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Feeding value of field bean (*Vicia faba* L. var. *minor*) for laying hen pullets

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ABSTRACT. Concerns over the sustainability of using soybean in poultry diets, has steered the need to develop alternative protein sources for modern poultry production. This experiment examined the effect of nine different United Kingdom grown field bean (*Vicia faba* L. var. *minor*) cultivars from the same harvest year on apparent metabolizable energy (AME) and dry matter digestibility (DMD) when fed to Hy-Line Brown pullets from 14 to 16 weeks of age. A balancer feed was formulated to contain 11.54 MJ/kg AME and 166.4 g/kg crude protein. Nine nutritionally complete, meal-form diets were then prepared by mixing 200 g/kg of each field bean cultivar with 800 g/kg of balancer feed, making a total of ten diets. Each diet was fed to eight cages containing two birds. AME was determined via total collection technique over the last four days of the study. Relationships were examined between AME and the chemical composition of the beans. The overall determined AME value of the beans ranged from 9.31 MJ/kg DM to 12.26 MJ/kg DM, giving an average AME of 10.94 MJ/kg DM ($P < 0.001$). Total non-starch polysaccharide (NSP) content of the beans negatively correlated with their determined AME ($P < 0.05$) and also tended ($P = 0.066$) to negatively reduce AME based on regression analysis. There is evidence that total NSP may be used by nutritionists to predict AME value of field beans, however, stronger evidence is required. This information may be used by plant breeders to aid in the development of new field bean cultivars.

Introduction

Soybeans are rich in protein, essential amino acids, and other valuable nutrients, rendering them a valuable ingredient for the poultry feed sector. In 2018, the European Union (EU) imported 15.5 million tonnes of soybean and 18 million tonnes of soybean meal (IDH & IUCN NL, 2019). Due to the growing global demand for soybean meal (SBM), the price is continuously increasing, particularly after the EU restricted the use of animal protein in poultry diets (IDH & IUCN NL, 2019). These factors have led to a drive in the need for more sustainable feed ingredients, thus increasing the need to develop alternative protein sources for modern poultry production (Whiting et al. 2018; 2019; Karkelanov et al., 2020; 2021; Watts et al. 2020; 2021). The search for locally grown alternative protein sources, such as field bean (*Vicia faba* L. var. *minor*), is necessary and may decrease the dependency of the European poultry industry on imported SBM as a source of protein. Field bean have a high protein concentration and their amino acid profile is similar to that of soybean (Woyengo and Nyachoti, 2012), rendering them a suitable replacement for SBM, at least partially, in poultry diet formulations. The apparent metabolizable energy (AME) of field bean is another significant characteristic with regards to their feeding value which is an important factor to consider when formulating diets for poultry. The majority of studies assessing the AME of field bean has been carried out on broilers (Nalle et al., 2010; Abdulla et al., 2016a; b; 2017) however, there is a lack of information on the energy availability of field bean for laying hens and pullets. Dietary available energy may vary due to age (Yang et al., 2020), dietary form and processing (Pirgozliev et al., 2016), species (Priyankarage et al., 2008), dietary ingredient composition (Lim et al., 2021), rearing conditions (Pirgozliev et al., 2014) as well as other factors. Thus, the aim of this study was to examine the differences in AME of nine different field bean cultivar samples fed to laying hen pullets. The relationship between the chemical composition and AME of the field bean samples was also determined.

Material and methods

Field bean cultivar samples

Nine different flower colour, UK-grown field bean, including two spring (Fury and Maris Bead) and seven winter grown cultivars (Arthur, Buzz, Clipper, Divine, Honey, Sultan and Wizard) from the same harvest year were obtained from Askew & Barrett (Pulses) Ltd., Wisbech, UK. Proximate analysis, gross energy, carbohydrate, amino acid and mineral contents, phenolic compounds, grain quality and viscosity of the freshly milled bean samples were measured and presented in previous reports (Abdulla et al., 2021a; b). The laboratory analyses of field bean cultivars used in this study are presented in Table 2.

Diet formulation

A wheat-soybean meal balancer diet was prepared, containing wheat (675 g/kg) and soybean meal (180 g/kg) as main ingredients, giving an AME of 11.54 MJ/kg and a crude protein (CP) content of 166.4 g/kg (Table 1). Nine diets were then produced by mixing 200 g/kg of each of the nine different field bean cultivars with 800 g/kg of the balancer feed. In total, ten experimental diets were compared, including the balancer and the diets containing the field bean. Freshly milled field bean samples were used in the formulation of the diets and were fed as mash. All diets approximately met or exceeded the dietary specifications for Hy-Line Brown laying hen pullets (Hy-Line, Studley, UK). Diets did not contain any coccidiostat, antimicrobial growth promoters, prophylactic or other similar additives.

Table 1. Ingredient composition (g/kg, as-fed), calculated and analysed energy and nutrient content of the experimental laying hen pullet's balancer formulation

Ingredient	Balancer feed, g/kg
Wheat	676.2
Soybean meal (crude protein = 48%)	180.0
Soy oil	20.0
NaCl	5.0
Lysine	1.0
Methionine	2.5
Tryptophan	0.3
Dicalcium phosphate	20.0
Limestone	95.0
Vitamin/mineral premix[1]	1.1
Total	1000
Calculated composition	
apparent metabolizable energy, MJ/kg	11.54
crude protein, g/kg	166.4
crude fat, g/kg	34.9
available lysine, g/kg	8.0
methionine + cysteine, g/kg	7.4
Ca, g/kg	42.1
P, g/kg	6.9
Determined composition[2]	
apparent metabolisable energy, MJ/kg	11.45
dry matter, g/kg	906.0
gross energy, MJ/kg	14.74
crude protein, g/kg	139.7
crude fat, g/kg	26.7

This balancer was fed as part of a complete diet comprised 200 g/kg of each experimental field bean sample and 800 g/kg of the balancer; [1] vitamin and mineral premix provided (units per kg/feed): μg: retinol 2160, cholecalciferol 75; mg: α-tocopherol 25, menadione 1.5, riboflavin 5, pantothenic acid 8, cyanocobalamin 0.01, pyridoxine 1.5, thiamine 1.5, folic acid 0.5, niacin 30, biotin 0.06, iodine 0.8, copper 10, iron 80, selenium 0.3, manganese 80, zinc 80; [2] dry matter, gross energy, crude protein and crude fat were determined in duplicates

Husbandry and sample collection

The experiment was conducted at the National Institute of Poultry Husbandry and approved by the Harper Adams University Research Ethics Committee (Project number PG26-201404). A total of 160, 14-week old, Hy-Line Brown laying hen pullets were obtained from a commercial supplier (Country Fresh Pullets Ltd., Oswestry, UK). On arrival, the birds were randomly allocated to 80 metal cages, two bird in a cage, with 8 replications per treatment. Bird housing was equipped with scratching area, perch, trough drinkers inside and a separate feeder at the front. The pullets were not in lay thus laying nests were not provided. Housing dimensions were 0.61 m × 0.61 m × 0.95 m and consisted of a wire mesh flooring (area of 0.372 m^2) which contained no bedding material. Room temperature was maintained at 21 °C and relative humidity was between 50 and 70%. The birds had *ad libitum* access to feed and water. Lighting was set to 10-h day length upon arrival and maintained until the end of the study at 16 weeks of age. To ensure all birds were healthy and environmental conditions were adequate, birds were observed at least twice a day. The birds were offered the experimental diets on arrival to allow them to acclimatize to the diets prior to excreta collection. The birds received the experimental diets for 14 days, as the first 10 days were given to birds to adjust to the feed and conditions. During the final 4 days of the experiment, excreta were quantitatively collected daily and dried promptly at 60 °C, until a constant weight. Feed intake was also measured for the same period. The dried excreta, as well as representative balancer diet and bean samples were ground to pass through a 0.8 mm screen. The dry matter (DM) and gross energy (GE) of dried excreta and the DM, GE, CP (N × 6.25) and fat in diets were determined as described by Dei et al. (2008). The phytate content in beans was determined by HPLC, as previously described (Kwanyuen and Burton, 2005).

The AME of diets and beans and DMD of the diets were determined using total collection technique using the following equations:

$$AME_{\text{whole diet}}\ [\text{MJ/kg DM}] = \frac{(GE_{\text{intake}}[\text{MJ}] - GE_{\text{output}}\ [\text{MJ}])}{\text{Feed intake [kg DM]}}$$

$$AME_{\text{field bean}}\ [\text{MJ/kg DM}] = \frac{AME_{\text{whole field bean diet}} - (AME_{\text{balancer diet}} \times 0.8)}{0.2}$$

$$DMD_{\text{whole diet}} = \frac{DM_{\text{intake}} - DM_{\text{output}}}{DM_{\text{intake}}}$$

where: GE_{intake} was the dietary intake for the collecting period multiplied by the gross energy of the diet, GE_{output} was the dry excreta collected multiplied by the gross energy of the excreta, DM_{intake} was the dietary dry matter intake for the collecting period and DM_{output} was the dry matter of the excreta collected.

Statistical procedure

The observational unit was the cage with two laying hen pullets. Statistical analyses were performed using the GenStat 19th statistical software package (GenStat for Windows; IACR, Rothamstead, Hertfordshire, UK). The AME and the DMD coefficient of the experimental field bean samples were statistically compared using a randomised block analysis of variance. The position of pens within the room was used as the blocking factor. Duncan's multiple range test was used to determine significant differences between field bean treatment groups. The coefficients of correlation between all studied variables were also obtained. Simpe linear regression analysis was used to test the relationship between AME and laboratory measurements of dietary field bean samples. In all instances, differences were reported significant at $P < 0.05$.

Results and discussion

The detailed chemical composition and physi-cal characteristics of the experimental field bean cultivar samples were published in our previous reports (Abdulla et al., 2021a; b). Selected laboratory analyses of field bean cultivars used in this study are presented in Table 2. In brief, the range of lightness scores varied from 88 (cv. Sultan) to 95 (cultivars Divine, Fury, Honey) (CV = 2.5%). There was a range of total starch

Table 2. Laboratory analyses of lightness, starch, crude protein, non-starch polysaccharides, condensed tannins and phytate of field bean cultivar sample used in this study[1]

Diet	*L**	*a**	*b**	Starch, g/kg DM	CP, g/kg DM	NSP tot, g/kg DM	NSP ins, g/kg DM	NSP sol, g/kg DM	CT, mg/g DM	PHY, mg/g DM
Arthur	94	1.07	17.72	488	271	148.6	98.3	50.3	2.8	9.9
Buzz	91	1.27	14.69	452	276	189.7	139.2	50.6	2.9	20.8
Clipper	92	1.17	18.94	397	285	250.4	177.6	72.8	5.3	16.6
Divine	95	0.99	17.59	434	300	180.4	134.0	46.4	6.2	13.4
Fury	95	1.21	18.22	464	281	180.5	136.4	44.1	4.7	13.8
Honey	95	1.06	17.04	517	294	158.8	95.9	62.9	3.9	13.5
Maris bead	93	1.01	19.05	443	305	155.5	125.5	30.0	4.5	13.9
Sultan	88	1.44	22.29	467	245	190.2	135.4	54.8	7.3	10.6
Wizard	94	1.18	19.34	424	300	193.2	150.4	42.8	6.0	19.8
Mean	93	1.16	18.32	454	284	183.0	132.5	50.5	4.8	14.7
CV%	2.5	12.3	11.2	7.8	6.6	16.5	18.8	24.3	31.3	25.5

*L** – lightness-darkness degree of bean flour 0–100 representing dark to light, *a** – redness-greenness degree of bean flour with a higher positive *a** value indicating more red, *b** – yellowness-blueness degree of bean flour with a higher positive *b** value indicating more yellow, CP – crude protein in beans, NSP tot, NSP ins and NSP sol, is respectively total, non-soluble and soluble non-starch polysaccharide contents in beans, CT – condensed tannins, as tannic acid equivalents, content in beans, PHY – phytate content of beans, CV% – coefficient of variation; [1] data adapted from our previous studies (Abdulla et al., 2021a) content with 397 g/kg the lowest (cv. Clipper) and 517 g/kg the highest (cv. Honey) (CV = 7.8%). The crude protein content varied from 245 g/kg (cv.Sultan) to 305 g/kg (cv. Maris Beads) (CV = 6.6%). There was a range of total non-starch polysaccharides (NSP tot) content with 148.6 g/kg the lowest (cv. Arthur) and 250.4 g/kg the highest (cv. Clipper) (CV = 16.5%). The mean condensed tannin concentration was 4.8 g/kg (CV = 31.3%), and cv. Arthur had the lowest (2.8 g/kg) and cv. Sultan had the highest (7.3 g/kg) condensed tannin concentration. The phytate content varied from 9.86 g/kg (cv. Arthur) to 20.84 g/kg (cv. Buzz) with mean value of 14.7 mg/g (CV = 25.5%).

The determined dietary chemical composition is presented in Table 1 and was within the expected range for pullets. The differences observed between some of the calculated and determined values are due to differences in values used in software for dietary formulation and the real chemical composition of dietary feed ingredients. In this study the inclusion of field bean was limited to 200 g/kg diets to ensure pullets received a nutritionally complete diet that would not compromise welfare, however, this may have limited establishing differences among cultivars due to the high inclusion of the balancer.

The AME of the balancer diet was 11.45 MJ/kg (Table 1) and was later used to determine the AME in the studied field bean cultivar samples. The AME value of the balancer diet was not directly compared with the AME values of the diets containing 200 g/kg beans.

The results on feed intake, AME of field bean and diets and dietary DMD are shown in Table 3. The overall determined AME value of the bean containing diets was 12.67 MJ/kg DM and varied between 12.23 (Clipper based diet) and 13.13 (Wizard based diet) MJ/kg DM ($P < 0.001$). The overall determined AME value of the beans was 10.94 MJ/kg DM, which is similar to other reports with laying hens (Perez-Maldonado et al., 1999) and broilers (Nalle et al., 2010). Similar to dietary analysis, the AME for Clipper was the lowest, at 9.31 MJ/kg DM and the AME of Wizard was the highest, 12.26 MJ/kg DM ($P < 0.001$). Clipper had the highest content of NSP (72.8 g/kg DM NSP sol and 250.4 g/kg DM NSP tot, respectively) and the lowest content of total starch, 397 g/kg DM, within all field bean cultivars fed in the study. In comparison, Wizard had one of the lowest contents of NSP (42.8 g/kg DM NSP sol and 193.2 g/kg DM NSP tot, respectively) and 424 g/kg DM total starch. The AME of Clipper was 1.84 MJ/kg lower than the mean of the other eight samples. The differences in DMD followed

Table 3. Feed intake (FI) of laying hen pullets fed diets containing 200 g/kg of one of the nine different UK grown field bean cultivar samples. Apparent metabolizable energy (AME) of nine UK grown field bean cultivar samples and AME and total tract dry matter (DMD) digestibility coefficients of the whole diets fed to laying hen pullets

Diet	FI, g DM bird day	AME beans, MJ/kg DM	AME diet, MJ/kg DM	DMD diet
Arthur	70^{ab}	12.20^{d}	12.85^{bc}	0.678^{ab}
Buzz	65^{a}	10.46^{abc}	12.60^{ab}	0.672^{ab}
Clipper	59^{a}	9.31^{a}	12.23^{a}	0.657^{a}
Divine	83^{ab}	11.67^{cd}	13.01^{bc}	0.703^{b}
Fury	62^{a}	9.96^{ab}	12.30^{a}	0.650^{a}
Honey	80^{ab}	11.28^{bcd}	12.86^{bc}	0.686^{ab}
Maris Bead	63^{a}	10.93^{bcd}	12.40^{a}	0.652^{a}
Sultan	95^{b}	10.44^{abc}	12.62^{ab}	0.667^{ab}
Wizard	94^{b}	12.26^{d}	13.13^{c}	0.696^{b}
Mean	75	10.94	12.67	0.673
CV%	32.1	13.0	3.1	4.7
SEM	8.5	0.503	0.137	0.0113
P-value	0.014	<0.001	<0.001	0.012

CV% – coefficient of variation, SEM – pooled standard error of means; each value represents mean of eight replicate pens of two laying hen pullets each; FI, AME and DMD coefficients were determined during the 4 last days of the study; $^{a–d}$ – values within a column with different superscripts differ at $P < 0.05$

a pattern similar to the AME response and supported the overall AME results ($P = 0.012$). The observed difference in metabolizable energy and DMD were similar to the differences in feed intake as birds fed Clipper consumed much less feed than birds fed the Wizard based diet ($P = 0.014$). The impact on the relationship between feed intake and dietary AME has been extensively studied and research has found that dietary energy does not accurately correlate with feed intake and in at least some genotypes does not have any effect (Classen, 2017).

Table 4 shows selected correlation coefficients between determined AME and compositional profile of the experimental field bean cultivar samples fed to laying hen pullets. There was a negative correlation ($r = -0.635$, $P < 0.05$) between AME and total NSP content of the beans, further supporting the observed differences in AME. Poultry do not produce enzymes capable of digesting dietary NSP and so it was not surprising to observe a reduction in AME and DMD when feeding beans high in NSP. Although the exact antinutritive role of NSP is not completely understood, it is assumed that the mode of action combines encapsulation of dietary nutrients and/or increases the viscosity of the intestinal digesta (Bedford, 2000; Pirgozliev et al., 2010). Thus, supporting the observed negative correlation between AME and NSP contents of beans.

Table 4. Correlation coefficients between determined AME and compositional profile of field bean cultivar sample fed to laying hen pullets

	AME	*L**	*a**	*b**	Starch	CP	NSP tot	NSP ins	NSP sol	CT
*L**	0.383									
*a**	−0.437	−0.776								
*b**	−0.094	−0.499	0.399							
Starch	0.307	0.130	−0.043	−0.178						
CP	0.289	0.765	−0.806	−0.364	−0.263					
NSP tot	−0.635	−0.348	0.395	0.183	−0.752	−0.110				
NSP ins	−0.562	−0.286	0.354	0.231	−0.914	0.031	0.918			
NSP sol	−0.418	−0.275	0.251	−0.022	0.009	−0.333	0.591	0.223		
CT	−0.105	−0.365	0.343	0.785	−0.417	−0.132	0.401	0.474	0.018	
PHY	−0.127	0.086	0.120	−0.442	−0.510	0.377	0.460	0.557	0.001	−0.121

*L** – lightness-darkness degree of bean flour, *a** – redness-greenness degree of bean flour, *b** – yellowness-blueness degree of bean flour, AME (MJ/kg DM) – apparent metabolisable energy, Starch (g/kg DM), CP (g/kg DM) – crude protein in beans, NSP tot, NSP ins and NSP sol (g/kg DM) is respectively total, non-soluble and soluble non-starch polysaccharide contents in beans, CT (mg/g DM) – condensed tannins, as tannic acid equivalents, content in beans, PHY (g/kg DM) – phytate; $P < 0.01$ ($r^2 \geq 0.582; 0.632 \leq r^2$); $P < 0.05$ ($r^2 \geq 0.632; 0.765 \leq r^2$); $P < 0.001$ ($r^2 \geq 0.765$)

The linear regression confirmed that AME contents of the field bean samples tended to decrease ($P = 0.066$) with increasing total NSP amount ($r^2 = 0.320$, SE = 0.830). Taken together, there is evidence from the two analyses that total NSP may be used by nutritionists to predict AME value of field bean samples, however, stronger evidence is required to support this.

Surprisingly, there was not a significant correlation ($P > 0.05$) between AME and starch content of studied field bean. As AME is a measurement of the available energy in carbohydrates, fats and proteins it can be expected that an additional digestibility study may bring clearer information as suggested by the DMD coefficients.

There was no correlation ($P > 0.05$) between AME and tannins in this study, which disagrees with previous reports (Vilariño et al., 2009). However, in accordance with our results, Abdulla et al. (2021a) also did not show a correlation between metabolizable energy and tannin content in the same bean samples when fed to broiler chickens, thus suggesting that the tannin content was relatively low to exhibit antinutritional properties. Indeed, Vilariño et al. (2009) provoked the negative response to dietary AME by adding 9.8 g/kg DM of condensed tannins, although the mean total tannin concentration in the field bean used in this study was 4.2 g/kg DM. This may also explain the lack of correlation ($P > 0.05$) between AME and bean colour since colour correlates with tannin content (Oomah et al., 2011).

Conclusions

The results of this experiment have indicated that these nine field bean cultivar samples had different energy and dry matter digestibility for laying hen pullets. Generally, the commercial poultry industry requires poultry diets to have high energy densities, although this depends on production requirements. Nutritionists will only be able to accurately incorporate meaningful amounts of field bean in these diets if the beans have a well-defined metabolizable energy value. It is therefore crucial that they are able to identify and only use samples that meet their specifications. The results of the present experiment have shown that there is a large range in the determined metabolizable energy of nine different field bean cultivar samples. There is some evidence that total NSP may be used by nutritionists to predict AME value of field bean samples, however, stronger evidence is required in support. This information may be used by plant breeders who may be able to incorporate it in the development of new field bean cultivars.

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Conflict of interest

The Authors declare that there is no conflict of interest.

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