AGRICULTURAL AND FOOD SCIENCE IN FINLAND

Vol. 12 (2003): 35–47.

Faba beans in diets for growing-finishing pigs

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Two experiments were carried out to study the effects of using the new faba bean (*Vicia faba* L.) cultivar Kontu as a domestic protein source for growing-finishing pigs. In Experiment 1, 120 pigs were used with a body weight (BW) of 25–110 kg to study the effects of replacing 0, 25, 50, 75, and 100% of rapeseed meal with faba beans in barley + rapeseed meal based diets. Restrictedly fed grower and finisher diets contained 137–317 and 114–260 g kg^{-1} faba beans, respectively. A barley + soya bean meal based diet was included as a control. The replacement of rapeseed meal with faba beans exerted a quadratic effect on daily weight gain and on the feed conversion ratio of pigs in the growing period and during total fattening ($P < 0.05$). The growth rate of growing pigs declined when 75 or 100% of rapeseed meal was replaced with faba beans. In addition, the complete replacement of rapeseed meal with faba beans decreased feed consumption ($P < 0.05$). The best overall growth performance and feed conversion ratio were observed when 50% of rapeseed meal was replaced with faba beans. These pigs had a better feed conversion ratio than those fed a barley + soya bean based meal diet ($P < 0.05$). The Minolta L* value of the *longissimus dorsi* muscle decreased linearly ($P < 0.01$) with increasing dietary faba bean levels. This indicates that the meat became darker. Therefore, Experiment 2 was carried out with 20 pigs (25–107 kg BW) to study the effect of faba beans on the colour and ultimate pH of the meat. The pigs were fed barley + soya bean meal or barley + faba bean based diets (243 g kg^{-1} faba beans). The ultimate pH of the *longissimus dorsi* muscle was higher in pigs fed the faba bean diet ($P = 0.05$), but meat colour did not differ between the treatments ($P > 0.05$). In conclusion, inclusion of over 200 g kg^{-1} of faba beans in barley + rapeseed meal based diets is not recommended for growing pigs because it may result in reduced growth performance. Faba beans may influence meat colour, but this phenomenon should be investigated further.

Key words: pigs, legumes, performance, meat quality

Manuscript received August 2002

Introduction

The faba bean (*Vicia faba* L.) is an annual legume that grows best under cool and moist conditions. Faba bean seeds have a relatively high crude protein (CP) content, about 300 g kg^{-1} dry matter, which makes them a valuable alternative to imported soya bean products as a domestic protein source in animal feeding (Thacker 1990, Gatel 1994). Furthermore, faba beans are capable of fixing atmospheric nitrogen, which results in increased residual soil nitrogen for use by subsequent crops. In Finland, two domestic faba bean cultivars, Ukko (Hankkija) and Kontu (Boreal Plant Breeding Ltd), are available. These white-flowered cultivars require a relatively long growing season, 111 days (Järvi et al. 2000), and they are thus recommended for for cultivation in southern Finland only. The cultivar Ukko has long been the major faba bean cultivar grown in Finland, but it is now being replaced by the new, higher yielding cultivar Kontu. In cultivation experiments conducted by MTT 1992–1999, the Kontu faba bean gave average yields of 3421 kg ha^{-1}, resulting in nearly 30% higher protein yields per hectare compared to peas (Järvi et al. 2000). However, the use of Kontu faba beans in pig feeding has not been investigated so far.

The protein of faba beans has a relatively high lysine content, similar to that of soya bean protein, but like most legume seeds, it is deficient in methionine (Gatel 1994). Because of the low methionine content, faba beans cannot be used as a sole source of supplemental protein in diets for growing-finishing pigs (Thacker 1990). Rapeseed protein, which is rich in sulphur-containing amino acids, complements well the amino acid composition of legumes (Bell et al. 1981, Castell and Cliplef 1993). Several studies have demonstrated that increasing dietary faba bean levels result in reduced daily weight gain and in an increased feed conversion ratio of growing pigs, particularly when the dietary faba bean level exceeds 200 g kg^{-1} feed (Aherne et al. 1977, O'Doherty and McKeon 2001). The reduced growth performance could be related to antinutritive factors present in faba beans. Faba beans contain tannins, protease inhibitors, and lectins, which may interfere with the digestion of nutrients and reduce pig growth (Thacker 1990, Grala et al. 1993). Furthermore, the crude fibre content is relatively high, 79–97 g kg^{-1} dry matter, and the fibre is poorly digestible, which partially accounts for the lower net energy value compared to peas (Partanen et al. 2001).

Feeding can have a significant impact on certain quality attributes of meat, e.g. flavour and tenderness (Coma 2001), and effects on meat quality should be considered when evaluating the optimal inclusion level of a feedstuff in pig diets. However, there is a scarcity of information concerning the effects of faba bean diets on meat quality. Madsen et al. (1990) reported decreased taste scores for pork when growing-finishing pigs were fed diets high in peas. Although later results of Castell and Cliplef (1993) did not confirm these findings, there is some hesitation to use diets high in legume seeds for growing-finishing pigs. Therefore, the aim of this study was to investigate the use of the faba bean cv. Kontu in diets of growing-finishing pigs and to investigate this cultivar's effects on pig performance, carcass traits, and meat quality.

Material and methods

Two growth experiments were carried out using a total of 140 growing-finishing pigs. The experimental procedures of both experiments were evaluated and approved by the Animal Care Committee of MTT Agrifood Research Finland.

Experiment 1

A total of 120 growing-finishing pigs (106 Landrace and 14 Landrace × Yorkshire) with an initial body weight (BW) of 25 kg were used in the experiment. The pigs were kept in pens measuring 1.0 m × 2.5 m, one gilt and one barrow per

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Table 1. Analysed chemical composition of faba beans, rapeseed, and soya bean meal used in Experiments 1 and 2.

	Faba beans	Rapeseed meal	Soya bean meal
Dry matter, g kg^{-1}	877	891	891
In g kg^{-1} dry matter			
Ash	37	69	64
Crude protein	320	368	466
Ether extract	25	93	45
Crude fibre	97	136	72
Amino acids, g per 16 g nitrogen			
Lysine	5.9	5.4	5.5
Methionine	0.5	1.9	1.1
Cystine	1.3	1.9	1.6
Threonine	2.9	4.4	3.6
Isoleucine	3.7	3.8	3.9
Leucine	6.5	6.8	6.6
Valine	3.4	4.9	4.7
Phenylalanine	4.0	4.4	4.5
Tyrosine	3.1	3.3	3.2
Arginine	8.9	6.0	6.3
Histidine	2.6	2.7	2.3
Proline	4.2	5.4	4.8
Glycine	3.9	4.7	3.8
Serine	4.3	4.3	4.3
Alanine	4.0	4.4	4.0
Aspartic acid	9.2	7.3	9.1
Glutamic acid	15.6	14.3	16.3

pen. Pigs were divided into 10 blocks according to BW. Within a block, pens were randomly allotted to one of the following six experimental diets: one barley + soya bean meal based diet (S), one barley + rapeseed meal based diet (R), and four barley + rapeseed meal based diets in which 25, 50, 75, or 100% of rapeseed meal was substituted with faba beans (F25, F50, F75, and F100). Faba beans cv. Kontu were from the same batch that was used in the digestibility experiment of Partanen et al. (2001), and the beans' composition as well as that of solvent extracted rapeseed and soya bean meals (Raision Yhtymä Oyj, Raisio, Finland) are shown in Table 1. The barley used was of the cultivars Loviisa (CP 100 g kg^{-1}) and Kustaa (CP 108 g kg^{-1}) in grower and finisher diets, respectively. The diets were supplemented with a mineral and vitamin premix (Premivit-Sika LT, Suomen Rehu Oy, Helsinki, Finland) that contained free lysine and threonine. The faba bean diets were also supplemented with free methionine. The formulations of the experimental diets are presented in Table 2. Barley and faba beans were used after grinding in a hammer mill with a 3.5-mm and 4-mm sieve, respectively, and were mixed with all supplements in a Gehl 170 Mix-All grinder-mixer (Gehl Company, West Bend, Wisconsin, USA).

Two-phase feeding was applied. Grower and finisher diets were formulated to contain 7.8 and 7.0 g, respectively, apparent ileal digestible lysine and 4.6 and 4.1 g apparent ileal digestible methionine + cystine per feed unit, which corresponds to 9.3 MJ NE (Tuori et al. 1996). Grower diets were fed for five weeks. Pigs were fed twice a day according to a restricted age-based feeding scale (1.2–3.0 FU d^{-1}; ca 80% of *ad libitum* feed intake). Feed refusals were not meas-

Table 2. Ingredients and calculated composition of barley + soya bean meal based diet (S), barley + rapeseed meal based diet (R), and barley + rapeseed meal based diets in which 25, 50, 75, or 100% of the rapeseed meal was replaced with faba beans (F25, F50, F75, and F100) in Experiment 1.

Treatment	S	R	F25	F50	F75	F100
Grower diets						
Ingredients, g kg^{-1} feed						
Barley	799	749	667.5	662.1	656.8	651.5
Soya bean meal	171	–	–	–	–	–
Rapeseed meal	–	220	165	110	55	–
Faba beans	–	–	137	197	257	317
Mineral and vitamin premix[1]	30	30	30	30	30	30
L-Lysine HCl	–	1.0	–	–	–	–
DL-Methionine	–	–	0.5	0.9	1.2	1.5
Calculated composition						
Net energy, MJ kg^{-1}	9.0	8.7	8.6	8.7	8.7	8.8
Feed units kg^{-1} (1 FU = 9.3 MJ NE)	0.97	0.94	0.93	0.94	0.94	0.95
Crude protein, g kg^{-1}	158	158	160	158	157	156
Apparent ileal digestible amino acids, g FU^{-1}						
Lysine	7.8	7.8	7.8	7.8	7.8	7.8
Methionine + cystine	4.5	4.6	4.6	4.6	4.6	4.6
Threonine	4.7	4.3	4.4	4.2	4.0	3.8
Tryptophan	1.6	1.4	1.5	1.4	1.3	1.3
Finisher diets						
Ingredients, g kg^{-1} feed						
Barley	831	790.2	721.8	717.5	713.2	710
Soya bean meal	140	–	–	–	–	–
Rapeseed meal	–	180	135	90	45	–
Faba beans	–	–	114	163	212	260
Mineral and vitamin premix[1]	29	29	29	29	29	29
L-Lysine HCl	–	0.8	–	–	–	–
DL-Methionine	–	–	0.2	0.5	0.8	1.0
Calculated composition						
Net energy, MJ kg^{-1}	9.3	9.1	9.0	9.0	9.1	9.1
FU kg^{-1}	1.00	0.98	0.97	0.97	0.98	0.98
Crude protein, g kg^{-1}	154	145	154	153	152	151
Apparent ileal digestible amino acids, g FU^{-1}						
Lysine	7.0	7.0	7.0	7.0	7.0	7.0
Methionine + cystine	4.2	4.1	4.1	4.1	4.1	4.1
Threonine	4.3	3.9	4.0	3.9	3.7	3.5
Tryptophan	1.4	1.3	1.3	1.3	1.2	1.2

[1] The premix (Premivit-Sika LT, Suomen Rehu Oy) contained the following per kg: 41 g lysine, 5.3 g threonine, 215 g Ca, 56 g P, 19 g Mg, 133 g NaCl, 3045 mg Fe, 800 mg Cu, 800 mg Mn, 4060 mg Zn, 6 mg I, 10 mg Se, 185 000 IU vitamin A, 18 500 IU vitamin D_3, 1 800 mg vitamin E, 76 mg thiamin, 195 mg ribiflavin, 117 mg pyridoxine, 0.76 mg vitamin B_{12}, 7.6 mg biotin, 567 mg pantothenic acid, 773 mg niacin, 57 mg folic acid, and 76 mg vitamin K.

ured; instead, the daily feed allowance was decreased temporarily (0.2–0.3 FU d^{-1}) when pigs exhibited feed refusal. Water was available *ad libitum* in drinking nipples.

Pigs were slaughtered when they reached a BW of 108 kg. Carcass lean percentage was determined with a Hennessy GP4 grading probe (Hennessy Grading Systems Ltd., Auckland,

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New Zealand). Carcass fatness was measures in terms of back and side fat thicknesses. The thickness of fat was calculated as the mean of five measurements that were taken at the shoulder, in the middle, and at three locations of ham. The thickness of side fat was determined on the last rib, 8 cm from the midline. Ham was dissected into fat and lean with bones to determine the ham lean percentage. The colour of the *longissimus dorsi* muscle was determined with a Minolta DP301 device (Minolta Camera Co., Ltd., Osaka, Japan) in terms of lightness (L*), redness (a*), and yellowness (b*), as well as by visual scoring using a scale from 1 to 5 with 0.5-point intervals (1 = extremely pale, 5 = extremely dark).

For the determination of organoleptic traits, samples were taken from the *longissimus dorsi* muscle in front of the last rib from 60 randomly selected carcasses (one pig per pen) and frozen. The frozen samples were thawed and prepared for sensory evaluation as described by Siljander-Rasi et al. (1996). A trained, seven-member test panel graded the fried samples for taste, juiciness, and tenderness using a 7-point rating scale (1 = weak pork flavour, very dry, very tough; 7 = strong pork flavour, very juicy, very tender). Each sample's mean score was calculated for use in the statistical analysis.

Experiment 2

A total of 20 growing-finishing pigs (12 Landrace and 8 Landrace × Yorkshire) with an initial body weight of 25 kg were used to investigate the effect of faba beans on meat colour. Two gilts and two barrows from the same litter formed a block. Within the block, the pigs were randomly allotted to one of the following two dietary treatments: a barley + soya bean meal based diet (S) and a barley + faba bean based diet (F). Both diets were formulated to be similar in apparent ileal digestible lysine (7.8 g FU^{-1}) and methionine + cystine content (4.5 g FU^{-1}). The faba beans were from the same batch that was used in Experiment 1. The barley, soya bean meal, and whey protein concentrate used in the diets contained 110, 419, and 695 g kg^{-1} of CP, respectively. The formulations of the experimental diets are presented in Table 3. The feed mixtures were prepared as in Experiment 1. Pigs were fed twice a day according to a restricted age-based feeding scale (1.2–3.2 FU d^{-1}; ca 85% of *ad libitum* feed intake). Water was available *ad libitum* from drinking nipples.

The experiment lasted for 89 days. At slaughter, blood samples were taken during the bleeding of stunned pigs and measured immediately for haemoglobin content (HemoCue B-Haemoglobin Photometer, HemoCue AB, Sweden). Furthermore, the pH of the *longissimus dorsi* muscle was measured within 1 h from slaughter with a PHM201 portable pH meter (Radiometer, Denmark) using a Mettler Toledo Inlab® 427 electrode. The measurements of carcass and ham lean percentage and of back and side fat thicknesses were carried out as in Experiment 1. Furthermore, the *longissimus dorsi* and *semimembranosus* muscles were measured for ultimate pH (24 h) with a Knick 752 pH meter (Knick Elektronische Messgeräte GmbH & Co., Germany) using an Ingold 427 electrode. Meat colour (L*, a*, and b*) was measured as described in Experiment 1. Drip loss was measured by weighing a ca. 100-g meat sample before and after storage in a 0.5-l Minigrip plastic bag at 4°C for 3 days.

Chemical analyses

Cereals and protein feedstuffs were sampled prior to feed mixing and analysed for ash, ether extract, and crude fibre according to the standard methods (AOAC 1990). Nitrogen (CP = 6.25 × N) was determined by the Dumas Method with a Leco FP 428 N analyser (Leco Corp., St Joseph, USA). Amino acids, except tryptophan, were analysed according to the Commission Directive 98/64/EC. The nutrient composition of complete diets was calculated from the analysed composition of feed ingredients. The net energy content (1 FU = 9.3 MJ NE) and the amount of ap-

Table 3. Ingredients and calculated composition of barley + soya bean meal (S) and barley + faba bean based (F) diets in Experiment 2.

Treatment	S	F
Ingredients, g kg^{-1} feed		
Barley	781.8	698.8
Soya bean meal	192.1	–
Faba beans	–	242.6
Whey protein concentrate	–	32.7
Mineral and vitamin premix[1]	13.0	13.0
Limestone	7.9	7.8
Monocalcium phosphate	4.1	4.7
L-Lysine HCl	1.1	–
DL-Methionine	–	0.4
Calculated composition		
Net energy, MJ kg^{-1}	8.9	8.7
Feed units kg^{-1} (1 FU = 9.3 MJ NE)	0.96	0.94
Apparent ileal digestible amino acids, g FU^{-1}		
Lysine	7.8	7.8
Methionine + cystine	4.5	4.5
Threonine	4.5	4.1
Tryptophan	1.8	1.4

[1] Per kilogram of feed, the premix supplied: 2.3 g Ca, 0.8 g P, 0.5 g Mg, 3.3 g NaCl, 103 mg Fe, 22 mg Cu, 91 mg Zn, 23 mg Mn, 0.28 mg Se, 0.28 mg I, 5170 IU vitamin A, 517 IU vitamin D_3, 50 mg vitamin E, 2 mg thiamin, 5 mg riboflavin, 3 mg pyridoxine, 20 mg vitamin B_{12}, 0.2 mg biotin, 14 mg pantothenic acid, 20 mg niacin, 2 mg folic acid, and 2 mg vitamin K.

parent ileal digestible amino acids in feedstuffs was calculated based on analysed chemical composition and tabulated digestibility coefficients as described by Tuori et al. (1996). The apparent ileal digestible tryptophan contents were calculated based on tabulated values for tryptophan content in feedstuffs (Tuori et al. 1996) as well as for digestibility coefficients (AmiPig 2000). During the experiments, the dry matter content of each diet was determined every second week by drying samples at 103°C over night.

Statistical analysis

The data of Experiment 1 were analysed with the MIXED procedure of SAS (1998) using a model in which treatment was the fixed effect and the block was the random effect (Snedecor and Cochran 1989). The pen was the experimental unit. The differences between the treatments were identified with the Tukey test when the F-test was significant ($P < 0.05$). Furthermore, the effect of the dietary faba bean level was investigated with orthogonal polynomials (linear, quadratic, cubic, and quartic effect). Visual colour scores were tested with the Kruskall-Wallis test. In Experiment 2, the data were analysed using a model in which treatment was the fixed effect and block was the random effect (Snedecor and Cochran 1989). In both experiments, residuals were checked for normality and were plotted against fitted values.

Results and discussion

The CP content of Kontu faba beans was similar to that reported for the faba bean cultivars Kontu and Ukko by Järvi et al. (2000). Compared to

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the protein in soya bean and rapeseed meal (Table 1), faba bean protein was richer in lysine, but it contained less methionine, cystine, and threonine. The determined amino acid profiles are in accordance with previous reports (Bell et al. 1981, Gatel 1994, Bell et al. 2000). The tryptophan content of faba bean protein is also lower than that of soya bean meal and rapeseed meal protein (Bell et al. 1981, Gatel 1994).

The pigs in Experiment 1 were in good health throughout the experiment and completed the experiment successfully, except that one pig in treatment F75 was removed from the experiment at 48 kg BW because of a leg injury. One pig, also in treatment F75, was slaughtered at 95 kg BW because it had diarrhoea for several days in the finishing period and performance was poor. These pigs were removed from the calculations.

Table 4 shows that increasing substitution of rapeseed meal with faba beans exerted a quadratic effect on daily weight gain and the feed conversion ratio of growing pigs ($P < 0.05$). Both the daily weight gain and the feed conversion ratio worsened when 75 or 100% of rapeseed meal was replaced with faba beans, i.e., in diets containing 257 and 317 g kg^{-1} beans, respectively. With lower dietary faba bean levels (137 and 197 g kg^{-1} feed), the performance of growing pigs did not differ from those fed barley + soya bean meal or barley + rapeseed meal based diets ($P > 0.05$). Some growing pigs offered barley + faba bean based diet exhibited feed refusal, and their daily allowances were reduced. This resulted in lower daily feed consumption in treatment F100 compared to that of the other treatments ($P < 0.05$). In the finishing period, no significant differences between dietary treatments were observed in daily weight gain, feed consumption, or the feed conversion ratio of the pigs. During the total fattening period, the dietary faba bean level exerted a quadratic effect on daily weight gain and the feed conversion ratio ($P < 0.05$), the best growth results being observed in pigs fed diets in which 50% of rapeseed meal was replaced with faba beans. The daily weight gain and feed conversion ratio of these pigs was better than in those fed the barley-rapeseed meal diet ($P < 0.05$), and the feed conversion ratio was better than in those fed the barley-soya bean meal diet ($P < 0.05$). Pigs fed the barley + rapeseed meal based diet performed as well as those fed the barley + soya bean meal based diet ($P > 0.05$).

The observed adverse effects of high dietary faba bean levels on the performance results of growing pigs are in agreement with previous studies. Aherne et al. (1977) reported reduced feed intake, reduced growth performance, and increased feed conversion ratios when the dietary faba bean level exceeded 200 g kg^{-1} feed. According to Petersen and Schulz (1978), up to 50% of soya bean meal can be replaced with faba beans in diets for growing pigs without negative effect on pig performance. Recently, O'Doherty and McKeon (2001) reported a linear decrease in daily weight gain and an increase in the feed conversion ratio of growing pigs offered diets containing 125 to 375 g kg^{-1} of field beans. Faba beans do not seem to have negative effects on the performance of finishing pigs (Aherne et al. 1977, O'Doherty and McKeon 2001). Pigs fed barley-soya bean meal or barley-rapeseed meal diets performed equally well. In the study of Castell and Cliplef (1993), total replacement of soya bean meal with rapeseed meal reduced growth performance and increased the feed conversion ratio of growing pigs offered diets *ad libitum*, whereas finishing pigs performed equally well in both groups. According to Siljander-Rasi et al. (1996), heat-treated, low-glucosinolate rapeseed meal can be used as the sole protein source for growing-finishing pigs when diets are supplemented with free lysine and are given restrictedly.

The reduced growth performance of growing pigs fed diets high in faba beans could partly be related to the unbalanced dietary amino acid supply. The experimental diets were formulated to provide similar amounts of apparent ileal digestible lysine and methionine + cystine per feed unit with the help of free amino acids. However, the apparent ileal digestible threonine and tryptophan contents were not adjusted and thus declined with increasing dietary faba bean levels

Table 4. Performance, carcass characteristics, and meat quality of pigs fed a barley + soya bean meal based diet (S), a barley + rapeseed meal based diet (R), or barley + rapeseed meal based diets in which 25, 50, 75, or 100% of rapeseed was replaced with faba beans (F25, F50, F75, and F100) in Experiment 1.

Treatment	S	R	F25	F50	F75	F100	SEM	P
Pens	10	10	10	10	10	10		
Pigs	20	20	20	20	18	20		
Weight, kg								
Initial	25.0	25.2	25.0	24.9	25.2	25.1	0.45	0.92
At the end of grower period$^{L, Q}$	50.4^{b}	50.2^{b}	50.5^{b}	50.0^{b}	48.7^{b}	43.1^{a}	0.83	0.001
Final	111.0	110.5	110.8	111.2	110.2	109.8	0.54	0.42
Days in trial$^{L, Q}$	98.5^{a}	98.1^{a}	96.7^{a}	95.7^{a}	97.4^{a}	103.4^{b}	1.46	0.002
Weight gain, g d^{-1}								
Grower period$^{L, Q}$	770^{c}	759^{bc}	771^{c}	760^{bc}	712^{b}	545^{a}	17.7	0.001
Finisher period	939	932	959	986	959	954	16.9	0.24
Total fattening$^{L, Q}$	880^{bc}	873^{b}	894^{bc}	908^{c}	874^{b}	823^{a}	11.1	0.001
Feed consumption, kg DM d^{-1}								
Grower period$^{L, Q, C}$	1.48^{b}	1.53^{b}	1.52^{b}	1.50^{b}	1.51^{b}	1.28^{a}	0.022	0.001
Finisher period^{Q}	2.45^{a}	2.50^{bc}	2.54^{d}	2.52^{cd}	2.51^{cd}	2.48^{ab}	0.014	0.001
Total fattening$^{L, Q, K}$	2.12^{a}	2.17^{b}	2.19^{b}	2.17^{b}	2.17^{b}	2.10^{a}	0.012	0.001
Feed consumption, FU d^{-1}								
Grower period$^{L, Q, C}$	1.61^{b}	1.62^{b}	1.60^{b}	1.58^{b}	1.60^{b}	1.37^{a}	0.023	0.001
Finisher period	2.72	2.72	2.75	2.73	2.74	2.71	0.014	0.43
Total fattening$^{L, Q, K}$	2.35^{b}	2.35^{b}	2.35^{b}	2.33^{b}	2.36^{b}	2.28^{a}	0.013	0.001
Feed units per kg gain								
Grower period$^{L, Q}$	2.10^{a}	2.13^{ab}	2.07^{a}	2.09^{a}	2.25^{b}	2.56^{c}	0.053	0.001
Finisher period	2.94	2.94	2.88	2.79	2.93	2.86	0.050	0.15
Total fattening$^{L, Q}$	2.69^{bc}	2.70^{bc}	2.64^{ab}	2.58^{a}	2.74^{bc}	2.78^{c}	0.039	0.005
Carcass weight, kg^{L}	83.7	83.4	83.1	83.3	81.6	81.9	0.70	0.13
Slaughter loss, %^{L}	24.6	24.5	24.9	25.2	25.9	25.4	0.41	0.07
Back fat, mm	22.9	23.6	22.7	23.8	21.9	23.3	0.69	0.41
Side fat, mm	16.9	16.3	15.7	16.7	15.7	16.2	0.72	0.73
Carcass lean, %	58.9	58.8	59.4	59.3	59.2	59.1	0.35	0.81
Ham lean, %	85.8	86.6	87.2	86.3	86.9	86.2	0.38	0.17
Colour of meat								
Minolta L* (lightness)^{L}	58.3^{c}	56.4^{c}	53.4^{b}	53.3^{ab}	51.7^{ab}	51.3^{a}	0.82	0.001
Minolta a* (redness)	8.3^{c}	7.3^{bc}	6.1^{a}	6.4^{ab}	6.2^{a}	6.4^{ab}	0.36	0.001
Minolta b* (yellowness)^{L}	5.5^{b}	4.8^{b}	3.4^{a}	3.7^{a}	3.4^{a}	3.4^{a}	0.31	0.001
Visual colour score[1]	2.4^{a}	2.6^{a}	3.2^{b}	2.9^{ab}	3.3^{b}	3.1^{b}	0.12	0.001
Organoleptic quality[2]								
Taste	4.8	5.1	5.0	4.9	5.1	4.9	0.10	0.25
Juiciness	4.5	4.6	4.9	4.7	5.0	4.7	0.14	0.13
Tenderness	4.4	4.7	4.7	4.6	4.8	4.3	0.24	0.64

FU = feed unit, which is equal to 9.3 MJ NE (Tuori et al. 1996).

a,b,c,d Treatments with different superscripts differ significantly ($P < 0.05$). Based on polynomial regression, the effect of dietary faba bean level is ^{L}linear, ^{Q}quadratic ($P < 0.05$), ^{C}cubic ($P < 0.05$), or ^{K}quatric ($P < 0.05$).

1 Visual colour scoring was carried out using a scale from 1 to 5 with 0.5-point intervals (1 = extremely pale, 5 = extremely dark).

2 Organoleptic quality was evaluated by a 7-member panel using a scale from 1 to 7 (1 = weak flavour, very dry, very tough; 7 = strong flavour, very juicy, very tender).

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(Table 2). According to Boisen et al. (2000), there are considerable differences in recommendations for the optimum ratios of apparent ileal digestible amino acids relative to lysine: methionine + cystine 50–63%, threonine 60–75%, and tryptophan 15–19%. Both in grower and finisher diets, the ratio of methionine + cystine and tryptophan to lysine were within these recommendations. However, the minimum recommendation for the threonine to lysine ratio (60%) was met only in the barley-soya bean meal diet. When rapeseed meal was gradually replaced with faba beans, the threonine to lysine ratios declined from 56 to 49% and from 57 to 50% in grower and finisher diets, respectively. However, the performance results of growing pigs did not start to decline until over 50% of rapeseed meal was replaced with faba beans, i.e., when the threonine to lysine ratios was below 54%. No reduction in growth rate was seen in the finishing period with increasing dietary faba bean content. Siljander-Rasi et al. (unpublished results) found no differences in the performance results of growing-finishing pigs offered diets with threonine to lysine ratios of 55–70%, but higher ratios improved the carcass lean percentage. In our trial, however, no differences in carcass lean percentage were found between dietary treatments.

Faba beans are known to contain various antinutritive factors, e.g. tannins, lectins, and trypsin inhibitors, which may have contributed to the decreased performance results observed with high faba bean diets. Faba beans contain varying levels of condensed tannins, which are located in the seed hulls. The tannin content is lower in white-flowering than in coloured cultivars (Grala et al. 1993). Condensed tannins in faba beans decrease the ileal and faecal digestibility of nutrients, in particular of protein and amino acids. This is a result of tannins interacting with both dietary and endogenously secreted proteins in the intestinal tract (Jansman et al. 1995). According to Grala et al. (1993), the trypsin inhibitors and lectins play a lesser role in the nutritive value of faba beans in pig feeding, and their levels are lower in faba beans than in peas and considerably lower than in raw soya beans (Gatel 1994). Antinutritive factors are also present in soya beans and rapeseeds, but they are primarily destroyed during heat treatment.

Carcass traits of pigs did not differ between dietary treatments ($P > 0.05$). Furthermore, the organoleptic meat quality (taste, tenderness, and juiciness) was similar in the different dietary treatments ($P > 0.05$). This is in accordance with the results of Castell and Cliplef (1993), who reported no differences in the organoleptic meat quality of pigs offered barley-soya bean meal diets or barley-rapeseed meal diets in which rapeseed meal was gradually replaced with peas. Siljander-Rasi et al. (1996) reported no differences in organoleptic meat quality in pigs offered diets in which soya bean meal was gradually replaced with rapeseed meal. In our study, no relationship was found between organoleptic meat quality and carcass lean percentage or fat thickness, which is in accordance with the results of Blanchard et al. (2000).

An unexpected finding was that gradual replacement of rapeseed meal with faba beans resulted in darker meat in the *longissimus dorsi* muscle as indicated by a linearly decreasing Minolta L* value ($P < 0.05$). Also, the Minolta b* value (yellowness) decreased linearly with increasing dietary faba bean levels ($P < 0.05$). The meat was palest in pigs fed a barley + soya bean meal based diet. Both Minolta a* (redness) and b* (yellowness) values were lower in pigs fed diets containing faba beans than in those fed the barley + soya bean meal based diet ($P < 0.05$). Meat colour did not differ between pigs offered barley + soya bean meal and barley + rapeseed meal based diets ($P > 0.05$). Visual pink colour is a combination of redness and lightness (or darkness); the darker and redder a sample is, the more intensely pink it appears. Among the Minolta colour coordinates, L* value is considered the best predictor of visual pink colour in pork (Brewer et al. 2001). There was a strong negative correlation between the Minolta L* value and visual colour scores ($r = -0.83$, $P < 0.001$), and the latter confirmed the finding that meat colour was improved by feeding pigs faba bean diets. The L* value is a good overall indicator of PSE (pale, soft, and exudative) and DFD (dark, firm, and dry) meat in pork (Brewer et al. 2001). The colour of the *longissimus dorsi* muscle is considered normal when the L* value is between 48 and 54. Values 55–60 are considered slightly pale, and those over 60 are extremely pale. Meat is dark when the L* value is below 48 (M. Honkavaara, personal communication). In this data, the range of Minolta L* values was 51–65 and 41–59 in diets without and with faba beans, respectively. The respective ranges for visual colour scores were 1.5–3.0 and 2–4.5. In faba bean treatments, a total of 11 pigs had L* values below 48. Although L* values below 48 could be considered DFD meat (Brewer et al. 2001), darker meat did not result in reduced sensory meat quality. In fact, the Minolta L* value was negatively correlated with taste (r = –0.30, $P < 0.05$), tenderness (r = –0.32, $P < 0.05$), and juiciness (r = –0.42, $P < 0.01$), indicating that darker meat got better scores for organoleptic quality.

According to Dransfield et al. (1985), pigs fed diets high in rapeseed meal (30 g kg^{-1} feed) had increased pigmentation and produced slightly darker meat. However, Castell and Cliplef (1993) found no differences in visual meat colour in pigs fed barley + soya bean meal or barley + rapeseed meal based diets. Published information about the effect of faba beans on meat colour is scarce. In previous faba bean experiments carried out at our research station (Alaviuhkola 1979, Suomi 1979), in two studies out of four, faba bean diets gave higher visual colour scores than control diets which contained no faba beans. Faba bean diets also resulted in lower EEL reflectomer values compared to those of the control diet, indicating that meat became darker.

The colour of meat is related to the pH development in meat after slaughtering. As pH increases, visual pink colour increases, and the L* value decreases (Brewer et al. 2001). Pale meat is associated with a low ultimate pH, which is a result of post-slaughtering lactate formation from muscle glycogen stores (Rosenvold et al. 2001b). Because the ultimate pH of meat was not measured in previous trials, Experiment 2 was carried out to see if the improvement in meat colour observed with faba bean diets could be explained by changes in the ultimate pH of meat. Table 5 shows that the ultimate pH of the *longissimus dorsi* muscle of pigs fed the barley + faba bean based diet was higher than that of pigs fed the barley + soya bean meal based diet ($P = 0.05$). However, no differences were observed in the colour of the *longissimus dorsi* muscle. The *semimembranosus* muscle was considerably paler than the *longissimus dorsi* muscle, but dietary treatments did not affect its colour or ultimate pH ($P > 0.05$). Dietary treatments also did not affect drip loss ($P > 0.05$). Although dietary treatments did not affect meat colour, a negative correlation was found between the ultimate pH and the Minolta L* value of the *longissimus dorsi* muscle in pigs offered an F diet (r = –0.94, $P < 0.001$), but not in pigs offered the S diet (r = –0.10, $P > 0.05$). It is possible that the number of observations was too small to show differences in meat colour between dietary treatments. Three pigs had to be removed from treatment F (vomiting and ill appearance, prolapsed rectum, and leg problems). Pigs performed equally well in treatments S and F, except that the feed conversion ratio tended ($P = 0.07$) to be greater in pigs fed an F diet. The performance results correspond to those of Experiment 1.

Muscle glycogen concentration at the time of slaughter is one important factor influencing the ultimate pH. Recently, successful attempts have been made to improve the colour of pork with strategic finishing feeding (Rosenvold et al. 2001a, b), i.e. feeding finishing pigs diets with a low amount of easily digestible carbohydrates to reduce muscle glycogen stores. Both rapeseed meal and faba beans are high in fibre; the non-starch polysaccharide content is 220 and 190 g kg^{-1} dry matter, respectively. Cellulose is an important constituent of the cell walls, constituting up to 43% of non-starch polysaccharides in faba beans, whereas the proportion is lower in soya bean meal and rapeseed meal, 29 and 24%, respectively (Bach Knudsen 1997). Cellulose is

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Table 5. Performance and carcass characteristics of pigs fed barley + soya bean meal (S) or barley + faba bean based (F) diets in Experiment 2.

Treatment	S	F	SEM	P
Pigs	10	8		
Initial weight, kg	24.9	25.4	0.81	0.45
Final weight, kg	108.0	106.1	1.89	0.46
Weight gain kg d^{-1}	934	910	19.6	0.37
Feed consumption, kg DM d^{-1}	2.24	2.19	0.026	0.18
Feed consumption, FU d^{-1}	2.42	2.44	0.029	0.53
Feed units per kg gain	2.59	2.69	0.036	0.07
N	10	7		
Blood hemoglobin, mg l^{-1}	135	139	3.5	0.19
Carcass weight, kg	81.9	79.9	1.64	0.39
Slaughter loss, %	24.3	25.0	0.58	0.41
Back fat, mm	19.6	20.2	1.54	0.63
Side fat, mm	14.2	14.3	1.58	0.93
Carcass lean, %	60.1	59.8	0.49	0.54
Ham lean, %	87.1	86.2	0.88	0.35
Longissimus dorsi				
pH 45 min	6.12	6.16	0.099	0.74
pH 24 h	5.56	5.65	0.045	0.05
Meat colour[1]				
Minolta L*	55.0	54.4	1.06	0.58
Minolta a*	6.4	7.0	0.63	0.28
Minolta b*	3.5	3.6	0.43	0.80
Drip loss, %	5.7	6.1	0.74	0.53
Semimembranosus				
pH 24 h	5.62	5.74	0.070	0.18
Meat colour[1]				
Minolta L*	62.2	61.3	1.03	0.55
Minolta a*	5.0	5.6	0.82	0.35
Minolta b*	4.2	4.2	0.55	0.97
Drip loss, %	4.4	5.8	0.67	0.15

[1] L* = lightness, a* = redness, b* = yellowness. Visual scoring was carried out using a scale of 1 to 5 with 0.5-point intervals (1 = extremely pale, 5 = extremely dark).

fermented in the large intestine by microbes, and it is absorbed in the form of volatile fatty acids (Wenk 2001). Faba beans have been shown to influence carbohydrate metabolism; lower plasma glucose concentrations have been measured in rats offered faba bean diets compared to those offered diets with peas or soya beans (Fernández-Quintela et al. 1998). However, it is unknown if feeding faba bean diets to pigs influences their muscle glycogen stores, thus increasing the ultimate pH and improving meat colour. Therefore, the effect of faba beans on pig muscle glycogen stores and meat colour should be investigated further.

Conclusions

It has been shown that faba beans can be used up to an inclusion level of 200 g kg^{-1} in diets for growing pigs. Higher levels may impair growth performance. However, no limitation is needed for finishing pigs. Faba beans may also have a positive influence on meat colour, but further research is required to explain the phenomenon.

Acknowledgements. The authors wish to thank the Finnish Ministry of Agriculture and Forestry for financing this study.

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SELOSTUS

Härkäpapu lihasikojen ruokinnassa

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Härkäpapu (*Vicia faba* L.) on palkokasvi, joka on siementen melko suuren valkuaispitoisuuden (raakavalkuaista 300 g kg^{-1} kuiva-ainetta) vuoksi potentiaalinen soijaa korvaava kotimainen valkuaisrehu. Kahdessa kasvatuskokeessa selvitettiin uuden Kontu härkäpapulajikkeen sopivuutta lihasikojen valkuaisrehuksi ja härkäpapuruokintojen vaikutusta lihan laatuun.

Ensimmäisessä kasvatuskokeessa verrattiin ohra-soijarouhe- ja ohra-rypsirouhepohjaisia ruokintoja ohra-rypsirouhe-härkäpapuruokintoihin, joissa rypsirouheesta 25, 50, 75 tai 100 % korvattiin härkäpavulla. Alkukasvatusrehuissa oli 137–317 ja loppukasvatusrehuissa 114–260 g/kg papua. Kokeessa oli 120 lihasikaa, jotka kasvatettiin pareittain 25 kg alkupainosta 110 kg loppupainoon. Korvattaessa 75–100 % rypsirouhetta härkäpavulla sikojen päiväkasvu ja rehuhyötysuhde huononivat alkukasvatuksessa verrattuna ohra-soijarouhe- ja ohra-rypsirouhepohjaisiin ruokintoihin. Rehun syönti pieneni, kun rypsi korvattiin kokonaan härkäpavulla. Loppukasvatuksessa sikojen päiväkasvussa ja rehuhyötysuhteessa ei ollut eroja erilaisten ruokintojen välillä. Koko kasvatusajan päiväkasvu ja rehuhyötysuhde oli paras, kun 50 % rypsirouheesta korvattiin härkäpavulla. Tällä ruokinnalla siat kasvoivat paremmin kuin ohra-rypsirouheruokinnalla, ja rehuhyötysuhde oli parempi kuin ohra-rypsirouhe- tai ohra-soijarouheruokinnalla. Rypsirouheen asteittainen korvaaminen härkäpavulla ei vaikuttanut sikojen teuraslaatuun tai lihan aistinvaraiseen laatuun, mutta tummensi selkälihaksen väriä.

Toisessa kasvatuskokeessa selvitettiin härkäpapuruokinnan vaikutusta lihan väriin ja pH:hon. Kokeessa oli 20 lihasikaa, joille syötettiin ohra-soijarouhe- tai ohra-härkäpapupohjaista rehua 25–107 kiloisina. Selkälihaksen pH oli 24 h teurastuksesta korkeampi ohra-härkäpapu- kuin ohra-soijarouheruokinnoilla, mutta lihan värissä ei havaittu eroja.

Tulosten perusteella härkäpapua suositellaan lihasikojen alkukasvatusrehuun korkeintaan 200 g/kg, sillä suuremmat määrät voivat huonontaa kasvua. Loppukasvatuksessa härkäpavun käytölle ei ole rajoitteita. Härkäpapu saattaa tummentaa lihan väriä, mutta tämä ilmiö vaatii lisätutkimusta.