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Nutritional value of faba beans (*Vicia faba* L.) fed to young pigs

W. Grala[1], A.J.M. Jansman[2,3], P.van Leeuwen[2], J. Huisman[2], G.J.M. van Kempen[2] and M.W.A. Verstegen[3]

[1] *The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences, 05-110 Jabłonna, Poland*
[2] *TNO-Institute for Toxicology and Nutrition, Department of Animal Nutrition and Physiology (ILOB), Wageningen, PO Box 15, 6700 AA Wageningen, The Netherlands*
[3] *Agicultural University Wageningen, Department of Animal Nutrition, Haagsteeg 4, 6708 PM Wageningen, The Netherlands*

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ABSTRACT

The nutritional value of four varieties of faba beans (*Vicia faba* L.) originating from Poland (var. *Kamir* and *Martin*) and the Netherlands (var. *Toret* and *Pistache*) was evaluated on young pigs (20–35 kg) in two experiments. The condensed tannin content in the beans was from $<0.1\%$ (white-flowered var. *Toret*) to 0.55% (coloured-flowered var. *Martin*). In the ileal digestibility experiment (PVTC-cannula) the experimental diets consisted of 70% basal diet and 30% faba beans (FB). In the N balance/growth performance experiment the diets contained 50% of crude protein (CP) from FB and 50% from the basal diet. The apparent ileal CP digestibility of FB decreased from 74.3 to 68.8% with an increase of tannin content. The ileal amino acids (AA) digestibility of var. *Toret* was higher as compared to that of var. *Martin*. The apparent faecal digestibility of CP depended on the tannin content in FB ($R^2 = 0.70$, $P \leqslant 0.01$). The N retention and body weight gain (BWG) of pigs fed the *Toret* diet were higher ($P \leqslant 0.01$) as compared to those fed the *Martin* diet. It was concluded that the low content of condensed tannins in FB ($<0.1\%$) had a positive effect on ileal digestibility of CP and AA and on growth rate of young pigs.

KEY WORDS: faba bean, condensed tannins, ANFs, nutritional value, ileal digestibility, pigs

INTRODUCTION

Faba beans (*Vicia faba* L.) could be an important source of protein as an alternative feedstuff to soya bean oil meal. The faba bean (FB) is fairly high in protein, and with the exception of methionine level, has a balanced pattern of indispensable amino acids (AA) (Tacker, 1990). Some antinutritional factors

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(ANFs) present in FB (e.g. tannins, lectins and trypsin inhibitors) may interfere with the digestion of nutrients, and decrease growth rate of pigs (Aherne et al., 1977; Jansman et al., 1992a). In particular, condensed tannins may bind to dietary proteins and/or inhibit the activity of digestive enzymes, and increase the secretion of endogenous proteins (Marquardt, 1989).

This study present the results of evaluation of the ileal and faecal digestibility of nutrients in young pigs, and of influence on their growth performance of four varieties of FB orginating from Poland or from the Netherlands. One of these was white-flowered, low in condensed tannin content variety, and the others were coloured-flowered varieties with higher tannin content.

MATERIAL AND METHODS

Faba bean varieties. Two Polish (var. *Kamir* and *Martin*) and two Dutch (var. *Toret* and *Pistache*) FB varieties were used in the experiments. The condensed tannin content was measured according to the vanilin-H_2SO_4 method (Kuhla and Ebmeier, 1981), lectins were measured according to the ELISA-method (Hamer et al., 1989), and the activity of trypsin inhibitors (TIA) according to the Kakade method modified by Van Oort et al. (1989).

Ileal digestibility experiment. The experiment was performed on 30 cannulated pigs. Each experimental group consisted of six male castrated animals, fitted with PVTC-cannula (Van Leeuwen et al., 1991). Pigs were housed individually in metabolic cages. At the beginning of the experiment the mean body weight (BW) of the animals was ± 20 kg.

The different varieties of FB were included into the diets at the expense of 30% of the basal diet:

Diet I : 100% basal diet;
„ II : 70% basal diet + 30% var. *Toret*,
„ III : 70% basal diet + 30% var. *Pistache*,
„ IV : 70% basal diet + 30% var. *Kamir*,
„ V : 70% basal diet + 30% var. *Martin*.

The composition of the basal diet is given in Table 1. The diets were balanced for ileal digestible AA and net energy content according to the CVB Dutch Table of Feedstuffs (1991). Chromic oxide (Cr_2O_3) was used as digestibility marker at a level of 2.5 g/kg diet.

The pigs were fed at a level of 2.7 times their assumed maintenance requirements for energy (2.7×419 kJ ME/kg$^{0.75}$; ARC, 1981). Mash wet diets (water : feed = 2 : 1) were offered to pigs twice daily. The digesta was collected over a period of four days (4×12 h); it was freezed immediately after sampling. The

pooled digesta was freeze-dried and analyzed for the content of essential nutrients and Cr_2O_3. The AA analysis was performed in Jabłonna using Beckman System 6300 High Performance analyzer.

The apparent ileal digestibility of the beans was calculated from the difference between the digestibility of the basal diet and the experimental diets.

TABLE 1

Formulation and calculated chemical composition of the basal diet

Formulation	%	Chemical composition	%
Barley	30.44	Dry matter	87.90
Maize	35.00	Crude protein	15.90
Maize starch	5.00	Ether extract	4.42
Meat meal	2.00	Crude fibre	1.79
Fish meal	5.00	Ash	5.41
Skim-milk powder	10.00	Net energy (MJ/kg)	9.78
Whey powder	5.00	Ca	0.93
Soya oil	1.50	Available P	0.67
Cane molasses	2.00	Lys	1.04
L-lysine HCl	0.20	Met + Cys	0.68
DL-methionine	0.10	Thr	0.73
L-threonine	0.10	Trp	0.199
L-tryptophan	0.03		
$CaCO_3$	0.80		
Monocalciumphosphate	0.70		
NaCl	0.30		
$KHCO_3$	0.40		
Premix[1]	1.43		

To each of the experimental diets in the ileal digestibility trial 0.25% of Cr_2O_3 was added as a marker

[1] The premix supplied per kg feed: 9000 IU vit. A; 1800 IU vit. D_3; 40 mg vit. E; 5 mg riboflavin; 30 mg niacin; 12 mg panthotenic acid; 100 mg choline, 40 μg vit. B_{12}; 2 mg vit. B_1; 3 mg vit. B_6; 0,1 mg biotin; 1 mg folic acid; 3 mg vit. K; 50 mg ascorbic acid; 200 mg $ZnSO_4 \cdot H_2O$; 15 mg MnO_2; 400 mg $FeSO_4 \cdot 7H_2O$; 2.5 mg $CoSO_4 \cdot 5H_2O$; O.5 mg KJ; 40 mg $CuSO_4 \cdot 5H_2O$; O.2 mg $Na_2SeO_3 \cdot 5HO$; 40 mg tylosine

N balance/growth performance experiment. The experiment was performed on six experimental groups of six castrated male pigs each (BW $\pm$20 kg). The animals were housed as in the previous experiment. The pigs were fed with a basal diet, similar to that used for ileal digestibility trial, and the diets containing FB. The experimental diets contained 50% of crude protein (CP) from the varieties of FB and 50% from the basal diet. A diet with soya bean meal (SBM) was used as a positive reference. The following diets containing 16% CP were used in the experiment:

Diet I : 100% basal diet;
„ II : 50% CP of basal diet + 50% CP of var. *Toret*,
„ III : 50% CP of basal diet + 50% CP of var. *Pistache*,
„ IV : 50% CP of basal diet + 50% CP of var. *Kamir*,
„ V : 50% CP of basal diet + 50% CP of var. *Martin*,
„ VI : 50% CP of basal diet + 50% CP of SBM.

The pigs were fed twice a day at 8 a.m. and 4 p.m. with wet diets (water : pellets = 2:1). The amount of feed/animal/day was calculated in similar way as in the ileal digestibility trial.

The experiment lasted 30 days; faeces and urine for N balance were quantitatively collected over 10 days period. BWG and feed conversion (FC) were measured for the whole trial. The apparent faecal CP digestibility of the beans (FB and SBM) was calculated from the difference between the digestibility of the basal diet and diets containing beans.

Statistical analysis. The results were statistically analyzed using one-way analysis of variance. Digestibility coefficients of the nutrients were regressed on tannin contents in the diets using a simple linear regression. All statistical tests were performed using SPSS Statistical Package.

RESULTS AND DISCUSSION

As expected, the white-flowered var. *Toret* had the lowest condensed tannin content while the coloured-flowered var. *Pistache, Kamir* and *Martin* had a higher tannin content (Table 2). The highest lectin content was observed in low-tannin var. *Toret*. TIA found in FB was not high and ranged from 1.74 to 2.26 mg/g.

TABLE 2

Chemical composition (%) of faba beans originated from Poland (PL) and the Netherlands (NL)

Variety	DM	CP[1]	CF	Ash	Tannins[2]	Lectins[3]	TIA[4]
Toret (NL)[5]	86.62	30.96	9.10	3.44	<0.10	3.20	1.93
Pistache (NL)	87.80	27.69	7.80	3.10	0.29	0.40	2.26
Kamir (PL)	87.55	29.33	7.90	3.64	0.42	2.90	2.16
Martin (PL)	87.49	26.75	8.60	3.29	0.55	2.30	1.74

[1] N × 6.25; [2] % catechin equivalents (vanillin-H_2SO_4 method); [3] haemagglutination units per mg of sample; [4] mg trypsin inhibited per gram of sample; [5] white-flowered var.; the other varieties are coloured-flowered

Table 3 shows that apparent ileal digestibility coefficients of dry matter (DM), organic matter (OM), ash and N-free extractives (NFE) of the basal diet were

significantly ($P \leqslant 0.01$) higher than those found for diets containing FB. In the case of CP, the digestibility of the diet with low-tannin content was significantly higher ($P \leqslant 0.01$) than that of the diet with high-tannin var. *Martin*. In similar study by Jansman et al. (1992a) the differences in CP digestiblity between low- and high-tannin varieties were larger than those in our study (on average +5.8 and +3.4 units, respectively). In another study by Jansman et al. (1992b) an inclusion of high-tannin hulls from FB depressed the apparent ileal digestibility by 10 and 7 units in the diets containing high- and low-soluble protein respectively.

TABLE 3

Apparent ileal digestibility (%) of the diets containing 30% of faba beans fed to young pigs

Item	CP[1]	DM	OM	Ash	NFE
Basal diet	78.3[a]	79.5[a]	81.3[a]	53.8[a]	82.1[a]
Diets with:					
Toret[2]	76.5[ab]	71.7[b]	73.7[b]	39.8[b]	72.8[c]
Pistache	76.3[ab]	73.3[b]	75.3[b]	42.1[b]	74.8[b]
Kamir	75.4[bc]	72.3[b]	74.1[b]	41.4[b]	73.7[bc]
Martin	73.1[c]	72.3[b]	74.2[b]	40.8[b]	74.6[bc]
SEM[3]	0.88	0.66	0.65	1.10	0.68

[1] N × 6.25; [2]white-flowered var.; the other varieties are coloured-flowered; [3]standard error of the mean
[a, b, c] values with a different superscript within a column differ significantly at $P \leqslant 0.01$

In contrast to the diets, the biggest difference found in the ileal CP digestibility between *Toret* and *Martin* (+5.5 units) was not confirmed statistically (Table 4). However, there was a strong tendency to decrease the CP digestibility with an increase of tannin content in the beans. Our results are in agreement with data of Buraczewska et al. (1993) who determined an ileal digestibility of the coloured-flowered FB (var. *Kamir, Martin, Alen*) using semi-synthetic diets.

TABLE 4

Apparent ileal digestibility (%) of faba beans

Faba beans	CP[1]	DM	OM	Ash	NFE
Toret[2]	74.3	53.1	56.0	−13.0	45.0[b]
Pistache	73.6	58.8	61.3	− 5.7	55.6[a]
Kamir	71.5	55.4	57.9	− 7.1	50.7[ab]
Martin	68.8	55.5	58.2	−11.2	53.2[a]
SEM[3]	2.00	2.36	2.28	6.02	2.60

[1] N × 6.25; [2]white-flowered var.; the other varieties are coloured-flowered; [3]Standard error of the mean
[a, b] values with a different superscript within a column differ significantly at $P \leqslant 0.05$

The ileal digestibility of low-tannin FB *Toret* was lower than expected. In the earlier studies by Jansman et al. (1992a) and van der Poel et al. (1993) in which the CP digestibility of low-tannin FB was about 11-12 digestibility units higher than those of high-tannin FB.

It was found a negative ash digestibility in the beans. It seems that this results from relatively low ash content and a low absorption of ash up to the end of the small intestine in pigs.

The apparent AA ileal digestibility of var. *Toret* was significantly higher than of var. *Martin* (Table 5). The smallest differences were found for Arg and Lys while the largest for Pro, Cys, Gly, Trp and Met (2.3, 4.0, 31.8, 17.2, 16.4, 15.2 and 13.1 units, respectively). In particular, the difference was high in the digestibility of proline.

TABLE 5

Apparent ileal digestibility (%) of amino acids of faba beans

Amino acids	*Toret*[1]	*Pistache*[2]	*Kamir*[2]	*Martin*[2]	P⩽	LSD[3]
Lys	82.4[a]	80.6[ab]	82.4[a]	78.4[b]	0.10	3.6
Met	84.7[a]	85.0[a]	77.8[ab]	71.6[b]	0.01	7.3
Cys	66.2[a]	56.5[ab]	51.0[b]	49.0[b]	0.01	10.5
Thr	72.8[a]	69.4[ab]	71.2[ab]	64.4[b]	0.14	7.5
Trp	71.0[a]	68.9[a]	66.2[a]	55.8[b]	0.01	7.7
Ile	79.6[a]	78.3[ab]	76.0[ab]	74.0[b]	0.12	5.0
Leu	81.1[a]	79.2[a]	76.7[ab]	74.4[b]	0.03	4.6
Phe	76.3[a]	72.4[ab]	74.1[ab]	70.3[b]	0.15	5.3
Val	77.1[a]	75.5[a]	72.0[ab]	69.1[b]	0.05	5.9
Tyr	74.8[a]	67.6[b]	73.1[ab]	68.9[b]	0.06	5.8
Arg	91.4[a]	89.8[ab]	89.8[ab]	89.1[b]	0.12	2.0
His	85.2[a]	81.5[ab]	78.1[bc]	76.6[c]	0.01	4.0
Ala	72.1[a]	70.3[a]	68.4[ab]	63.1[b]	0.07	7.0
Asp	81.0[a]	78.6[ab]	76.7[ab]	74.1[b]	0.05	4.9
Glu	85.6[a]	81.7[ab]	81.1[ab]	77.8[b]	0.01	4.0
Gly	74.3[a]	68.3[ab]	65.7[b]	57.9[c]	0.01	7.4
Pro	79.9[a]	62.4[b]	53.9[c]	48.1[c]	0.01	7.8
Ser	80.4[a]	76.4[ab]	78.8[a]	72.7[b]	0.05	5.5

[1]white-flowered; [2]coloured-flowered var.; the other varieties are coloured-flowered; [3]list of significant differences ($p = 0.05$, $df = 20$)

[a, b, c] means within rows not having a common superscript differ significantly

Eggum and Christensen (1975, cited in Mehansho et al., 1983) reported a negative effect of tannins on the availability of Pro, Gly and Glu in rats. Also in the study by Jansman (1993) a significant decrease in proline digestibility was found in rats fed diets containing a high-tannin FB hulls. Mitaru et al. (1984) reported also that the greatest difference in the apparent ileal digestibility of proline was found between low- and high-tannin sorghum. Considerable

differences in the AA digestibility found in our study between low- and high-tannin FB support other observations (Marquardt, 1989) on high affinity of condensed tannins to proteins. Hagerman and Butler (1981) demonstrated that tannins have a particular high affinity for proline-rich proteins (PRPs). The authors suggest that proline leads probably to a loose open structure readily accessible to tannins and to the formation of hydrogen bonds with the phenolic groups of tannins. Jansman (1993) reported that tannins from FB stimulate the parotid glands to increase the secretion of PRPs in rats. The PRPs then interact with dietary condensed tannins to reduce their anti-nutritional effects.

The results of the digestibility trial incline to supposition that other ANFs present in FB (lectins, TIA) have no considerable effect on the digestibility of nutrients in pigs. That corresponds with other studies (Aherne et al., 1977; Buraczewska et al., 1992; Jansman et al., 1989; 1992a; Van der Poel et al., 1992) where the heating of FB (to inactivate lectins and/or TIA) was not very beneficial to its nutritional value for pigs.

TABLE 6

Apparent faecal digestibility (%) of diets (CP, DM, CF) and faba or soya beans (CP)

Item	Diets			Beans
	CP[1]	DM	CF	CP[1]
Basal	88.3^{bc}	88.6^{b}	24.7^{b}	
SBM	89.0^{ab}	90.3^{a}	50.6^{a}	89.5^{ab}
Toret[2]	89.9^{a}	90.8^{a}	49.1^{a}	91.2^{a}
Pistache	87.6^{c}	88.9^{b}	34.0^{b}	86.7^{b}
Kamir	87.7^{bc}	88.9^{b}	32.5^{b}	86.9^{b}
Martin	85.1^{d}	87.7^{c}	26.4^{b}	81.6^{c}
rms[3] (df = 28)	1.06	0.50	75.9	4.36

[1]N × 6.25; [2]white flowered var.; the other varieties are coloured-flowered; [3]residual mean square
a, b, c, d values within columns not having a common superscript are significantly different ($P \leqslant 0.01$)

Results of the N balance/growth performance experiment are given in Tables 6 and 7. The faecal digestibility coefficients for CP, DM and crude fibre (CF) of the diet containing var. *Martin* confirmed the minor value of this variety evaluated in the ileal digestibility trial. The values for that diet were significantly ($P \leqslant 0.01$) lower than those for the basal diet and for the other experimental diets. The faecal CP digestibility of the beans var. *Toret* and its diet was similar to SBM and higher than coloured-flowered FB. The difference between var. *Toret* and var. *Martin* was about 10 digestibility units and was much higher than that measured on the ileum level. The CP digestibility of the diets with FB was significantly ($P \leqslant 0.01$) affected by tannin content in the diets ($R^2 = 0.70$, $P \leqslant 0.01$). In similar experiment

by Jansman et al. (1993) the apparent faecal CP digestibility of the diet containing white-flowered var. *Blandine* was 2 to 4 digestibility units higher than other coloured-flowered varieties. In the study by Liebert and Gebhard (1983) (semi-synthetic diets) the apparent faecal CP digestibility of a white-flowered variety was 3 to 4 digestibility units higher than coloured-flowered one.

TABLE 7

Growth performance results of pigs fed diets containing 50% of protein originated from the faba beans

Item	BWG[1]	FC[2]
Basal diet	504[b]	1.84[bc]
SMB diet	558[a]	1.70[a]
Diets with:		
Toret[3]	560[a]	1.75[ab]
Pistache	526[b]	1.78[bc]
Kamir	526[b]	1.82[bc]
Martin	510[b]	1.85[c]
rms[4] (df = 28)	447.9	0.004

[1]body weight gain, g/day, [2]feed conversion, kg/kg BWG
[3]white-flowered var.; the other varieties are coloured-flowered;
[4]residual mean square
[a, b, c] values within columns with a common superscripts are not significantly different ($P \leqslant 0.01$)

The highest N retention in pigs fed the FB diets was found on the *Toret* diet while the lowest on *Martin* diet (60.9 vs 57.5% of N intake; $P \leqslant 0.01$). The N balance experiment with rats performed by Pastuszewska et al. (1993), using the same FB varieties has also confirmed a superiority of the low-tannin var. *Toret*.

The growth (BWG) of pigs (4 weeks) on the *Toret* diet was superior ($P \leqslant 0.01$) to other diets containing FB, however, FC on that diet was better only when compared to the *Martin* diet (Table 7). The results with the *Toret* diet were as good as with the SBM diet. Aherne et al. (1977) reported that each 5% coloured-flowered FB added to a diet (from 0 to 30%), replacing 2.8% grain and 2.2% SBM, resulted in the reduction in FC of 10-20 g/day. Mateos and Puchal (1981) reported that inclusion of 25% FB into the diet (0.21% tannin content) was responsible for slightly depressing effect on the growth rate of pigs. In our study we found that tannins in the diets containing coloured-flowered FB [calculated range from 0.08% (var. *Pistache*) to 0.16% (var. *Martin*)] decreased both the apparent faecal digestibility of CP and DM, and growth rate of pigs.

CONCLUSIONS

Both trials with cannulated and intact animals have shown significant differences in the nutritive value between white- and coloured-flowered faba beans for growing pigs. The content of condensed tannins seems to affect adversely the nutritive value of faba beans. Particularly, the ileal digestibility trial showed this with regard to the apparent amino acid digestibility. The N balance/growth performance experiment has confirmed these observations in respect to the faecal apparent digestibility of protein and to N retention in pigs. It appears that other AFNs (lectins, trypsin inhibitors) in faba beans are playing a lesser role in nutritive value of faba beans in pig feeding.

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STRESZCZENIE

Wartość pokarmowa nasion bobiku (*Vicia faba* L.) w żywieniu młodych świń

Celem badań było określenie wartości pokarmowej bobików pochodzących z Polski (PL) i Holandii (NL) w żywieniu rosnących świń (20–35 kg). Testowano biało- (odm. *Toret*, NL) i kolorowokwitnące (odm. *Pistache*, NL; *Kamir*, PL; *Martin*, PL) bobiki zawierające odpowiednio <0,1; 0,29; 0,42 i 0,55% skondensowanych tanin. W doświadczeniu na świniach przetokowanych (kaniule PVTC) mieszanki doświadczalne zawierały 70% diety kontrolnej i 30% odpowiednich bobików. W doświadczeniu wzrostowo-bilansowym 50% białka pochodziło z diety kontrolnej i 50% z nasion bobiku.

Strawność pozorna do końca jelita cienkiego białka nasion bobików zmniejszała się wraz ze wzrostem zawartości w nich tanin (74,3; 73,6; 71,5 i 68,8%). Strawność aminokwasów do końca jelita cienkiego bobiku *Toret* była większa niż bobiku *Martin*. Szczególnie duża różnica wystąpiła w strawności proliny (31,8 jednostek). Strawność białka do końca przewodu pokarmowego zależała od zawartości tanin w nasionach bobiku ($R^2=0,70$; $P \leqslant 0.01$). Współczynniki retencji azotu i przyrosty świń żywionych mieszanką z bobikiem *Toret* były większe niż świń żywionych mieszanką z bobikiem *Martin*. Nie stwierdzono, aby inne związki antyżywieniowe (lektyny, inhibitory trypsyny) wpływały ujemnie na wartość pokarmową badanych bobików.

Wyciągnięto wniosek, że białko bobiku o najniższej zawartości tanin skondensowanych (<0,1% – *Toret*) jest najlepiej trawione i wykorzystywane przez młode świnie.