The nutritional value of zero-tannin faba bean for grower-finisher pigs

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Zijlstra, R. T., Lopetinsky, K. and Beltranena, E. 2008. **The nutritional value of zero-tannin faba bean for grower-finisher pigs.** Can. J. Anim. Sci. **88**: 293–302. The nutrient profile of zero-tannin faba bean and its effects on performance and carcass characteristics of grower-finisher pigs was investigated. In exp. 1, chemical characteristics were analyzed. Faba bean contained (as fed) 27.5% crude protein (CP), 1.75% lysine, 0.88% threonine, and 0.21% methionine. Twelve 55-kg barrows were fitted with an ileal cannula and fed twice daily at 3 × maintenance either a 96% faba bean diet or a 62% faba bean diet containing cornstarch to measure apparent total tract energy and ileal amino acid (AA) digestibility, respectively, and calculate standardized ileal digestible (SID) AA and net energy (NE) content. After a 6-d acclimation, faeces were collected for 2 d and ileal digesta for 2 d. Apparent total tract energy digestibility, and digestible energy and NE content were 88.5%, and 3.47 and 2.27 Mcal kg^{-1} (as fed), respectively. Apparent ileal digestibility was 85.9, 76.1, and 74.1%, and SID AA content was 1.54, 0.70, and 0.16% (as fed), for lysine, threonine, and methionine, respectively. In exp. 2, 100 grower pigs in 20 pens were fed either a soybean or faba bean-based diet regimen from 35 to 115 kg. Diets were formulated to equal NE and SID [Grower (35 to 60 kg), 2.40/3.95; Finisher 1 (60 to 90 kg), gilts 2.38/3.15, barrows 2.38/2.76; Finisher 2 (90 to 115 kg), gilts 2.38/2.92, barrows 2.35/2.55; Mcal kg^{-1} NE/g SID lysine $Mcal^{-1}$ NE, respectively] using determined NE and SID values for faba bean. Pigs were weighed, feed intake was measured, and carcass measurements were obtained. From 35 to 115 kg, average daily feed intake (ADFI; 2.58 and 2.56 kg d^{-1}, respectively) and gain (0.96 and 0.98 kg d^{-1}) did not differ between faba bean and soybean meal. Feed efficiency was 0.02 higher for soybean meal than for faba bean in the Grower phase ($P<0.05$). At slaughter, back fat thickness did not differ; however, loin depth was 4.0 mm thicker for soybean meal than for faba bean ($P<0.05$). In summary, zero-tannin faba bean has an attractive nutrient profile and does not alter ADFI or average daily gain (ADG) of grower-finisher pigs at inclusion rates up to 30%. The reduced feed efficiency in the Grower phase and reduced lean thickness for pigs fed faba bean indicate that dietary AA supply might have been limiting for the faba bean diets early in the study. In conclusion, the zero-tannin faba bean is a worthwhile energy and protein feedstuff to consider in swine feed formulation.

Key words: Digestibility, energy, faba bean, growth performance, nutritional value, pig

Zijlstra, R. T., Lopetinsky, K. et Beltranena, E. 2008. **Valeur nutritive de la féverole sans tanins pour les porcs d'élevage**. Can. J. Anim. Sci. **88**: 293–302. Les auteurs ont tenté d'établir le profil nutritif de la féverole sans tanins et son incidence sur le rendement des porcs d'élevage ainsi que sur les paramètres de leur carcasse. Dans le cadre d'une première expérience, ils en ont analysé les propriétés chimiques. La féverole (servie aux animaux) contenait 27,5 % de protéines brutes, 1,75 % de lysine, 0,88 % de thréonine et 0,21 % de méthionine. Douze castrats de 55 kg ont été dotés d'une canule à l'iléon puis ont reçu deux fois par jour le triple de leur ration d'entretien sous forme d'aliment contenant 96 % de féverole ou 62 % de féverole et de la fécule de maïs. L'expérience devait servir à mesurer la digestibilité apparente de l'énergie dans l'ensemble du système digestif et celle des acides aminés (AA) dans l'iléon, respectivement. Elle a aussi permis de calculer la teneur normalisée en AA digestibles dans l'iléon (NDI) ainsi que la concentration d'énergie nette (EN) de l'aliment. Après une période d'adaptation de six jours, les auteurs ont recueilli les fèces des animaux pendant deux jours et les digests de l'iléon pendant le même laps de temps. La digestibilité apparente de l'énergie dans le système digestif et la concentration d'énergie digestible et de EN s'établissaient respectivement à 88,5 %, et à 3,47 et 2,27 Mcal par kg (ration servie aux animaux). La digestibilité apparente de la lysine, de la thréonine et de la méthionine dans l'iléon s'établissait respectivement à 85,9, à 76,1 et à 74,1 %, tandis que leur NDI était de 1,54, 0,70 et 0,16 % (ration servie aux animaux). Dans une deuxième expérience, les auteurs ont donné à 100 porcs répartis dans 20 enclos une ration à base de soja ou de féverole, du poids de 35 kg à celui de 115 kg. Les rations étaient formulées pour fournir la même quantité de EN et de NDI [croissance (35 à 60 kg), 2,40/3,95; finition 1 (60 à 90 kg), truies nullipares 2,38/3,15, castrats 2,38/2,76; finition 2 (90 à 115 kg), truies nullipares 2,38/2,92, castrats 2,35/2,55; Mcal de NE par kg g^{-1} de NDI de lysine par Mcal de EN, respectivement), selon les valeurs de EN et de NDI préétablies pour la

Abbreviations: **AA**, amino acid; **ADF**, acid detergent fibre; **ADFI**, average daily feed intake; **ADG**, average daily gain; **AID**, apparent ileal digestibility; **BW**, body weight; **CP**, crude protein; **DE**, digestible energy; **DM**, dry matter; **G:F**, feed efficiency; **GE**, gross energy; **NDF**, neutral detergent fibre; **NE**, net energy; **SID**, standardized ileal digestibility

féverole. Les animaux ont été pesés et on a mesuré leur prise alimentaire, puis établi les paramètres de leur carcasse. De 35 à 115 kg, la prise alimentaire moyenne (PAM; 2,58 et 2,56 kg par jour, respectivement) et le gain quotidien moyen (GQM; 0,96 et 0,98 kg par jour) sont les mêmes pour la féverole et le tourteau de soja. L'indice de consommation est 0,02 fois plus élevé pour le tourteau de soja que pour la féverole durant la croissance ($P < 0{,}05$). L'épaisseur du gras dorsal était identique à l'abattage, mais la longe des sujets nourris de tourteau de soja avait 4,0 mm de plus que celle des porcs engraissés à la féverole ($P < 0{,}05$). En résumé, la féverole sans tanins présente un profil nutritif intéressant et ne modifie ni la PAM ni le GQM des porcs d'élevage jusqu'à concurrence de 30 % de la ration. La baisse de l'indice de consommation observée durant la croissance et les muscles moins épais relevés chez les porcs engraissés de féverole indiquent que les AA de cette dernière pourraient avoir constitué un facteur limitant au début de l'étude. Bref, la féverole sans tanins est une source valable d'énergie et de protéines qu'on pourrait envisager pour l'engraissement des porcs.

Mots clés: Digestibilité, énergie, féverole, croissance, valeur nutritive, porc

In temperate climate zones that do not receive sufficient heat, daylight, or moisture to support the cultivation of soybean, other legume seeds remain an attractive alternative for crop rotation to grains due to their atmospheric N fixation capability. Faba bean (*Vicia faba* minor, also known as field, broad, or horse bean) can be cultivated in cool, moist environments, such as northern Alberta. Coloured-flower cultivars of faba bean contain 0.40 to 2.15% of the anti-nutritional factor condensed tannin (Jansman 1993), in particular in the hull (Bos and Jetten 1989). Tannins may reduce feed intake and nutrient digestibility, especially for protein, and thereby reduce growth in swine (Marquardt et al. 1977; Jansman 1993). In contrast, white-flower cultivars have a reduced condensed tannin concentration (Cabrera and Martin 1989) at 0.06 to 0.75% (Jansman 1993), and might be a more attractive amino acid (AA) source for swine than coloured-flower cultivars. The white-flower cultivars have been referred to as zero-tannin faba bean (Duc et al. 1999).

The nutritional value of zero-tannin faba bean is not well established. For example, the digestible nutrient values were not included in the North America feedstuffs dataset for swine [National Research Council (NRC) 1998]. Furthermore, although digestibility studies have been conducted with pigs fed zero-tannin faba bean in the past (e.g., Sauvant et al. 2004), growth performance studies of pigs fed diets containing zero-tannin faba bean relative to soybean meal have not been published. The hypothesis for the present study was that grower-finisher pigs fed diets containing zero-tannin faba bean could reach a similar growth performance and carcass characteristics as pigs fed diets containing soybean meal, provided that the diets were formulated to an equal energy and AA profile.

The objectives of the present study were: (1) to determine the apparent ileal AA digestibility (AID) and energy digestibility in cannulated grower pigs to calculate the standardized ileal digestible (SID) AA and net energy (NE) content of zero-tannin faba bean, and (2) to determine whether feeding a diet containing up to 30% zero-tannin faba bean and formulated based on SID AA and NE content resulted in growth performance and carcass characteristics similar to grower-finisher pigs fed a diet containing soybean meal. Diet regimes were specific for barrows and gilts, and gender differences and the interaction between diet regime and gender were studied.

MATERIALS AND METHODS

Experimental Protocol

The animal protocols were approved by the University of Saskatchewan Committee on Animal Care and Supply, and followed principles established by the Canadian Council on Animal Care (1993). Two experiments were conducted at the Prairie Swine Centre Inc. in Saskatoon, SK.

Twelve samples of zero-tannin faba bean (Snowbird) were collected in the Barrhead area of north-central Alberta. One of these samples was selected as the most representative and was the sole sample used for the animal protocols. The other feedstuffs (wheat, barley, and soybean meal) were obtained via commercial supply channels and were of unknown origin.

Exp. 1 – Digestibility Study

Two diets were tested in one experimental period using cannulated finisher pigs: one Energy diet containing 96.3% zero-tannin faba bean as the sole source of energy and one Amino acid diet containing 61.8% zero-tannin faba bean as the sole source of AA and corn starch (Table 1). Chromic oxide was included as an indigestible marker. The diets were fortified to meet or exceed vitamins and mineral requirements (NRC 1998).

Twelve crossbreed barrows [Camborough-22 $\times$ Line 65; PIC Canada Ltd., Winnipeg, MB; initial body weight (BW), 55 kg] were surgically fitted with a T-cannula at the distal ileum. Each pig was randomly fed one of two diets in one period to provide six observations per diet, for a total of 12 observations. Pigs were housed in individual metabolism pens (1.5×1.5 m) that allowed freedom of movement (Widyaratne and Zijlstra 2007). To avoid orts, daily feed allowance was adjusted to $3 \times$ maintenance [3×110 kcal digestible energy (DE) kg^{-1} $BW^{0.75}$; NRC 1998], which was fed in two equal meals at 0800 and 1600. Diets were fed as a wet mash, with water added to feed (approximately 1:1, wt/wt) immediately after adding feed to the feeder. Pigs had free access to water throughout the experiment. The

Table 1. Ingredient composition and calculated and analyzed energy and protein content of diets used in the digestibility study

Ingredient (%)	Energy diet[z]	Amino acid diet[y]
Zero-tannin faba bean	96.3	61.8
Corn starch	–	34.5
Limestone	1.1	1.1
Di-calcium phosphate	0.8	0.8
Vitamin mix[x]	0.5	0.5
Mineral mix[w]	0.5	0.5
Chromic oxide	0.4	0.4
Salt	0.4	0.4
Calculated nutrient content (as fed)		
DE (Mcal kg^{-1})	3.40	3.68
Crude protein (%)	26.4	17.0
Analyzed nutrient content (as fed)		
DE (Mcal kg^{-1})	3.33	3.45
Crude protein (%)	26.8	17.3

[z]Zero-tannin faba bean was considered the sole energy source.
[y]Zero-tannin faba bean was considered the sole AA source.
[x]Provided per kg of diet: vitamin A, 8250 IU; vitamin D_3, 825 IU; vitamin E, 40 IU; niacin, 35 mg; D-pantothenic acid, 15 mg; riboflavin, 5 mg; menadione, 4 mg; folic acid, 2 mg; thiamine, 1 mg; D-biotin; 200 µg; vitamin B_{12}, 25 µg.
[w]Provided per kg of diet: Zn, 100 mg as zinc sulphate; Fe, 80 mg as ferrous sulphate; Cu, 50 mg as copper sulphate; Mn, 25 mg as manganous sulphate; I, 0.5 mg as calcium iodate; Se, 100 µg as sodium selenite.

10-d experimental period consisted of a 6-d acclimation to the experimental diets, followed by a 2-d collection of faeces, and then a 2-d collection of ileal digesta.

Faeces were collected for a minimum of two times per day at 0800 and 1600. Faeces were collected using plastic bags attached to a ring system glued to the skin around the anus (Van Kleef et al. 1994). Digesta samples were collected for 10 h d^{-1} using bags containing diluted formic acid attached to the opened cannula barrel. Collected faeces and digesta were pooled by pig and frozen at approximately -20°C. Prior to analyses, faeces and digesta were thawed, homogenized, subsampled, and freeze-dried.

Exp. 2 – Performance Study

Two diet regimens, one based on faba bean and one on soybean meal, were formulated for a performance study with crossbreed grower-finisher pigs (Camborough-22 $\times$ Line 65; PIC Canada Ltd., Winnipeg, MB; initial BW, 36.2 $\pm$ 3.4 kg; initial age, 91 $\pm$ 7 d). The study consisted of three phases: a Grower phase with pigs from 35 to 60 kg BW, a Finisher 1 phase with pigs from 60 to 90 kg BW, and a Finisher 2 phase with pigs from 90 kg BW to slaughter weight (Table 2). During the Grower phase, barrows and gilts received the same diet within each regimen. During the Finisher 1 and 2 phases, barrows and gilts received diets with a different nutrient profile within each regimen. The two diet regimes and two genders were compared in a 2 $\times$ 2 factorial arrangement for a total of four treatments.

The main ingredients of the soybean meal diets that served as the control were wheat, barley, and soybean meal (Table 2). The faba bean diets contained up to 30% faba bean, in substitution for soybean and wheat, and were formulated to an identical NE and SID AA profile as the soybean meal diets without further restrictions. The faba bean diets for Finisher 1 and 2 were void of soybean meal, whereas the Grower diet contained 5.9% soybean meal to meet nutrient specifications. Diets were formulated to meet or exceed the requirements for AA and other nutrients (NRC 1998) to the following specifications (NE, Mcal kg^{-1} and SID lysine g Mcal^{-1} NE): Grower, 2.40 and 3.95; Finisher 1 gilt, 2.38 and 3.15; Finisher 1 barrow, 2.38 and 2.76; Finisher 2 gilt, 2.38 2.92; Finisher 2 barrow, 2.35 and 2.55. Threonine, methionine, and tryptophan were formulated as a ratio to lysine (NRC 1998). For feed formulation, the NE values for feedstuffs were obtained from Sauvant et al. (2004) and the SID AA values from NRC (1998). The switch from grower diet to experimental diet was abrupt, i.e., without having a period of mixing the diets together. Diets were formulated without antimicrobials or animal by-products.

A total of 100 pigs (50 barrows and 50 gilts) were selected based on BW and average daily gain (ADG) since birth, randomized within gender, and housed in one room, with five pigs per pen, in 20 pens. Barrows and gilts were penned separately, and each of the two experimental diet regimens was fed to five pens of barrows and five pens of gilts, for a total of 10 observations per diet regimen. The flooring of the pens (2.36 $\times$ 1.68 m) was fully slatted concrete and the siding was sturdy PVC-planking. A single-space dry feeder was located at the front corner of the pen and a nipple drinker was located at the centre back of the pen. The room was maintained within the thermo-neutral zone of the pigs, with a 14-h light (0700 to 2100)/10-h dark cycle. Diets were provided as a dry mash and diets and water were supplied ad libitum throughout the experiment.

The duration of the three study phases was 35 d for the Grower phase, 28 d for the Finisher 1 phase, and 13 d until the first pig reached slaughter weight in the Finisher 2 phase. All pigs were weighed at the start of the experiment (day 0), and at the end of the Grower, Finisher 1 and Finisher 2 phase to obtain the average BW per pen. Feed disappearance was measured on each weigh day. The data were used to calculate ADG, average daily feed intake (ADFI), and feed efficiency (G:F). At slaughter of the first pig, the component of the study to determine differences in growth performance variables between the diet regimens was discontinued, but each pig reached slaughter weight (115 $\pm$ 3.5 kg BW) by continuing feeding of the specific diet regimen. Prior to slaughter, pigs were weighed individually to confirm attainment of a pre-established market weight as per the local marketing grid. Pigs were tattooed with a unique number upon reaching market weight and slaughtered

Table 2. Ingredient composition and calculated nutrient content of diets used in the grower, finisher 1, and finisher 2 phases of the performance study

			Finisher 1 (60 to 90 kg)				Finisher 2 (90 kg to slaughter weight)			
	Grower (35 to 60 kg)		Gilt		Barrow		Gilt		Barrow	
Ingredient (%)	Faba	SBM	Faba	SBM	Faba	SBM	Faba	SBM	Faba	SBM
Barley	–	–	37.21	27.68	37.43	27.16	48.08	40.30	72.86	66.75
Wheat	59.66	75.56	29.00	53.74	29.70	54.38	23.30	43.73	3.60	19.80
Faba bean	30.00	–	30.00	–	29.30	–	25.00	–	20.00	–
Soybean meal	5.90	20.00	–	15.00	–	15.00	–	12.50	–	10.00
Limestone	1.43	1.42	0.89	0.89	0.89	0.89	0.90	0.90	0.89	0.89
Dicalcium phosphate	0.80	0.74	0.94	0.86	0.94	0.86	0.78	0.72	0.82	0.77
Canola oil	0.60	0.80	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin mix[z]	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Mineral mix[y]	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
L-lysine-HCl	0.18	0.22	0.11	0.12	–	–	0.12	0.13	0.08	0.09
L-threonine	0.14	0.06	0.10	0.01	0.04	–	0.09	0.02	0.05	–
DL-methionine	0.09	–	0.05	–	–	–	0.03	–	–	–
Calculated nutrient content (as fed)										
Net energy (Mcal kg^{-1})	2.40	2.40	2.38	2.38	2.38	2.38	2.38	2.38	2.35	2.35
SID lysine (g MCal^{-1} NE)[x]	3.95	3.95	3.15	3.15	2.76	2.76	2.92	2.92	2.55	2.55
SID lysine (%)	0.95	0.95	0.75	0.75	0.66	0.66	0.69	0.69	0.60	0.60
Calcium (%)	0.74	0.74	0.65	0.65	0.65	0.65	0.63	0.63	0.63	0.63
Available phosphorus (%)	0.30	0.30	0.32	0.32	0.32	0.32	0.28	0.28	0.28	0.28

[z]Provided per kg of diet: vitamin A, 6600 IU; vitamin D_3, 660 IU; vitamin E, 32 IU; niacin, 28 mg; D-pantothenic acid, 12 mg; riboflavin, 4 mg; menadione, 3.2 mg; folic acid, 1.6 mg; thiamine, 0.8 mg; D-biotin; 160 µg; vitamin B_{12}, 20 µg.
[y]Provided per kg of diet: Zn, 80 mg as zinc sulphate; Fe, 64 mg as ferrous sulphate; Cu, 40 mg as copper sulphate; Mn, 20 mg as manganous sulphate; I, 0.4 mg as calcium iodate; Se, 80 µg as sodium selenite.
[x]Other essential AA were formulated as a ratio to lysine (NRC 1998).

at a local commercial abattoir. After evisceration, warm carcass weight was recorded to calculate dressing percentage. Carcass back fat and loin depth were measured with a Destron probe (Model PG–100, Anitech Identification System Inc., Ottawa, ON). The values were used to predict lean yield based on the grading equation applicable at the time of the study (Saskatchewan Pork International, Saskatoon, SK). The final pig reached slaughter weight 3 wk after first pig.

Chemical Analyses

Feed and freeze-dried faeces and digesta were ground in a Retsch mill (model ZMI, Brinkman Instruments, Rexdale, ON) over a 1-mm screen and analyzed for dry matter (DM) by drying at 135°C in an airflow type oven for 2 h (method 930.15; AOAC 1990). Chromic oxide content of feed, faeces, and digesta was analyzed by a spectrophotometer (LKB-Ultraspec III model 80–2097–62; Pharmacia, Cambridge, UK) at 440 nm after ashing at 450°C overnight (Fenton and Fenton 1979).

For pigs fed the Energy diet, gross energy (GE) content of faba bean, feed, faeces, and digesta was analyzed by an adiabatic bomb calorimeter (Model 5003, Ika-Werke GMBH & Co. KG, Staufen, Germany); benzoic acid was used as a standard. For pigs fed the Amino acid diet, faba bean, feed, and digesta samples were analyzed for AA (method 982.30E; AOAC 1990) at the University of Missouri (Colombia, MO). The faba bean samples were analyzed for moisture, ash, crude protein (CP), acid-detergent fibre (ADF), neutral detergent fibre (NDF), crude fibre, and ether extract at Norwest Labs (Lethbridge, AB) according to AOAC (1990) methods. Starch was measured using the amyloglucosidase/α-amylase method with a final glucose analysis using a spectrophotometer at 510 nm (method 996.11; AOAC 1990).

Calculations and Statistical Analyses

For each pig observation, the AID of AA and ileal and total tract digestibility of energy were calculated for the Amino acid and Energy diet, respectively, using the indicator method (Adeola 2001). Digestibility values for the faba bean ingredient sample were assumed equal to the Amino acid and Energy diet. For exp. 1, statistical analyses were not conducted, because the objective was to describe the nutritional value of one sample of zero-tannin faba bean. Pig was the experimental unit for calculations. The NE content of the faba bean sample was calculated using a prediction equation and analyzed DE content and chemical characteristics (Noblet 1994a). The SID of AA was calculated from AID coefficients (Yin et al. 2002), based on the mean endogenous AA composition of basal endogenous protein (Jansman et al. 2002) so that the SID AA content could be reported. The digestible nutrient content was calculated using total nutrient content multiplied by the digestibility coefficients.

For exp. 2, pen was considered the experimental unit for the performance variables and carcass characteristics. Means are reported as least-squares means ($\pm$ pooled standard error of the mean). Performance variables were analyzed by analysis of variance using the MIXED procedure (Wang and Goonewardene 2004) of SAS (SAS Institute, Inc. 1996) using a statistical model with the factors being diet regime, gender, and diet regime $\times$ gender according to a 2×2 factorial arrangement. Initial BW or warm carcass weight was used as covariate for the analysis of performance or carcass variables, respectively, except for dressing percentage. To test the hypotheses, $P < 0.05$ was considered significant. If pertinent, trends ($0.05 < P = 0.10$) were reported and $P > 0.10$ was considered non-significant.

RESULTS

Chemical Characteristics and Nutrient Digestibility

The 12 faba bean samples had a range of 7.5 to 16.8% moisture, 2.7 to 3.4% ash, 21.8 to 27.5% CP, 8.4 to 12.5% ADF, 11.3 to 19.8% NDF, and 0.9 to 1.4% ether extract (as fed; data not shown). The faba bean sample selected for the present animal studies contained 27.3% CP, 19.8% NDF, and 43.7% starch (as fed; Table 3), and 1.75% lysine, 0.88% threonine, 0.21% methionine, and 0.25% tryptophan (as fed).

The energy digestibility in the tested faba bean sample was 60.2% at the ileum and 88.5% for the total tract,

Table 3. Chemical characteristics of the zero-tannin faba bean used in the digestibility and performance studies

Variable (% as fed)	Zero-tannin faba bean
Moisture	13.4
Crude protein	27.3
Starch	43.7
Ether extract	1.0
Acid detergent fibre	9.6
Neutral detergent fibre	19.8
Crude fibre	7.8
Gross energy (Mcal kg^{-1})	3.92
Ash	3.1
Amino acid	
Alanine	1.06
Arginine	2.38
Aspartic acid	2.89
Cysteine	0.36
Glutamic acid	4.61
Glycine	1.11
Histidine	0.72
Isoleucine	1.13
Leucine	1.96
Lysine	1.75
Methionine	0.21
Phenylalanine	1.13
Proline	1.09
Serine	0.99
Threonine	0.88
Tryptophan	0.25
Valine	1.28
Tyrosine	0.76

resulting in a DE content of 3.47 kcal kg^{-1} (Table 4). The calculated NE content using the determined DE content and chemical characteristics was 2.27 kcal kg^{-1}.

The AID was 85.9% for lysine, 76.1% for threonine, 74.1% for methionine, and 76.4% for tryptophan (Table 5), resulting in an AID lysine content of 1.50% (as fed). Following the correction for basal endogenous losses, the SID lysine content was 1.54% (as fed).

Growth Performance and Carcass Characteristics

Eight pigs were removed from the experiment from separate pens. Reasons for exclusion were tail biting (four pigs; three faba bean and one soybean meal), rectal prolapse (two pigs; two faba bean), ulcer (one pig; soybean meal), and lame (one pig; soybean meal). Exclusions were thus likely not related to dietary regimen.

Diet regime and gender did not interact for ADG, ADFI, G:F, and final BW ($P > 0.05$; Table 6), so that solely differences in the main factors were described. For the entire study period, ADG, ADFI, and final BW was 42 g d^{-1}, 380 g d^{-1}, and 6.5 kg higher, respectively, for the barrows than the gilts ($P < 0.05$). The G:F was 0.03 higher for the gilts than the barrows ($P < 0.05$).

For the entire study period, ADG, ADFI, G:F, and final BW were not different between the faba bean and soybean meal diet regime ($P > 0.05$; Table 6). In the Grower phase, ADFI did not differ ($P > 0.05$) between the diet regimes; ADG tended to be 37 g d^{-1} higher ($P = 0.10$) and G:F was 0.02 higher for the soybean meal than for the faba bean regime ($P < 0.05$). In the Finisher 1 phase, G:F tended to be 0.02 lower for the faba bean regime ($P < 0.10$), while ADG and AFDI did not differ. In the Finisher 2 phase, ADG, ADFI, and G:F did not differ between the diet regimes.

Diet regime and gender did not interact for carcass characteristics ($P > 0.05$; Table 6), so that solely differences in the main factors were described. At slaughter, BW and dress weight were not different between the two diet regimes and between the two genders ($P > 0.05$, Table 7). Dressing percentage was 1.4% unit higher for the soybean meal than the faba bean regime ($P < 0.05$). Back fat thickness did not differ between the two diet regimes ($P > 0.05$), but back fat was 3.6 mm thicker for the barrows than the gilts ($P < 0.05$). Loin depth was 4.0 mm thicker for the soybean meal than the faba bean regime ($P < 0.05$), and loin depth was 6.9 mm thicker for the gilts than the barrows ($P < 0.05$). Calculated lean yield did not differ between the soybean meal and the faba bean regime ($P > 0.05$), but was 1.8% unit higher for the gilts than the barrows ($P < 0.05$).

Table 4. Apparent ileal and total tract energy digestibility, digestible energy content and calculated net energy of zero-tannin faba bean determined using the Energy diet in the digestibility study

Variable[z]	Zero-tannin faba bean
Ileal digestibility	
Energy (%)	60.2
DE content (Mcal kg^{-1} as fed)	2.36
Total tract digestibility	
Energy (%)	88.5
DE content (Mcal kg^{-1} as fed)	3.47
NE content (Mcal kg^{-1} as fed)[y]	2.27

[z]Means based on six pig observations.
[y]Calculated using NE (kcal kg^{-1} DM) $= 0.703 \times$ DE (kcal kg^{-1} DM; 3970) $+ 1.58 \times$ crude fat (g kg^{-1} DM; 12) $+ 0.47 \times$ starch (g kg^{-1} DM; 437) $- 0.97 \times$ CP (g kg^{-1} DM; 318) $- 0.98 \times$ crude fibre CP (g kg^{-1} DM; 91) $= 2618$ (Noblet 1994a). Then, NE (Mcal kg^{-1} as fed) $= 2.618 \times (1 - 0.134) = 2.27$.

Table 5. Apparent ileal amino acid digestibility and content of zero-tannin faba bean and standardized ileal amino acid content determined using the Amino acid diet in the digestibility study

Variable[z]	Zero-tannin faba bean
Apparent ileal digestibility (%)	
Protein	75.6
Lysine	85.9
Threonine	76.1
Methionine	74.1
Cysteine	64.4
Tryptophan	76.4
Isoleucine	82.3
Valine	80.0
Leucine	84.3
Apparent ileal digestible amino acid (% as fed)	
Lysine	1.50
Threonine	0.67
Methionine	0.15
Cysteine	0.23
Tryptophan	0.19
Isoleucine	0.93
Valine	1.02
Leucine	1.65
Standardized ileal digestible amino acid (% as fed)	
Lysine	1.54
Threonine	0.70
Methionine	0.16
Cysteine	0.25
Tryptophan	0.20
Isoleucine	0.99
Valine	1.10
Leucine	1.75

[z]Means based on six pig observations.

DISCUSSION

In western Canada, a diet for grower-finisher pigs containing wheat and barley as the main energy feedstuff and a pulse (cool-season legume) seed as the supplemental protein feedstuff should theoretically provide sufficient energy and AA to support a predictable growth performance. Nonetheless, soybean meal remains a popular protein feedstuff in swine diets primarily due to insufficient knowledge about the nutritional quality of Canadian pulse seeds and uncertainties about the effects of feeding pulse seeds on voluntary feed intake, subsequent swine growth performance and carcass characteristics. Implementation of risk

Table 6. Growth performance of grower-finisher pigs fed diets based on either faba bean or soybean meal

	Gilt		Barrow		Pooled	*P* value		
Variable[z]	Faba bean	Soybean meal	Faba bean	Soybean meal	SEM	Diet	Gender	Diet × Gender
ADG (kg d^{-1})								
Grower	0.864	0.873	0.926	0.990	0.02	0.10	<0.01	0.21
Finisher 1	0.913	0.924	1.032	1.069	0.03	0.37	<0.01	0.62
Finisher 2	1.154	1.084	1.054	0.992	0.05	0.21	0.08	0.94
Total	0.977	0.961	1.004	1.017	0.02	0.93	0.04	0.42
ADFI (kg d^{-1})								
Grower	1.959	1.964	2.160	2.167	0.07	0.92	<0.01	0.99
Finisher 1	2.719	2.593	3.223	3.208	0.08	0.42	<0.01	0.53
Finisher 2	2.978	2.916	3.383	3.261	0.07	0.25	<0.01	0.70
Total	2.552	2.491	2.922	2.878	0.07	0.45	<0.01	0.90
Feed efficiency								
Grower	0.442	0.445	0.429	0.457	0.007	0.04	0.96	0.11
Finisher 1	0.336	0.358	0.320	0.334	0.009	0.08	0.06	0.66
Finisher 2	0.386	0.373	0.311	0.305	0.013	0.47	<0.01	0.78
Total	0.388	0.392	0.354	0.365	0.006	0.25	<0.01	0.59
Final body weight (kg)								
Grower	62.23	62.06	65.21	67.14	0.81	0.29	<0.01	0.21
Finisher 1	87.81	87.95	94.09	97.09	1.20	0.21	<0.01	0.25
Finisher 2	102.81	102.04	107.80	109.99	1.28	0.58	<0.01	0.26

[z]Least-squares means based on five pen observations per diet regime and gender combination.

management during feed formulation will, therefore, reduce or avoid the inclusion of pulse seeds such as zero-tannin faba bean. The present study indicates that the pulse seed zero-tannin faba bean does not reduce voluntary feed intake up to a 30% dietary inclusion and contains a distinct energy and AA profile that supports equivalent growth to pigs fed soybean meal diets. However, pigs fed zero-tannin faba bean had a reduced loin thickness and dressing percentage compared with pigs fed diets based on soybean meal.

Compared with field pea included in the North American feedstuff table (NRC 1998), the zero-tannin faba bean contained more CP and SID AA, indicating that the prolonged N fixation period for faba bean compared with field pea (Mayer et al. 2003) indeed increases protein and AA content. The contents of protein, fibre, and ether extract of the zero-tannin faba bean used in the present swine studies were similar to faba bean used in a recent study from Finland (Partanen et al. 2003) and included in a French data base (Sauvant et al. 2004), indicating that the macro nutrient composition of faba bean seed is similar globally. The range in chemical characteristics among zero-tannin faba bean samples, in particular protein, fibre, and fat, in the present study indicates that a range in DE content exists among batches of zero-tannin faba bean of the same cultivar, similar to barley, wheat, and field pea in western Canada (Fairbairn et al. 1999; Zijlstra et al. 1999, 2000).

The measured total-tract energy digestibility coefficient of 89% and GE content of 3.92 Mcal kg^{-1} (as-fed) in the present study was 3% and 0.07 Mcal kg^{-1}, respectively, higher than the digestibility coefficient of 86% and GE content of 3.85 Mcal kg^{-1} (as-fed) included in the French data base for zero-tannin faba bean (Sauvant et al. 2004). Combined, the resulting DE content of 3.47 Mcal kg^{-1} (as-fed) was 0.14 Mcal kg^{-1} higher than the reported values of 3.33 Mcal kg^{-1} (as-fed; Sauvant et al. 2004), and further provides evidence of the valuable energy content of zero-tannin faba bean. The zero-tannin faba bean is thus similar in DE content

Table 7. Carcass characteristics of the grower-finisher pigs fed diets based on either faba bean or soybean meal

	Gilt		Barrow		Pooled	*P* value		
Variable[z]	Faba bean	Soybean meal	Faba bean	Soybean meal	SEM	Diet	Gender	Diet × Gender
BW at slaughter (kg)	116.9	115.1	116.2	115.2	0.81	0.10	0.70	0.61
Dress weight (kg)	91.8	92.4	92.0	92.1	0.90	0.71	0.99	0.80
Dressing (%)	78.4	80.3	79.2	80.0	0.51	0.03	0.68	0.33
Back fat (mm)	16.7	16.0	20.8	19.0	0.94	0.16	0.01	0.50
Loin depth (mm)	64.1	69.1	58.3	61.2	1.60	0.03	0.01	0.51
Lean yield (%)	61.3	62.2	59.5	60.4	0.48	0.09	0.01	0.94

[z]Least-squares means based on five pen observations per diet regime and gender combination.

as field pea with a reported range in DE content of 3.10 to 3.74 Mcal kg^{-1} as-fed (NRC 1998; Zijlstra et al. 2000; Sauvant et al. 2004). The NE content was predicted using an established prediction equation (Noblet 1994a) using the measured DE content and chemical characteristics, an approach that has the lowest error to predict NE content. The resulting NE content in the present study of 2.27 Mcal kg^{-1} (as-fed) was 0.07 Mcal kg^{-1} higher than the 2.20 Mcal kg^{-1} (as-fed) reported previously (Sauvant et al. 2004), and was a result of a combination of a higher DE and starch content of the zero-tannin faba bean used in the present study. The ileal digestibility of 60% means that, by difference, 29% of the GE in zero-tannin faba bean is fermented in the large intestine, reflecting the high content of fermentable carbohydrates such as the 2 to 4% oligosaccharides stachyose, raffinose, and verbascose (Duc et al. 1999).

Apart from energy, zero-tannin faba bean also provides CP and AA. In the present study, the content of total AA of the faba bean was similar to values measured previously (Mariscal-Landín et al. 2002; Sauvant et al. 2004). For example, total lysine in the present study was 0.03% higher than zero-tannin faba bean reported in the French data base (Sauvant et al. 2004). The 6.4% lysine as a percentage of CP fell within the reported range of 6.3 to 6.4% for faba bean (Mariscal-Landín et al. 2002; Sauvant et al. 2004). The AID for lysine in zero-tannin faba bean was identical to the French data base (Sauvant et al. 2004) but higher than the 83% reported previously for faba bean (Mariscal-Landín et al. 2002). The SID content of lysine was 0.02% higher than the 1.52% reported for zero-tannin faba bean in the French data base (Sauvant et al. 2004). Combined, our measured digestible AA values are close to values reported in Europe for zero-tannin faba bean.

Voluntary feed intake of pigs is affected by several factors, including diet (Nyachoti et al. 2004). The current paradigm is that inclusion of faba bean above 20% may reduce voluntary feed intake (Aherne et al. 1977; Partanen et al. 2003) and thereby hamper growth. Therefore, faba bean inclusion in the present study was limited to 30% to provide a challenge to the pigs, while controlling the unknown risk of reduced feed intake. Interestingly, feed intake was not hampered, indicating that 30% inclusion of zero-tannin faba bean or its remaining anti-nutritional factors such as vicine and convicine (Wang and Ueberschär 1990; Duc et al. 1999) did not hamper voluntary feed intake.

Reduced feed efficiency may reflect reduced nutrient digestion (Wondra et al. 1995). The reduced G:F and trend toward a reduced growth for pigs fed faba bean diets in the Grower period indicate that nutrient digestion was reduced. The digestibility study was conducted with pigs averaging 55 kg, i.e., pigs with a more developed gastro-intestinal tract than pigs in the Grower phase, and increased age of pigs coincides with increased nutrient digestibility (Noblet et al. 1994b). Reduced nutrient digestibility and achieved dietary digestible nutrient content might have been due to insufficient adaptation to oligosaccharides for pigs fed faba bean diets early in the Grower phase (Smiricky et al. 2002). Furthermore, the digestibility experiment using finisher pigs may have overestimated AA digestibility of zero-tannin faba beans for grower pigs. Growth performance differences were not observed in the Finisher phases of the experiment, indicating that achieved digestible nutrient profiles were similar for pigs fed the two diet regimes. On the other hand, diets in the Finisher 2 phase contained either 20 or 25% faba bean instead of 30% in the Grower and Finisher 1 phases. The effect of a reduced faba bean content on masking potential difference in ADG and G:F in the Finisher 2 phase can thus not be excluded entirely.

The reduced dressing percentage of pigs fed faba bean diets indicate that the viscera of these pig had a higher mass, reflecting the higher fibre content in zero-tannin faba bean than soybean meal (20 vs. 13% NDF; NRC 1998). Increased dietary fibre is known to stimulate intestine mass (Jørgensen et al. 1996). The reduced dressing percentage also indicates that pigs fed diets containing faba bean should be marketed at a higher body weight than pigs fed soybean meal-based diets to achieve a similar dress weight, as was achieved by chance in the present study.

Pigs fed faba bean diets had a reduced loin depth and thus protein mass at slaughter (De Lange et al. 2003), an indication of a reduced AA supply during the grower-finisher phase. Based on a similar ADG, this result was not expected, but, together with the reduced feed efficiency, seems indicative of a reduced AA supply for the pigs fed faba bean diets (Friesen et al. 1994). Potential reasons for this difference might be: changes in AA requirements, changes in digestibility, or errors in assumptions for feed formulation. The increased mass of viscera of pigs fed faba bean diets may have increased the AA and energy requirements of the viscera (Nyachoti et al. 1997), thereby reducing AA and energy supply for muscle growth. Digestibility of AA was expressed as SID that corrects AID for basal endogenous losses; however, ingredient-specific endogenous losses were ignored and the true ileal digestibility of AA might have been lower than the SID, thereby underestimating AA supply for muscle growth (Stein et al. 2007). The total AA content of the faba bean might have been overestimated due to lab error and the total AA content of the specific batch of soybean meal might have been underestimated. Together with a diet formulated at lysine requirements, these might have given an advantage to the pigs fed soybean meal. Finally, one SID for a key AA within the specific batch of faba bean might have been overestimated in the present study.

A gender by diet interaction was not observed for the performance and carcass characteristics in the present study. The measured gender effect followed expected differences with a higher ADFI and ADG combined with a lower G:F for barrows than gilts (Augspurger et al. 2002; Latorre et al. 2003). Increased back fat and reduced lean for barrows compared with gilts is common (Nold et al. 1997), but may also indicate that the barrows received a nutrient regime that was not optimum. Perhaps an increased dietary lysine to energy ratio throughout the entire grower-finisher phase might have increased protein deposition in the barrows (NRC 1998).

In summary, zero-tannin faba bean has an attractive nutrient profile and does not alter ADFI or ADG of grower-finisher pigs at inclusion rates up to 30%. The reduced feed efficiency in the Grower phase and reduced lean thickness for pigs fed faba bean indicate that dietary AA supply might have been limiting for the faba bean diets early in the study and that a gap in knowledge about the digestible nutrient profile of the zero-tannin faba bean remains for grower pigs. In conclusion, the zero-tannin faba bean is a worthwhile energy and protein feedstuff to consider in swine feed formulation.

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