Italian Journal of Animal Science

ISSN: (Print) 1828-051X (Online) Journal homepage: https://www.tandfonline.com/loi/tjas20

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To cite this article: Alessandro Dal Bosco, Silvia Ruggeri, Simona Mattioli, Cecilia Mugnai, Federico Sirri & Cesare Castellini (2013) Effect of Faba Bean *Vicia Faba* Var. *Minor*) Inclusion in Starter and Growing Diet on Performance, Carcass and Meat Characteristics of Organic Slow-Growing Chickens, Italian Journal of Animal Science, 12:4, e76, DOI: 10.4081/ijas.2013.e76

To link to this article: https://doi.org/10.4081/ijas.2013.e76

Published online: 18 Feb 2016.

PAPER

Effect of faba bean (*Vicia faba* var. *minor*) inclusion in starter and growing diet on performance, carcass and meat characteristics of organic slow-growing chickens

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Abstract

This paper assesses the effect of faba bean (*Vicia Faba minor*), in partial substitution of soybean, on productive performance, carcass and meat traits of slow-growing chickens reaed under the organic method. Faba bean was used in both starter (1-21 d) and growing/finisher diets (22-120 d). One thousand birds were fed two different diets containing respectively, soybean or faba bean as the main protein source for the entire rearing period. The birds of each group were slaughtered at 120 d of age. The productive performance of group F was the worst, with a higher mortality rate, indicating that faba bean diets are not able to cover the nutritional requirements of birds mainly in the first rearing period. The main carcass and meat qualitative traits, were not affected by the treatment, whereas minor modification regards saturated and monounsaturated fatty acids.

Introduction

The organic livestock system is ruled by EU-Regulation 1804/1999, which provides specifications for housing conditions, breeding and animal care, disease prevention, veterinary treatment and feed. Organic diets should be formulated with the organic ingredients without synthetic forms of amino acids and GMO ingredients; thus, it is crucial to formulate feed with lower quantity of soybean, which has a high risk of GMO contamination (Hanson *et al.*, 2004), and use genotypes having lower protein and amino acids requirements (Leclercq *et al*., 1993; Pesti *et al.*, 1994; Rosa *et al*., 2001). Slow-growing birds meet such request and are recommended for the better adaptation to the outdoor environment and to a longer rearing period (Castellini *et al.*, 2002; Fanatico *et al*., 2005). In Mediterranean countries the most interesting legume alternative to soybean is the faba bean (*Vicia Faba* var. *minor*) that can grow easily in dry areas and is, to some extent, organically cultivated (Sodi, 2009). Faba bean has a quite high level of protein (about 26%) and starch (about 30%) but the presence of anti-nutritional constituents, such as vicine and convicine, and the low sulphur amino acid content reduce its nutritional value in poultry feed (Rubio *et al.*, 1990). Heat treatment can improve the nutritional quality of this raw material by removing or destroying some anti-nutritive factors, responsible for the reduced chick weight, feed efficiency and retention of dry matter, protein and crude fibre (Diaz *et al*., 2006; Ward *et al*., 1977). However, vicine, convicine and tannins are heat-stable constituents located respectively in the cotyledons and hulls and cannot be easily removed by technological processes. The results on the use of fava beans in poultry diet, as an alternative protein source in place of soybean meal, have been contradictory (Crepon, 2006). Some studies resulting in adverse effects on performance, and others resulting in growth performance similar to control diets at various inclusion level (Farell *et al.*, 1999; Ravindran, 2002; Nalle *et al*., 2010). In our previous study (Perella *et al.*, 2009) we demonstrated the effectiveness of the faba bean inclusion (without synthetic amino acids) in slow-growing birds, only if administered after a starter period. On the basis of these considerations, the present study verified the partial substitution of soybean with faba bean in both starter and growing diets on the productive performance, carcass characteristics and meat quality of slow-growing chickens reared under organic system.

Materials and methods

Animals, diets and experimental design

The experiment was carried out at the Agricultural farm of the University of Perugia during Spring 2012. All the animals were reared according to EU Regulation 1804/99 (European Commission, 1999) and to Italian directives on animal welfare for experimental and other scientific purposes (Italian Regulation, 1992).

One thousand one day-old slow-growing chicks (Gaina, Avicola Berlanda, Padova, Italy) were divided into 2 experimental groups (4 replicates each of 125 birds/group). One group was fed starter (S1, 1-20 days) and growing (S2, 21-120 days) soybean-based diets; the other group fed starter (F1, 1-20 days) and growing/finisher diets (F2, 21-120 days) with the partial substitution of soybean with extruded faba bean. Diets were formulated according to NRC (1994) recommendations for slow-growing chickens (Table 1). Feed and water were provided *ad libitum*. All birds were kept from hatching to 20 days of age in an environmentally controlled poultry house with temperature and relative humidity ranging from 22 to 30 °C and from 65 to 70% respectively. At 21 days of age they were transferred to a straw bedded poultry house (0.10 m^2/bird), equipped with feeders and drinkers and with free access to open air runs (4 m^2/bird). The chicks were vaccinated against Marek and New Castle disease and coccidiosis (Paracox®).

Individual body weights (20% of the animals in each group) were recorded every 20 days and daily weight gain (DWG) and feed efficiency (FE) were calculated accordingly. Bird mortality was recorded daily.

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Key words: Faba bean, Slow-growing chicks, Organic system, Performance, Quality.

Acknowledgments: this study was supported by the Efficiency, Quality and Innovation in Organic Livestock (E.QU.I.ZOO.BIO) project.

Received for publication: 31 May 2013.
Revision received: 5 July 2013.
Accepted for publication: 13 July 2013.

Italian Journal of Animal Science 2013; 12:e76
doi:10.4081/ijas.2013.e76

Analytical determinations of diets

The analyses of the chemical composition of diets were carried out according to the AOAC methods (1995) and the metabolizable energy was estimated according to the method described by Carrè and Rozo (1990).

The extraction and purification of vicine and convicine of diets were carried out by the HPLC reference method according to Quemener (1988). Faba bean were ground in an IkA-Universal M20 mill for 3 min to a particle size of less than 0.5 mm. A 500 mg quantity of sample was weighed in a centrifuge tube and 15 mL of aqueous uridine solution (0.4 mg mL^{-1}) was added. The tube contents were homogenized for 2 min with a Polytron homogenizer equipped with 10S Model axis and centrifuged at 25,000 g for 5 min. Portions of 10 mL of supernatant were transferred to another centrifuge tube and 60 µL of 1 N HCl was added in order to precipitate most of the proteins at their isoelectric pH (pH_i~4.2). The mixture was shaken and centrifuged at 2500 g for 5 min. An aliquot of supernatant (100 µL) was diluted six times with ultrapure water and maintained at 4°C until glucoside HPLC analysis. The HPLC system consisted of an HP series 1100, Rheodyne Loot injector, Supelcosil LC PAH (15 cm x 4.6 mm) Column, UV detector and the wavelength was adjusted to 273 nm. Ultrapure water was eluted at flow rate of 1 mL min^{-1}.

The tocopherol level was measured on 1 g of homogenised sample, in 5 mL of distilled water and 4 mL of ethanol. After mixing the mixture of hexane containing BHT (200 mg/L) was added, the supernatant was evaporated, and then redissolved in 300 µL of acetonitrile. The quantitative determination of carotenoids was analysed in HPLC (Jasco, pump model PU-1580, equipped with an autosampler sistem, model AS 950-10, Tokyo, Japan) on a Ultrasphere ODS column (250 x 4.6 mm internal diameter, 5 µm particles size; CPS analitica, Milano, Italy). The solvent system consisted of a solution A (methanol/water/acetonitrile 10/20/70) and solution B (methanol/ethyl-acetate 70/30). The flow was 1 mL/min and the elution program was a gradient starting from 90% A in a 20-min step to 100% B and then a second isocratic step of 10 min. The detector was an UV-VIS spectrophotometer (Jasco UV2075 Plus) set at 325 nm and 450 nm for retinol and lutein/zeaxantin/beta-carotene respectively. The different carotenoids were identified and quantified by comparing the sample with pure commercial standards (Sigma-Aldrich, Steinheim, Germany; Extrasynthese, Genay, France).

Carcass dissection and characteristics

At 120 days of age, a representative sample of 10 birds per diet (with a weight ranging between ±10% of the mean weight of the overall birds), were slaughtered in the processing plant of the Agricultural Farm of the University of Perugia, 12 h after feed withdrawal. Chickens were stunned by electrocution (110 V; 350 Hz) before killing. After killing, the carcasses were immersed in the scalder (56.5°C

Table 1. Composition, analyzed contents of nutrients (% DM except dry matter), energetic value (MJ/kg), and contents of vicine and convicine (%) in starter and finisher diets.

	Starter		Growing	
	S1	F1	S2	F2
Maize, %	53.0	47.0	49.0	44.0
Wheat, %	-	-	14.0	10.0
Extruded soybean flakes, %	29.0	20.0	24.0	12.5
Extruded faba bean, %	-	16.0	-	16.0
Gluten feed, %	14.5	14.0	9.5	13.5
Soybean oil, %		0.5		0.5
Salt, %	0.3	0.2	0.2	0.2
Calcium phosphate, %	1.10	1.10	1.10	1.10
Calcium carbonate, %	1.60	1.60	1.60	1.60
Minerals and vitamins°, %	0.6	0.6	0.6	0.6
Chemical composition				
Dry matter, %	88.33	88.50	88.00	88.07
Crude protein, % DM	18.97	18.46	16.25	16.03
Ether extract, % DM	8.06	6.75	6.65	5.39
Crude fibre, % DM	4.64	4.99	4.20	4.62
Ash, % DM	6.58	6.06	5.65	5.35
Metabolizable energy#, MJ/kg	12.78	12.83	12.66	12.50
Lysine, %	1.05	1.03	0.87	0.87
Methionine + cysteine, %	0.66	0.59	0.59	0.53
Threonine, %	0.74	0.60	0.62	0.50
Thryptophan, %	0.22	0.16	0.19	0.15
Lutein, mg/100g	0.90	1.02	0.95	1.09
Zeaxanthin, mg/100g	0.33	0.40	0.20	0.35
β-carotene, mg/100g	0.07	0.06	0.08	0.05
α-tocopherol, mg/100g	3.19	2.95	3.96	3.60
γ- tocopherol, mg/100g	9.95	12.70	10.07	14.10
δ- tocopherol, mg/100g	2.39	2.76	2.15	3.04
Vicine, mg/100g	nd	0.20	nd	0.17
Convicine, mg/100g	nd	0.08	nd	0.10

°Amounts per kg: Vit. A, 11.000 U; Vit. D_3, 2000 U; Vit. B_1, 2.5 mg; Vit. B_2, 4 mg; Vit. B_6, 1.25 mg; Vit. B_{12}, 0.01 mg; natural tocopherol, 30 mg; biotin, 0.06 mg; Vit. K, 2.5 mg; niacin, 15 mg; folic acid, 0.30 mg; panthotenic acid, 10 mg; choline chloride, 600 mg; Mn, 60 mg; Fe, 50 mg; Zn, 15 mg; I, 0.5 mg; C,o 0.5 mg. #Estimated according to Carrè and Rozo (1990); nd, not determined.

for 1 min), plucked, eviscerated (non-edible viscera: intestines, proventriculus, gall bladder, spleen, esophagus and full crop) and stored for 24 h at 4°C. The carcass weight losses occurring during refrigeration were calculated as difference of weight before and after refrigeration. Full and empty gastrointestinal tract were also individually weighed and the weight of the *ingesta* was calculated by the difference.

The head, neck, legs, edible viscera (heart, liver, gizzard) and fat (perivisceral, perineal and abdominal) were removed and weighed; the ready-to-cook carcasses (RCC) were then weighed. Biometric measurements were carried out following the standard procedure (Romboli *et al*., 1996). The breasts and drumsticks were also removed from the carcasses and weighed, and their yields were calculated as a percentage of the RCC.

Meat quality

Analyses were immediately carried out in duplicate to determine the proximate composition. Moisture, ash and total nitrogen were obtained using AOAC (1995) methods (N. 950.46B, 920.153, and 928.08, respectively). The total protein content was calculated using Kjeldahl nitrogen and a conversion factor of 6.25. The total lipids content was extracted from 5 g of each homogenized sample and calculated gravimetrically (Folch *et al.*, 1957). The ultimate pH (pH_u) was measured 24 h after killing on refrigerated carcasses with a Knick digital pHmeter (Broadly Corp., Santa Ana, CA, USA). The colour parameters were measured using a tristimulus analyser (Minolta Chroma Meter CR-200, Azuchi-Machi Higashi-Ku, Osaka 541, Japan), with the CIELAB Colour System (Commission Internationale de L'Eclairage, 1976). Shear force was evaluated on cores (1.25 cm Ø 2 cm length) obtained from the mid-portions of roasted samples by cutting them perpendicularly to the direction of fiber, using an Instron, model 1011, equipped with a Warner-Blatzler Meat Shear apparatus. The cooking loss was measured on samples of about 20 g placed in open aluminum pans and cooked in an electric oven (pre-heated to 200°C) for 15 min to an internal temperature of 80°C. The cooking loss was estimated as percentage of the weight of the cooked samples (cooled for 30 min to about 15°C and dried on the surface with a paper towel), with respect to the weight of the raw samples. The fatty acid composition was determined on lipids extracted from muscle samples. Total lipids were extracted in duplicate from 5 g of each homogenized sample and calculated gravimetrically (Folch *et al.,* 1957). Fatty acids were quantified as methyl esters (FAME) with a Mega 2 Carlo Erba gas chromatograph (model HRGC, Milano, Italy), using a D-B wax capillary column (0.25 mm Ø, 30 m long). The FAME peaks were identified by comparing the retention time with the commercially available FAME standards. The fatty acid compositions were calculated using the peak areas and expressed on percentage basis. The average amount of each fatty acid was used to calculate the sum of the total saturated (SFA), total monounsaturated (MUFA), and total polyunsaturated (PUFA) fatty acids. The α-Tocopherol level of meat was assessed according to Hewavitharana *et al*. (2004) with HPLC method (Jasco, pump model PU-1580, equipped with an autosampler sistem, model AS 950-10, Tokyo, Japan) on a Ultrasphere ODS column (250 x 4.6 mm internal diameter, 5 µm particles size; CPS analitica, Milano, Italy). Tocopherols were identify using a FD detector (model Jasco, FP- 1520) set at excitation and emission wavelength of 295 nm and 328 nm, respectively and were quantified using external calibration curves prepared with increasing amounts of pure tocopherols in ethanol.

Susceptibility of breast muscle tissue homogenates to iron-induced lipid oxidation was determined according to the method proposed by Kornbrust and Mavis (1980). Homogenates were incubated at 37°C and aliquots were removed at fixed time intervals (0, 30, 60, 90, and 150 min) for measurement of 2-thiobarbituric acid-reactive substances (TBARS). Protein content of the meat was determined according to the Lowry procedure (Lowry *et al*., 1951) and TBARS expressed as nmoles malondialdehyde (MDA)/mg protein.

Statistical analyses

Data were analysed with a one-way linear model for the effects of dietary regimen. The significance of differences was evaluated by *t*-test (STATA, 2005). Non parametric variables were analysed with CHISQ.

Results and discussion

In Table 1 are reported the formulation, chemical composition, energetic value (MJ kg^{-1}), some amino acids, vicine, convicine and the main antioxidants and fatty acid profile of the diets. Partial substitution of soybean with faba bean slightly affected the protein content of diets, whereas lipid amounts were more influenced (8.06 and 6.65 *vs* 6.75 and 5.39, respectively for S1, S2 and F1 and F2). Others chemical differ-

Table 2. Fatty acid composition of the experimental diets.

	Starter		Growing	
	S1	F1	S1	F1
C14:0, %	0.27	0.17	1.54	1.45
C16:0, %	11.40	17.48	12.74	18.56
C18:0, %	3.84	2.62	4.56	3.84
∑ Saturated, %	15.51	20.28	18.84	23.85
C16:1, %	0.27	0.17	0.41	0.53
C18:1, %	23.45	25.35	24.15	27.48
∑ Monounsaturated, %	23.72	25.52	24.56	28.01
C18:2n-6, %	53.59	50.70	48.05	44.26
C18:3n-3, %	7.19	3.50	8.51	3.89
∑ Polyunsaturated, %	60.78	54.20	56.56	48.15

Each value represents the mean of three determinations.

Table 3. Productive performance of chickens in the two dietary groups.

	Starter	Finisher	Pooled SE*	N/Group
Final live weight, g	2541[b]	2315[a]	210	100
Feed intake, g/d	80.2	81.0	4.4	-
Daily weight gain, g/d	20.9[b]	19.0[a]	1.6	100
Feed efficiency, g/d	3.7[a]	4.0[b]	-	4
Mortality rate, %	9.2[a]	12.4[b]	1.8*	-

*χ^2-test. [a,b]P<0.05.

ences of diets involved the antioxidant amount; F diets showed higher levels of γ-tocopherol (12.70 and 14.10 *vs* 9.95 and 10.07, mg/100g, respectively for F1, F2 and S1, S2) and lower α-tocopherol (2.95, 3.60 *vs* 3.19, 3.96 mg/100g, respectively for F1, F2 and S1, S2). The amounts of vicine and convicine in the F1 and F2 diets were, respectively 0.20%, 0.08% and 0.17%, 0.10% of dry matter. These values agree with those observed in our previous study (Perella *et al.,* 2009). Laudadio *et al.* (2011), replacing soybean with dehulled-micronized fava beans (310 g/kg) from 14 days to slaughter age (49 days), obtained values of vicine and convicine equal to 0.11% and 0.01%, respectively.

The fatty acid composition showed that both F diets (starter and finisher) have a higher level of saturated and monounsaturated fatty acids whereas PUFA were lower (Table 2). In particular, the α-linolenic acid was very low probably due to the modest amount present in faba bean (Grela and Günter, 1995). The effect of diet on productive performance are reported in Table 3; F fed birds, with respect to the S group, showed a lower final live weight, daily weight gain and higher feed efficiency. Mortality was also affected by diet: birds fed F diets showed a higher mortality rate. Table 4 describes the influence of the diet during different phases of the rearing cycle. Daily feed intakes between groups were not significantly different in the considered periods; on the contrary, the daily weight gain and the feed efficiency of F birds was lower until 60 days of age while later on both groups showed similar values. The lower performance here recorded could be mainly attributed to the starter diets because previous results (Perella *et al*., 2009) showed that similar formulation with faba bean for growing period produced the same productive performance. This negative effect of the faba bean on performance could be ascribed to various reasons: lower level of some essential aminoacids (methionine plus cysteine, threonine and tryptophan) and the presence of vicine, convicine and tannins as anti-nutritional factors. Moreover, the lower daily weight gain of F birds until 60 days of life was probably due to the fact that the faba bean diets, especially in animals at younger ages, were not able to satisfy the requirements of animals inducing a growth depression, as observed by Marquardt *et al*., (1976) and Rubio *et al.* (1990). The partial recovery of performance reached by the F2 group at the end of productive cycle is probably due to decreasing of the nutrient requirement of older birds. In this sub-period the F2 diet seemed able to meet their requirements; moreover, birds at older age were less susceptible to the antinutritional factors and showed a kind of compensatory growth. Mosier (1986) hypothesized that birds have a specific set point for body weight at a certain age, and when they are behind their scheduled growth curve, they try to reach this weight in a shorter time (Wilson and Osbourn, 1960; Mosier, 1986). Sterling *et al. (*2002) found that young chicks, beside the high nutritional requirements of protein and essential amino acids, are more sensitive to the presence of antinutritional substances in feed. The physiological background might be related to incomplete development of the gastrointestinal tract (Wijtten *et al.,* 2004), which affects the digestion efficiency in the consecutive growing phases (Vieira and Moran, 1999; Ravindran, 2002).

Table 4. Influence of diet on feed intake, daily gain and feed efficiency of chickens in the two dietary groups.

	Soybean diet	Faba bean diet	Pooled SE
Feed intake, g/d			
1-20 d	14.5	13.5	2.0
21-40 d	47.8	48.7	3.2
41-60 d	84.7	86.9	7.3
61-80 d	108.9	108.2	14.1
81-100 d	115.4	117.9	8.7
101-120 d	109.8	110.8	10.2
Daily weight gain, g/d			
1-20 d	8.6[b]	7.4[a]	1.0
21-40 d	19.8[b]	15.9[a]	1.7
41-60 d	26.4[b]	22.8[a]	2.0
61-80 d	27.4	25.6	2.1
81-100 d	24.5	23.5	2.0
101-120 d	18.5	18.8	1.7
Feed efficiency, g/g			
1-20 d	1.5[a]	2.0[b]	0.2
21-40 d	2.4[a]	3.3[b]	0.6
41-60 d	3.1[a]	3.9[b]	0.8
61-80 d	3.9	4.3	0.6
81-100 d	5.0	4.9	1.2
101-120 d	6.0	5.8	1.2

N=100 per group per time (every 20 days). [a,b]P<0.05.

Table 5. Characteristics of carcass of chickens in the two dietary groups.

	Soybean diet	Faba bean diet	Pooled SE
Eviscerated carcass, g	2068[b]	1891[a]	85
Dressing out, EC/LW	81.4	81.7	2.15
Refrigeration losses, %	0.13	0.12	0.02
Gastro-intestinal tract, %	11.50	11.80	1.85
Gastro-intestinal content, %	5.82	5.90	0.55
Abdominal fat, %	1.00	0.90	0.15
Ready to cook carcass, g	1557	1433	174
Dressing out, RCC/LW	61.3	61.9	2.19
Breast yield, % RCC	15.00	15.30	1.22
Thigh yield, % RCC	16.8	17.0	0.82
Biometric measurements			
Tibia length, cm	13.98	13.51	0.86
Sternum, cm	13.85	13.66	1.02
Carena , cm	11.22	10.85	0.38
Rostrum, cm	2.94	2.73	0.42
Breast width, cm	5.93	6.10	1.03
Breast layer thickness, cm	2.21	2.18	0.26
Meat to bone ratio	2.55	2.65	0.57

EC, eviscerated carcass; LW, live weight; RCC, ready to cook carcass. N=10 per group; [a,b]P<0.05.

Such findings agree with our results where the depressive effect of the faba bean in starter diets was partially compensated in the following growing phases. Moschini *et al.* (2005), using diets with 50% of faba bean, in broilers reared under intensive conditions, observed lower weight gains compared to a soybean group in the first 20 days of life. It should be considered that even if the essential amino acids are higher than NRC requirement, probably they are less available. Several authors (Ortiz *et al*., 1993, Lacassagne *et al*., 1988; Grosjean *et al*., 2000) reported that tannins of faba bean reduce energy and protein digestibility in poultry due to formation of tannin–protein complexes. Vilariño *et al*. (2009), comparing faba bean seeds selected for low or high tannins and low or high vicine and convicine contents, confirm that tannins reduced apparent energy and protein digestibility of faba bean in chickens whereas vicine and convicine have a negative effect only on energy. It is also reported that dehulling and micronization of faba bean further reduces the vicine and convicine content and reduces the antinutritional effect on poultry diets (Laudadio *et al*., 2011). Regarding feed efficiency, F birds showed the worst values during the early and middle phases of growth (1-60 d) in agreement with the previously reported considerations. Also Diaz *et al*. (2006) observed a higher feed conversion ratio during the grower period using extruded faba bean in place of soybean in conventionally reared chickens.

Carcass traits are reported in Table 5. Carcasses of F chickens were lighter than the S ones; the dressing percentage, abdominal fat, and breast and drumstick yield were not affected by the diet. Biometric measures were not affected by diet, although there were slightly superior (n.s.) in S birds; heavier animals have a larger skeleton with a higher bone size. Regarding carcass characteristics, Moschini *et al*. (2005), using 25 or 50% of faba bean diets, did not observe significant effects on dressing, breast and thigh percentages, whereas Diaz *et al*. (2006) observed a higher breast meat percent yield in birds consuming faba bean diet compared to the control group. The chemical characteristics of the breast and drumstick meat are reported in Table 6. As expected, considering the lower fat content of the F diet, the lipid content of breast and drumstick was significantly lower in F birds, while dry matter, crude protein and ash were not affected by diet. Meluzzi *et al*. (2009) studying the partial substitution of soybean with faba bean (40%) in diets for organic chickens observed a slight increment of protein in breast and a decrease of fat and ash in thigh meat. Physical characteristics of meat are given in Table 7. Faba bean diets influenced only ultimate pH of breast: F bird showed a significantly higher pHu than the S birds in the breast (5.86% *vs* 5.73%). The pHu is known to influence the structure of myofibrils and consequently the water holding capacity and the colour of the meat (Warris, 2000); this relationship were not fully confirmed in our study where the lower pHu of S bird reduced the

Table 6. Chemical characteristics of the breast and drumstick in the two dietary groups.

	Soybean diet	Faba bean diet	Pooled SE
Breast			
Dry matter, %	26.19	25.64	0.97
Crude protein, %	23.80	23.55	0.85
Ether extract, %	1.20^{b}	0.99^{a}	0.19
Ash, %	1.19	1.10	0.24
Gross energy, MJ/kg DM	21.75	21.64	1.58
Drumstick			
Dry matter, %	25.05	24.47	1.14
Crude protein, %	20.11	19.78	0.73
Ether extract, %	4.05^{b}	3.91^{a}	0.43
Ash, %	0.89	0.78	0.36
Gross energy, MJ/kg DM	24.05	23.87	1.29

DM, dry matter; N=10 per muscle per group. ^{a,b}P<0.05.

Table 7. Technological properties of breast and drumstick in the two dietary groups.

	Soybean diet	Faba bean diet	Pooled SE
Breast			
Ultimate pH	5.73^{a}	5.86^{b}	0.09
WHC, %	51.45	52.71	4.14
Cooking loss, %	32.67	32.79	3.65
L*	57.10	55.25	5.05
a*	4.42	5.54	1.41
b*	2.20	2.93	0.85
Shear value, kg/cm^{2}	2.39	2.03	0.77
Drumstick			
Ultimate pH	6.16	6.14	0.09
WHC, %	59.69	60.15	3.98
Cooking loss, %	32.65	31.03	3.04
L*	56.00	56.41	4.87
a*	9.41	10.45	1.73
b*	3.15	4.28	0.47
Shear value, kg/cm^{2}	3.05	3.15	0.46

WHC, water holding capacity; n=10 per muscle per group. ^{a,b}P<0.05.

Table 8. Fatty acids composition of breast and drumstick in the two dietary groups.

	Soybean diet	Faba bean diet	Pooled SE
Breast, %			
∑ Saturated	31.98	34.70	4.36
∑ Monounsaturated	26.90	29.27	2.58
∑ Polyunsaturated	41.12^{b}	36.03^{a}	4.15
C20:5n-3 EPA	0.69	0.58	0.10
C22:6n-3 DHA	1.52	1.34	0.24
Drumstick, %			
∑ Saturated	30.85	33.10	3.21
∑ Monounsaturated	29.75	31.25	2.89
∑ Polyunsaturated	39.40^{b}	35.65^{a}	3.00
C20:5n-3 EPA	0.31	0.29	0.14
C22:6n-3 DHA	1.10	1.01	0.34

N=10 per muscle per group. ^{a,b}P<0.05.

water holding capacity (WHC) but did not affect meat colour.

The partial substitution of soybean with faba bean affected the proportion of SFA and MUFA (Table 8), which were both higher in the F group in comparison to S group in breast and drumstick, according to Meluzzi *et al.* (2009). The diet also influenced the total PUFA, which were higher in S birds than in F birds (41.12 *vs* 36.03 and 39.40 *vs* 35.65 respectively, in breast and drumstick). Such trend is consistent with the fatty acid profile of F diets which showed a lower percentage of PUFA. These findings are in contrast with Laudadio *et al*. (2011) who observed that the PUFA concentration in the breast and drumstick muscles of standard fast-growing chicken increased with the inclusion in diet of micronized-dehulled peas, whereas the SFA concentration was similar. Moreover, the n-6:n-3 PUFA ratio of the broiler muscles decreased significantly in the experimental group. Antioxidant amount (Table 9) was affected by diet, showing a trend difficult to explain. Indeed, F birds showed a lower level of α-tocopherol respect to S ones, whereas lutein, zeaxanthin and γ-tocopherol (only in breast) were higher. The protective effect of tocopherol on inhibition of lipid oxidation in poultry and other animal species is widely known (Buckley and Morrisey, 1992); however, despite the low levels of this antioxidants detected in F birds, the susceptibility to oxidation resulted similar in the two groups (Figure 1).

Table 9. Antioxidant profile of breast and drumstick in the two dietary groups.

	Soybean diet	Faba bean diet	Pooled SE
Breast			
Lutein, ng g^{-1}	56.16[a]	61.21[b]	5.20
Zeaxanthin, ng g^{-1}	1.76[a]	2.04[b]	0.20
α-tocopherol, mg kg^{-1}	3.70[b]	2.60[a]	0.31
γ-tocopherol, mg kg^{-1}	0.29[a]	0.60[b]	0.04
δ-tocopherol, mg kg^{-1}	0.02	0.01	0.01
Drumstick			
Lutein, ng g^{-1}	82.01[a]	101.36[b]	8.15
Zeaxanthin	1.98[a]	2.64[b]	0.30
α-tocopherol, mg kg^{-1}	6.10[b]	3.19[a]	0.45
γ-tocopherol, mg kg^{-1}	0.55	0.64	0.04
δ-tocopherol, mg kg^{-1}	0.03	0.03	0.01

N=10 per muscle per group. a,bP<0.05.

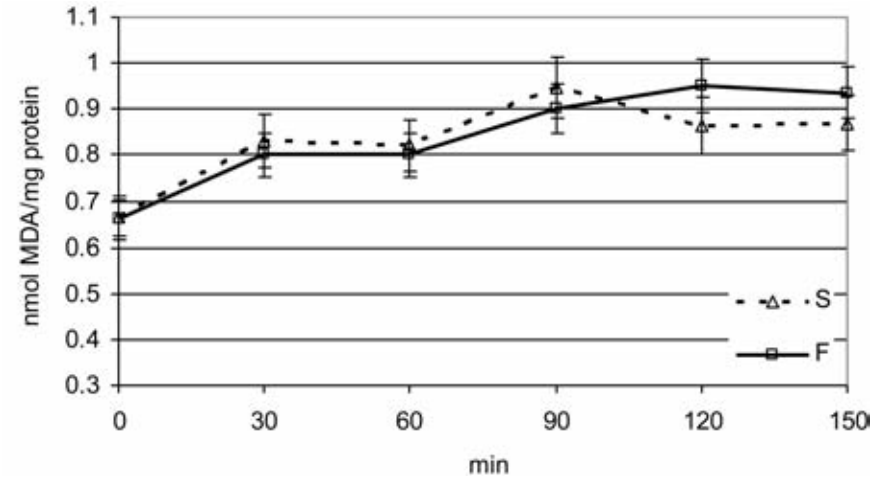

Figure 1. Influence of the diet on susceptibility to lipid oxidation (induced TBARS) of breast meat (95% upper and lower limits). S, soybean; F, faba bean; n=10 per time per group.

Conclusions

It can be concluded that, under the specific experimental conditions of the present study, the partial substitution of soybean with faba bean in starter diets of chicks is not advisable. The dietary requirements of slow-growing chickens are not completely satisfied when fed faba beans; the content of antinutritional compounds probably reduces the digestibility of protein, and consequently the utilization of amino acids such as lysine, methionine and cysteine. The chickens fed F diet, compared with S diet, showed a growth depression particularly in the first rearing period when the gastrointestinal tract is not completely developed and birds are more susceptible to the anti nutritional factors. The meat quality was partially affected by dietary treatment with lower PUFA and antioxidant content in F group, even if the oxidative stability did not show differences. Heat treatments can partially improve the nutritional characteristics of faba bean, except for tannins and the main glucosides, vicine and convicine, which are thermostable. Further trials with dehulled and micronized faba bean should be done; alternatively, faba bean varieties free of tannins and low in vicine and convicine should be selected.

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