Growth performance and carcass characteristics of guinea fowl broilers fed micronized-dehulled pea (*Pisum sativum* L.) as a substitute for soybean meal

V. Laudadio,* S. N. Nahashon,† and V. Tufarelli*[1]

*Department of Animal Production, University of Bari "Aldo Moro," Valenzano 70010, Italy; and †Department of Agricultural Sciences, Tennessee State University, Nashville 37209-1561

ABSTRACT This study was conducted to evaluate the effect of substitution of soybean meal (SBM) with dehulled-micronized peas (*Pisum sativum*) in diets of guinea fowl broilers on their growth performance, carcass yields, and fatty acid composition of meat. One hundred forty 1-d-old guinea fowl keets were randomly assigned to 2 dietary treatments, which were fed from hatch to 12 wk. The birds were fed 2 wheat middling-based diets comprising a control diet, which contained SBM (78 g/kg) and a test diet containing dehulled-micronized peas (180 g/kg) as the main protein source. The substitution of SBM with peas had no adverse effect on growth performance, dressing percentage, or breast and thigh muscle relative weights of the guinea broilers. However, a reduction of abdominal fat content ($P < 0.05$) was observed in birds fed the pea diet compared with the control. Breast and thigh meat of birds fed the pea diet had higher lightness scores ($P < 0.05$) and water-holding capacity ($P < 0.01$) than the control. Meat from guinea fowls fed the pea diet had less cholesterol ($P < 0.01$) and lipids ($P < 0.05$), and higher concentrations of phospholipids ($P < 0.05$). Feeding peas increased polyunsaturated fatty acid concentration in breast and thigh muscles, and decreased the saturated fatty acid concentration. Feeding the pea diet also lowered the n-6/n-3 polyunsaturated fatty acid ratio of the guinea broiler muscles. Our results suggest that replacing the conventional SBM as the protein source with dehulled-micronized pea meal in diets of guinea fowls broilers can improve carcass quality and favorable lipid profile without adversely affecting growth performance traits.

Key words: guinea fowl, pea, growth, carcass, meat quality

2012 Poultry Science 91:2988–2996
http://dx.doi.org/10.3382/ps.2012-02473

INTRODUCTION

Poultry meat is a popular and versatile proteinaceous food consumed in large amounts relative to other meats. Enriched poultry meat can therefore serve as a vehicle for supplying nutrients such as the n-3 fatty acids (**FA**) whose human consumption is below recommendations (Laudadio and Tufarelli, 2011). Previous modifications of poultry meat quality through manipulation of diet and rearing conditions have been reported (Aletor et al., 2003; Rymer et al., 2010; Nasr and Kheiri, 2011). These modifications also include enrichment of poultry products with health-promoting substances, which have been reported to contain anticarcinogenic properties and reduce plasma cholesterol and fatness (Crespo and Esteve-Garcia, 2001; Aletor et al., 2003). Previous reports (Crespo and Esteve-Garcia, 2001) demonstrate that feeding poultry different dietary sources increased the n-3 FA content of meat.

Although the enrichment of broiler meat with nutrients that confer health-promoting properties has been researched extensively, there is paucity of such information relating to alternative poultry, such as the guinea fowl. Guinea fowl production for meat is a potentially advantageous enterprise in many parts of the world (Nahashon et al., 2006). Guinea fowl meat, as alternative meat to chicken, has already proven to be a profitable activity in the United States, Canada, and also in European markets such as France and Italy (Nahashon et al., 2005; Tufarelli et al., 2007). However, there still remains a challenge in profitability emanating from increasing cost of production, which is primarily due to feeding cost. Price variations on the feedstuffs market, the increasing cost of traditional feed ingredients such as corn and SBM due to their increased demand in the biofuel industry, and the increasing demand for alternative poultry justify the need for less-conventional feed ingredients.

Soybean meal (**SBM**) is the most widely used protein source in the formulation of poultry diets. However, when the price of SBM increases, poultry nutritionists seek alternative sources of protein that are more economical in formulating least-cost poultry rations.

Received May 15, 2012.
Accepted July 29, 2012.
[1]Corresponding author: vincenzo.tufarelli@uniba.it

Pea (*Pisum sativum*) is considered as a potential feed ingredient in diets of pigs (Stein et al., 2006) and poultry (Nalle et al., 2011). Moreover, peas contain high amounts of protein and energy, and their amino acid content is similar to that of soybean (Fru-Nji et al., 2007; Tufarelli et al., 2012). The inclusion of a high amount of raw peas in diets has been reported to have a detrimental effect on the performance of broilers and laying hens (Igbasan and Guenter, 1997; Diaz et al., 2006). This was attributed to the presence in the seeds of various biologically active compounds usually referred to as antinutritional factors/toxic substances (Douglas et al., 1991). The effects of the antinutritional factors limit the use of raw legumes, although various processing techniques tend to reduce the content of antinutritional factors of the seed while increasing the protein content (Khattab et al., 2009; Laudadio et al., 2011).

Several studies indicate that heat processing (such as micronization treatment) increases the digestible nutrients available to poultry, resulting in improved growth and production (Igbasan and Guenter, 1996). Further, removal of hulls increases the concentration of digestible nutrients for broilers to a level comparable with that of SBM (Medugu et al., 2011). Our previous studies indicated that dehulled-micronized pea was suitable for use in the diets of broiler chickens and laying hens (Laudadio and Tufarelli, 2010, 2012). However, little attention has been given to the evaluation of the effects of processed legume seeds in the diet of guinea fowls. Therefore, the aim of this research was 2-fold: (1) to evaluate the effect of substitution of SBM with dehulled-micronized peas (*Pisum sativum*) in diets of guinea fowl broilers on their growth performance; and (2) to evaluate the effect of feeding dehulled-micronized peas on profiles of health-promoting substances in breast and thigh meats of guinea fowl broilers.

MATERIALS AND METHODS

Experimental Birds and Management

This research was conducted in a commercial poultry facility located in the Bari Province, Italy, observing the animal welfare Legislative Decree 116/92, Council Directive 98/58/EC, received in Italy by Legislative Decree 146/2001, and Council Directive 2007/43/CE, received in Italy by the governmental Decree 181/2010 and Legislative Decree 267/2003.

A total of one hundred forty 1-d-old female guinea fowl broilers were obtained from a commercial hatchery and raised in a conventional controlled environment house. Birds were individually weighed and randomly assigned to 14 concrete floor pens covered with pine wood shavings to a depth of at least 2 inches (5.08 cm). Each pen housed 10 birds and was equipped with a pan feeder and a manual drinker. The birds were reared under standard brooding and rearing conditions outlined by Bell and Weaver (2002) and were provided 23 h light: 1 h darkness throughout the experimentation period.

Dietary Treatments

The guinea fowl broilers were fed two 84-d experimental diets, a wheat middling-soy diet (control) and wheat middling-micronized-dehulled pea diet. Each diet was replicated 7 times, with each replicate comprising one pen of 10 birds. The diets (Table 1) were isocaloric and isonitrogenous containing 18.5% CP and 13.0 MJ of ME/kg of diet, designed to meet or exceed the bird's requirements (Larbier and Leclercq, 1994). Feed (pellet form) and water were provided ad libitum throughout the trial. The BW and ADFI, from which ADG and feed conversion ration (FCR) were calculated, were measured. Mortality was recorded as it occurred.

Preparation of Feed Ingredients

The 2 dietary protein sources evaluated were SBM (48% CP) and micronized-dehulled peas (*Pisum sativum* cv. Spirale), 31% CP and 1.7% crude fiber, as previously reported by Laudadio and Tufarelli (2010). The major grain energy source for both diets, wheat middlings, was obtained from durum wheat (*Triticum durum* Desf. cv. Appulo). The wheat middlings were previously sieved to separate the fibrous components to obtain a product with average crude fiber content ~3% (Laudadio and Tufarelli, 2011). Pea seeds, organically and locally grown, were tempered overnight to the preferred moisture content (240 g/kg) as recommended by Khattab et al. (2009) using distilled water. Tempered seeds were heated to 130°C using a small experimental bench-top micronizer composed of a tubular quartz infrared lamp (115 V) with a tungsten wire filament enclosed in a ceramic casing (Research Inc., Eden Prairie, MN). Pea processing times were 1.5 min. Dehulling was accomplished with the aid of a roller mill and hulls were separated from cotyledons by air classification. Ingredient and chemical composition of the diets are shown in Table 1.

Sample Collection

On d 84 of the trial, 3 guinea fowl broilers of average BW were randomly selected from each pen following a 12-h fasting period, weighed individually, and killed by cervical dislocation and then were immediately bled. The abdominal fat (consisting of fat surrounding the gizzard, proventriculus, and in the abdominal body cavity), breast (pectoralis major), and drumstick (peroneous longus) muscles were removed and weighed immediately. Muscles from the breast and thigh were immediately stored at −80°C for assessing crude fat content, and others were individually stored in plastic bags at 4°C for meat quality analysis.

Meat Quality Determinations

Muscle pH. At 24 h after killing, the breast and thigh muscle pH was measured at a depth of 2.0 cm be-

Table 1. Ingredients and chemical analysis of diets fed to guinea fowl broilers

Item	Diet	
	Soybean	Pea
Ingredient, g/kg		
Wheat middlings[1]	860.0	762.2
Soybean meal (48% CP)	78.0	—
Peas (31% CP)	—	180.0
Sunflower oil	20.0	20.0
Dicalcium phosphate	16.0	13.0
Calcium carbonate	10.0	12.0
L-Lys HCl	5.0	3.0
Vitamin-mineral premix[2]	2.5	2.5
L-Thr	2.5	1.5
Sodium chloride	2.0	2.0
Sodium bicarbonate	2.0	2.0
DL-Met	1.2	1.0
Enzyme[3]	0.8	0.8
Chemical analysis, %		
DM	89.54	89.47
CP	18.46	18.53
Lipid	5.03	4.95
Crude fiber	3.52	3.19
Ash	5.61	5.31
Calculated analysis		
ME, MJ/kg	13.07	13.04
Lys, %	0.97	0.95
Ca, %	1.00	1.00
Total P, %	0.73	0.72
Available P, %	0.39	0.38
Met + Cys, %	0.75	0.73
Thr, %	0.74	0.72
Fatty acid,[4] %		
Σ SFA	33.45	28.97
Σ MUFA	32.28	29.89
Σ PUFA	34.27	41.14
Total n-6	32.02	38.34
Total n-3	1.47	2.21

[1]Wheat middlings obtained from durum wheat (*Triticum durum* Desf. cv. Appulo).

[2]Supplied per kilogram of diet: vitamin A 12,500 IU; vitamin E 10 mg; vitamin D 2,200 IU; niacin 35.0 mg; D-pantothenic acid 12 mg; riboflavin 3.63 mg; pyridoxine 3.5 mg; thiamine 2.4 mg; folic acid 1.4 mg; biotin 0.15 mg; vitamin B 0.03 mg; Mn 60 mg; Zn 40 mg; Fe 1,280 mg; Cu 8 mg; I 0.3 mg; Se 0.2 mg.

[3]Provided per kilogram of product: endo-1,4-β-glucanase, 800,000 U; endo-1,3(4)-β-glucanase 1,800,000 U; endo-1,4-β-xylanase 2,600,000 U.

[4]SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

low the surface. This was performed using a combined glass-penetrating electrode (Ingold, Mettler Toledo, Greifensee, Switzerland).

Color and Drip Loss. Color measurements were assessed on the carcass surface over the breast and drumstick muscles and on a freshly exposed cut surface of muscle. A Minolta CR-300 chromameter (Minolta, Osaka, Japan) was set to the L* (lightness), a* (redness), and b* (yellowness) Commission Internationale d'Eclairage scale, as described by Combes et al. (2008). Drip loss was measured by the filter paper method as suggested by Kauffman et al. (1986).

Water-Holding Capacity. The water-holding capacity (**WHC**) of breast and thigh meat was measured after killing according to Sun and Luo (1993). A 0.5-g breast muscle or thigh muscle sample was pressed onto an oven-dried Whatman 125-mm filter paper (Maidstone, Kent, UK) at 207 bar. The WHC values were calculated as the ratio of the area of expressed water to the area of the pressed meat sample as measured with a planimeter (model 4236, Keuffel and Esser, Hoboken, NJ).

Chemical Analysis. Meat samples were assayed for moisture (945.15), ash (967.05), and CP (990.03) by oven, muffle furnace, and Kjeldahl methods, respectively, as described in AOAC International (2000). Total lipids were extracted according to the method of Folch et al. (1957). Phospholipid and total cholesterol content of the meat samples were quantified using the procedures described by Bartlett (1959) and Sperry and Webb (1950), respectively. Determination of 4-hydroxyproline was performed according to the procedures of Kindt et al. (2003) using electrospray mass spectrometry (LCQ, Thermo Electron, Waltham, MA) to avoid any derivatization step.

FA Composition. In preparation for FA composition analysis, samples of diets, breast, and thigh meat (5 g each) were freeze-dried and then ground. Briefly, methyl heptadecanoate (no. 51633, Fluka, St. Louis, MO) was dissolved into *n*-hexane (1 mg/mL) as an internal standard. Methyl esters of the FA were prepared (Sukhija and Palmquist, 1988); samples (300 mg each) and 5 mL of internal standard were incubated (2 h at 80°C) with methanolic acetyl chloride in a total volume of 9 mL. After cooling to room temperature, 7 mL of 7% (wt/vol) K_2CO_3 was added with mixing, and then the organic phase was collected after centrifuging at 1,500 × *g* for 2 min at 4°C. The FA methyl esters were fractionated over a CP-SIL883 column (100 m × 0.25 mm i.d., film thickness 0.20-μm fused silica; Varian, Palo Alto, CA) in a Shimadzu (model 2GC17A, Shimadzu, Kyoto, Japan) gas chromatograph with a Hewlett-Packard HP 6890 gas system (Palo Alto, CA) and using flame ionization detection. Helium was used as the carrier gas at a constant flow rate of 1.7 mL/min. The oven temperature was programmed as follows: 175°C, held for 4 min; 175 to 250°C at 3°C/min; and then maintained for 20 min. The injector port and detector temperature was 250°C. Samples (1 μL) were injected by an auto-sampler. Output signals were identified and quantified from the retention times and peak areas of known calibration standards. Composition was expressed as percentages of the total FA.

The saturation (**S/P**), atherogenic (**AI**), and thrombogenic (**TI**) indexes were calculated according to Ulbricht and Southgate (1991) and the hypocholesterolemic/hypercholesterolemic ratio (**HH**) was calculated, as suggested by Santos-Silva et al. (2002), as follows:

$$S/P = (C14{:}0 + C16{:}0 + C18{:}0)/\Sigma MUFA + \Sigma PUFA;$$

$$AI = (C12{:}0 + 4 \times C14{:}0 + C16{:}0)/[\Sigma MUFA + \Sigma(n\text{-}6) + \Sigma(n\text{-}3)];$$

$$TI = (C14{:}0 + C16{:}0 + C18{:}0)/[0.5 \times \Sigma MUFA + 0.5 \times \Sigma(n\text{-}6) + 3 \times \Sigma(n\text{-}3) + \Sigma(n\text{-}3)/\Sigma(n\text{-}6)];$$

$$HH = [(C18{:}1n\text{-}9 + C18{:}2n\text{-}6 + C20{:}4n\text{-}6 + C18{:}3n\text{-}3 + C20{:}5n\text{-}3 + C22{:}5n\text{-}3 + C22{:}6n\text{-}3)/(C14{:}0 + C16{:}0)],$$

where **MUFA** = monounsaturated FA; **PUFA** = polyunsaturated FA.

Statistical Analysis

Data were analyzed using the ANOVA option of the general linear model of SAS/STAT software (SAS Institute, 2004) as a completely randomized design with the 2 dietary treatment or crude protein sources (SBM and peas) as main effects. The statistical model used was $Y_{ijk} = \mu + P_i + R_{ij} + \varepsilon_{ijk}$, where Y_{ijk} = response variables from each individual replication or pen, μ = the overall mean; P_i = the effect of dietary protein source; R_{ij} = the inter-experimental unit (replications) error term; and ε_{ijk} = the intra-experimental unit error term. When there was a significant F-value, means were compared by the Student-Newman-Keul's method. Significance implies $P < 0.05$ unless stated otherwise.

RESULTS

Mean performance traits of guinea fowl broilers fed diets containing either SBM or dehulled-micronized pea meal are presented in Table 2. Mean differences in BW, ADG, ADFI, and FCR of the guinea fowl broilers fed the SBM-based diet were not different ($P > 0.05$) from those of birds fed the dehulled-micronized pea meal diet. Likewise, mean mortality was very low and was not different between birds fed the SBM-based control diet and those fed the dehulled-micronized pea-based diet (1.8 and 1.7%, respectively). The eviscerated carcass yield, which was determined after the removal of the head, neck, and feet, was approximately 70% and was also not different ($P = 0.183$) between the 2 dietary treatment groups. Also the yield in breast and thigh plus drumstick was not different between the treatment groups (Table 3). However, a reduction ($P = 0.022$) in abdominal fat pad content was observed in birds fed the dehulled-micronized pea-based diet compared with the SBM-based diet (1.49 versus 1.89%, respectively). The breast and thigh meat pH was not different among the dietary treatment groups. Whereas differences in mean meat drip loss, protein, or ash percentage of guinea fowl broilers fed either of the 2 dietary treatments were not different, birds fed the dehulled-micronized pea-based diet exhibited an increase in fat content of both the breast and thigh muscles compared with birds fed the SBM-based control diet ($P < 0.05$). Also, inclusion of dehulled-micronized pea meal in the diets of broilers increased the lightness (L*) of the breast ($P = 0.029$) and thigh ($P = 0.008$) muscles, as depicted by higher L* values. The breast meat color (a* and b*) was not influenced by dietary treatment, but a higher a* value ($P < 0.05$) for thigh muscle was noted in birds fed dehulled-micronized pea meal compared with birds fed the SBM-based control diet. Although the saturation index (a/b ration) of breast meat was not different between the SBM and dehulled-micronized-based dietary treatments (2.81 and 2.83, respectively), a higher ($P < 0.05$) saturation index was observed in thigh muscle of the birds fed the dehulled-micronized pea meal than those fed the SBM-based diet (8.47 and 8.08, respectively). This is an indication that feeding the dehulled-micronized pea meal increased the darkness of the thigh muscle. The WHC of breast and thigh meat of guinea fowl broilers fed the dehulled-micronized pea meal was about 4% higher than that of broilers fed the SBM-based diets ($P = 0.008$ and $P = 0.009$, respectively).

The effects of diet on the total phospholipids, lipids, and cholesterol contents of breast muscles of guinea fowl broilers are presented in Table 4. The lipids and total phospholipids concentration in breast meat of guinea fowl broilers fed the dehulled-micronized pea-based diet were higher ($P = 0.029$ and $P = 0.018$, respectively) than those of birds fed the SBM-based diet. However, the breast meat of birds on the dehulled-micronized pea-based diets exhibited a lower content of cholesterol ($P = 0.007$) compared with birds fed the control SBM-based diet.

The FA compositions of breast meat of guinea fowl broilers fed the SBM-based control and the dehulled-micronized based diets are presented in Table 5. The FA profiles of the breast muscle of guinea fowl broilers fed the dehulled-micronized pea-based diet showed a lower fraction of total saturated FA (**SFA**) and MUFA

Table 2. Effect of dietary protein source on growth performance of guinea fowl broilers at 12 wk of age

	Diet			
Item	Soybean	Pea	SEM	P-value
Final BW, g	1,969	1,981	34.57	0.185
ADG, g/d	23.4	23.6	0.19	0.201
ADFI, g/d	66.8	66.9	0.41	0.366
FCR,[1] g/g	2.85	2.83	0.03	0.157
Mortality, %	1.8	1.7	0.39	0.581

[1]FCR = feed conversion ratio.

Table 3. Effect of dietary protein source on carcass yield and meat quality parameters of guinea fowl broilers at 12 wk of age (n = 21)

	Diet			
Item	Soybean	Pea	SEM	*P*-value
Carcass trait[1]				
Eviscerated carcass	69.4	69.6	0.15	0.183
Breast	23.4	23.7	0.11	0.125
Thigh and drumstick	22.5	23.1	0.09	0.086
Abdominal fat	1.89	1.49	0.05	0.022
Meat parameter				
Breast				
pH_{24}[2]	5.72	5.76	0.03	0.270
L* (lightness)	47.03	49.21	0.62	0.029
a* (redness)	16.15	16.89	0.71	0.083
b* (yellowness)	5.74	5.96	0.32	0.119
WHC,[3] %	61.67	63.84	0.29	0.008
Drip loss, %	1.52	1.41	0.06	0.062
Moisture, %	73.25	73.05	0.39	0.126
Protein, %	23.61	23.54	0.16	0.069
Fat, %	1.85	2.17	0.12	0.037
Ash, %	1.29	1.24	0.07	0.303
Thigh				
pH_{24}[2]	5.81	5.79	0.03	0.105
L* (lightness)	41.78	43.22	0.59	0.008
a* (redness)	17.04	18.89	0.48	0.045
b* (yellowness)	2.11	2.23	0.26	0.177
WHC,[3] %	67.25	69.61	0.36	0.009
Drip loss, %	1.49	1.45	0.07	0.086
Moisture, %	75.65	75.36	0.38	0.223
Protein, %	19.45	19.26	0.17	0.098
Fat, %	3.85	4.49	0.29	0.029
Ash, %	1.05	0.89	0.06	0.274

[1]Percentage of BW at slaughter.

[2]pH_{24} = pH at 24 h postmortem.

[3]WHC = water-holding capacity.

($P = 0.019$ and $P = 0.025$, respectively) compared with birds fed diets containing SBM-based diets. On the other hand, the percentage of total PUFA was about 11% higher ($P = 0.003$) in meats from guinea fowl broilers fed the dehulled-micronized pea-based diet, particularly docosapentaenoic. The percentage docosapentaenoic in breast muscle of birds on the pea-based diets was 34% higher than that of birds fed the SBM-based diets ($P = 0.036$). Although not different, mean concentration of eicosapentaenoic acid (**EPA**) and docosahexaenoic acid (**DHA**) in the breast meat of guinea broilers fed the dehulled-micronized-based diets was 31 and 44%, respectively, higher than that bird fed the SBM-based diets. Likewise, differences in the ratio of saturated to unsaturated FA were not different; however, the percentage content of n-6 PUFA in the breast muscle of guinea broilers fed the dehulled-micronized pea-based diets was higher ($P = 0.008$) than that of broilers fed the SBM diet. On the other hand, the ratio of n-6 to n-3 (n-6/n-3) was lower in birds on the pea-based diet than those on the SBM-based diet, an indication that breast muscle of guinea broilers fed the dehulled-micronized pea-based diet exhibited a higher content of the n-3 FA than those fed the SBM-based diet. Mean differences in the AI and TI and their ratios of the guinea broilers in the 2 dietary treatments were similar ($P = 0.174$ and $P = 0.096$, respectively).

However, the HH ratio in breast meat from birds fed the dehulled-micronized-based diets was higher than those fed SBM-based diets (2.59 versus 2.34, respectively). These HH ratios suggest that the dehulled-micronized pea-based diet may contain more hypocholesterolemic properties than the SBM-based control diet.

The FA compositions of thigh meat of guinea fowl broilers fed the SBM-based control and the experimental diets are presented in Table 6. The FA profiles of the

Table 4. Effect of dietary protein source on total of lipids, phospholipids, and cholesterol contents in breast meat (pectoralis major) from guinea fowl broilers

	Diet			
Item	Soybean	Pea	SEM	*P*-value
Total lipids, g/kg	0.19	0.22	0.013	0.029
Total phospholipids, mg/g	4.23	5.24	0.211	0.018
Total cholesterol, mg/g	0.39	0.29	0.014	0.007

Table 5. Effect of dietary protein source on the fatty acid composition (% of total FA) of breast meat (pectoralis major) from guinea fowl broilers at 12 wk of age (n = 21)

	Diet			
Item	Soybean	Pea	SEM	*P*-value
C12:0 Lauric	1.22	0.97	0.15	0.071
C14:0 Myristic	4.34	5.11	0.19	0.063
C16:0 Palmitic	20.51	18.51	0.26	0.031
C18:0 Stearic	0.71	0.39	0.09	0.041
C14:1 n-5 Myristoleic	0.42	0.29	0.08	0.088
C16:1 n-7 Palmitoleic	4.62	4.16	0.11	0.103
C18:1 n-9 Oleic	35.26	34.13	0.38	0.056
C18:2 n-6 Linoleic	28.42	30.17	0.36	0.009
C18:3 n-3 α-Linolenic	0.27	0.59	0.05	0.022
C18:3 n-6 γ-Linolenic	0.55	0.71	0.06	0.093
C20:4 n-6 Arachidonic	0.79	1.09	0.06	0.042
C20:5 n-3 EPA[1]	1.34	1.75	0.13	0.112
C22:5 n-3 DPA[1]	0.98	1.31	0.12	0.036
C22:6 n-3 DHA[1]	0.57	0.82	0.05	0.095
Σ SFA[2]	26.78	24.98	0.32	0.019
Σ MUFA	40.30	38.58	0.41	0.025
Σ PUFA	32.92	36.44	0.56	0.003
Σ PUFA n-6	29.76	31.97	0.39	0.008
Σ PUFA n-3	3.16	4.47	0.15	0.054
n-6/n-3[3]	9.42	7.15	0.20	0.023
S/P[4]	0.37	0.33	0.03	0.139
Atherogenic index	0.53	0.53	0.02	0.174
Thrombogenic index	0.57	0.49	0.03	0.096
HH[5]	2.34	2.59	0.06	0.042

[1]EPA = eicosapentaenoic acid; DPA = docosapentaenoic acid; DHA = docosahexaenoic acid.

[2]SFA = saturated fatty acids; MUFA = monunsaturated fatty acids.

[3]n-6/n-3 = polyunsaturated FA (PUFA) n-6/PUFA n-3 ratio.

[4]S/P = saturated fatty acid/unsaturated fatty acid.

[5]HH = hypocholesterolemic/hypercholesterolemic ratio.

thigh muscle of guinea fowl broilers fed the dehulled-micronized pea-based diet had a lower fraction of SFA and MUFA ($P = 0.031$ and $P = 0.026$, respectively) compared with birds fed the SBM-based control diets. On the other hand, the concentration of the PUFA (n-6 and n-3) in thigh muscle was higher ($P = 0.017$) in birds on the dehulled-micronized pea-based diet than those fed the SBM-based diets. The dehulled-micronized pea-based diets also were associated with a higher concentration of EPA in the guinea fowl broiler thigh muscle. A lower ($P = 0.021$) ratio of n-6/n-3 was observed in birds fed the dehulled-micronized pea-based diets than those on the SBM-based control diet, which is further evidence that, as opposed to n-6, the concentration of n-3 in thigh meat was higher when guinea fowl broilers were fed the dehulled-micronized pea-based diets. The TI was lower ($P = 0.041$) and the HH ratio was higher ($P = 0.044$) in broilers fed the pea-based diets compared with those fed the SBM-based control diets. Hence, the dehulled-micronized pea based diets tend to favor hypocholesterolemic properties of the thigh muscle of guinea fowl broilers.

DISCUSSION

The effects of inclusion of dietary pea meal in diets of guinea fowl broilers on their growth performance and meat quality, which would include functional food properties such as the content of n-3 and n-6 FA composition, have not been reported. Therefore, cross-referencing in the discussion of findings in this report will be based on findings from other poultry species such as chickens and turkeys. The adequate growth performance of guinea fowl broilers fed diet containing micronized pea meal was consistent with previous reports conducted on broiler chickens (Igbasan and Guenter, 1996; Crepon, 2006; Laudadio and Tufarelli, 2010). However, contrary to these reports, McNeill et al. (2004) reported poor growth rate and feed efficiency of broiler chickens fed diets containing 20% pea meal. In their study, the diets were not balanced for ME and digestible amino acids. Thus, variations in the formulation of the experimental diets and levels of inclusion of pea meal in poultry diets appear to be the main cause of inconsistencies in bird performance.

In the presented study, no differences were shown in dressing percentage and contents of major muscles (breast, drumstick, and thighs) in carcasses of guinea fowl broilers fed diets with and without micronized-dehulled pea meal. Similar findings were reported by Laudadio and Tufarelli (2010), where broiler chickens were fed diets containing 40% pea meal substituted for SBM. In their report, these weights of breast muscle portion of the carcass of guinea fowl fed the pea meal diet correspond to the average breast muscle weight of the French guinea fowl broiler reported earlier in Nahashon et al. (2005). Similar to birds fed the SBM-based diet, the optimum performance of birds fed the pea-based diets is

Table 6. Effect of dietary protein source on the fatty acid composition (% of total FA) of thigh meat (biceps femoris) of guinea fowl broilers at 12 wk of age (n = 21)

	Diet			
Item	Soybean	Pea	SEM	*P*-value
C12:0 Lauric	1.89	1.46	0.19	0.077
C14:0 Myristic	4.72	4.95	0.30	0.144
C16:0 Palmitic	22.41	20.62	0.42	0.008
C18:0 Stearic	0.98	0.47	0.09	0.009
C14:1 n-5 Myristoleic	0.77	0.31	0.05	0.008
C16:1 n-7 Palmitoleic	5.11	5.36	0.21	0.085
C18:1 n-9 Oleic	33.35	32.47	0.52	0.053
C18:2 n-6 Linoleic	27.02	29.07	0.26	0.036
C18:3 n-3 α-Linolenic	0.44	0.62	0.06	0.045
C18:3 n-6 γ-Linolenic	0.54	0.71	0.09	0.043
C20:4 n-6 Arachidonic	0.59	0.81	0.08	0.061
C20:5 n-3 EPA[1]	1.03	1.38	0.13	0.024
C22:5 n-3 DPA[1]	0.74	1.01	0.12	0.062
C22:6 n-3 DHA[1]	0.41	0.76	0.10	0.058
Σ SFA[2]	30.00	27.50	0.43	0.031
Σ MUFA[2]	39.23	38.14	0.41	0.026
Σ PUFA	30.77	34.36	0.39	0.017
Σ PUFA n-6	28.15	30.59	0.32	0.029
Σ PUFA n-3	2.62	3.77	0.12	0.053
n-6/n-3[3]	10.74	8.11	0.23	0.021
S/P[4]	0.43	0.38	0.10	0.096
Atherogenic index	0.62	0.58	0.11	0.053
Thrombogenic index	0.68	0.57	0.09	0.041
HH[5]	2.72	2.96	0.04	0.044

[1]EPA = eicosapentaenoic acid; DPA = docosapentaenoic acid; DHA = docosahexaenoic acid.

[2]SFA = saturated fatty acids; MUFA = monounsaturated fatty acids.

[3]n-6/n-3 = polyunsaturated FA (PUFA) n-6/PUFA n-3 ratio.

[4]S/P = saturated fatty acid/unsaturated fatty acid.

[5]HH = hypocholesterolemic/hypercholesterolemic ratio.

in part attributed to a well-balanced amino acid profile coupled with the supplementation of lysine, methionine, and threonine. The dietary inadequacy and balance of amino acids is known to be the reason of diminished content of breast muscles in carcasses of poultry (Nasr, 2011). Although the abdominal fat content of guinea fowl broilers was reduced ($P < 0.05$) when SBM was replaced with pea meal in their diets, the abdominal fat content of the birds expressed as a percentage of BW at slaughter was lower than that reported earlier in broiler chickens (Laudadio and Tufarelli, 2010). This and other studies have demonstrated that the guinea fowl broiler tends to deposit less abdominal fat and have leaner carcasses than broiler chickens (Nahashon et al., 2005; Laudadio and Tufarelli, 2010).

The content of moisture, ash, and protein in breast and thigh muscles of guinea fowl broilers from our study were consistent with previous reports where chickens (Igbasan and Guenter, 1996; Laudadio and Tufarelli, 2010) and turkeys (Savage et al., 1986) were fed pea-based diets. Mikulski et al. (1997) also reported that micronized pea meal can be included in diets of growing turkeys up to 20 to 24% of the diet as a partial replacement of SBM without adversely affecting performance, dressing percentage, or meat quality. These reports are also in agreement with the recommendations of Castell et al. (1996) that peas can be included as a protein source in diets of turkeys by up to 25% of the diet without adversely affecting bird performance.

The color of muscles of the guinea broilers was influenced by the dietary substitution of SBM for micronized pea meal. Meat color is an indicator of meat quality and is one of the first characteristics noted by customers, especially in boneless products. In our study, there were differences ($P < 0.05$) in mean colorimetric indexes of muscles between guinea fowl broilers fed the SBM-based diet compared with those fed the micronized pea meal diet. Inclusion of the pea meal in the diet led to darker breast and leg meats and increased redness of thigh meat. Nevertheless, these values were in the normal range and therefore these muscles would not be considered to be excessively dark (Woelfel et al., 2002). Our findings are consistent with previous reports (Laudadio and Tufarelli, 2010) and may be explained, in part, by higher lipid content in these muscles which may also contain less lipid-soluble pigments such as xanthophylls. Regardless of the dietary treatments, the colorimetric indices of breast and thigh muscles of guinea fowl broilers in this study were higher than those reported earlier in broiler chickens (Laudadio and Tufarelli, 2010), demonstrating that the muscles of guinea fowl broilers tend to be darker in color than those of broiler chickens.

Total lipid content of meat contributes to both the flavor and, most importantly, the nutrient composition of poultry. Phospholipids act as essential components of cell membranes and play a key role in their structure and function. A significant number of studies have demonstrated that phospholipids have many health functions, such as enhancing memory performance of the aging brain, preventing atherosclerosis, inflammation, and hyperlipidemia (Park and Pariza, 2007; Tian et al., 2010). In the present study, the higher concentration of phospholipids found in the muscle of birds fed the pea diets compared with those fed the SBM control diet is probably a reflection of the higher total lipid or fat content of guinea fowl broilers on the pea diet as a result of the enhanced fatness of their meat as previously reported by Wood et al. (2008). There was little difference in the proportion of phospholipids relative to total lipids (25 and 30%, respectively, for the pea and SBM control dietary groups). The increase in total lipid content of breast meat in guinea broilers fed peas could be related to the diet, which played an important role in altering the content of total lipid. The cholesterol content in poultry meat is one of the most important quality indices and its level in meat can be modified by feed ingredients (Ponte et al., 2004). In our study, the breast and thigh muscle of birds fed the pea-based diet contained a lower level of cholesterol than those fed the SBM-based diet, which may also be attributed to the difference in feed composition. The micronized pea-based diet may contain biologically active substances capable of influencing metabolism of cholesterol in poultry and ultimately altering the cholesterol content in meat of poultry species such as the guinea fowl broiler.

Feeding dehulled-micronized peas was associated with a reduction of total SFA and MUFA and an increase in PUFA of guinea fowl broilers. The production of meat containing high concentrations of PUFA is of considerable interest because PUFA are considered as functional ingredients capable of reducing the incidence of coronary heart disease and other chronic diseases (Peiretti et al., 2007). Poultry meat is one of the main dietary sources of PUFA in human diets and is widely consumed all over the world. While the dietary supply of the PUFA, especially the n-3 FA, has declined over the years, poultry meat has been and continues to serve as significant source of these FA (Raper et al., 1992; Rymer et al., 2010).

The inclusion of peas in the diet of guinea fowl broilers was associated with a diminishing concentration of palmitic and stearic acids. These SFA are well known for their outstanding hypercholesterolemic properties that have been implicated in elevating cholesterol levels in blood serum and meat (Baggio et al., 2002). Findings that were in agreement with our observations were reported by Laudadio and Tufarelli (2011) where broiler chickens were fed diets containing micronized pea substituted for SBM. It was also noted that irrespective of dietary treatments, guinea fowl broilers tend to have a higher content of n-3 FA than broiler chickens in the report of Laudadio and Tufarelli (2011). But the greatest contribution in muscle fat of guinea broilers fed the pea diet, even irrespective of the dietary composition, was the concentration of oleic (C18:1) and linoleic (C18:2 n-6) acids. In the present study, the increase in PUFA, particularly EPA and DHA, which was observed in birds fed the pea-based diet, demonstrate that peas could replace a conventional protein source in guinea fowl broiler rations without affecting their productive parameters and meat characteristics. The use of peas in diets improved TI and HH ratio of guinea broiler muscles. These observations indicate that inclusion of peas in diets of guinea fowl and possibly other food animals can enrich these animal proteins with functional food properties providing healthy balanced diets that prevent human diseases. Similar observations were also made in meat of chickens (Castellini et al., 2005) and rabbits (Peiretti et al., 2007).

In conclusion, our trial demonstrated that total replacement of SBM with micronized-dehulled pea meal in diets of guinea fowl broilers had no adverse effect on growth performance and carcass yield. Additionally, inclusion of the pea meal in the diet enriched the meats of guinea fowl broilers with PUFA, thereby improving their nutritional value and offering an alternative method for enhancing the quality and marketability of guinea fowl meat.

ACKNOWLEDGMENTS

The present research was part of the project supported by the Apulia Region, Italy (Programma Integrato per la Prevenzione e la Riduzione dell'Inquinamento da Nitrati di Allevamenti Avicoli, Asse 6, Programma per la Tutela dell'Ambiente).

REFERENCES

Aletor, V. A., K. Eder, K. Becker, B. R. Paulicks, F. X. Roth, and D. A. Roth-Maier. 2003. The effects of conjugated linoleic acids or an α-glucosidase inhibitor on tissue lipid concentrations and fatty acid composition of broiler chicks fed a low-protein diet. Poult. Sci. 82:796–804.

AOAC International. 2000. Official Methods of Analysis. 17th ed. AOAC Int., Gaithersburg, MD.

Baggio, S. R., E. Vicente, and N. Bragagnolo. 2002. Cholesterol oxides, cholesterol, total lipid and fatty acid composition of turkey meat. J. Agric. Food Chem. 50:5981–5986.

Bartlett, G. R. 1959. Phosphorus assay in column chromatography. J. Biol. Chem. 234:466–468.

Bell, D. E., and W. D. Weaver Jr. 2002. Feeding commercial egg-type layers. Pages 287–328 in Commercial Chicken Meat and Egg Production. D. E. Bell and W. D. Weaver, ed. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Castell, A. G., W. Guenter, and F. A. Igbasan. 1996. Nutritive value of peas for non ruminant diets. Anim. Feed Sci. Technol. 60:209–227.

Castellini, C., A. Dal Bosco, C. Mugnai, and M. Pedrazzoli. 2005. Oxidative stability and sensory attributes of poultry meat during display according to age and rearing system. Ital. J. Anim. Sci. 5:355–365.

Combes, S., I. González, S. Déjean, A. Baccini, N. Jehl, H. Juin, L. Cauquil, B. Gabinaud, F. Lebas, and C. Larzul. 2008. Relationships between sensory and physicochemical measurements in meat of rabbit from three different breeding systems using canonical correlation analysis. Meat Sci. 80:835–841.

Crepon, K. 2006. Nutritional value of legumes (pea and faba bean) and economics of their use. Pages 332–366 in Recent Advances in Animal Nutrition. P. C. Garnsworthy and J. Wiseman, ed. Nottingham University Press, Nottingham, UK.

Crespo, N., and E. Esteve-Garcia. 2001. Dietary fatty acid profile modifies abdominal fat deposition in broiler chickens. Poult. Sci. 80:71–78.

Diaz, D., M. Morlacchini, F. Masoero, M. Moschini, G. Fusconi, and G. Piva. 2006. Pea seeds (*Pisum sativum*), faba beans (*Vicia faba* var. minor) and lupin seeds (*Lupinus albus* var. multitalia) as protein sources in broiler diets: Effect of extrusion on growth performance. Ital. J. Anim. Sci. 5:43–53.

Douglas, J. H., T. W. Sullivan, R. Abdul-kadir, and J. H. Rupnow. 1991. Influence of infrared (micronization) treatment on the nutritional value of corn and low- and high-tannin sorghum. Poult. Sci. 70:1534–1539.

Folch, J., M. Lees, and G. H. A. Sloane-Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497–509.

Fru-Nji, F., E. Niess, and E. Pfeffer. 2007. Effect of graded replacement of soybean meal by faba beans (*Vicia faba* L.) or field peas (*Pisum sativum* L.) in rations for laying hens on egg production and quality. Jpn. Poult. Sci. 44:34–41.

Igbasan, F. A., and W. Guenter. 1996. The enhancement of the nutritive value of peas for broiler chickens: An evaluation of micronization and dehulling processes. Poult. Sci. 75:1243–1252.

Igbasan, F. A., and W. Guenter. 1997. The influence of micronization, dehulling, and enzyme supplementation on the nutritional value of peas for laying hens. Poult. Sci. 76:331–337.

Kauffman, R. G., G. Eikelenboom, S. M. Merkus, and M. Zaar. 1986. The use of filter paper to estimate drip loss of porcine musculature. Meat Sci. 18:191–200.

Khattab, R. Y., S. D. Arntfield, and C. M. Nyachoti. 2009. Nutritional quality of legume seeds as affected by some physical treatments, Part 1: Protein quality evaluation. LWT-Food Sci. Technol. 42:1107–1112.

Kindt, E., K. Gueneva-Boucheva, J. Rekhter, M. D. Humphries, and H. Hallak. 2003. Determination of hydroxyproline in plasma and tissue using electrospray mass spectrometry. J. Pharm. Biomed. Anal. 33:1081–1092.

Larbier, M., and B. Leclercq. 1994. Nutrition and Feeding of Poultry: Intake of Food and Water. Nottingham University Press, Nottingham, UK.

Laudadio, V., E. Ceci, and V. Tufarelli. 2011. Productive traits and meat fatty acid profile of broiler chickens fed diets containing micronized fava beans (*Vicia faba* L. var. minor) as the main protein source. J. Appl. Poult. Res. 20:12–20.

Laudadio, V., and V. Tufarelli. 2010. Growth performance and carcass and meat quality of broiler chickens fed diets containing micronized-dehulled peas (*Pisum sativum* cv. Spirale) as a substitute of soybean meal. Poult. Sci. 89:1537–1543.

Laudadio, V., and V. Tufarelli. 2011. Pea (*Pisum sativum* L.) seeds as an alternative dietary protein source for broilers: Influence on fatty acid composition, lipid and protein oxidation of dark and white meats. J. Am. Oil Chem. Soc. 88:967–973.

Laudadio, V., and V. Tufarelli. 2012. Effect of treated field pea (*Pisum sativum* L. cv Spirale) as substitute for soybean extracted meal in a wheat middlings-based diet on egg production and quality of early laying brown hens. Arch. Geflügelk. 76:1–5.

McNeill, L., K. Bernard, and M. G. MacLeod. 2004. Food intake, growth rate, food conversion and food choice in broilers fed on diets high in rapeseed meal and pea meal, with observations on sensory evaluation of the resulting poultry meat. Br. Poult. Sci. 45:519–523.

Medugu, C. I., A. O. Raji, J. U. Igwebuike, and E. Barwa. 2011. Alternative cereal grains and cereal by-products as sources of energy in poultry diets—A review. Res. Opin. Anim. Vet. Sci. 1:530–542.

Mikulski, D., J. Jankowski, A. Faruga, and M. Mikulska. 1997. The effect of enzyme supplementation of triticale-barley feeds on fattening performance of turkeys. J. Anim. Feed Sci. 6:391–399.

Nahashon, S. N., N. Adefope, A. Amenyenu, and D. Wright. 2005. Effects of dietary metabolizable energy and crude protein concentrations on growth performance and carcass characteristics of French guinea broilers. Poult. Sci. 84:337–344.

Nahashon, S. N., S. E. Aggrey, A. Adefope, A. Amenyenu, and D. Wright. 2006. Modeling growth characteristics of meat type guinea fowl. Poult. Sci. 85:943–946.

Nalle, C. L., V. Ravindran, and G. Ravindran. 2011. Nutritional value of peas (*Pisum sativum* L.) for broilers: Apparent metabolisable energy, apparent ileal amino acid digestibility and production performance. Anim. Prod. Sci. 51:150–155.

Nasr, J. 2011. Effect of different levels of amino acids on carcass composition and yield in broilers. Anim. Prod. Sci. 51:1123–1126.

Nasr, J., and F. Kheiri. 2011. Effects of different levels of lysine on carcass yields and composition in broiler. Res. Opin. Anim. Vet. Sci. 1:655–661.

Park, Y., and M. V. Pariza. 2007. Mechanisms of body fat modulation by conjugated linoleic acid (CLA). Food Res. Int. 40:311–323.

Peiretti, P. G., P. P. Mussa, L. Prola, and G. Meineri. 2007. Use of different levels of false flax (*Camelina sativa* L.) seed in diets for fattening rabbits. Livest. Sci. 107:192–198.

Ponte, P. I. P., I. Mendes, M. Quaresma, M. N. M. Aguiar, J. P. C. Lemos, L. M. A. Ferreira, M. A. C. Soares, C. M. Alfaia, J. A. M. Prates, and C. M. G. A. Fontes. 2004. Cholesterol levels and sensory characteristics of meat from broilers consuming moderate to high levels of alfalfa. Poult. Sci. 83:810–814.

Raper, N. R., F. J. Cronin, and J. Exler. 1992. Omega-3 fatty acid content of the US food supply. J. Am. Coll. Nutr. 11:304–308.

Rymer, C., R. A. Gibbs, and D. I. Givens. 2010. Comparison of algal and fish sources on the oxidative stability of poultry meat and its enrichment with omega-3 polyunsaturated fatty acids. Poult. Sci. 89:150–159.

Santos-Silva, J., R. J. B. Bessa, and F. Santos-Silva. 2002. Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II. Fatty acid composition of meat. Livest. Prod. Sci. 77:187–194.

SAS Institute Inc. 2004. SAS/STAT User's Guide. Release 8.1. Statistical Analysis System. SAS Institute Inc., Cary, NC.

Savage, T. F., H. S. Nakaue, Z. A. Holmes, and T. M. Taylor. 1986. Feeding value of yellow peas (*Pisum sativum* l. variety Miranda) in market turkeys and sensory evaluation of carcasses. Poult. Sci. 65:1383–1390.

Sperry, W. M., and M. Webb. 1950. A revision of the Sehoenheimer–Sperry method for cholesterol determination. J. Biol. Chem. 187:97–106.

Stein, H. H., A. K. R. Everts, K. K. Sweeter, D. N. Peters, R. J. Maddock, D. M. Wulf, and C. Pedersen. 2006. The influence of dietary field peas (*Pisum sativum* L.) on pig performance, carcass quality, and the palatability of pork. J. Anim. Sci. 84:3110–3117.

Sukhija, P. S., and D. L. Palmquist. 1988. Rapid method for determination of total fatty acid content and composition of feedstuffs and feces. J. Agric. Food Chem. 36:1202–1206.

Sun, Y. M., and M. Luo. 1993. Livestock and Poultry Meat Science. Shandong Science and Technology Press, Jinan, China.

Tian, Y., S. Zhu, M. Xie, W. Wang, H. Wu, and D. Gong. 2010. Composition of fatty acids in the muscle of black-bone silky chicken (*Gallus gellus domesticus brissen*) and its bioactivity in mice. Food Chem. 126:479–483.

Tufarelli, V., M. Dario, and V. Laudadio. 2007. Effect of xylanase supplementation and particle-size on performance of guinea fowl broilers fed wheat-based diets. Int. J. Poult. Sci. 4:302–307.

Tufarelli, V., S. Naz, R. U. Khan, D. Mazzei, and V. Laudadio. 2012. Milk quality, manufacturing properties and blood biochemical profile from dairy cows fed peas (*Pisum sativum* L.) as dietary protein supplement. Arch. Tierzucht 55:132–139.

Ulbricht, T. L., and D. A. T. Southgate. 1991. Coronary heart disease: Seven dietary factors. Lancet 338:985–992.

Woelfel, R. L., C. M. Owens, E. M. Hirschler, R. Martinez-Dawson, and A. R. Sams. 2002. The characterization and incidence of pale, soft, and exudative broiler meat in a commercial processing plant. Poult. Sci. 81:579–584.

Wood, J. D., M. Enser, A. V. Fisher, G. R. Nute, P. R. Sheard, R. I. Richardson, S. I. Hughes, and F. M. Whittington. 2008. Fat deposition, fatty acid composition and meat quality: A review. Meat Sci. 78:343–358.