

PAPER

Pea (*Pisum sativum*) and faba bean (*Vicia faba* L.) seeds as protein sources in growing-finishing heavy pig diets: effect on growth performance, carcass characteristics and on fresh and seasoned Parma ham quality

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Abstract

The effect of pea and faba bean inclusion in growing-finishing heavy pig diets was evaluated. The following iso-lysine and iso-energetic diets offered to the pigs in three phases (40-80; 80-120; 120-160 kg) were compared: CTR, control diet with soybean meal (SBM) as protein source; RP, CTR diet where pea replaced SBM; RF, CTR diet where faba bean replaced SBM. 126 animals were randomly distributed in 3 homogeneous groups with 42 animals each (7 pens with 6 animals each per treatment). The RP and RF diets did not negatively affect the carcass characteristics both of the pigs slaughtered at the conventional weight (127.5 kg) and heavy pigs (158.5 kg). The pigs fed the RP and RF diets ate similarly to the pigs fed the CTR overall the trial but RF pigs grew better than CTR animals. The subcutaneous fat of the fresh hams destined for Parma ham production and obtained from pigs fed RP diet had a higher omega 3 fatty acid percentage. Moreover, the RP and RF diets resulted in fat with better omega 3/omega 6 ratio compared with CTR. All the fat samples had iodine numbers within the limit value (70) reported by the Production Disciplinary of Parma ham. No treatment effect was found on the analytical and sensorial characteristics of the Parma hams, except for the aged taste which was more intense in the hams obtained from pigs fed the RF diet. These results indicate that pea and faba bean may be used as an alternative to imported SBM.

Introduction

Soybean meal (SBM) is used worldwide as the most important protein source for monogastric animals. It contains a high level of essential amino acids which are easily digestible. Grain legumes are used in smaller quantities as dietary protein sources as supplements of SBM. Nevertheless, there is a great interest in the use of home grown protein sources such as legumes (pea, faba bean, lupin etc.) because of the high market price of SBM totally imported from non-European markets. Moreover, the forbidden use of Genetically Modified Organism (GMO) feed ingredients and solvent-extracted oil seed meals such as SBM and rapeseed meal in organic farming increases interest towards alternative protein sources to SBM (European Commission, 2007). The potential utilization of legumes as sources of protein and energy for pigs is governed by their essential amino acids and digestible energy content, but also by the possible presence of antinutritional factors [such as tannins, lectins, protease inhibitors, non-starch-polysaccharides (NSP) and alkaloids] that can have negative effects on animal growth rate. In diets offered to growing-finishing pigs, field peas may be included from 60% to 70% without negatively affecting pig performance and/or carcass composition (Petersen and Spencer, 2006; Stein *et al.*, 2006). At these inclusion levels, all the SBM could be replaced by field peas. Lower carcass drip losses and a more desirable color of the *longissimus* muscle have been reported for pigs fed diets containing field peas. Likewise, pork palatability has not been influenced by dietary field peas (Stein *et al.*, 2006). No limitation has been reported for faba beans in finishing pig diets (Partenen *et al.*, 2003). There is a scarcity of information concerning the effects of faba bean diets on meat quality.

The aim of this study was to evaluate the effect of pea and faba bean seed inclusion in growing-finishing heavy pig diets on growth performance, carcass characteristics and on fresh and seasoned Parma ham quality.

Materials and methods

Animals, housing and experimental design

Animal care and use practices during this trial conformed to the Directive of the European Council (1986) which regulates the

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welfare of animals used in research and for scientific purposes, and to the regulations of good laboratory practices (European Parliament and Council, 2004a,b).

The study was carried out in the CERZOO facility (S. Bonico, Piacenza, Italy) using D x (LW x L) female and castrated male pigs homogeneously distributed in the treatments. According to the experimental design three different diets were compared. After a pre-experimental period of 12 days, 126 animals (38.6±6.2 kg LW) were randomly distributed in 3 homogeneous groups with 42 animals each (7 pens with 6 animals each per treatment). The animals in each pen were of the same gender. The pens were assigned in a randomized complete block design using the Randomized Procedure of SAS software (1999) release 8.0. According to the CERZOO procedure, during the 12 days of the pre-experimental period the animals were fed medicated feed containing chlortetracycline (1000 mg/kg of active principle) and spiramycin (400 mg/kg of active principle).

Dietary treatments

The following experimental diets were compared: i) CTR group: pigs fed the control diet with SBM as a protein source; ii) RP group: pigs fed the CTR diet where raw pea (*Pisum sativum*) replaced totally SBM as a protein source; iii) RF group: pigs fed the CTR diet where raw faba bean (*Vicia faba* L.) replaced totally SBM as a protein source. Three growing phases were considered during the experimental period on the basis of the pig live weight, as follows: phase 1, from 40 to 80 kg LW; phase 2,

from 80 to 120 kg LW and phase 3, from 120 to 160 kg LW

The diets were formulated to be iso-lysine and iso-energetic, and meet the INRA (1989) requirements for the growth phases 1 and 2. The requirements for the growth phase 3 were satisfied on the basis of the CERZOO typical Italian diets for animals of this live weight verified during a long period of experience in CERZOO. The diets were offered as pelleted feed at 9% of their metabolic weight (live weight^{0.75}) during the global trial period (196 days). Between two subsequent weight controls (every 28 days), the feed offered was adjusted weekly on the basis of a hypothetical gain in the sub-period (week). At the weight control the feed was adjusted on the basis of the true pig live weights.

Animal performance

The pigs were fed their respective diets twice a day, with *ad libitum* access to water provided with an automatic drinker for each pen. During the 196 days of the feeding period, the offered feed was recorded daily as the feed refused, while the body weight were measured every 28 days to calculate the feed intake (FI), the feed conversion ratio (FCR) and the average daily gain (ADG) for each replicate.

Blood parameters

At the end of the growth trial (day 196), blood samples were taken from 21 pigs (7 samples per treatment). Blood samples were taken from the jugular vein, from 6 hour fasted animals following the Vacutainer method with lithium heparin as anti-coagulant. The samples were immediately centrifuged and plasma frozen (-20°C). Plasma samples were analyzed for urea, total protein, alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP) and total bilirubin according to Bertoni *et al.* (1998).

Carcass characteristics

The carcass characteristics were evaluated twice during the trial: i) at 127.5 (± 21.8) kg LW (day 140 from the start of the trial) on 6 pigs per treatment (4 castrated males and 2 females) and ii) at the end of the trial (day 196 from the start of the trial) on all the remaining pigs (158.5 ± 22.6 kg LW). At slaughter, the pigs were electrically stunned, dehaired, eviscerated, and the carcasses weighed. The following determinations were recorded using a Fat-O-Meat'er (FOM) instrumentation: fat thickness of the lumbar (SL, only for the pigs slaughtered at 158.5 kg) and thoracic regions (SR); loin thickness (F); meat reflectance (RW); carcass

lean percentage. On the carcasses of the pigs slaughtered at 158.5 kg the meat pH was also measured at 45' and 24 hours post mortem on fresh and cold hams, respectively.

Subcutaneous fat

Samples of subcutaneous fat were collected from the fresh hams of all pigs slaughtered (both at 127.5 and 158.5 kg) and were analyzed for iodine number and fatty acid composition.

Parma ham quality

After a 24 h chilling period, fresh hams obtained from the pigs slaughtered at 158.5 kg LW were trimmed and cured to produce the typical round-shape of PDO (Protected Designation of Origin) Parma ham according to its production disciplinary, and subsequently allowed to age (Consorzio del Prosciutto di Parma, 2007). The fresh hams were weighed after trimming and during the different phases of seasoning to evaluate weight losses.

Moisture, crude protein, ether extract and proteolysis index were determined on 6 seasoned ham (14 months) samples for each thesis (18 in total). The chemical analyses were carried on minced lean meat from *Biceps femoris* muscle.

A panel of trained 10 members evaluated 1 mm thick slices of the hams for the following attributes: seasoned, fresh meat and cheese

smell of the lean, and aged, salty and bitter taste. The evaluation of the following attributes were also made on the Biceps femoris muscle: colour uniformity and red colour intensity, marbling score, tyrosine crystals, consistency and surface oiliness. The attributes were rated by numeric scales ranging from 0 (devoid of the attribute) to 9 (maximum perception).

Chemical analyses

The protein sources (SBM, pea and faba seeds) and the diets (CTR, RP and RF) were sampled before the beginning of each experimental phase. Samples were analyzed for moisture, ash, crude protein, crude fibre, ether extract and total sugars according to ASPA (1980) and Martillotti *et al.* (1987) methods; for acid detergent fibre (ADF) and neutral detergent fibre (NDF) (Van Soest *et al.*, 1991), and for starch according to the polarimetric method (AOAC, 2000). The digestible and net energy were calculated according to Whittemore (1980) and Noblet *et al.* (1994) equations, respectively. Amino acids were determined using the Carlo Erba model 3A29 amino acid analyser (Carlo Erba Strumentazione, Corsico, Italy) (Moore, 1963; Eggum, 1968; Moore *et al.*, 1980).

The analytical characteristics of the protein sources used in the study are shown in Table 1. Pea and faba bean seeds had a relatively high

Table 1. Analytical characteristics of the protein sources used in the experimental diets.

	Soybean meal	Pea seeds	Faba bean seeds
Chemical composition			
Dry matter, %	88.6	88.0	88.3
Crude protein, %	45.1	19.9	25.9
Ether extract, %	1.3	1.2	1.6
Crude fibre, %	6.2	6.8	7.8
Ash, %	6.1	3.3	3.4
Starch, %	6.0	41.2	32.7
Total sugar, %	9.3	3.8	4.0
Neutral detergent fibre, %	17.9	16.3	27.6
Acid detergent fibre, %	6.7	8.8	11.4
Amino acids			
Aspartic acid, %	4.9	2.7	2.5
Threonine, %	1.8	0.8	0.9
Serine, %	2.5	1.1	1.3
Glutamic Acid, %	8.6	3.5	4.3
Proline, %	2.5	0.9	1.2
Glycine, %	1.9	0.9	1.1
Alanine, %	2.0	0.9	1.1
Valine, %	2.3	0.9	1.2
Methionine, %	0.7	0.2	0.2
Isoleucine, %	2.3	0.9	1.1
Leucine, %	3.5	1.4	1.9
Tyrosine, %	1.7	0.6	0.8
Phenylalanine, %	2.4	1.0	1.1
Histidine, %	1.2	0.4	0.6
Lysine, %	2.8	1.4	1.6
Arginine, %	3.5	1.4	2.3
Tryptophan, %	0.6	0.2	0.2
Cystine, %	0.7	0.3	0.3

crude protein content (19.9 and 25.9% on an as-fed basis, respectively). The analytical compositions of SBM, pea and faba bean seeds were similar to those reported in literature (NRC, 1998).

The ingredients and chemical composition of the basal and experimental diets for each growth period are reported in Table 2. The diets were similar regarding the nutrient supply. The nutrient requirements for each growth period were satisfied through the formulated diets.

The linoleic acid contents of the diets and the fatty acid composition of hams' subcutaneous fat were determined by Gas Chromatography. In particular, the lipid extraction from the samples of diets and subcutaneous fat previously ground (30 and 10 g, respectively) was carried out using a modified Folch's technique (Christie, 1989; Prandini *et al.* 2007). The lipids were then esterified using the method described by Bannon *et al.* (1985) with

modifications (Prandini *et al.* 2007). Fatty acid methyl esters were quantified using a Varian 3350 gas chromatograph (GC) (Varian Assoc., Inc., Sunnyvale, CA, USA) equipped with a Varian CP-8200 automatic sampler (Varian Assoc., Inc.), a split injector, a flame ionization detector (FID) and a CP-Select CB capillary column for FAME (100 m x 0.25 mm i.d.; 0.25 µm film thickness; Chrompack, Varian, Inc., CA, USA). The injection volume was 1 µL. The carrier gas was high-purity helium with a head pressure of 38 psi and flow rate of 1.3 mL/min. The injector and detector temperatures were kept at 250°C. The column oven temperature was programmed at 170°C for 33 min, from 170 to 240°C at 4°C/min for 14.5 min. Peak identification was possible with the aid of external standards (Oil Reference Standard, AOCS n° 6, Supelco, Inc., Bellefonte, PA, USA; FAME MIX C 20:1-C 20:5, Supelco). The fatty acids were expressed as percentage of the total fatty acids, calculated with peak areas corrected by instru-

mental response factors. The iodine number was measured in the samples of subcutaneous fat according to the AOAC method (1990).

Moisture content in Parma ham was measured according to the ISO method 1442 (2010). Crude protein was determined by the Kjeldhal method (AOAC, 2000) using a conversion coefficient of 6.25 to convert nitrogen (g) in protein. The total fat, after acid hydrolysis, was extracted by Soxhlet extraction using diethyl ether according to the ISO method 1443 (1991). The proteolysis index (percent ratio between nitrogen soluble in 5% trichloroacetic acid, determined by the Kjeldhal method after protein precipitation with trichloroacetic acid, and total nitrogen) was measured according to the method described by Careri *et al.* (1993).

Statistical analysis

All the data were statistically processed to determine the differences between protein sources. Statistical analysis was performed

Table 2. Ingredients and chemical composition of the CTR, RP and RF diets used in D x (LW x L) female and castrated pigs in the three experimental phases (40-80, 80-120 and 120-160 kg LW).

	CTR			RP			RF		
	40-80	80-120	120-160	40-80	80-120	120-160	40-80	80-120	120-160
Ingredients, %									
Corn	38.65	40.31	37.96	25.05	26.56	44.91	25.02	32.72	25.30
Barley	15.00	15.00	15.00	5.00	20.00	5.93	5.00	13.60	20.00
Soybean meal 44% CP	15.94	12.90	8.05						
Pea				33.08	24.32	20.00			
Faba bean							30.56	24.00	20.00
Wheat bran	5.57	7.30	15.00			15.00	4.00		15.00
Wheat milling	20.00	20.00	20.00	32.70	25.00	10.00	30.00	25.00	15.00
Coconut oil	1.54	1.48	0.78	1.53	1.45	0.88	2.53	1.82	2.05
Calcium carbonate	1.94	1.89	1.92	1.34	1.24	2.01	1.39	1.22	1.63
Bicalcium phosphate	0.36	0.35	0.30	0.62	0.80	0.40	0.55	0.84	0.17
Sodium chloride	0.46	0.41	0.41	0.40	0.40	0.45	0.40	0.40	0.40
Lysine HCl 50%	0.29	0.21	0.20	0.02	0.08	0.07	0.27	0.25	0.15
DL Methionine				0.01			0.03		
L Tryptophan							0.002		
Premix ^o	0.25	0.15	0.15	0.25	0.15	0.15	0.25	0.15	0.15
Chemical composition									
Dry matter, %	88.94	88.92	91.75	88.36	88.79	91.31	87.94	89.19	90.92
Crude protein, %	16.04	15.13	14.10	15.78	14.80	13.80	15.90	14.90	13.70
Ether extract, %	4.64	4.68	4.51	3.97	4.63	4.73	4.87	4.63	4.83
Crude fibre, %	3.50	4.21	4.82	3.54	4.48	4.53	3.89	4.48	4.73
Ash, %	5.24	5.21	5.76	4.46	4.83	5.06	4.22	4.83	4.79
Starch, %	44.20	46.31	44.30	48.21	46.40	43.90	45.50	47.85	44.56
Linoleic acid, %	1.55	1.59	1.65	1.47	1.40	1.51	1.53	1.52	1.43
Lysine, %	0.81	0.71	0.60	0.82	0.72	0.59	0.80	0.70	0.61
Threonine, %	0.52	0.50	0.49	0.57	0.48	0.54	0.56	0.52	0.52
Methionine+Cystine, %	0.52	0.51	0.49	0.50	0.45	0.46	0.50	0.45	0.45
Tryptophan, %	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14
Digestible energy [§] , Kcal/kg	3422	3354	3363	3371	3322	3381	3313	3298	3350
Net energy [§] , Kcal/kg	2559	2561	2608	2548	2571	2601	2506	2549	2578

CTR, control diet with soybean meal as protein source; RP, CTR diet where raw pea (*Pisum sativum*) totally substituted soybean meal; RF, CTR diet where raw faba bean (*Vicia faba L.*) totally substituted soybean meal; ^oPremix composition for kg of feed: vit. A 15,500 U; vit. D₃ 1800 U; vit. E acetate 35 mg; Cu 145 mg; Se 0.18 mg; flavofosfolipol 21 mg; [§]digestible energy calculated according to Whittemore (1980) equation; [§]net energy calculated according to Noblet *et al.* (1994) equation.

according to the General Linear Model (GLM) procedure of SAS software package (1999), release 8.0, with protein sources as independent variables in an analysis of variance within a randomized complete block design, between random error as the error term. The treatment means were compared using Student's t-test. The data related to the growth performance were covariates by animal live weight at the start of the study, whereas those related to the carcass characteristics were covariates by carcass weight at slaughter. Statements of statistical significance were based upon $P < 0.05$.

Results and discussion

Animal performance and carcass characteristics

The growth performance and carcass characteristics of the pigs slaughtered at 127.5 (day

140) and 158.5 kg LW (day 196) are shown in Table 3.

No effect of interaction between dietary treatment and animal sex was observed on the growth performance and carcass characteristics of all the pigs used in the study (*data not shown*). The dietary treatment affected the live weight of the pigs after 140 days of trial and ADG both after 140 days of trial and at end trial (day 196). In particular, the pigs receiving the RF diet had a higher ADG ($P < 0.05$) than those receiving the CTR and RP diets in the 0-140 d period and than those fed the CTR diet in the 0-196 d period. The pigs fed the control and experimental diets had similar FI and FCR during the period 0-140 d and overall the trial (0-196 d period). The amount of feed really ingested overall the trial was lower than that theoretical [9% of the animal metabolic weight (live weight^{0.75})] for all the dietary treatments. This derived from the fact that the feed was not distributed on Sunday afternoons and a minor

amount of feed was offered to the animals when there was residual feed of the previous day in the manger. No treatment effect was observed on the carcass characteristics of the pigs slaughtered at 127.5 kg LW. Whereas, effects due to the dietary treatment were found on the carcass characteristics of the pigs slaughtered at 158.5 kg LW and in particular, on carcass weight and FOM parameter. The RF diet resulted in animals with a higher carcass average weight at the slaughterhouse followed by the RP (without statistically significant difference) and CTR (with statistically significant difference, $P < 0.05$) diets. The RF diet reported also a higher F value than the CTR diet with a statistically significant difference ($P < 0.05$).

The results show that the replacement of soybean meal with pea or faba bean (and other ingredients) does not negatively affect growth performance both of the pigs slaughtered at 127.5 kg and at 158.5 kg. Indeed, the pigs fed

Table 3. Growth performance of slaughtered after 140 and 196 days of trial fed three different diets (data covariates by live weight at the start of the study) and carcass characteristics of the pigs slaughtered at 127.5 (± 21.8) and 158.5 (± 22.6) kg LW (data covariates by carcass weight at the slaughtering).

	CTR	Diet RP	RF	SE	Treatment effect, P value
Live weight, kg					
140 d	120.6 ^a	126.1 ^{ab}	135.7 ^b	3.58	0.02
196 d	152.9	157.4	165.6	3.91	0.09
Average daily gain, g					
0-140 d	586.3 ^a	624.4 ^a	693.9 ^b	20.18	0.002
0-196 d	583.7 ^a	606.6 ^{ab}	648.0 ^b	16.49	0.03
Feed intake, kg/head/day					
0-140 d	2.0	2.0	2.1	0.08	0.55
0-196 d	2.2	2.2	2.3	0.08	0.63
Feed conversion ratio					
0-140 d	3.4	3.3	3.1	0.08	0.07
0-196 d	3.7	3.7	3.6	0.07	0.26
Carcass traits at 127.5 kg LW					
Carcass weight [‡] , kg	95.3	93.4	93.0	2.07	0.60
FOM parameters					
SR, mm	17.0	17.5	17.3	1.25	0.93
F, mm	57.0	55.4	54.0	1.65	0.53
RW	33.9	34.1	34.2	0.77	0.98
Carcass lean, %	54.0	53.6	53.7	1.01	0.92
Carcass traits at 158.5 kg LW					
Carcass weight [‡] , kg	132.6 ^a	138.2 ^{ab}	143.3 ^b	2.53	0.01
FOM parameters					
SL, mm	26.3	27.2	29.4	1.04	0.11
SR, mm	24.9	24.2	25.3	0.97	0.69
F, mm	57.0 ^a	59.6 ^{ab}	63.0 ^b	1.41	0.01
RW	33.9	31.6	32.4	1.09	0.32
Carcass lean, %	51.6	52.1	51.6	0.64	0.73
pH 45 min [^]	6.7	6.8	6.7	0.03	0.30
pH 24 h [§]	5.6	5.6	5.7	0.01	0.27

CTR, control diet with soybean meal as protein source; RP, CTR diet where raw pea (*Pisum sativum*) totally substituted soybean meal; RF, CTR diet where raw faba bean (*Vicia faba* L.) totally substituted soybean meal; SE, treatment standard error; [‡]last day of the growth trial; [§]weight of the cold carcass measured according to the Decision of the European Commission (2001); FOM, Fat-O-Meat[®] parameters; SR, fat thickness of the thoracic region; SL, fat thickness of the lumbar region; F, loin thickness; RW, mean reflectance of the meat; [^]pH at 45 min *post-mortem* measured on fresh hams; [§]pH at 24 h *post-mortem* measured on cold hams. ^{ab}Different letters on the same row correspond to statistically significant differences ($P < 0.05$).

the RP and RF diets ate similarly to the pigs fed the CTR overall the trial but RF pigs grew better than CTR animals. Recently, Stein *et al.* (2004) and Prandini *et al.* (2005) have shown that field peas may be included from 15 to 20% in diets offered to nursery pigs. At these concentrations, no negative effect on pig performance has been recorded. Other studies have demonstrated that faba beans can be used up to an inclusion level of 20% in diets for growing pigs. Higher levels may reduce growth performance (Aherne *et al.*, 1977; O'Doherty and McKeon, 2001; Partanen *et al.*, 2003). Our results related to the carcass characteristics show that the pea and faba bean inclusion in diets for growing-finishing pigs does not negatively affect the carcass composition of pigs up to 127.5 kg LW. These results are in agreement with recently published data indicating that no difference in pig performance and carcass composition is obtained if growing-finishing pigs are fed corn (and/or other ingredients)-based-diets containing pea or faba bean and no soybean meal (Partanen *et al.*, 2003; Petersen and Spencer, 2006; Stein *et al.*, 2006).

Even though none of the experimental diets affected the carcass characteristics of the pigs slaughtered at the conventional live weight of 127.5 kg, differences associated to the type of dietary treatment were observed on the carcass characteristics of the heavy pigs slaughtered at 158.5 kg LW. Indeed, the carcasses of the pigs fed the RF diet had better characteristics than those of the pigs receiving the CTR

diet, showing a higher weight and loin thickness (F), and similar levels of fat. The RP diet resulted in carcasses with characteristics similar to those obtained by all the other dietary treatments.

Blood parameters

The data obtained by the analyses of the blood samples did not indicate any significant effect of dietary treatment and interaction between dietary treatment and animal sex (*data not shown*).

Subcutaneous fat

Fatty acid composition and iodine number of fresh ham's subcutaneous fat obtained from pigs slaughtered at 127.5 and 158.5 kg LW are reported in Table 4.

No effect of interaction between dietary treatment and animal sex was observed on the fatty acid composition and iodine number of the subcutaneous fat of all the fresh hams analysed (*data not shown*). Dietary treatment affected linoleic acid level, omega 6 fatty acid percentage, omega 3/omega 6 ratio, and MUFA (monounsaturated fatty acids) and PUFA (polyunsaturated fatty acids) levels in subcutaneous fat of pigs slaughtered at 127.5 kg LW. The CTR diet resulted in higher linoleic acid and omega 6 fatty acid percentages with statistically significant differences ($P<0.05$) compared with the RP diet. The RP diet gave subcutaneous fat with the highest omega 3/omega

6 ratio and MUFA level, and the lowest PUFA percentage with statistically significant differences ($P<0.05$) versus the other dietary treatments.

The subcutaneous fat obtained from pigs slaughtered at 158.5 kg LW was affected by dietary treatment for omega 3 fatty acid percentage and omega 3/omega 6 ratio. The RP diet resulted in the highest omega 3 fatty acid level and omega 3/omega 6 ratio (with $P<0.05$ versus CTR and RF diet). The CTR diet resulted in the lowest omega 3/omega 6 ratio with statistically significant differences ($P<0.05$) compared with the other two dietary treatments.

The results show that the subcutaneous fat of fresh ham, obtained from pigs of 127.5 kg LW fed a diet containing pea, has a better fatty acid composition. Indeed, it was characterized by a higher omega 3/omega 6 ratio. Clinical studies indicate that the ingested ratio of omega 3 to omega 6 fatty acids is important for maintaining cardiovascular health (Okuyama, 2001; Griffin, 2008). Both omega 3 and omega 6 fatty acids are essential, so humans must include them in their diet. Omega 3 and 6 fatty acids compete for the same metabolic enzymes. The metabolites of omega 6 fatty acids are more inflammatory (e. g. arachidonic acid) than those of omega 3. This necessitates that omega 3 and omega 6 are consumed in a balanced proportion; healthy ratios of omega 3/omega 6 range from 1/1 to 1/4. A high omega 3/omega 6 fatty acid ratio is more desirable for

Table 4. Fatty acid composition and iodine number of fresh ham's subcutaneous fat obtained from pigs slaughtered at 127.5 ($\pm$ 21.8) and 158.5 ($\pm$ 22.6) kg LW fed three different diets (the data for fatty acid classes were expressed as % of the total fatty acids).

	CTR	Diet RP	RF	SE	Treatment effect, P value
Fatty acid composition at 127.5 kg LW					
Linoleic acid, %	15.95 ^b	13.18 ^a	14.58 ^{ab}	0.54	0.01
Omega 3, %	1.04	1.17	1.10	0.03	0.07
Omega 6, %	16.77 ^b	13.9 ^a	15.30 ^{ab}	0.58	0.01
Omega 3/Omega 6	0.060 ^a	0.084 ^b	0.072 ^a	0.001	<0.0001
SFA, %	45.36	45.01	46.18	0.68	0.48
MUFA, %	35.83 ^a	38.92 ^b	36.42 ^a	0.61	0.01
PUFA, %	17.81 ^b	15.08 ^a	16.40 ^b	0.61	0.02
Iodine number	62.86	61.32	60.64	1.19	0.36
Fatty acid composition at 158.5 kg LW					
Linoleic acid, %	14.83	13.50	13.54	0.62	0.09
Omega 3, %	0.99 ^a	1.20 ^b	1.10 ^a	0.03	0.01
Omega 6, %	17.13	15.65	15.70	0.65	0.07
Omega 3/Omega 6	0.058 ^a	0.077 ^c	0.070 ^b	0.001	<0.0001
SFA, %	41.15	42.28	41.49	0.45	0.17
MUFA, %	41.17	41.30	42.17	0.59	0.34
PUFA, %	18.12	16.85	16.80	0.66	0.11
Iodine number	63.86	63.03	62.81	1.07	0.54

CTR, control diet with soybean meal as protein source; RP, CTR diet where raw pea (*Pisum sativum*) totally substituted soybean meal; RF, CTR diet where raw faba bean (*Vicia faba* L.) totally substituted soybean meal; SE, treatment standard error; SFA, saturated fatty acids (C 10:0+C 12:0+C 14:0+C 15:0+C 16:0+C 17:0+C 18:0); MUFA, monounsaturated fatty acids (C 14:1+C 16:1+C 17:1+C 18:1+C 20:1); PUFA, polyunsaturated fatty acids (C 18:2ω6+C 18:3ω3+C 20:2ω6+C 20:3ω3+C 20:3ω6+C 20:4ω6); ^{a,b,c}Different letters on the same row correspond to statistically significant differences ($P<0.05$).

reducing the risk of many of the chronic diseases of high prevalence in developing countries (Simopoulos, 2008). Moreover, the subcutaneous fat of fresh ham, obtained from pigs of 127.5 kg LW fed the diet containing pea, had a lower PUFA level compared to the subcutaneous fat of fresh ham obtained from pigs fed the other two diets, and, at equal contents of SFA, a higher MUFA content. A lower PUFA level preserves the fat from lipid oxidation avoiding the formation of undesirable compounds which depreciate the product.

The results related to the fatty acid composition of the subcutaneous fat of fresh ham obtained from pigs slaughtered at 158.5 kg LW, show that the RP diet resulted in fat with a better fatty acid composition due to a higher omega 3 fatty acid content. Moreover, subcutaneous fat derived from pigs fed the diets containing pea or faba bean had a better omega 3/omega 6 ratio. The iodine number gives a measure of the unsaturation level of the lipids. A fat with a lower iodine number is less

exposed to lipid oxidation resulting more compact and white. A fat with these characteristics is more appreciated by consumers (Toscani *et al.*, 2003). All the samples of subcutaneous fat had an iodine number within the limit value of 70 reported by the Production Disciplinary of Parma ham (Consorzio del Prosciutto di Parma, 2007). Also, the linoleic acid percentage affects fat consistency and must not exceed 15% according to the Production Disciplinary of Parma ham (Consorzio del Prosciutto di Parma, 2007). In our study, subcutaneous fat obtained from pigs fed the three diets had linoleic acid levels within the limit value mentioned above.

Parma ham quality

Table 5 shows the ham weight losses during seasoning (data refer to fresh ham on arrival at the seasoning) and, the chemical analysis and panel test of the seasoned ham.

No effect of interaction between dietary treatment and animal sex was observed on the

weight losses, chemical analysis and panel test of the hams (*data not shown*). Statistically significant differences ($P<0.05$) were found between dietary treatments starting from the first salting phase where the RP and RF diets reported lower weight losses than the CTR diet. These significant differences were also detected in the subsequent phases (after salting, before and after toeletting, and drying) and disappeared at greasing and seasoning at 12 and 14 months.

No treatment effect was found on the analytical and sensorial characteristics the seasoned hams, except for the aged taste which was more intense in the ham obtained from pigs fed the RF diet (with $P<0.05$ *vs* CTR and RP diets). Treatment effects tending to significance were detected on the seasoned smell ($P=0.05$) and bitter taste ($P=0.07$) with a more intense perception of the first attribute and a less intense perception of the second in the ham obtained from pigs fed the RF diet.

Our results do not show any differences in

Table 5. Ham weight losses during seasoning (data referred to fresh ham at seasoning factory arrival). Chemical analysis and panel test of the seasoned ham.

	CTR	Diet RP	RF	SE	Treatment effect, P value
Trimmed ham weight, kg	14.5	14.9	15.2	0.13	0.40
Ham weight losses					
First salting, %	3.2 ^b	2.3 ^a	2.2 ^a	0.23	0.005
After salting, %	6.8 ^b	5.8 ^a	5.6 ^a	0.26	0.003
Before toeletting, %	16.6 ^b	15.2 ^a	15.1 ^a	0.36	0.005
After toeletting, %	17.4 ^b	16.1 ^a	16.0 ^a	0.37	0.01
Drying, %	22.3 ^b	21.2 ^a	20.9 ^a	0.37	0.03
Greasing, %	29.4	28.5	28.0	0.45	0.11
Seasoning at 12 months, %	34.5	33.7	33.3	0.51	0.24
Seasoning at 14 months, %	35.6	34.9	34.4	0.53	0.25
Chemical analysis of the <i>Biceps femoris</i>					
Moisture, %	51.9	51.2	51.5	0.54	0.66
Crude protein, %	30.9	30.6	30.0	0.77	0.51
Ether extract ^o , %	9.3	10.0	11.4	1.15	0.46
Proteolysis index	25.9	25.3	26.7	1.96	0.88
Panel test [‡]					
Evaluation of the <i>Biceps femoris</i>					
Uniformity of lean color	5.6	5.7	5.9	0.29	0.76
Intensity of lean red color	6.4	6.1	6.3	0.22	0.77
Marbling score	4.4	4.6	4.2	0.43	0.87
Tyrosine crystals	2.4	2.2	0.6	0.72	0.17
Consistency	5.0	4.6	5.5	0.37	0.27
Surface oiliness	2.1	2.0	2.2	0.21	0.80
Evaluation of the slice					
Seasoned smell	5.8	5.8	6.1	0.10	0.05
Fresh meat smell	1.3	1.6	1.3	0.21	0.62
Cheese smell	1.4	1.9	1.6	0.17	0.26
Aged taste	5.6 ^a	5.5 ^a	6.1 ^b	0.16	0.03
Salty taste	5.2	5.2	5.3	0.17	0.91
Bitter taste	2.6	2.8	1.6	0.37	0.07

CTR, control diet with soybean meal as protein source; RP, CTR diet where raw pea (*Pisum sativum*) totally substituted soybean meal; RF, CTR diet where raw faba bean (*Vicia faba L.*) totally substituted soybean meal; SE, treatment standard error; ^oether extract of the lean; [‡]panel test carried out according to the attribute technique; the organoleptic characteristics were evaluated from 0 to 9: a more intense perception of the attribute correspond to a higher value. ^{ab}Different letters on the same row correspond to statistically significant differences ($P<0.05$).

the chemical characteristics of the seasoned hams obtained from pigs fed the control and experimental diets. The chemical compositions of all the seasoned hams were within the limit values set by the Production Disciplinary of Parma ham except for moisture contents which were lower in all the analyzed ham samples (Consorzio del Prosciutto di Parma, 2007).

Conclusions

In conclusion, considering our results, pea (*Pisum sativum*) and faba bean (*Vicia faba* L.) seeds represent valuable alternative protein sources to SBM in pig diets. These feedstuffs may be used up to 20-30% in growing-finishing heavy pig diets without negative effects on the growth performance, carcass characteristics and quality of fresh and seasoned Parma ham. At these inclusion levels, all the SBM is replaced with pea or faba bean.

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