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Nutritional value of diets containing field bean (*Vicia faba* L.) seeds with high or low proanthocyanidin levels for pig*

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ABSTRACT

The nutritional value of pig diets containing about 30% field beans characterized by various levels of condensed tannins was studied. In a 54-day experiment on 24 Polish Large White x Duroc barrows (25-63 kg BW) four diets were fed: HT containing high-tannin field beans (cv. Nadwiślański), LT with low-tannin field beans (cv. Caspar), DHT with hulled high-tannin field beans, and DHTF with hulled high-tannin field beans and added white flowering pea hull fibre. The proanthocyanidin content of the HT, LT, DHT and DHTF diets was 591, 8, 70 and 70 mg/kg, respectively. Nutrient and energy digestibility, nitrogen balance, daily weight gain, and feed utilization were determined.

The digestibility of N-free extractives and energy was significantly higher ($P<0.01$), while that of crude protein was non significantly higher ($P=0.07$) in the LT and DHT diets than in the HT diet. Daily nitrogen retention and utilization did not differ significantly among groups. Daily body weight gains (684-693 g) and feed conversion (3.02-3.07 kg/kg) also did not differ significantly among groups. Despite a slightly lower nutritional value as expressed by metabolizable energy and digestible protein, the HT diet that contained 0.1% phenols and 0.06% proanthocyanidins did not lower the growth rate of 25-63 kg pigs (which gained slightly under 700 g daily) in comparison with animals fed the LT and DHT diets.

KEY WORDS : field bean, proanthocyanidins, nutritional value, pigs

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INTRODUCTION

Polyphenols, especially condensed tannins (proanthocyanidins) are among the most important antinutrients in field beans. These compounds are found primarily in seed hulls. The amount of tannins can be decreased by selection for white-flowering low-tannin varieties, or by hulling seeds of high tannin varieties. In studies on pigs it was found that low-tannin varieties of field beans have higher crude protein and amino acid digestibilities (total and ileal) (Van der Poel et al., 1992; Grala et al., 1993; Jansman et al., 1993) and energy digestibility (Grosjean et al., 1995) than high-tannin varieties. The use of hulled seeds of high-tannin varieties also increases the digestibility of feed components, mainly energy (Pastuszewska et al., 1974; Bourdon and Perez 1992; Buraczewska et al., 1992; Flis et al., 1994).

In theory, the higher ileal and total crude protein and amino acid digestibility of field beans with a lowered tannin content, and their higher digestible and metabolizable energy levels should increase the nutritional value of these beans in the diets of pigs in comparison with high tannin seeds, however, the results of studies carried out to date are not unequivocal. In the experiments of Fekete et al. (1985) the nutritional value of diets containing 15% low-tannin field beans was similar to that of diets with high-tannin (0.075% tannins) varieties in the feeding of weaned pigs (10-25 kg). In contrast, in the studies of Grala et al. (1993) young pigs (20-35 kg) receiving ca. 30% low-tannin field beans in the diets had a significantly higher growth rate than those consuming high-tannin varieties. In these studies a reduction in growth rate and feed utilization was found when the tannin content of diets equaled 0.08%. The results of the above studies show that lowering the tannin content in the diet to under 0.08% field bean tannins can increase the growth rate and improve feed utilization in very young pigs, but determining the precise admissible level of tannins is difficult, among others due to the various methods of estimating these compounds. It is also unknown if and to what degree lowering the content of field bean tannins in diets can affect the growth rate of fattening pigs.

The objective of this experiment was to determine the effects of lowering the total dietary contents of phenols and condensed tannins from field beans by using a low-tannin field bean variety or hulled seeds of high-tannin varieties on the digestibility of dietary components, nitrogen balance, body weight gain and feed utilization in the first phase of fattening.

MATERIAL AND METHODS

Animals and diets

Four groups each of 6 Polish Large White x Duroc barrows with a starting weight of 25 kg were fed one of four diets: HT, with high-tannin field beans; LT,

with low-tannin field beans; DHT, with hulled high-tannin field beans and added white-flowering pea hull fibre (Table 1). The spring varieties of field beans used were: the Polish coloured-flowered variety Nadwiślański (HT) and Dutch white-flowering Caspar (LT) imported from Germany. The HT field beans were hulled mechanically and the hulls were blow-separated. The yield of hulled seeds was 80%, but the hulling was not complete since 2.3% of the hull remained in the cotyledons. The content of field beans in the diets was 27.8 (diets DHT and DHTF), 30 (HT) and 33.2% (diet LT) and supplied about 45% of total crude protein in the diet. The remainder of the dietary crude protein was from soyabean oilmeal and cereals.

The diets were balanced according to the Nutrient Requirements of Pigs (1993). They contained about 17% crude protein and, after supplementation with crystalline lysine and methionine, contained 0.9 % lysine and 0.27% methionine (Table 1).

The experiment lasted 54 days. The pigs were maintained in individual metabolic cages and were fed twice daily on mash diets, mixed with water (feed:water 1:1); feeding level ranged from 1.4 to 2.4 kg. On day 45-50 of the experiment (at 56 kg BW), nitrogen balance and nutrient and energy digestibility were determined by the balance method. Faeces and urine collections were carried out for 5 days. Two average samples of 10% were taken from pooled one-day collections. One sample was preserved with sulphuric acid, the other dried. Nitrogen was determined in the sulphuric acid-preserved sample, the other was used to estimate the remaining components and energy. Urine collected in containers was preserved with sulphuric acid and 3% of the daily amount was used for nitrogen determination.

Chemical analysis

The basic nutrient components of feeds and in faeces, as well as urinary N were determined by conventional methods. Total energy in feed mixtures and in dried faeces was determined using an adiabatic bomb calorimeter. NDF and ADF in feeds were determined according to Van Soest and Wine (1967) using a Fibertec apparatus. The starch content was determined polarimetrically after eluting soluble sugars with 70% ethanol (Soral-Śmietana, 1993).

Total phenols and proanthocyanidins in diets were computed from their content in the ingredient. Phenols were determined using a colour reaction with the Folin-Ciocalteau reagent (Naczk and Shahidi, 1989), proanthocyanidins (condensed tannins) by a dye reaction of cyanidine in butanol-HCL (Oszmiański et al., 1988). The amino acid composition of feed protein was determined using a Czech AAAT 339 M amino acid analyzer. The metabolizable energy content in diets was calculated using the Hoffman and Schieman equation on the basis of the chemical composition and digestibility coefficients determined experimentally, adjusting for sugar and bacterial fermentation of structural polysaccharides according to Müller and Kirchgessner (Nutrient Requirements of Pigs, 1993).

TABLE 1

Composition and nutritional value of diets for growing pigs (26-63 kg BW)

Indices	Diet[1]			
	HT	LT	DHT	DHTF
Ingredients, g/kg				
barley	413.0	371.1	440.0	411.9
wheat	200.0	200.0	200.0	200.0
soyabean meal	55.0	65.0	50.0	50.0
field bean cv. Nadwiślański (HT)	300.0	–	–	–
field bean cv. Caspar (LT)	–	332.0	–	–
dehulled cv. Nadwiślański (DHT)	–	–	278.0	278.0
pea hulls	–	–	–	28.0
minerals[2]	24.0	24.0	24.0	24.0
mineral-vitamin premix	7.0	7.0	7.0	7.0
L-lysine HCL (78%)	0.3	0.2	0.3	0.4
DL-methionine (99%)	0.7	0.7	0.7	0.7
Chemical analysis, % air dry basis				
dry matter	87.46	87.34	87.28	87.36
crude ash	4.34	4.37	4.16	4.50
crude protein	16.89	16.75	17.12	17.03
crude fibre	4.87	4.89	3.45	4.76
ADF	6.25	6.24	4.62	6.10
phenols, mg/kg	1035	510	622	634
proanthocyanidins, mg/kg	591	8	70	70
Nutritional value, g/kg				
lysine	9.02	9.05	8.97	9.00
methionine	2.73	2.72	2.75	2.70
threonine	5.94	5.96	5.95	5.90
tryptophan	1.75	1.83	1.75	1.70
Ca	7.48	7.54	7.44	7.50
P-total	5.60	5.64	5.55	5.50
digestible CP, g/kg[3]	131	134	136	135
metabolizable energy, MJ/kg[3]	12.43	12.77	12.91	12.60
crude protein from field bean, %	45	45	45	45

[1] HT = high tannin diet, LT = low tannin diet, DHT = dehulled high tannin diet, DHTF = dehulled high tannin diet+fibre from pea seed hulls

[2] limestone (1.3%) + bicalcium phosphate (0.8%) + salt (0.3%)

[3] value calculated according to chemical composition of diet and digestibility coefficients of nutrients of diets

Statistical analysis

The results were subjected to one-way variance analysis and the Duncan multiple range test. The correlations between phenols and proanthocyanidins intake with crude protein and gross energy digestibilities of the diets were computed.

RESULTS AND DISCUSSION

Hulling high-tannin field bean seeds led to an increased crude protein content (32.00 vs. 29.47%) and a decrease in cell wall polysaccharide contents; total fibre and ADL were affected more (2.77 vs 8.21% and 0.50 vs 1.31%, respectively), while NDF was less affected (15.22 vs 17.81%; Table 2). In other studies (Buraczewska et al., 1992; Flis et al., 1994) similar changes in the composition of field beans after hulling were found. The pea hulls used in the DHTF diet to bring the ADF level up to that in group HT were well cleaned, as indicated by the very low content of crude protein and starch and the high content of crude fibre and ADF (65.7%). Nearly identical contents of CF, ADF and NDF in pea hulls were found in a study by Leterme et al. (1996).

The content of phenolic compounds in HT field beans in our study was lower than the content of tannins found in the coloured-flowered varieties of field beans, while the content of phenols in LT field beans (Caspar) was higher than of tannins in white-flowering varieties of field beans in the works of Jansman et al. (1993) and Grosjean et al. (1995). The proanthocyanidin contents found in our experiment (2.28 and 0.03g/kg DM in HT and LT varieties) was closer to the level of tannins in analogous varieties of field beans (Grala et al., 1993). The somewhat lower level of proanthocyanidins in the seeds of both varieties could have resulted from their partial oxidation during the relatively long (about 1 year) storage of the seeds after harvesting. The hulled high tannin seeds contained 35% less phenols and about 8 times less proanthocyanidins than whole seeds, however, the content of these compounds in hulled seeds was higher than in the low tannin variety of field bean.

The protein of hulled field beans contained less methionine than the protein from whole beans (0.70 vs 0.89g/16gN). The content of other essential amino acids was similar in HT, DHT and LT field beans (Table 2). The metabolizable energy content in hulled beans, estimated from chemical composition, was about 5% higher than in whole seeds (15.78 vs 15.03 MJ/kgDM). The estimated increase in metabolizable energy due to hulling of field beans was lower than the 9-11% rise in digestible energy found in earlier studies on animals (Pastuszewska et al., 1974; Flis et al., 1994)

The digestibility of dietary components of the LT diet containing the low-tannin field beans and the DHT diet containing hulled high tannin field beans was similar

TABLE 2

Chemical composition of high-tanin (HT), low-tannin (LT), dehulled high tannin (DHT) field bean seeds and pea hulls, % DM

Item	Field bean			Pea hulls
	HT	LT	DHT	
Dry matter	86.23	86.81	86.35	88.08
Ash	3.36	4.07	3.58	2.97
Crude protein	29.39	26.36	31.99	4.50
Ether extract	1.55	1.37	1.34	0.56
Crude fibre	8.21	7.51	2.77	57.70
NDF	17.81	18.00	15.22	70.07
ADF	11.25	10.55	4.84	65.69
ADL	1.31	1.29	0.50	0.67
NDF-ADF (hemicelluloses)	6.56	7.45	10.38	4.38
ADF-ADL (cellulose)	9.94	9.26	4.34	65.02
Starch	43.98	44.60	45.80	10.40
Phenols[1], g/kg DM	4.00	1.77	2.59	0.48
ProACs[2], g/kg DM	2.28	0.03	0.29	Trace
AA, g/16 gN				
lysine	6.64	6.69	6.65	6.86
threonine	3.53	3.57	3.51	3.96
methionine	0.89	0.93	0.70	1.35
cystine	1.26	1.31	1.32	1.62
Gross energy, MJ/kg DM	19.33	18.96	19.28	18.84
ME, MJ/kg DM[3]	15.03	14.61	15.78	

[1] as sinapic acid

[2] proanthocyanidins-as cyanidin chloride

[3] calculated from chemical composition according to Noblet and Perez (1993; equation no. 37)

(Table 3). In comparison with the HT diet, nitrogen-free extractives (NFE) and gross energy (GE) of diets LT and DHT were significantly better digested ($P<0.01$), but the digestibility of crude protein (CP) and crude fibre (CF) although slightly higher, did not differ significantly. Comparison of the digestibility of diets HT, LT and DHTF, that did not differ in ADF contents, but differed in the contents of phenols and proanthocyanidins, shows that ADF had a negative effect on the digestibility of GE, NFE and, to a lesser degree, on the digestibility of CP and CF. The correlation between the consumption of phenols and proanthocyanidins with crude protein and energy digestibility was significantly negative (Table 4). The difference in the digestibility of components in diets DHT and DHTF, containing equal amounts of proanthocyanidins but different amounts of ADF, and the differences in the digestibility between diet HT and DHT, differing both in proanthocyanidins and ADF contents, showed a greater effect of proanthocyanidins than ADF on digestibility in pigs. This could have been caused by small differences in the ADF content

TABLE 3

Digestibility coefficients, N balance and growth performance of growing pigs fed HT, LT, DHT and DHTF diets

	Group[1]				SE
	HT	LT	DHT	DHTF	
ProAcs, mg/kg	591	8	70	70	
ADF, g/kg	63	62	46	61	
Digestibility coefficients, %					
crude protein	77.8	79.9	79.2	79.1	0.30
ether extract	50.7	55.9	51.0	49.3	1.60
crude fibre	28.8	33.9	34.2	32.7	0.63
N-free extractives	89.7^{B}	91.8^{A}	92.0^{A}	91.1^{A}	0.15
gross energy	81.1^{B}	83.4^{A}	83.9^{A}	82.5^{AB}	0.21
N balance					
intake, g/day	64.8	64.4	65.7	65.2	0.00
in faeces, g/day	14.4	12.9	13.7	13.6	0.20
in urine, g/day	28.4	30.0	31.4	30.5	0.43
retained, g/day	22.0	21.5	20.6	21.1	1.90
retained:intake, %	33.9	33.4	31.4	32.4	2.93
Performance					
initial BW[2], kg	25.7	25.6	26.3	25.7	0.34
final BW, kg	62.6	63.0	63.3	62.9	0.41
ADG[3], g	684	693	687	689	5.09
FCE[4], kg/kg	3.07	3.02	3.05	3.04	0.02

[1] see Table 1; [2] body weight; [3] average daily gain; [4] feed conversion efficiency
AB – P≤0.01

TABLE 4

Correlations and regression between dietary parameters and digestibility of crude protein and gross energy (y = a + bx)

X	Y	Correlation coefficient	Intercept a	Slope b
Phenols intake	Protein digestibility n=18	– 0.495*	81.73	– 0.0016
Phenols intake	Energy digestibility	– 0.661**	85.58	-0.0019
ProACs intake	Protein digestibility n=18	– 0.480*	79.66	– 0.0013
ProACs intake	Energy digestibility	– 0.641**	83.11	– 0.0016

* significant at P<0.05; ** significant at P<0.01

in diets when whole field beans were replaced by hulled beans (6.30 vs 4.60%, respectively for diets HT and DHT).

At an approximately 30% content of field beans in the diets of 56 kg pigs, the replacement of high tannin seeds with low-tannin ones led to increased crude protein digestibility by 2.1, and of energy by 2.3 percentage points. Similar results were obtained in studies on 15-30 kg pigs by Jansman et al. (1993). In their studies, diets with 30% coloured-flowered field beans had 1.7-3.9 percentage point lower crude protein digestibility and 1.2-2.7 percentage point lower organic matter digestibility than a diet with white-flowering field beans, depending on the tannin content. Also in the studies of Grala et al. (1993) the digestibility of components of diets containing about 30% high tannin varieties of field beans was significantly lower in young pigs than of a diet with the white-flowering variety.

A significant rise in the digestibility of NFE and GE and an insignificant increase in the digestibility of CP in the DHT diet, with hulled seeds, in our experiment is in agreement with the results of other authors. In the study by Buraczewska et al. (1992) the ileal digestibility of a semi-synthetic diet containing about 45% hulled field beans was non significantly higher, and the digestibility of organic matter was significantly higher than of the diet with whole field beans. Also Bourdon and Perez (1992), on the basis of results obtained in France, stated that hulling field beans increases the digestibility of crude protein and energy, but affects energy digestibility more.

Pigs in group DHT fed hulled field beans in comparison with those in group HT fed whole beans excreted slightly less nitrogen in faeces, and insignificantly more nitrogen in urine (31.4 vs 28.4 g/day; Table 3). In earlier studies, and using higher amounts of field beans in diets (51 and 46%), Pastuszewska et al. (1974) found that pigs receiving hulled field beans excrete significantly less nitrogen in faeces and more in urine than pigs fed whole field beans. In the present study daily nitrogen retention and utilization of absorbed nitrogen did not differ significantly among groups, and only in the group receiving hulled field beans daily nitrogen retention and the ratio of the nitrogen retained to nitrogen intake were somewhat lower than in the remaining groups.

In the period of growth from 25 to 63 kg body weight, average daily gain (ADG) was 684 to 693 g and did not differ significantly among groups. Feed utilization (FCR) equaled 3.02 to 3.07 kg per kg body weight gain and was not significantly different. Fekete et al. (1985) also did not find significant differences in ADG and FCR in 10-25 kg pigs fed diets containing 15% HT or LT field beans. However, Grala et al. (1993) using diets containing about 30% field beans found that the lower level of condensed tannins in field beans had a positive effect on the growth rate of young (20-35 kg) pigs. In the studies of the cited authors, a significant decrease in daily gains was found even at a small, 0.08%, content of tannins in diets. In our studies, the content of phenols and proanthocyanidins in the HT diet

was 0.1 and 0.06%, respectively. It results from this that such a level of these ANFs in the diet of 25-63 kg pigs that gain under 700 g daily does not affect their growth rate. It may also suggest that the negative effects of the tannins would have been visible if the pigs had a higher growth rate, or if a lower level of crude protein and metabolizable energy had been used in the diet.

CONCLUSIONS

It could be concluded that the LT diet with the low-tannin field beans and the DHT diet with hulled high-tannin field beans containing low levels of proanthocyanidins had a significantly higher energy digestibility and slightly higher (P=0.07) crude protein digestibility than the HT diet with high-tannin field beans containing the highest level of proanthocyanidins. The HT diet with 0.1% phenolic compounds and 0.06% proanthocyanidins, despite a somewhat lower nutritional value measured as the metabolizable energy and crude protein contents, did not lower the growth rate of 25-63 kg pigs that gained somewhat under 700 g daily, in comparison with those fed the LT or DHT diets.

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STRESZCZENIE

Wartość odżywcza mieszanek z udziałem nasion bobiku (*Vicia faba* L.) zawierających wysoki lub niski poziom proantocyjanidyn w żywieniu rosnących świń

Oznaczono wartość odżywczą mieszanek z udziałem około 30% nasion bobiku o zróżnicowanej zawartości skondensowanych tanin w 54-dniowym doświadczeniu przeprowadzonym na 24 wieprzkach mieszańcach rasy Wielkiej Białej Polskiej x Duroc (25-63 kg m.c.). Zastosowano cztery mieszanki: HT – z udziałem nasion bobiku wysokotaninowego (Nadwiślański), LT – z nasionami bobiku niskotaninowego (Caspar), DHT – z odłuszczonymi nasionami bobiku wysokotaninowego i DHTF – z odłuszczonymi nasionami bobiku wysokotaninowego, ale z dodatkiem włókna z łuski białokwitnącego grochu. Zawartość proantocyjanidyn w mieszankach HT, LT, DHT i DHTF wynosiła odpowiednio 591, 8, 70 i 70 mg/kg. Oznaczono strawność składników pokarmowych i energii mieszanek, bilans azotu oraz przyrosty dzienne i wykorzystanie paszy.

Stwierdzono istotnie większą ($P<0,01$) strawność związków bezazotowych wyciągowych i energii oraz nieistotnie większą ($P=0,07$) strawność białka ogólnego mieszanek LT i DHT w porównaniu z mieszanką HT. Dobowa retencja azotu oraz wykorzystanie azotu pobranego, a także przyrosty dzienne (684-693g) i zużycie paszy (3,02-3,07 kg/kg) nie różniło się istotnie między grupami. Mieszanka HT, zawierająca 0,1% fenoli i 0,06% proantocyjanidyn, mimo trochę mniejszej wartości pokarmowej, mierzonej zawartością energii metabolicznej i białka ogólnego strawnego, nie wpłynęła na zmniejszenie tempa wzrostu świń od 25 do 63 kg w porównaniu ze zwierzętami żywionymi mieszankami LT i DHT.