Dietary micronized-dehulled white lupin (*Lupinus albus* L.) in meat-type guinea fowls and its influence on growth performance, carcass traits and meat lipid profile

V. Tufarelli,[1] R. Demauro, and V. Laudadio

Veterinary Science and Animal Production Section, Department of Emergency and Organ Transplantation, University of Bari "Aldo Moro", 70010 Valenzano, Bari, Italy

ABSTRACT The present study aimed to evaluate the effects of dietary substitution of soybean meal (SBM) with micronized-dehulled white lupin (*Lupinus albus* L. cv. Multitalia) in guinea fowl broilers on their growth performance, carcass traits, and meat fatty acids composition. A total of 120 one-day-old guinea fowl females were randomly assigned to 2 treatments which were fed from hatch to 12 wk of age. Birds were fed 2 wheat middlings-based diets comprising of a control treatment which contained SBM (195 g/kg) and a test diet containing micronized-dehulled lupin (240 g/kg) as the main protein source. Replacing SBM with treated lupin had no adverse effect on growth traits, dressing percentage, or breast and thigh muscles relative to the weight of guinea fowls. A decrease ($P < 0.05$) of abdominal fat was found in guinea fowls fed lupin-diet. Breast muscle from birds fed lupin had higher lightness (L^*) ($P < 0.01$) and redness (a^*) ($P < 0.05$) scores and water-holding capacity ($P < 0.05$) than the SBM-control diet. Meat from guinea fowls fed lupin had less total lipids ($P < 0.05$) and cholesterol ($P < 0.01$), and higher concentrations of phospholipids ($P < 0.01$). Feeding treated lupin increased polyunsaturated fatty acid (PUFA) levels in breast meat and decreased saturated fatty acid (SFA) concentrations. Our findings suggest that replacing SBM as protein source with micronized-dehulled lupin in meat-type guinea fowl diet can improve carcass qualitative characteristics, enhancing also meat lipid profile with no effect on growth traits.

Key words: guinea fowl, sweet lupin, growth, carcass, meat quality, technology

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INTRODUCTION

Consumption of all meat-types are decreasing with the exception of poultry meat, which has increased by 80% in the last 3 decades, and this trend has stimulated interest in improving the poultry meat (Puvača et al., 2014). Enriched poultry products can therefore serve as a vehicle for supplying nutrients such as the omega-3 fatty acids whose human consumption is below recommendations (Laudadio et al., 2012). Modifications of poultry product quality through manipulation of their diet and rearing conditions have been reported (Khan et al., 2012; Dhama et al., 2015). These changes also include enrichment of poultry products with health-promoting substances which has been reported to reduce plasma cholesterol (Elkin, 2006; Laudadio et al., 2015). While the enrichment of broiler meat with ingredients that confer health-promoting properties has been extensively studied, there is lack of such information relating to alternative poultry species, such as the guinea fowl. Meat-type guinea fowl production is a potentially advantageous activity in many countries (Nahashon et al., 2005). Guinea fowl meat, as an alternative to chicken, has already proven to be a cost-effective activity in the United States, Canada, and also in European markets such as France and Italy (Tufarelli et al., 2007; Laudadio et al., 2012). However, there remains a challenge in profitability emanating from the increasing cost of production, which is primarily due to feeding costs. Price variations in the feedstuffs market, the growing cost of conventional feeds such as SBM and corn due to their increased demand in the biofuels industry, and the increasing demand for alternative poultry justifies the need for less-conventional and locally produced feed ingredients that can be used in organic poultry diets (Mieczkowska and Smulikowska, 2005; Mikulski et al., 2012; Krawczyk et al., 2015). Soybean meal (**SBM**) is the most widely used protein source in poultry formulations. However, when SBM price increases, poultry nutritionists seek alternative protein sources that are more economical in formulating least-cost rations.

Lupin (*Lupinus albus* L., namely white lupin) is suited as a feed for poultry due to the high protein content, low alkaloid level (Chiofalo et al., 2012), high level of unsaturated fatty acids

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[1]Corresponding author: vincenzo.tufarelli@uniba.it

(Boschin and Arnoldi, 2011), and is attractive in terms of both price and market availability in many countries (Cazzato et al., 2012). Moreover, the inclusion of lupin in poultry diets can improve the value of raw materials originating from these animals and in this respect, feeds with optimal levels of essential fatty acids will have a substantial effect on the nutritional value of poultry meat (Laudadio and Tufarelli, 2011; Drazbo et al., 2014). The inclusion of a high levels of raw lupin in the diet has been reported to have a detrimental effect on productive performance of broilers and laying hens (Olkowski et al., 2005; Diaz et al., 2006). This was mainly attributed to the presence in seeds of a variety of biologically active compounds usually referred to as antinutritional factors (Son and Ravindran, 2012). According to Cheeke (1998) these could include quinolizidine alkaloids (mainly lupanine in *Lupinus albus*), manganese (if the content of the soil where the lupins are grown is high), oligosaccharides (such as α-galactosides), and saponins. Moreover, Cheeke and Kelly (1989) reported that poultry are much more tolerant of lupin alkaloids than swine. In that study, it was shown that levels of white lupin seed of up to 30% of the diet had little or no growth-depressing effects in poultry, whereas with swine, reduced performance was noted with about 10% dietary lupin. Thus the effects of the antinutritional factors limit the use of raw legumes, although various processing techniques tend to decrease the level of these compounds while increasing the protein content (Khattab et al., 2009; Laudadio et al., 2011).

In many legume seeds, previous studies reported that heat processing such as micronization increases the digestible nutrients available to birds, resulting in enhanced productive performances (Igbasan and Guenter, 1997). Moreover, hull removal from legume seeds increased the levels of nutrients for broilers to a concentrations comparable with SBM (Medugu et al., 2011). Our earlier studies indicated that micronized-dehulled legumes are suitable for inclusion in the diet of both broiler chickens and laying hens (Laudadio and Tufarelli, 2010, 2011, 2012). Nevertheless, to date, little attention has been given to the assessment of the effects of processed legume seeds in the guinea fowls diet. Therefore, the scope of this trial was 2-fold: to assess the effect of the substitution of SBM with dehulled-micronized white lupin in the diet of meat-type guinea fowls on their growth performance; and to evaluate the influence of feeding micronized-dehulled lupin on the profiles of health-promoting substances in guinea fowl meat.

MATERIALS AND METHODS

The present research was conducted 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 governmental Decree 181/2010 and Legislative Decree 267/2003.

Feed Processing

Locally grown lupin (*Lupinus albus* L. cv. Multitalia, the most common lupin cultivar produced in Italy and considered a low-alkaloid variety) seeds were used. Dehulling of lupin seeds was accomplished with the aid of a roller mill and the hulls were separated from the cotyledons by air classification. Seeds were tempered overnight to the preferred moisture content (~240 g/kg) as recommended by Khattab et al. (2009). 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). Processing times for lupin seeds were 1.5 min. 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 in order to obtain a product with average crude fiber content ~3% (Laudadio and Tufarelli, 2011).

Birds and Management

The present trial was conducted in a poultry facility located in the Bari Province, Italy, and involved a total of 120 one-d-old female guinea fowl broilers obtained from a commercial hatchery, and raised in a conventional controlled environment house. Guinea fowls were individually weighed and randomly assigned to 12 concrete floor pens covered with wood shavings. Each pen housed 10 birds and was equipped with a pan feeder and a manual drinker. Birds were reared under standard brooding and rearing conditions as outlined by Bell and Weaver (2002) and were provided 23L:1D throughout the feeding trial.

Dietary Treatments

Guinea fowls were fed 2 experimental diets for 84 d: a wheat middling-soybean meal (control) and wheat middling-micronized-dehulled lupin meal. Each dietary treatment was replicated 6 times, with each replicate comprising one pen of 10 birds. Diets were isoenergetic and isonitrogenous containing 20.5% CP and 12.2 MJ of ME/kg (Table 1) designed to meet or exceed the bird's requirements (Larbier and Leclercq, 1994). Feed (mash form) and water were provided for ad libitum throughout the feeding trial. The BW and ADFI, from which ADG and G:F were calculated, were measured. Birds' mortality rate was recorded.

Table 1. Ingredients, chemical analysis, and fatty acid composition (% of total FA) of diets fed to guinea fowls.

	Diets	
Ingredients, g/kg as-fed basis	Soybean	Lupin
Wheat middlings[1]	741.5	694.0
Soybean meal	195.0	-
Lupin meal[2]	-	240.0
Sunflower oil	17.0	15.0
Calcium carbonate	14.0	16.0
Dicalcium phosphate	13.0	12.0
Vitamin-mineral premix[3]	5.0	5.0
L-Lys HCl	4.4	6.0
Sodium chloride	2.5	2.5
Enzyme[4]	2.0	2.0
Sodium bicarbonate	2.0	2.0
DL-Met	1.6	4.5
Choline chloride	1.0	1.0
Chemical analysis,%		
Dry matter	89.54	89.72
CP	20.49	20.61
Crude fibre	2.98	3.03
Crude fat	3.63	3.53
Ash	5.18	5.21
Chemical analysis[5]		
ME (MJ/kg of diet)	12.1	12.2
Lys,%	1.14	1.02
Calcium,%	1.01	1.02
Met + Cys,%	0.79	0.78
Available P,%	0.31	0.32
Fatty acids,%		
Σ SFA	32.95	32.11
Σ MUFA	31.776	33.91
Σ PUFA	35.28	37.98
Total n-6	31.63	34.02
Total n-3	1.71	2.01

[1]Wheat middlings obtained from durum wheat (*Triticum durum* Desf. cv. Appulo; Laudadio and Tufarelli, 2011).

[2]Lupin meal obtained from dehulled and micronized lupin seeds (*Lupinus albus* L.).

[3]Supplied per kg of diet: vitamin A 12,000 IU; vitamin E, 10 mg; vitamin D 2,200 IU; niacin 35 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.

[4]Provided per kg 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.

[5]Values are the means of 3 analyses per sample.

Sample Collection

From each pen, a total of 3 guinea fowls of average BW were randomly selected on d 84 of the trial following a 12 h fasting period. The birds were individually weighed and killed by cervical dislocation, and then were immediately bled. 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. Breast muscles were immediately stored at -80°C for determining lipid content. The other items were individually stored in plastic bags at 4°C for meat qualitative analysis.

Chemical Analysis

Raw lupin and micronized-dehulled lupin meal were analyzed to determine chemical composition as well as amino acid and total alkaloid content, as described in detail by Laudadio and Tufarelli (2011). Meat samples were analyzed for moisture (method 945.15), ash (967.05) and crude protein (990.03) by oven, muffle furnace, and Kjeldahl methods, respectively (AOAC, 2000). Total lipids were extracted according to the method of Folch et al. (1957). Meat total phospholipid and cholesterol levels were determined using the methods described by Bartlett (1959) and Sperry and Webb (1950), respectively.

Meat Quality Analyses and Fatty Acid Composition

At 24 h after killing, the breast muscle pH was assessed at 2.0 cm depth below the surface using a combined glass-penetrating electrode (Ingold, Mettler Toledo, Greifensee, Switzerland). Color measurements were determined on the carcass surface over the breast muscles and on a freshly exposed cut surface. A Minolta CR-300 chromameter (Minolta, Osaka, Japan) was set to the L^* (lightness), a^* (redness), and b^* (yellowness) Commission Internationale de l'Eclairage scale (Combes et al., 2008). Drip loss was measured by the filter paper method as reported by Kauffman et al. (1986).

Breast meat water-holding capacity (**WHC**) was measured after killing according to Sun and Luo (1993). A 0.5 g breast muscle sample was pressed onto oven dried Whatman 125 mm filter paper (Maidstone, Kent, UK) at 207 bar. The value of WHC was 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).

In preparation for fatty acid (**FA**) composition analysis, samples of diets and breast 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, and the organic phase was then 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

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

	Diet			
Item[1]	Soybean	Lupin	SEM	*P*-value
Final BW, g	1,968	1,960	29.96	0.292
ADG, g/day	23.2	23.1	0.31	0.417
ADFI, g/day	66.7	65.0	0.49	0.042
G:F, g/g	2.87	2.82	0.07	0.051
Mortality,%	1.7	1.2	0.09	0.339

[1]BW, body weight; ADG, average daily weight gain; ADFI, average daily feed intake; FCR, feed conversion ratio.

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 were 250°C. Samples (1 μl) were injected by an auto-sampler. Output signals were identified and quantified from the retention times and the peak areas of known calibration standards. Composition was expressed as percentages of the total FA. The saturation (S/P) index was calculated as follows: S/P = (C14:0 + C16:0 + C18:0)/ΣMUFA + ΣPUFA, where: MUFA = monounsaturated FA and PUFA = polyunsaturated FA.

Statistical Analysis

Data were analyzed using the ANOVA option of the GLM of SAS/STAT software (SAS Institute, Cary, NC) (2004) as a completely randomized design with the 2 dietary treatment or protein sources (soybean and lupin) as main effects, and the pen was the experimental unit. The statistical model used was as follows: $Y_{ijk} = \mu + P_i + R_{ij} + (_{ijk}$, 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 $(_{ijk}$ = the intra-experimental unit error term. When there was a significant *F*-value, means were compared by T-test. Unless stated otherwise, significance implies $P < 0.05$.

RESULTS

The mean growth performance of guinea fowls fed diets containing either SBM or micronized-dehulled lupin are presented in Table 2. Mean differences in BW, ADG and FCR of the birds fed the SBM-based diet were not different ($P > 0.05$) from those fed the dehulled-micronized lupin diet. Likewise, mean mortality rate was low and was not different between the 2 treatments (~1.0%, $P = 0.339$). Conversely, after 12 weeks, the guinea fowls from lupin group were characterized by a lower ADFI ($P = 0.042$).

Eviscerated carcass yield, determined after the removal of the head, neck, and feet, was approximately 69.0% and it was also not different ($P = 0.441$) between the 2 dietary groups (Table 3). Further, the breast and thigh plus drumstick yields were similar between the

Table 3. Effect of dietary protein source on carcass yield and breast meat quality of guinea fowl broilers at 12 weeks of age.

	Diet			
Item	Soybean	Lupin	SEM	*P*-value
Carcass traits[1]				
Eviscerated carcass	69.3	69.0	0.17	0.441
Breast	23.4	23.0	0.12	0.596
Thigh and drumstick	22.5	22.1	0.13	0.113
Abdominal fat	1.88	1.41	0.08	<0.05
Meat quality				
pH_{24}[2]	5.72	5.70	0.03	0.332
L^* (lightness)	47.03	48.23	0.49	<0.01
a^* (redness)	16.15	17.19	0.39	<0.05
b^* (yellowness)	5.74	5.61	0.27	0.299
WHC[3],%	61.47	62.55	0.35	<0.05
Drip loss,%	1.52	1.49	0.07	0.257
Moisture,%	73.35	73.64	0.37	0.301
Protein,%	23.52	23.44	0.21	0.367
Fat,%	1.84	1.65	0.12	<0.05
Ash,%	1.29	1.27	0.04	0.441

[1]Percentage of body weight at slaughter; [2]pH_{24}, pH at 24 h post-mortem; [3]WHC, water-holding capacity.

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	Lupin	SEM	*P*-value
Total lipids, g/kg	0.18	0.17	0.022	<0.05
Total phospholipids, mg/g	4.25	5.05	0.101	<0.01
Total cholesterol, mg/g	0.41	0.31	0.019	<0.01

treatments. A decrease in abdominal fat pad content however was found in guinea fowls fed the lupin-based diet when compared to the control SBM diet (1.41 vs. 1.88%, respectively; $P < 0.05$). Breast meat pH was not different among the dietary treatment groups. While meat drip loss, moisture, protein, or ash percentage of guinea fowl broilers fed either of the 2 dietary treatments were not significantly different, birds fed the processed lupin-based diet showed a decrease in fat when compared to those fed the SBM diet ($P < 0.05$). Including processed lupin meal in the guinea fowls diet increased the lightness and redness of the breast meat ($P < 0.01$ and $P < 0.05$, respectively), as depicted by higher L^* and a^* values. The breast meat WHC of guinea fowls fed the lupin meal was higher than those on SBM based diet ($P < 0.05$).

The effect of the diets on the total lipids, phospholipids, and cholesterol levels of the guinea fowls breast meat are reported in Table 4. Total lipids and cholesterol level in breast meat from birds fed the micronized-dehulled lupin diet were lower than those of control SBM diet ($P < 0.05$ and $P < 0.01$, respectively). Conversely, the breast meat of guinea fowls on the micronized-dehulled based diet exhibited higher phospholipids content when compared to birds fed the control treatment ($P < 0.01$).

The breast meat FA compositions of guinea fowls fed the SBM control and the micronized-dehulled lupin

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 weeks of age.

	Diet			
Item	Soybean	Lupin	SEM	*P*-value
C12:0 Lauric	1.22	1.11	0.13	0.071
C14:0 Myristic	4.34	4.47	0.15	0.103
C16:0 Palmitic	20.51	19.01	0.20	0.066
C18:0 Stearic	0.71	0.40	0.12	<0.05
C14:1 n-5 Myristoleic	0.42	0.51	0.07	0.123
C16:1 n-7 Palmitoleic	4.62	4.63	0.11	0.202
C18:1 n-9 Oleic	35.26	33.92	0.21	<0.05
C18:2 n-6 Linoleic	28.42	29.79	0.17	<0.05
C18:3 n-3 α-Linolenic	0.27	0.45	0.05	<0.05
C18:3 n-6 γ-Linolenic	0.55	0.75	0.08	<0.05
C20:4 n-6 Arachidonic	0.79	1.19	0.08	<0.01
C20:5 n-3 EPA	1.34	1.63	0.13	0.062
C22:5 n-3 DPA	0.98	1.42	0.11	<0.01
C22:6 n-3 DHA	0.57	0.72	0.07	<0.05
Σ SFA	26.78	24.99	0.25	<0.05
Σ MUFA	40.30	39.06	0.30	<0.05
Σ PUFA	32.92	35.95	0.31	<0.01
Σ PUFA n-6	29.76	31.73	0.22	<0.05
Σ PUFA n-3	3.16	4.22	0.12	<0.05
n-6/n-3[1]	9.42	7.52	0.11	<0.05
S/P[2]	0.37	0.33	0.03	0.207

EPA, eicosapentaenoic acid; DPA, docosapentaenoic acid; DHA, docosahexaenoic acid.

[1]n-6/n-3, PUFA n-6/PUFA n-3 ratio.

[2]S/P, saturated fatty acid/unsaturated fatty acid.

diets are presented in Table 5. The FA profiles of breast muscle when birds were fed the lupin diet reported a lower fraction of total saturated FA (**SFA**) and monounsaturated FA (**MUFA**) ($P < 0.05$) when compared to those fed a diet containing SBM. The percentage of total polyunsaturated FA (**PUFA**) however was about 9% higher ($P < 0.01$) in meats from guinea fowls fed the micronized-dehulled lupin-based diet, particularly docosapentaenoic (**DPA**; +44%; $P < 0.01$) and docosahexaenoic (**DHA**; +26%; $P < 0.05$) acid. The n-6 to n-3 ratio (n-6/n-3) was lower in guinea fowls on the lupin-based diet than birds fed SBM. The differences in the saturation index (S/P) were not different; however, the percent content of n-6 PUFA in guinea fowls breast muscle fed lupin diet was higher ($P < 0.05$) than that those fed the SBM, whereas n-3 PUFA resulted greater ($P < 0.05$) in meat from birds fed lupin treatment.

DISCUSSION

In meat-type guinea fowls, dietary micronized-dehulled sweet lupin and its effects on growth traits and meat quality have not been investigated. Thus, cross-referencing of our findings will be based on available data from the literature of other poultry species such as chickens and/or turkeys. Our hypothesis is that processed legume seeds would confer functional properties to guinea fowl meat, such as improving the content of n-3 and n-6 FA.

The chemical analysis revealed that the total alkaloid content of processed sweet lupine seeds used in our study was very low compared with the values previously reported for sweet varieties of lupin (Sujak et al., 2006). In another recent study conducted by Zduńczyk et al. (2014), the total alkaloid content of low-alkaloid lupine cultivars was 0.027%, with lupanine as the predominant constituent. Our values agree with those observed by Resta et al. (2008) who determined total alkaloid contents in the different cultivars of lupin.

From our findings, it was found that the inclusion of processed lupin meal at 240 g/kg in the guinea fowl diet did not negatively affect the growth rate of birds during the whole feeding trial; whereas, a reduction of ADFI was noted in the lupin group, this result did not however result in a significant worsening of FCR. The results of the present study are in agreement with those recently observed by Krawczyk et al. (2015) who found that the inclusion of yellow lupine seeds at up to 24% in turkey diets did not depress the growth rate of birds. A comparable trend was also reported by Nalle et al. (2011) in broiler chickens fed diets containing 20% of three narrow-leaved lupin cultivars, which showed influence on ADG, ADFI, and feed efficiency compared with a control soybean diet. Growth performances were also similar when SBM was partly replaced with up to 24% of white lupin in broiler diets (Laudadio and Tufarelli, 2011; Nalle et al., 2012). The satisfactory growth traits of meat-type guinea fowls fed a diet containing sweet lupin meal were consistent with previous reports conducted on broiler chickens and turkeys by Laudadio and Tufarelli (2011) and Zduńczyk et al. (2014), respectively. Hence, our level of micronized-dehulled lupin meal in the diet could be considered to be the optimal level of inclusion in order to obtain the same productive performance of meat-type guinea fowls fed conventional feed formulations, as the feed efficiency values between dietary groups were comparable.

In our study, no differences were reported for dressing percentage and contents of major muscles (breast, drumstick, and thigh) in guinea fowl carcasses fed a diet with and without micronized-dehulled lupin meal, with the exception of the abdominal fat pad that was reduced by feeding lupin. Recent studies conducted by Laudadio and Tufarelli (2011) and Laudadio et al. (2012) evaluating the effects of diets containing micronized-dehulled legume meals (lupin and pea, respectively) found that carcass parts yield was not affected in broiler chickens and guinea fowls fed these legume seeds when compared to birds fed conventional soybean meal-based rations. More recently, Krawczyk et al. (2015) reported that lupin-based diets did not cause significant changes in carcass characteristics of turkeys, except for abdominal fat pad and gizzard weights that tended to increase in birds fed lupin. In the present study, the weight of the breast muscle portion of guinea fowl carcasses for birds which had been fed lupin meal correspond to the average breast muscle weight of the French guinea fowl reported earlier in Nahashon et al. (2005) and Laudadio et al. (2012) in Pearl Grey guinea fowl. As for birds fed the SBM-based

diet, the optimal productive performance when fed the lupin diet is in part attributed to a well-balanced amino acid profile coupled with the supplementation of lysine, methionine, and threonine. In fact, the dietary inadequacy and balance of amino acids is well known to be the main reason for diminished content of breast muscle in poultry carcasses (Nasr, 2011).

The meat color indexes of guinea fowls were influenced by the dietary substitution of SBM for micronized-dehulled lupin meal. As is well known, meat color is a valuable indicator of quality and one of the first characteristics noted by consumers, especially in boneless products. Including lupin meal in the diet led to higher values of lightness in the breast meat. These values were in the optimal range as also reported by Woelfel et al. (2002). Furthermore, our findings are also consistent with a previous report by Laudadio et al. (2012) for guinea fowls fed other processed legume seeds (field pea). Total lipid content of the meat contributes to both the flavor and, most importantly, the nutrient composition of poultry. Phospholipids are an essential component of cell membranes and are fundamental to their function and structure. A significant number of studies have demonstrated that phospholipids have different positive health functions (Tian et al., 2010). In the present study, the higher concentration of phospholipids found in the muscles of birds fed the lupin diet, when compared to soybean, was a reflection of the total lipid content of guinea fowls on the lupin diet, as a result of the improved fatness of their meat (Wood et al., 2008). The level of cholesterol in poultry meat is one of the most important qualitative characteristics for consumers and its concentration can be efficiently modified by diet (Dhama et al., 2015). In the present study, the breast meat of guinea fowls fed a treated lupin-based diet contained a lower level of cholesterol than those fed the SBM-control diet, which may be attributed to the difference in feed composition.

Feeding meat-type guinea fowls with micronized-dehulled lupin resulted in a reduction of total SFA and MUFA, and in increased PUFA. The production of meat containing high levels of PUFA is of considerable interest, because of PUFA are considered to be functional ingredients capable of reducing the incidence of coronary heart disease and other chronic diseases in humans (Rymer et al., 2010; Laudadio et al., 2015). Including sweet lupin in the guinea fowls diet was associated with a diminishing level of stearic (C18:0) acid, and the SFA is well known for its hypercholesterolemic properties being implicated in elevating cholesterol levels in both serum and meat (Baggio et al., 2002). It was noted that guinea fowls tend to have a greater content of n-3 FA in meat than broiler chickens as reported by Laudadio et al. (2012). The higher numbers of very long-chain n-3 PUFAs can be explained by the fact that guinea meat has more phospholipids, and very long-chain n-3 PUFAs are preferentially incorporated into phospholipids vs. triglycerides. In addition, it is also possible that guinea fowls have more active hepatic fatty acid desaturase and elongase enzyme activities and are able to convert more α -linolenic acid to EPA, DPA, and DHA. However, the greatest contribution to the muscle fat of guinea fowls fed the lupin diet resulted from the levels of linoleic (C18:2 n-6), linolenic (C18:3 n-3), and arachidonic (C20:4 n-6) acids. In our study, an increase in PUFA, particularly DPA and DHA, was observed in guinea fowls fed the lupin-based diet, whereas the n-6/n-3 was lower in birds on the lupin-based diet. This finding is an indication that the breast muscle of guinea fowls fed the processed legumes exhibited a higher content of the n-3 FA than those on the SBM diet, and that the lupin could replace a conventional protein source, such as SBM, in guinea fowls rations without negatively affecting their meat quality.

In conclusion, our feeding study demonstrated that the total replacement of soybean with micronized-dehulled lupin meal in the diet of meat-type guinea fowls supported both productive performance and carcass yield. In addition, dietary inclusion of processed lupin enriched the guinea fowl meat with PUFA, thereby enhancing its nutritional value and also offering a viable alternative means of improving the quality and marketability of guinea fowl-meat.

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