soyabean meal	7.0
dicalcium phosphate	1.2
limestone	1.0
salt	0.3
mineral-vitamin premix	1.0
L-lysine HCL	0.2
Chemical composition, %	
dry matter	86.40
crude ash	4.44
crude protein	13.25
ether extract	2.73
crude fibre	4.57
N-free extractives	61.05
Gross energy, MJ/kg	15.94

determination. Urine was collected in containers with sulphuric acid in an amount lowering pH under 2.

Chemical analysis

The basic composition of feeds and faeces, and urinary N was determined using conventional methods, ether extract (EE) was determined following hydrolysis with HCl. NDF and ADF contents in feeds were determined according to Van Soest and Wine (1967) using a Fibertec apparatus. Soluble sugars were assayed according to Jacórzyński (1986), starch was determined (only in protein feeds) by an enzymatic method (Keppler and Decker, 1970). Total alkaloids (TA) were determined by a gravimetric method according to Wysocka et al. (1989). Total energy in feeds and in dried faeces was determined by combustion in an adiabatic bomb. The ME contents in the feed mixtures (Experiment 1) and in lupin seeds (Experiment 2) were computed on the basis of chemical composition and digestibility coefficients using the formula of Hoffmann and Schiemann (1980), with adjustments for the content of sugars and bacterially fermented structural polysaccharides (Müller and Kirchgessner, 1983). The amino acid composition of protein was determined using a Czech AAAT 339M amino acid analyzer. The essential amino acid index was computed according to Oser, using our own modification (Flis, 1993) in which we replace the amino acid composition of egg protein with the composition of the „ideal" protein for pigs (Wang and Fuller, 1990). The modified essential amino acid index computed this way is denoted M EAAI, and the limiting amino acid is denoted as M CS.

Statistical analysis

The results were subjected to statistical analysis using single factor variance analysis and the Duncan multiple range test.

RESULTS AND DISCUSSION

Hetman and Bardo lupin seeds contained somewhat more crude protein (CP) than the seeds of the Wat variety (36 vs. 32% DM) (Table 3). Lupin Wat contained more ether extract (EE) and crude fibre (CF) in comparison with the other two varieties. The starch content in the lupin seeds was very low (about 0.3% DM), in agreement with previous studies (Bourdon et al., 1980; Eggum et al., 1993). The highest alkaloid content (TA) was in the Wat variety (0.106% DM), i.e. three times more than in Hetman (0.035% DM) and twice that in Bardo

TABLE 3

Chemical composition of feeds, % DM

Ingredients	Soyabean meal	Lupins				Barley	Wheat
		Wat	Hetman	Bardo	dehulled Bardo		
Dry matter	88.97	91.53	91.55	91.20	92.86	85.43	86.63
Crude ash	7.18	4.27	4.43	4.70	5.09	2.75	2.27
Crude protein	51.59	31.85	36.58	36.10	43.27	13.58	12.67
Ether extract	3.53	11.49	10.70	10.39	11.64	3.36	2.98
Crude fibre	7.16	14.94	11.07	12.94	4.22	5.91	3.79
NDF	17.20	23.03	18.66	19.11	11.21	nd	nd
ADF	8.18	19.48	14.90	15.39	5.13	nd	nd
Starch	0.22	0.25	0.34	0.28	0.44	nd	nd
Solube carbohydrates	13.02	11.00	10.97	12.28	13.66	3.56	4.60
Total alkaloids	–	0.106	0.035	0.052	nd	–	–
Gross energy, MJ/kg	20.52	21.27	21.73	21.73	21.44	18.34	17.91
Amino acids, g/16 g N							
Thr	3.88	4.05	3.90	3.72	3.63	3.50	5.15
Cys	1.37	1.83	1.81	1.80	1.82	2.37	2.53
Met	1.41	0.97	0.89	0.92	0.87	1.44	1.65
Val	4.78	4.51	4.25	4.38	4.27	5.35	4.80
Leu	7.57	7.66	7.82	7.39	7.48	6.77	7.10
Ile	4.56	4.47	4.38	4.52	4.49	3.52	3.72
Tyr	3.75	4.48	4.58	4.63	4.91	3.56	3.31
Fen	5.21	3.98	4.19	4.06	4.02	5.43	4.58
Lys	5.86	5.17	4.75	4.90	4.88	3.61	3.16
His	2.41	2.37	2.13	2.19	2.05	2.34	2.38
M EAA[1]	90.2	87.1	83.5	84.2	82.6	86.1	85.1
M CS	64.1	44.1	40.5	41.8	39.6	55.5	48.6
Limiting AA	Met	Met	Met	Met	Met	Lys	Lys

[1] M EAAI – modified EAAI; M CS – modified CS – for detailes see Material and Methods

(0.052% DM). Buraczewska et al. (1993) also found that Wat had a higher TA content than Bardo and Hetman.

Dehulling lupin seeds (var. Bardo) increased their CP content from 36 to 43% DM (about 20%) and decreased NDF content by 41%, ADF and CF by 67%. These changes in the concentration of nutrients after dehulling lupin are comparable to those found by other authors (Brenes et al., 1993; Fernandez and Batterham, 1995; Smulikowska et al., 1995).

The M EAAI of Wat protein was a little higher than that of the Bardo and Hetman varieties (Table 3). The M CS index confirms that the first amino acid limiting the value of lupin seed protein for pigs is methionine, which occurs in amounts covering only 40-44% of the pig's requirements for this amino acid. Both the studies of Gdala et al. (1994) and our results show that it is necessary to

balance methionine and not total sulphur-containing amino acids in diets of pigs and poultry containing considerable amounts of lupin. Dehulling seeds slightly lowered the content of some essential amino acids, thus of M EAAI and M CS.

In the adaptation period preceding the Experiment 1, the pigs were least willing to eat the diet containing Wat seeds, which contained 0.019% TA, due to which the weight gains and body weight in this group were lower when the experiment began (Table 4).

TABLE 4

Growth performance, digestibility coefficients and N balance results (Experiment 1)

Indices	Groups[1]					Level significance
	C	W	H	B	dB	P
No of animals	5	4	5	5	5	
BW[2] at the beginning of adaptation period, kg	22.7	23.1	22.8	22.9	23.4	
BW at the beginning of experiment, kg	30.3	26.9	28.7	29.9	31.3	
Final BW, kg	56.2	46.5	53.0	54.0	57.2	
Feed intake, kg/day	1.767	1.443	1.677	1.715	1.743	
Feed intake, g/kg BW	40.9	39.4	41.1	41.0	39.4	0.304
ADG, g/day	719^{A}	545^{B}	678^{A}	675^{A}	719^{A}	0.001
ADG, %	100	76	94	94	100	
FC, kg/kg	2.46	2.67	2.48	2.55	2.42	0.125
CP[3] : BW gain, g/kg	433	465	436	447	435	0.412
ME[4] : BW gain, MJ/kg	31.7	33.3	31.9	32.3	31.6	0.675
Digestibility coefficients, %						
crude protein	83.3^{aA}	78.1^{cB}	81.5^{ab}	79.9^{bc}	81.8^{ab}	0.008
ether extract	48.1	53.7	54.4	51.8	52.4	0.209
crude fibre	32.3	26.4	35.1	36.0	30.4	0.317
N-free extractives	91.5^{a}	90.4^{bB}	91.9^{a}	91.4^{ab}	92.4^{a}	0.015
gross energy	81.8^{A}	77.7^{B}	81.6^{A}	80.6^{A}	82.4^{A}	0.001
ME, MJ/kg diet	12.87	12.50	12.90	12.70	13.05	
N balance						
intake, g/day	52.7	44.7	52.5	53.6	54.5	
retention, g/day	20.6^{A}	14.8^{bB}	20.7^{A}	19.4^{aAB}	20.8^{A}	0.017
retention, g/kg$W^{0.75}$	1.08	0.89	1.13	1.03	1.07	0.152
N retention : N intake, %	39.0	33.2	39.5	36.2	38.3	0.336

[1] main protein concentrate in the diet: soyabean meal (S) or lupin seeds v. Wat (W), v. Hetman (H), V. (Bardo (B), dehulled seeds v. Bardo (dB)

[2] BW – body weight

[3] CP – crude protein

[4] EM – metabolizable energy

a, b, c – $P<0.05$; A, B – $P<0.01$

Average daily intake of feeds containing the evaluated varieties of lupin seeds, expressed per kg body weight (BW), was similar and equaled about 40 g, i.e. 4% BW. The diet containing the Wat seeds was not eaten readily, and intake was drawn out over a period of a few hours. In groups H and B receiving diets with Hetman and Bardo seeds and containing 0.006 and 0.009% TA, daily weight gains (ADG) were insignificantly (6%) lower in comparison with group C. In group W fed the diet containing Wat seeds and containing 0.019% TA, ADG was significantly lower (24%), feed conversion (FC) was insignificantly lower than in group C. The amount of alkaloids introduced into the diet by the 20% of Wat seeds was found to be too high for the first stage of fattening period. In the experiment by Buraczewska et al. (1993) it was found that young pigs tolerate only up to 0.012% lupin TA from Wat seeds in their diets, while in this experiment the TA level was higher.

Pigs fed diets containing dehulled lupin Bardo (group dB) had insignificantly higher ADG (6%) from those fed whole seeds, and the same ADG as in the control group. Although the TA content in the dehulled seeds was not determined, it can be assumed that its content in the dB and B groups was similar. Better fattening performance ($P > 0.05$) of group dB than of group B, equal to that in the control group, can be attributed to the increased nutritional value of the diet due to the decreased fibre content from 5.89 to 3.88%.

Replacing a large part of soyabean meal with lupin Wat decreased the digestibility of all nutrients except fat and fibre. Replacing soyabean meal with Bardo seeds decreased only protein digestibility, while Hetman seeds did not affect the digestibility of any nutrients. The diet containing dehulled lupin was characterized by a higher ($P > 0.05$) digestibility of protein, N-free extractives and energy, and its energy value was higher by 0.35 MJ ME/kg than ME of the diet containing whole lupin.

Daily nitrogen retention per kg metabolic body weight did not differ significantly among groups, however in pigs fed the Wat-containing diet it was insignificantly lower. Nitrogen utilization was 36-39% with the exception of the group fed lupin Wat, in which it was 32% ($P > 0.05$).

Nutrients digestibility of white lupin varieties assessed in Experiment 2 did not differ significantly, except energy digestibility (Table 5). The digestibility of all nutrients was high: protein 80.3-83.7%, fat 66.2-71.9%, fibre 43.3-52.5% and N-free extractives 94-97%. The Hetman variety was characterized by a higher ($P < 0.05$) energy digestibility (84.7%) in comparison with Wat and Bardo (80.3 and 80.8%, respectively). These results show that there are only slight differences in the digestibility of protein and energy among the Polish varieties of white lupin.

Average protein digestibility of white lupin was lower than that of yellow lupin (82 vs. 86%) in the study by Flis (1993), while energy digestibility of white

TABLE 5

Digestibility coefficients of lupin seed nutrients and nutritive value of seeds (Experiment 2)

Indices	Lupin variety			Dehulled Bardo	Level of significance P
	Wat	Hetman	Bardo		
Digestibility coefficients, %	n=4	n=5	n=5	n=5	
crude protein	80.3	83.7	81.7	85.8	0.249
ether extract	71.9	67.0	66.2	71.7	0.429
crude fibre	43.3	52.5	45.8	37.6	0.475
N-free extractives	97.1	97.1	94.0	97.1	0.499
dry matter	81.2	82.5	78.8	85.3	0.068
energy	80.3^{bB}	84.7^{aAB}	80.8^{bB}	86.4^{aA}	0.003
Nutritive value, in DM					
GE[1], MJ/kg	21.27	21.74	21.74	21.44	
DE[2], MJ/kg	17.08	18.41	17.56	18.52	
ME[3], MJ/kg	13.99	14.57	14.06	16.02	
ME/GE, %	65.8	67.0	64.7	74.7	
DCP[4], g/kg	256	306	295	371	
lysine, g/kg	16.8	17.4	17.7	21.1	
crude fibre, g/kg	149	111	129	42	

[1] gross energy
[2] digestible energy
[3] metabolizable energy
[4] digestible crude protein
a, b – $P<0.05$; A, B – $P<0.01$

lupin (average 82%) was higher than in yellow lupin (average 72%; Flis, 1993). The higher digestibility of energy in white than in yellow lupin may result from its higher fat and lower fibre contents. In experiments on rats Eggum et al. (1993) showed that the energy digestibility of white lupin was higher than of a narrow-leafed variety.

Dehulling seeds had a greater effect on the digestibility of energy than of protein. The increase of protein digestibility (from 81.7 to 85.8%) was not significant, while the rise in energy digestibility (from 80.8 to 86.4%) was highly significant. In studies on young pigs Fernandez and Batterham (1995) also found a significant increase in energy digestibility of lupin (narrow-leafed) as the result of dehulling.

The tested lupin varieties contained from 17.1 to 18.4 MJ DE, from 14.0 to 14.6 MJ ME and 256 to 306 g DCP per kg DM. The Hetman variety had the greatest nutritional value. In comparison with whole seeds, the dehulled seeds contained (in DM) more DE (18.5 vs. 17.6 MJ), ME (16.0 vs. 14.1 MJ), DCP (371 vs. 295 g) and lysine (21.1 vs. 17.7 g) and less CF (42 vs. 129 g/kg DM). The higher nutritional value of dehulled seeds was due to the increased concentration of all

(except fibre) components and higher digestibility of nutrients of dehulled seeds. Fernandez and Batterham (1995) had also found that dehulling improved the nutritional value of lupin seeds for pigs, and Brenes et al. (1993) and Smulikowska et al. (1995) observed a similar effect on nutritional value for poultry.

CONCLUSIONS

Of the three compared Polish low-alkaloid varieties of white lupin, the higher nutritional value for growing pigs was found in the newer varieties, Hetman and Bardo, than in the older variety, Wat, mainly due to the its lower alkaloid content. When the seeds were added in an amount of 20% to the diets fed to the pigs in the range of BW 20 to 55 kg, only the Wat variety caused a significant deterioration of performance. Dehulling white lupin seeds increases the crude protein content (by 20%), decreases the crude fibre content (by 67%) and increases energy digestibility. In comparison with whole seeds, dehulled seeds contain more metabolizable energy (by 14%) and digestible protein (by 25%) and when used in iso-protein amounts allow for slightly better daily weight gain of pigs.

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STRESZCZENIE

Wpływ odmiany i odłuszczenia na wartość odżywczą nasion łubinu białego w żywieniu rosnących świń

W 36 dniowym doświadczeniu wzrostowym (Dośw. 1) na 24 wieprzkach (30-56 kg m.c.) określono wartość odżywczą trzech polskich odmian łubinu białego: całych nasion starszej odmiany Wat i nowszej odmiany Hetman oraz całych lub odłuszczonych nasion najnowszej odmiany Bardo.

Wprowadzając 20% całych nasion łub 16,5% odłuszczonych nasion, zmniejszono zawartość śruty sojowej z 19% w mieszance kontrolnej do 6-9% w mieszankach doświadczalnych.

W porównaniu z grupą kontrolną świnie otrzymujące łubin Wat (0,106% alkaloidów w s.m.) miały istotnie gorsze przyrosty dobowe i wykorzystanie paszy, natomiast otrzymujące łubin Hetman lub Bardo (odpowiednio 0,035 i 0,052% alkaloidów) miały tylko nieistotnie gorsze wskaźniki tuczu. U świń żywionych odłuszczonymi nasionami wyniki tuczu były takie same jak w grupie kontrolnej.

W drugim doświadczeniu (Dośw. 2) oznaczono strawność składników pokarmowych nasion trzech odmian łubinu oraz nasion odłuszczonych odm. Bardo metodą różnicową. Nie stwierdzono istotnych różnic w strawności białka ogólnego, ekstraktu eterowego, włókna surowego i związków bezazotowych wyciągowych ocenianych odmian łubinu. Łubin Hetman wyróżniał się największą strawnością energii. Odłuszczenie nasion wpłynęło na wzrost strawności energii z 80,8 do 86,4% ($P < 0,01$). Nasiona odłuszczone zawierały w s.m. więcej energii metabolicznej (16,0 vs. 14,1 MJ/kg) i strawnego białka (371 vs. 295 g/kg), zaś mniej włókna surowego (42 vs. 129 g/kg) niż nasiona całe.