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Utilization of Tannin-containing and Tannin-free Faba Beans (*Vicia faba*) by Young Chicks: Effects of Pelleting Feeds on Energy, Protein and Starch Digestibility

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ABSTRACT

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The nutritive value of the beans of a tannin-free cultivar of *Vicia faba* was compared with that of beans from 2 tannin-containing cultivars. Experimental diets containing 48% faba bean were given to 3-week-old chicks, either as pellets or as unpelleted ground feed. Protein from the tannin-free cultivar was more digestible (82.6%) than protein from the tannin-containing cultivars (68.2%), but starch from the tannin-containing cultivars was more digestible (84.5%) than starch from the tannin-free cultivar (75.1%). Pelleting the diets improved the digestibility of both protein and starch in all cultivars, the most pronounced effect being observed on starch digestibility (+10.8%). The apparent metabolisable energy values, corrected for nitrogen balance (AMEn), of the 3 cultivars of field beans were also improved by pelleting. The mean value of the increase in AMEn values owing to pelleting (1.23 MJ kg^{-1} DM) represented 12% of the AMEn value of unpelleted field beans. Regrinding after pelleting did not change the effects of pelleting.

INTRODUCTION

Heat treatment improves the utilization of faba bean seeds by young chicks and adult cockerels (Marquardt and Campbell, 1973, 1974; Marquardt et al., 1974; Huyghebaert and de Groote, 1979, 1980; Huyghebaert et al., 1979; Marquardt and Ward, 1979, 1984).

Previous studies (Edwards and Duthie, 1973; Guillaume, 1974; McNab and

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Wilson, 1974; Shannon and Clandinin, 1977; Guillaume, 1978; Bhargava and O'Neil, 1979) have shown that the heat treatment of field bean seeds results in a 7–15% increase in their apparent metabolisable energy (AME) value as measured in young birds; the extent of this effect depends in part on the cultivars tested (Guillaume, 1978).

The beneficial effect of heat treatment has been attributed to heat denaturation of trypsin inhibitors, haemagglutinins (Marquardt et al., 1974), antinicotinamide factors (Guillaume, 1974) and tannins (Guillaume and Gomez, 1977; Marquardt and Ward, 1979), which increases the utilization of dry matter (DM), nitrogen, ether-extractable compounds and minerals (Guillaume and Gomez, 1977; Guillaume, 1978; McNab and Wilson, 1974; Marquardt and Ward, 1979).

It is probable that the in vivo digestibility of faba bean starch is also affected by heat treatment. However, only Guillaume (1978) has reported such effects, and confirmation of this finding is required.

The treatments used by the above mentioned authors were: (1) autoclaving (Edwards and Duthie, 1973; Marquardt and Campbell, 1973, 1974; Marquardt et al., 1974, 1976; Shannon and Clandinin, 1977; Guillaume, 1978; Bhargava and O'Neil, 1979; Marquardt and Ward, 1979, 1984); (2) micronising (McNab and Wilson, 1974; Marquardt et al., 1976); (3) extruding and flocking (Marquardt et al., 1976; Huyghebaert and de Groote, 1979, 1980; (4) pelleting of seeds before their inclusion in whole diets (Guillaume, 1974; Marquardt et al., 1976; Huyghebaert and de Groote, 1979); and (5) pelleting of mash after inclusion of faba beans seeds (Huyghebaert and de Groote, 1980). Only the last treatment corresponds to the technical procedures used in the preparation of commercial poultry feedstuffs. It was therefore decided to test the procedure which is most commonly used in practice, i.e. the inclusion of seeds in a whole diet followed by pelleting of the mixture.

The effects of pelleting on the utilization of field beans by young chicks were studied by measuring starch and protein digestibility and determining AME values corrected for nitrogen retention (AMEn). Interaction of the effects of pelleting and the tannin content of the seeds was investigated by testing 3 field bean cultivars, one of which was tannin-free.

MATERIALS AND METHODS

Three faba bean cultivars were tested: 2 tannin-containing cultivars which are commonly used in France, (Soravi, a winter cultivar, and Alfred, a spring cultivar); and a tannin-free spring cultivar (Blandine) which has recently been officially registered in France.

The faba bean seeds were ground and mixed with an equal weight of a basal fraction (O), which was composed of ground maize, soya bean meal and DL-methionine. Four experimental diets were then prepared by the addition of

TABLE I

Composition of experimental field bean diets (%)

Diet composition (%)	Cultivar used in diet			
	0	Alfred	Soravi	Blandine
Basal[1]	96	48	48	48
Faba bean Alfred	—	48	—	—
Faba bean Blandine	—	—	—	48
Faba bean Soravi	—	—	48	—
Mineral and vitamin mixture[2]	4	4	4	4
Total	100	100	100	100

[1]Basal diet composition: Yellow maize, 67.77; soya bean meal (50% protein), 32.0; DL-methionine 0.23. (%).
[2]Mineral and vitamin content (kg^{-1} diet): vitamin A, 10 000 IU; vitamin D_3, 1500 IU; vitamin E, 15 mg; niacin, 25 mg; vitamin B_{12}, 0.008 mg; calcium pantothenate, 8 mg; vitamin K_3, 5 mg; riboflavin, 4 mg; pyridoxine, 1 mg; folic acid, 1 mg; biotin, 0.2 mg; butylated hydroxytoluene, 125 mg; choline chloride, 750 mg; Fe, 44 mg; Cu, 8.8 mg; Mn, 106 mg; Co, 0.3 mg; I, 1.2 mg; Se, 0.2 mg; Zn, 84 mg; NaCl, 4 g; dicalcium phosphate, 20 g; calcium carbonate, 10 g.

mineral and vitamin mixtures (MVM) at the 4% level (Table I). Each of the 4 experimental diets was then separated into 3 equal fractions which were either left untreated (G), pelleted (P) or pelleted and reground (PG), giving the following three groups of diets (OG, A(Alfred)G, B(Blandine)G, S(Soravi)G), (OP, AP, BP, SP) and (OPG, APG, BPG, SPG).

The diets were steam-pelleted using a pellet mill (PSI-La Mecanicca type CLM 12). The temperature of the meal leaving the conditioner was 66–71 °C, these conditions being similar to those used in feed industry. The die thickness of the pellet mill was 25 mm and the pellet diameter was 2.5 mm. The resulting pellets were cooled at room temperature before being ground with a laboratory Forplex hammermill (2-mm screen), in order to obtain a particle size similar to that of unpelleted diets (Diet group G) (Carré et al., 1987). Grinding caused only a slight increase in temperature (2–3 °C) compared with ambient conditions.

Particle-size determination was carried out on a duplicate 100-g sample with a laboratory siever (Buhler DLU 300) using a set of woven-wire cloth sieves having a diameter of 26 cm. The sieve openings were chosen according to Afnor specifications (NF X 11-501); the sieving time was 15 min. The size of particles was reported in terms of geometric mean diameter and geometric standard deviation by weight (NF X 11-635).

The bioassay was carried out using 192 16-day-old chicks of similar weight. The birds were male Hubbard broiler chicks. Pairs of chicks were randomly assigned to 96 metal cages. Each cage was furnished with a feeder, a drinker and a plastic tray for the collection of excreta.

A balance experiment was carried out from Day 17 to Day 24 on 16 birds (i.e., 8 cages) per diet using the total collection method described here. The birds were fed ad libitum during a 67-h adaptation period, then fasted for 7 h before the 72-h balance period during which the birds were fed ad libitum for 65 h and then fasted for 7 h. Excreta were collected during the balance period and stored at $-20°C$. Excreta were then freeze-dried, equilibrated at ambient temperature for 1 day, weighed, ground and kept in sealed plastic bags prior to analysis. Food intakes were corrected for variations in feed dry matter (DM) content observed between the beginning and the end of the balance feeding period.

Nitrogen was measured by Kjeldahl's method. Faecal nitrogen was measured on the faecal fraction separated from excreta by the procedure of Terpstra and de Hart (1974). Starch was measured in feed and excreta using the dimethylsulfoxide (DMSO) procedure (Boehringer Mannheim, 1980) as described by Carré et al. (1987). Gross energy of feed and excreta was measured with an adiabatic bomb calorimeter (Gallenkamp). The AMEn value of diets was calculated according to the procedure of Hill and Anderson (1958). The AMEn and digestibility values assigned to the field bean fractions were calculated by assuming additivity of the values assigned to field beans and basal fractions undergoing the same technical treatment.

The number of trypsin units inhibited per milligram dry matter (TUI mg^{-1} DM) was measured by two procedures (Valdebouze, 1977; American Oil Chemists' Society, 1975) and lipids according to Folch et al. (1957). Statistical analysis was performed by analysis of variance with comparison of means according to the Newman and Keuls test (Zivin and Bartko, 1976).

RESULTS

The proximate analysis of field beans showed little variation between the cultivars investigated (Tables II and III). However, Soravi seeds appeared to contain slightly less protein and starch. Temperatures during the pelleting process varied little between diets (Table IV). Particle sizes of ground (G), or pelleted and reground (PG), diets were similar. Cultivar type had no effect on particle size (Table V). The AMEn values of pelleted (P) faba beans were greater than those of unpelleted (G) beans ($P<0.001$). The mean increase was 1.23 MJ kg^{-1} which represents an improvement of 12%. Regrinding after pelleting slightly improved the AMEn values of faba beans (PG compared with P), but this effect (1.2% mean increase) was not significant (Table VI).

The AMEn values of the 3 faba bean cultivars seemed to be affected in different ways by pelleting, with effects increasing in the following order: Alfred, Soravi, Blandine. However, these differences in response to pelleting were not significant.

Differences in responses to pelleting became more clear when the digestibil-

TABLE II

Chemical composition of faba beans (% of DM)

Composition	Cultivar		
	Alfred	Soravi	Blandine
Total protein (N×6.25)	28.5	28.0	29.9
Starch	42.1	40.8	42.4
Lipids	1.7	1.8	1.8
Ash	3.4	3.8	3.5

TABLE III

Trypsin inhibitor level in raw faba bean seeds and mash or pelleted diets (TVI units mg^{-1} DM)

	Method	
	1	2
Faba bean cultivars		
Alfred (A)	2.8	2.9
Soravi (S)	2.1	3.1
Blandine (B)	2.9	2.8
Diet		
A		
Mash	2.6	2.8
Pelleted	1.6	2.5
S		
Mash	2.2	3.2
Pelleted	2.1	2.9
B		
Mash	2.3	3.2
Pelleted	1.6	2.4

Method 1: Valdebouze (1977).
Method 2: American Oil Chemists' Society (1975).

TABLE IV

Thermal conditions during pelleting

Diet group[1]	Temperatures (°C)	
	Mash before the die	Pellets after the die
OP, OPG	66–70	86–87
AP, APG	66–67	84
SP, SPG	71–72	86
BP, BPG	70–71	87–88

[1] O, control; P, pelleted; PG, reground pellets.

TABLE V

Particle sizes of the diets (mean diameter in $\mu m \pm s.d.$)

Diet type	Cultivar used in diet			
	0	Alfred	Soravi	Blandine
Mash	389±2.2	382±2.5	372±2.7	387±2.4
Reground pellets	404±1.9	372±2.2	406±2.1	374±2.1

TABLE VI

Effects of processing on classical (AME) and nitrogen-corrected metabolisable energy (AMEn) values in 3 cultivars of faba beans (MJ kg^{-1} DM)

	Cultivar used in diet			Mean
	Alfred	Soravi	Blandine	
AME				
Mash diet	11.16 ± 0.18^a	10.82 ± 0.18^a	10.78 ± 0.10^a	10.92
Pelleted diet	12.09 ± 0.13^b	12.01 ± 0.20^b	12.42 ± 0.15^b	12.17
Pelleted reground diet	12.13 ± 0.15^b	12.17 ± 0.08^b	12.71 ± 0.18^b	12.34
AMEn				
Mash diet	10.64 ± 0.16^a	10.30 ± 0.16^a	10.17 ± 0.09^a	10.37
Pelleted diet	11.50 ± 0.13^b	11.49 ± 0.18^b	11.80 ± 0.14^b	11.60
Pelleted reground diet	11.57 ± 0.12^b	11.61 ± 0.06^b	12.03 ± 0.18^b	11.74

Values are means±s.e. Values followed by a different superscript are significantly different ($P<0.01$).

ity of protein and starch in seeds from the 3 cultivars was investigated. Whatever the treatment considered, the highest protein digestibility values were always observed for the Blandine tannin-free cultivar ($P<0.05$) (Table VII). The differences between protein digestibility values for Blandine seeds and those for other cultivar seeds were in the range of 13.2–15.7%. The protein digestibility values for Alfred and Soravi beans were similar, the higher value found for Soravi not being significant (Table VII). Pelleting significantly increased ($P<0.05$) protein digestibility values in the Alfred and Blandine cultivars but not in the Soravi cultivar. Regrinding after pelleting did not improve protein utilization in any cultivar.

The starch digestibility values for pelleted or unpelleted seeds were always lower in the Blandine cultivar than in the other two ($P<0.01$), this difference being more pronounced in the case of unpelleted seeds (Table VIII). In each cultivar pelleting resulted in a strong improvement ($P<0.01$) in starch digestibility values; this increase was in the range 7.9 (Alfred)–14.6% (Blandine).

TABLE VII

Effects of processing on apparent protein digestibility in 3 cultivars of faba beans (%)

Diet type	Cultivar used in diet			
	Alfred (A)	Soravi (S)	Blandine (B)	Mean
Mash	66.9 ± 1.3^{a}	69.4 ± 1.9^{ab}	82.6 ± 1.0^{c}	73.0
Pelleted	70.6 ± 1.0^{b}	72.3 ± 1.3^{b}	87.2 ± 0.7^{d}	76.7
Pelleted, reground	70.6 ± 0.8^{b}	72.1 ± 0.8^{b}	86.5 ± 0.8^{d}	76.4
Mean	69.4	71.3	85.4	

Values are means ± s.e. Values followed by a different superscript are significantly different ($P < 0.05$).

TABLE VIII

Effects of processing on starch digestibility in 3 cultivars of faba beans (%)

Diet type	Cultivar used in diet			
	Alfred (A)	Soravi (S)	Blandine (B)	Mean
Mash	85.6 ± 0.9^{b}	83.4 ± 0.6^{b}	75.1 ± 0.4^{a}	81.4
Pelleted	93.5 ± 0.4^{d}	93.5 ± 0.8^{d}	89.7 ± 0.5^{c}	92.2
Mean	89.6	88.4	82.4	

Values are means ± s.e. Values followed by a different superscript are significantly different ($P < 0.01$).

DISCUSSION

The present results, showing higher protein digestiblity in tannin-free than in tannin-containing cultivars, are in agreement with previous studies carried out on young birds (Guillaume, 1978) and adult birds (Poulsen and Petersen, 1982), although these studies were different with respect to the levels of faba bean inclusion and the cultivars tested.

The protein digestibility values of untreated and heat-treated faba beans found in our assays were similar to those reported by Guillaume (1978). In both experiments, the heat treatment of diets (in the first case) and the heat treatment of faba beans (in the second case) induced only a slight increase in protein digestibility (4–9%). However, in our results, protein utilisation in the tannin-containing cultivars was not enhanced by heat treatment as much as Guillaume (1978) and Marquardt and Ward (1979) have reported. However, these authors used autoclaving in the preparation of their diets whereas the present study employed pelleting.

Guillaume (1978) reported that starch digestibility was lower for untreated tannin-free field beans than for tannin-containing field beans. The beneficial effect of heat treatment on starch digestibility in tannin-free cultivars found in this study (Table VIII) has also been reported by Guillaume (1978). But in contrast with the results of the present study, Guillaume (1978) did not find such an effect in tannin-containing cultivars. This apparent discrepancy may be due to the higher level of field bean inclusion in Guillaume's experiment, or to differences in the methods of measurement of starch glucose. Concerning the latter point, Carré and Brillouet (1986) have shown that the measurement of glucose by the glucose-oxidase method used by Guillaume (1978) is not suitable for tannin-containing cultivars.

The low energy values of untreated seeds of tannin-containing and tannin-free cultivars of faba beans arise because young chicks are unable adequately to digest their starch and/or protein fraction; the differences in protein and starch digestibility between mash and pelleted diets explained 71–88% of seed AMEn increases. The mean AMEn value (10.37 MJ kg^{-1} DM) of untreated faba beans, calculated for the 3 cultivars, was similar to values found by Edwards and Duthie (1970, 1972) for 11 samples of Throws M.S. field beans (10.50 MJ kg^{-1} DM), and for 6 winter cultivars and 6 spring cultivars (10.92 MJ kg^{-1} DM).

As shown in the present experiment and in Guillaume's (1978) study, the energy value of seeds tends to be slightly lower in tannin-free cultivars than in tannin-containing cultivars.

In conclusion, it may be stated that pelleting of whole diets, an interesting treatment owing to its widespread utilization, can greatly improve (1.23 MJ kg^{-1} DM mean increase) the AMEn value of field beans. The utilization of tannin-free field beans appears particularly valuable in that their proteins are more digestible than those of tannin-containing seeds. However, no great improvement in field bean AMEn value can be expected from using tannin-free instead of tannin-containing seeds, as starch digestibility remains somewhat lower in the former, even after pelleting.

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