Evaluation of faba bean (*Vicia faba* cv. Fiord) as a protein source for broilers

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Abstract

An experiment was conducted, using 960 sexed broiler chicks between 7 and 21 d of age, to measure their response to increasing contents of faba bean in the feed. The experimental design consisted of two sexes, six levels of faba bean (0 to 250 g/kg feed), two feed forms (mash and pellets) and two levels of methionine supplementation (0 and 1.5 g DL methionine/kg feed). Each treatment was replicated twice, using 96 pens and 10 chicks per pen. The responses were the same between sexes and between methionine levels. Where feeds were offered in a mash form, growth rate and feed conversion efficiency (FCE) declined linearly, and food intake increased linearly, with increasing faba bean content, but when the feeds were pelleted, performance was the same on all levels of faba bean, suggesting that heat generated during the pelleting process may have destroyed some heat labile anti-nutritional factor present in the faba bean. As most broiler feeds are pelleted, it would appear that faba beans could be used successfully as an alternative protein source in feeds for broilers, up to an inclusion level of 250 g/kg, when geographic, agronomic and economic conditions favour the use of these beans.

Keywords: Feed form, dilution trial, anti-nutritional factors
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Introduction

Faba beans (*Vicia faba*) may be considered a potential source of protein in poultry feeds, as they have an amino acid content similar to that of soybean, except for a lower methionine content (Bond *et al*., 1985). However, they contain small amounts of anti-nutritional factors, some of which have effects that are less acute than those found in soybeans. Trypsin inhibiting activity, for example, was found by Wilson *et al.* (1972) to be a fifth of the strength of the trypsin inhibitor activity in soybeans, but the concentration of haemagglutinins (lectins) is higher in faba beans than in most legumes and can cause a problem, as these chemicals agglutinate red blood cells. These authors also found the activity to be present in both the cotyledon and testa of faba beans, which led to the conclusion that 'dehulling of the bean is not, therefore, a means of eliminating trypsin inhibitor activity'. This is supported by the results of Guillaume & Bellec (1977) who found that a reduction in egg weight could not be prevented by the removal of the hulls, but contradicts the results published by Marquardt *et al.* (1973) that most of the anti-nutritional factors found in the beans are located in the dehulled cotyledon, which led them to recommend dehulling and heat-treating the bean for optimum efficiency of faba bean utilization. Knox *et al*. (1995) and Jansman *et al*. (1995) also indicated that the poorer digestibility of the starch from coloured-flowered varieties of faba bean is due to the higher proanthocyanidin (condensed tannin) content of the hulls of these varieties compared with the white-flowered varieties.

The variety of faba beans used in this trial was the same as that used in the trials of Brand *et al*. (1995) and Perez-Maldonado *et al*. (1999), and is the only variety grown commercially in South Africa. Brand *et al.* (1995) determined the alkaloid content of the beans using the method described by Ruiz (1911) and found no trace of any alkaloids in the seed. However, they did find that the beans contained tannin (0.48%). Similarly, Perez-Maldonado *et al.* (1999) measured the condensed tannin content using the method described by Perez-

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Maldonado & Norton (1996) and found a total of 15.1 *Desmodium intortum* equivalents. They did not specify whether they tested hulled or dehulled beans but it is presumed that hulls were present. The condensed tannin content of the dehulled faba beans was measured prior to conducting the present trial, the method used and the condensed tannin content being described in Emiola & Gous (2011). The level of these anti-nutritional factors were found to be very low (<0.5% catechin equivalents).

The two methods that have been investigated for improving the nutritive value of *Vicia faba* are autoclaving and methionine supplementation. Both methods have merits and disadvantages. Methionine-supplementation is expensive and partially improves the nutritive value, whereas autoclaving inactivates the trypsin inhibitors in the beans but may be responsible for a diminished nutritive value, and is not suitable for the treatment of large quantities of beans (McNab & Wilson, 1974). Wilson & McNab (1972) reported that broilers on an autoclaved feed limiting in methionine had a poorer rate of growth than those chicks fed a raw, but methionine-supplemented feed, which led to the conclusion that "there is no significant effect of autoclaving when methionine and cysteine levels are adequate". These levels should not be higher than 0.3% methionine as higher levels depress growth, which may be characteristic of methionine toxicity. Kadirvel & Clandinin (1974) reported a slower rate of growth in turkey poults and broiler chicks when the level of autoclaved beans was raised from 5 to 20% in the feed, whereas there were no detrimental consequences on growth rate in those fed raw beans. This decreased growth rate was attributed to a decreased availability of amino acids due to the heating treatment. Similar results were reported by Nitsan (1971), who noted that the process of autoclaving adversely affected the nutritive value of the field beans and failed to destroy the trypsin inhibitors in the beans.

It is evident from this review that the literature is inconsistent with regard to the effect of faba beans on growth and feed conversion of broiler chicks. A sensitive bioassay for determining the comparative nutritional value of faba beans and soybean oilcake meal can be accomplished using broiler chicks housed in wire-floored brooder cages, as the number of factors that may be assessed simultaneously is large. In our facilities, 96 cages are available for such purposes. The trial reported here was designed to evaluate faba beans as a protein source for broiler chickens using raw dehulled faba beans with and without supplementation with DL methionine, with the feed in a mash or pelleted form, the latter on the assumption that the heat generated during pelleting may be sufficient to destroy any heat labile anti-nutritional factors present in the faba beans.

Materials and Methods

The composition of the faba beans to be used in the trial was determined prior to formulating the basal feed containing this ingredient. Apparent metabolizable energy (AME) content was determined with adult roosters using the method of McNab & Blair (1988). The analysis for crude protein was performed with a LECO FP2000 nitrogen analyser (Dumas combustion method; AOAC official method 1984), crude fibre with a Dosi-fibre machine (AOAC official method 1984), and amino acids using a Pickering PCX5200 post-column derivatisation instrument (AOAC Official Method 994.12). Digestibilities of amino acids were calculated from the excreta amino acid contents obtained from the AME determination using the method of McNab (1995). Tryptophan content was not measured, and the value assigned to faba beans for this amino acid is an average of a number of values appearing in the literature. The proximate analysis of the faba beans used in the trial is given in Table 1.

Nine hundred and sixty one-week-old (168 g mean body weight) broiler chicks were used in the trial. Up to this age they were fed commercial broiler starter crumbles (230 g protein and 12.8 MJ AME/kg feed). Ten chicks were placed per pen, with males and females being kept separate. Each pen of chickens was weighed as a group, and the food that they received was weighed out in a bucket, and allocated to them as required. At the end of weeks one and two of the trial (when broilers were two and three weeks of age, respectively) the chicks were weighed again, and the food remaining in the trough and bucket was also weighed.

Two basal feeds were formulated using the WinFeed formulation programme (EFG Software, 2005) and the Aviagen (2006) amino acid recommendations for a starter feed. One of the basal feeds (faba basal) contained the maximum amount of dehulled faba bean possible (250 g/kg feed) without including high levels of oil, and the other (soybean basal) contained the same contents of all essential nutrients as the faba basal, but with no faba beans included (Table 2). These two basal feeds were blended to produce six levels of faba bean inclusion, from 0 to 250 g/kg feed using the following ratios of faba bean and soybean basal: 0:1.0;

0.2:0.8, 0.4:0.6, 0.6:0.4, 0.8:0.2 and 1.0:0. These blended feeds were then divided in two with one half being pelleted through a 1.8 mm die. The 12 resultant treatments were once again subdivided, with half being supplemented with 1.5 g DL methionine/kg feed. The experimental design therefore consisted of two sexes, six levels of faba beans, two feed forms and two levels of methionine supplementation, i.e. 48 treatments replicated twice.

Table 1 Apparent metabolizable energy (AME) content and nutrient composition (g/kg) of faba beans used in the study

Nutrient	Content (g/kg as is)	Digestibility (g/100 g)
AME(MJ/kg)	11.3	
Crude protein	234	
Dry matter	872	
Ash	42.7	
Crude fat	12.1	
Crude fibre	85.0	
Lysine	19.0	75.0
Methionine	2.1	78.0
Methionine+cystine	5.5	65.9
Threonine	5.8	84.6
Tryptophan	2.2	80.0
Arginine	24.3	78.7
Isoleucine	9.6	87.9
Leucine	18.3	87.1
Phenyl.+tyrosine	14.2	88.5
Valine	11.3	86.0
Calcium	1.5	
Avail. phosphorus	2.0	
Sodium	0.5	
Chlorine	1.0	
Potassium	12.0	

The variables measured in the trial were body weight initially (7 d) and at 14 and 21 d, food intake from 7 to 14 d and from 14 to 21 d, and mortality when this occurred. From these measurements, mean daily gain in weight, mean daily food intake and feed conversion efficiency (FCE) (g gain/kg feed consumed) were calculated.

Treatment means and the residual mean square for each variable in the experiment were obtained by analysis of variance (Genstat, 2005), but no treatment means were compared using this method of analysis. Because the trial was designed to measure the response to increasing dietary contents of faba bean, this response was determined by simple linear regression, and the effects of sex, methionine addition and pelleting on the response were compared using simple linear regression with groups (Genstat, 2005).

Results

The only factor having a significant effect on growth rate and feed intake was feed form, with pelleted feed resulting in higher feed intakes (P <0.001) and hence growth rates (P <0.001) and FCE (P <0.001) over all levels of faba bean inclusion (Table 3) than when feed was offered in mash form. There were no interactions between faba bean inclusion and methionine addition or sex, and the three-way interaction was also not significant. Consequently, only the interactions between faba bean inclusion and feed form are shown in Table 3, together with the main effects of feed form, methionine addition and sex on mean body weight gain, food intake and FCE.

Growth rate, food intake and FCE were regressed on faba bean inclusion in the feed, using feed form, added synthetic methionine, sex, and all combinations of these factors, as Groups in Genstat (2005). In the case of growth rate, the response to faba bean inclusion differed (Table 4) for mash and pellets in both the constant term (32.98 *vs*. 38.87) and regression coefficient (-1.007 *vs*. 0.0304), i.e. when the feeds were presented in a mash form growth rate declined significantly as faba bean inclusion was increased, whereas in the pelleted form the response was the same over all faba bean levels. Similarly, both the constant term (627 *vs*. 610) and regression coefficient (-1.641 *vs*. 0.284) differed significantly for mash and pellets when FCE was regressed against faba bean inclusion, again demonstrating that the significant decline in FCE with faba bean inclusion only occurred when the feed was offered in a mash form. However, only the constant terms differed for mash and pellets when food intake (51.97 *vs*. 42.95) was regressed against faba bean inclusion. In no other case did the response differ between levels of a factor either singly or in combination with other factors. Hence, the constant terms and regression coefficients given for growth rate, food intake and FCE for added methionine in Table 4 reflect the responses for sex as well as for the effect of adding synthetic methionine to the feeds.

Table 2 Composition (g/kg) of the faba bean and soybean basal feeds used

Ingredient	Faba bean	Soybean
Maize	264	452
Wheat bran	49.9	
Faba beans	250	
Soybean oilcake	150	250
Sunflower oilcake	100	110
Fish meal	100	104
L-lysine HCl	0.7	0.7
DL methionine	1.4	
Vit + Min premix	2.5	2.5
Limestone	11.3	10.4
Salt	0.0	0.04
Monocalcium phosphate	6.0	7.7
Sodium bicarbonate	4.5	4.7
Oil – sunflower	60.0	58.1
Calculated composition		
$AME_{n,}$ MJ/kg	12.8	12.8
Crude protein	258	263
Lysine – dig.	13.7	13.7
Methionine and cysteine – dig.	8.0	8.0

Only 11 chicks (1.15/100) died during the trial, and these mortalities occurred randomly across treatments.

Discussion

The alkaloid and condensed tannin contents of some varieties of faba beans are sufficient to reduce performance in poultry and pigs. However, the alkaloid content of the variety of faba beans used in this trial (*Vicia faba* cv. Fiord) was measured by Brand *et al*. (1995) to be 0.0, and Emiola & Gous (2011) measured the condensed tannin content to be <0.5% catechin equivalents. Little if any reduction in performance was therefore expected when this variety was used to replace other protein sources in the feed for broilers.

Perez-Maldonado *et al*. (1999) used a more comprehensive test of the tannin content of this variety of faba beans than did Emiola & Gous (2011). Their method described the content of free tannins, as well as protein- and fibre-bound tannins, but it is likely that they measured these in the intact bean, including the hulls. Because tannins are found usually in the hulls of faba beans, and in this trial dehulled faba beans were used, the condensed tannin content of the dehulled beans was very low. Nevertheless, from the results presented it appears that the faba beans used in this trial may have contained an unidentified anti-nutritional factor that was destroyed when the feeds were subjected to the pelleting process, even though the levels of alkaloids and condensed tannins were very low. The significant decline in growth rate and FCE with increasing faba bean inclusion occurred only when the feeds were offered in a mash form. The range of faba bean inclusions, when pelleted, resulted in similar responses, suggesting that no anti-nutritional factors were present in these feeds. It is interesting that the pelleting process provided sufficient heat to inactivate these deleterious factors, and that it was not necessary to resort to autoclaving to obtain these results. Both Nitsan (1971) and Kadirvel & Clandinin (1974) have suggested that by autoclaving the beans the availability of amino acids may be decreased due to the heating treatment. In the present trial, performance was significantly improved over all faba bean levels, but more so as the faba bean content was increased, suggesting firstly that broilers perform better on pelleted than on mash feeds, and secondly, that the heating process improved the quality of the faba beans in some way, rather than denaturing the amino acids to the extent that performance was harmed.

Table 3 Main effects of faba bean inclusion (g/kg), feed form, methionine addition and sex on mean body weight gain, food intake and food conversion efficiency (FCE) of sexed broilers fed mash or pellets, with or without the addition of DL methionine, from 7 to 21 d of age

Faba inclusion	Weight gain, g/bird d		Food in, g/bird d		FCE, g gain/kg feed	
	Mash	Pellets	Mash	Pellets	Mash	Pellets
0	32.1	38.7	51.5	60.3	624	642
50	33.1	40.0	53.3	61.5	621	650
100	32.7	38.6	53.8	60.2	607	640
150	31.1	38.0	50.9	60.7	611	627
200	31.5	40.8	52.7	63.2	598	646
250	29.8	39.4	51.4	61.8	579	637
Feed form						
Mash	31.7		52.3		607	
Pellets	39.3		61.3		640	
Methionine						
0	35.5		57.0		620	
+	35.5		56.5		627	
Sex						
Males	35.7		57.0		625	
Females	35.3		56.6		622	
Res. M.S.	5.60		7.77		518	

It has been suggested (Wilson & McNab, 1972) that there is no significant effect of autoclaving faba beans on performance when methionine and cysteine levels are adequate. The methionine content in the basal feeds in this trial was presumably sufficient, as the addition of synthetic methionine to these feeds had no effect on performance: had this not been the case, performance would have been expected to be poorer on the pelleted feed limiting in methionine than on the raw, but methionine-supplemented feed, according to

Wilson & McNab (1972). There was no interaction between feed form and methionine supplementation in this trial.

Because performance was the same on all pelleted treatments, the digestible nutrient contents of the feed ingredients used in formulating the two basal feeds must have been a true reflection of the nutritive value of the ingredients. This is a prerequisite when conducting response trials of this nature.

In two other trials conducted at the University of KwaZulu-Natal, involving the same source of faba beans, no negative responses were obtained when mash feeds were fed. One of the trials involved laying hens (Magoda & Gous, 2011) whilst the other used weaner pigs from 10 to 25 kg liveweight (Emiola & Gous, 2011). These larger birds and animals are presumably not as sensitive to anti-nutritional factors as are broiler chicks up to 21 d of age.

Table 4 Constant terms and regression coefficients describing the effects of faba bean inclusion on growth rate, food intake and feed conversion efficiency (FCE) in broilers between 7 and 21 d of age, and the effect of feed form and added methionine on these relationships

Parameter	Growth rate, g/d			Food intake, g/d			FCE, g gain/kg feed		
	Estimate	SE	t	Estimate	SE	t	Estimate	SE	t
Constant	33.0	0.62	0.001	52.0	0.58	0.001	627	6.04	0.001
Faba inclusion	-0.101	0.04	0.016	0.023	0.03	0.050	-1.64	0.40	0.001
Feed form									
Pellets	5.89	0.88	0.001	9.023	0.57	0.001	16.7	8.54	0.053
Faba.Pellets	0.131	0.06	0.027				1.36	0.56	0.018
Added methionine									
Constant	35.9	0.82	0.001	56.5	0.97	0.001	635	5.34	0.001
Faba inclusion	-0.035	0.05	0.519	0.023	0.06	0.723	-0.96	0.35	0.008

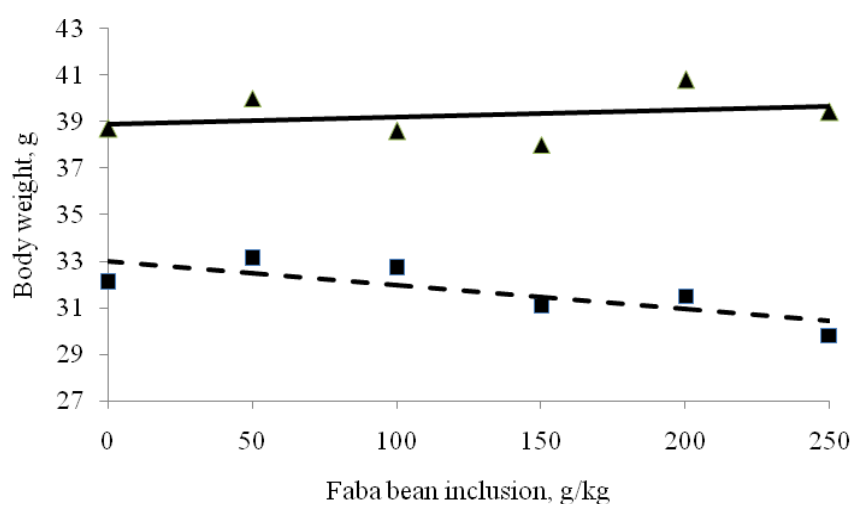

Figure 1 Response in body weight (g) at 21 d in broiler chicks fed increasing contents of faba bean in pelleted (▲, solid line) or mash (■, dashed line) feeds.

It is informative to make some comment about the statistical analysis used in the trial. Where an experiment is designed to measure the response to some quantitative input (e.g. faba bean inclusion, temperature, dietary protein content, etc.) it is not appropriate to use an analysis of variance or Duncan's multiple range test to determine if differences exist between means. These tests are designed to compare qualitative treatments such as sex, vaccine, strain or growth promoter and are inappropriate for response trials (Morris, 1991; Chew, 1996). In this trial the responses in growth rate and feed conversion efficiency to increasing dietary concentrations of faba bean were measured, and for this to be analysed correctly, a response surface of some sort needs to be fitted to the data. The objective of the trial reported here was to determine whether there were interactions between the various factors included in the design (sex, methionine supplementation and feed form) and the response to faba bean inclusion. This is accomplished with the use of simple linear regression with groups (Genstat, 2005). The groups in this case are the levels of each of the factors, and the objective is to determine whether the regressions for each level share a common intercept and/or a common slope. This is sometimes known as a test of parallelism. In spite of many experiments being designed to measure responses to various inputs, very few are analysed correctly. For example, the experiment reported by Farrell *et al.* (1999) that was designed to determine the optimum concentrations of four feed protein sources was incorrectly analysed, as they tested treatment means for significant treatment effects using the Tukey's HSD multiple range test. This lead to statements such as 'weight gain was highest at the two lowest faba bean inclusions and, at 240 to 360 g/kg, weight gain was lower (P <0·05) than at 180 g/kg. It is more meaningful, and easier, to describe the overall response to the inclusion of faba beans over the range used rather than to test for significant differences between levels.

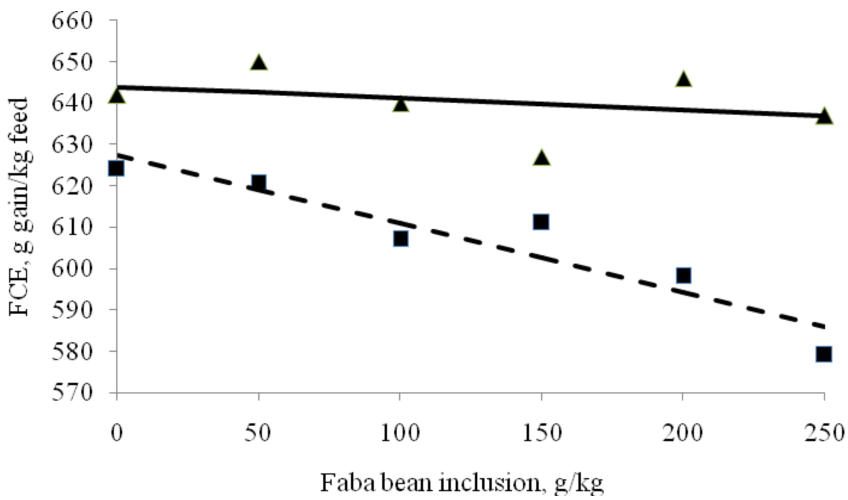

Figure 2 Response in feed conversion efficiency (g gain/kg feed) between 7 and21 d in broiler chicks fed increasing contents of faba bean in pelleted (▲, solid line) or mash (■, dashed line) feeds.

Conclusions

Faba beans appear to contain a heat labile compound that causes a reduction in performance of young broiler chickens, but which is destroyed by the conditions that prevail when the complete feed is pelleted. The compound was not identified in this trial, but is not condensed tannins. As most broiler feeds are pelleted, it would appear that faba beans could be used successfully as an alternative protein source in feeds for broilers when geographic, agronomic and economic conditions favour the use of these beans. Levels up to 250 g faba bean/kg feed may be fed without causing a decrease in performance in young broiler chickens.

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