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Variations in nutritional and antinutritional contents among faba bean cultivars and effects on growth performance of weaner pigs

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ABSTRACT

A total of 84 faba bean samples, 11 of color-flowered and 5 of white-flowered cultivars, were used to investigate variations in nutritional and antinutritional components among faba beans. There were no effects of flower color, but significant effects ($P < 0.05$) of cultivar within flower color were observed for starch, crude protein (CP), and neutral detergent fiber. The color-flowered cultivars had a greater content of condensed tannins (CT) and the white-flowered cultivars a greater content of vicine and convicine. Within the color-flowered cultivars, Alexia had the greatest (7.68 g/kg DM) and Julia the smallest (6.05 g/kg DM) CT content. The enzymatic in vitro digestibility of DM, OM, CP, and calculated standardized ileal digestibility of CP was greater ($P < 0.05$) in white-flowered than color-flowered cultivars. However, on a yield per hectare basis, color-flowered cultivars yielded more ($P < 0.05$) standardized ileal digestible (SID) CP and starch than white-flowered cultivars. Based on these results, 3 cultivars were selected for a growth study with weaner pigs. Gloria (a white-flowered cultivar) and Fuego and Julia (both color-flowered) were selected for deviating content of SID CP, where Julia had more SID CP than Fuego. The control diet contained soybean meal and potato protein as the main protein sources, whereas the experimental diets contained 10 and 20% Julia or Fuego (Julia10, Julia20, Fuego10, Fuego20) and 20% Gloria (Gloria), with a total of 6 experimental diets. The diets were fed to 300 pigs in a randomized complete block design with 5 groups of pigs over time (blocks), with each block comprising 6 pens of 10 piglets. The pigs were weaned at 5 weeks of age and received the experimental diets ad libitum for 27 days, starting immediately after weaning. For the total experimental period, pigs fed Julia10 and Julia20 had the greatest average daily body weight gain ($P < 0.05$) and pigs fed the control and Fuego20 had the smallest. Average daily feed intake was greater ($P < 0.05$) in pigs fed Julia10 and smaller in pigs fed Fuego20 ($P < 0.05$) than in pigs fed the other diets. Feed efficiency was greatest in pigs fed Julia20 and smallest in pigs fed the control. In conclusion, faba bean is a viable protein source in well-balanced diets to weaner pigs, with cultivar rather than flower color determining the nutritional value.

1. Introduction

Currently, about 63% of European protein feedstuffs are imported (EC, 2017). Although a wide range of actions have been taken to increase production of protein crops within the EU, problems still persist (Schreuder and de Visser, 2014). Faba bean (*Vicia faba* L.) is a grain legume rich in both starch and protein that can be grown throughout Europe and is considered an alternative to imported protein sources. Faba bean already dominates European grain legume production and production continues to increase (EC, 2017), but its potential is as yet unexploited, particularly in pig diets (Jezierny et al., 2010a). Compared with soybean meal, faba bean is lower in some indispensable amino acids. As most legumes, faba beans contain antinutritional factors (ANF) such as trypsin inhibitors, lectins, vicine, and convicine. Moreover, color-flowered faba bean cultivars contain tannins, whereas white-flowered faba bean cultivars have a small content (< 1%) of tannins. The concentrations of trypsin inhibitors and lectins are too low to be of practical significance in pig nutrition. Vicine and convicine may reduce egg size in laying hens (Vilariño et al., 2009), but appear to have no adverse effects in pigs (Crépon et al., 2010). Moreover, some faba bean genotypes are low in vicine and convicine (Duc et al., 1999).

The white-flowered cultivars of faba bean yield less than color-flowered, show poorer establishment, and have lower disease resistance (Martín et al., 1991). As a result, faba bean production is currently dominated by color-flowered cultivars (Crépon et al., 2010). Studies evaluating white- and color-flowered faba beans as a feedstuff for pigs report about 5% greater dry matter digestibility (DM) (Van der Poel et al., 1992) and about 10% greater crude protein (CP) digestibility in

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Table 1
Analyzed chemical composition (g/kg dry matter) of different faba bean cultivars.

Cultivar	DM[a]	Starch	CP[b]	NDF[c]	CF[d]	Ash	EE[e]
Color-flowered	893[a]	391	309	118	84	33[a]	17[a]
White-flowered	894[b]	392	308	119	83	35[b]	18[b]
SEM	3	3	2	2	3	1	0
Color-flowered							
Alexia (6)[f]	893	396	305[c,d]	122[a]	81[a,b]	33	14[a,b]
Ashleigh (3)	892	398	307[b,d]	117[a,b]	89[b]	33	16[a,b]
Bioro (3)	894	386	323[a,b]	114[a,b]	86[a,b]	33	16[a,b]
Boxer (3)	893	385	304[b,d]	124[a]	85[a,b]	32	18[c,d]
Fanfare (3)	894	383	305[b,d]	126[a]	92[b]	33	18[c,d]
Fuego (6)	894	393	300[c,d]	120[a,b]	85[b]	33	19[d]
Isabell (6)	893	392	312[b,d]	109[b]	79[a,b]	34	17[b,c]
Julia (6)	894	384	327[a]	113[a,b]	81[a,b]	34	14[a,b]
Marcel (6)	893	394	309[b,d]	113[a,b]	74[a]	35	17[c,d]
Oena (6)	892	393	312[b,d]	114[a,b]	87[b]	34	17[b,c]
Vertigo (6)	891	394	300[c,d]	123[a]	89[b]	33	17[c,d]
SEM[g]	4	5	4	3	4	1	1
White-flowered							
Banquise (6)	892	400[a]	290[c]	117	85	35[a,b]	18[a,b]
Gloria (6)	895	371[b]	342[a]	114	76	36[a,b]	17[a]
Imposa (6)	895	398[a]	301[b,c]	122	87	34[a]	20[b]
Taifun (6)	894	401[a]	304[b]	116	82	34[a,b]	19[a,b]
Tattoo (6)	893	389[a,b]	302[b,c]	123	86	36[b]	18[a,b]
SEM	4	5	3	3	4	1	1
P-value							
Flower color	0.043	0.513	0.360	0.584	0.320	< 0.001	< 0.001
Cultivar within flower color	0.287	< 0.001	< 0.001	0.001	0.003	< 0.001	< 0.001

[a–c]Values within part of column with different letters are different ($P < 0.05$).
[a] Dry matter.
[b] Crude protein.
[c] Neutral detergent fiber.
[d] Crude fiber.
[e] Ether extract.
[f] Number of samples for each cultivar within brackets.
[g] Standard error of mean.

white-flowered cultivars (Grosjean et al., 2001; Jansman et al., 1993; Van der Poel et al., 1992). However, tannins are complex substances that vary in structure, composition, and thereby the ability to bind to protein. Moreover, there is variation among color-flowered cultivars in tannin content and most likely also tannin composition (Duc et al., 1999; Jezierny et al., 2010a). It is therefore difficult to predict animal responses simply by knowing the level of faba bean inclusion. Some growth performance studies have found smaller average daily gain and feed conversion ratio in pigs fed color-flowered cultivars (Fekete et al., 1985), whereas others have found no effects (Flis et al., 1999; Royer et al., 2010). Crépon et al. (2010) concluded that reported detrimental effects may derive from suboptimal diet formulation, such as not balancing diets with crystalline amino acids. Because of the inconsistent results from using color-flowered faba bean in pig diets, the Swedish Board of Agriculture (2017) recommends that farmers grow white-flowered faba beans for use in pig diets.

The objective of the first part of the present study was to determine the nutritional and ANF contents in a range of faba bean cultivars. The results from this bean study (Tables 1–3) were used to select 3 different cultivars, 1 white-flowered and 2 color-flowered, that deviated in nutritional and tannin content. The selected cultivars were used in the second part of the study to evaluate effects on growth performance of weaner pigs.

2. Materials and methods

2.1. Bean cultivars

A total of 84 faba bean (*Vicia faba*) samples, 11 of color-flowered and 5 of white-flowered cultivars, all spring-sown, were used in the study. Most cultivars were cultivated both organically and conventionally at 3 different locations in southern Sweden, resulting in 6 samples per cultivar. However, the color-flowered cultivars Ashleigh, Bioro, Boxer, and Fanfare were only cultivated conventionally, and therefore 3 samples from those cultivars were used.

2.1.1. Chemical analysis

The beans were analyzed for DM by drying at 103 °C for 16 h and for ash after incineration at 550 °C for 3 h (Jennische and Larsson 1990). Crude fiber was determined according to Jennische and Larsson (1990) and ether extract according to EC (1998).

Starch including maltodextrines was analyzed with an enzymatic method described by Larsson and Bengtsson (1983). Neutral detergent fiber (NDF) was determined according to Chai and Udén (1998) with an ND solution (100%) of amylase and sulfite. The CP content (nitrogen × 6.25) was determined by the Kjeldahl method (Nordic Committee on Food Analysis, 2003), amino acids according to ISO (2005), and enzymatic in vitro digestibilities as described by Boisen (1991) and Boisen and Eggum (1991).

Condensed tannin (CT) content was determined using depolymerization followed by liquid chromatography. Depolymerization was achieved by methanolic HCl in the presence of cysteamine, separating tannin extension monomers from the terminal monomer. High performance liquid chromatography (HPLC) was performed with a diode-array detector (DAD)/fluorescence detector, which separates the reaction products. Mean degree of polymerization (DP) is calculated from the ratio of chromatogram peak area of all units to the peak area of terminal units (Gu, 2012). Vicine and convicine were determined based on a method described by Gutierrez et al. (2006). In brief, samples were extracted in ultrapure water (30 ml) in a hot water bath (90 °C) for 3 h. Cooled sample was centrifuged to remove solids. Concentrated HCl (100 µl) was added to thesupernatant (10 ml), followed by an additional centrifugation (10 min, 2500 × *g*). Samples were filtered through 0.45 µm Acrodisc GHP membrane filter (Pall corporation, Port Washington, NY, USA) before being analyzed by an Agilent 1100 series HPLC–DAD (Agilent, Santa Clara, CA, USA).As an analytical column Atlantis T-3 (2.1 × 150 mm, 3 µm) (Waters Corp., Milford, MA, USA) was used with a gradient of 50 mM phosphate buffer and methanol at 0.2 ml/min. Detection of vicine (Sigma-Aldrich, St. Louis, MO, USA) and convicine was done at 280 nm and for the identification purposes spectrum from 190 to 450 nm was recorded. Quantification of convicine was done by using the calibration curve of vicine.

2.1.2. Calculations

The standardized ileal digestibility of CP was estimated based on the enzymatic in vitro digestibility values according to Jezierny et al. (2010b). Other calculations as:

$$\text{Standardized ileal digestible (SID) CP kg per hectare} = 0.001 \times (\text{standardized ileal digestibility of CP} \times \text{CP}) \times \text{harvest level}$$

$$\text{Starch kg per hectare} = 0.001 \times \text{starch} \times \text{harvest level}$$

where standardized ileal digestibility of CP was expressed as digestibility coefficient, CP and starch in g/kg DM, and harvest level in kg DM/hectare. Values and data on harvest levels were extracted from SLU Field Research Unit Database (2017).