«Research Note»

**Feeding of Low-Fibre Sunflower (*Helianthus annus* L.)
Meal as Substitute of Soybean Meal in Turkey Rations:
Effects on Growth Performance and Meat Quality**

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Soybean meal (SBM) is the most widely and expensive protein source used in the formulation of poultry diets; however, when the price of SBM increases, poultry nutritionists seek alternative sources that are more economical in formulating least-cost rations. This research aimed to evaluate the effects of air classified sunflower meal (SFM) in diets of turkeys on their growth performance, carcass yields and meat quality. A total of 140 1-d-old female turkeys (Nicholas 500) were randomly assigned to two dietary treatments which were fed from hatch to 16 wk. The birds were fed two wheat middlings-based diets comprising of a control diet which contained SBM (145 g/kg) and a test diet containing micronized-air classified SFM (172 g/kg) as the main protein source. The substitution of SBM with sunflower had no adverse effect on growth performance and dressing percentage, improving breast and thigh muscles relative weights of the turkeys. A significant effect was found for feed intake ($P<0.05$) which was lower in birds fed diet containing sunflower compared to those fed soybean, without however any negative effects on feed efficiency ($P<0.05$). Meat from turkeys fed the sunflower diet had less cholesterol ($P<0.01$) and higher concentrations of phospholipids ($P<0.01$). Our results suggest that replacing the conventional SBM as protein source, with micronized-air classified SFM in diets of turkeys can improve carcass quality and favourable lipid profile without adverse effects on growth traits, reducing also the production costs.

Key words: growth performance, meat quality, sunflower, turkey

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Introduction

The 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.

Sunflower (*Helianthus annus* L.) is high oil-yielding seed crop cultivated worldwide, that adapts very well to a wide range of climatic and soil conditions. Sunflower meal (SFM), a by-product of sunflower oil extraction, is mainly available as animal feed (Kalmendal *et al.*, 2011). The energy content of SFM compares favorably with that of other oilseed meals and increases as the residual oil content increases and as the fiber content decreases. Moreover, compared to soybean or

rapeseed meal, SFM contains low antinutritional compounds and it is more resistant to contaminants (Canibe *et al.*, 1999; Bozzo *et al.*, 2008). Despite its dark appearance, lower energy, and the higher fiber content, as compared to SBM, the SFM is a competitive product with potential for continued improvement through the use of tail-end screening to further reduce its fiber content.

The SFM can be fed to many classes of livestock species and most SFM is fed to ruminants (Tufarelli *et al.*, 2009), but it has been reported that SFM could be successfully used also in poultry (Brenes *et al.*, 2008). However, the SFM crude fiber content may be up to three fold higher than SBM, with the portion of fiber originating from the husk being highly lignified and resistant to bacterial degradation in the digestive tract (Montagne *et al.*, 2003). This problem may be overcome by reducing the fiber content of SFM. Some promising results have been reported when meals are heat treated (Laudadio and Tufarelli, 2010b), pin-milled (Wu and Nichols, 2005) or air classified (Laudadio *et al.*, 2013).

Air classification is used to produce protein concentrates in cereals and legumes (Wu & Nichols, 2005). This process

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differentiates the protein (fine fraction) and fiber (coarse fraction) particles (Owusu-Ansah and McCurdy, 1991). The fine and light particles contain protein, whereas the coarse and heavier particles mostly contain fibrous granules. The fine particles enriched in protein may be useful for general food and feed applications, while the coarse fraction was rich in fiber and appropriate as a dietary fiber source (Ferrari *et al.*, 2009). Recently, the application of micronization in food and feed research has shown that the reduction of the particle size of various fiber-rich plant materials alters the structure, surface area and functional properties of the particles. Thus, micronization coupled to air fractionation was considered a useful tool for improving some technological performances and nutritional properties as well as to enrich the meal fractions of healthy compounds (Rizzello *et al.*, 2012). Our recent studies indicated that treated seeds result suitable for use in the diets of broiler chickens and laying hens as well as guinea fowls (Laudadio *et al.*, 2011; Laudadio and Tufarelli, 2012; Laudadio *et al.*, 2012). However, little attention has been given to the evaluation of the effects of processed SFM in turkey diet.

Therefore, our objective was to evaluate the effect of substitution of SBM with micronized-air classified SFM, which may have potential as feed ingredient for turkeys; and to evaluate the effect of feeding sunflower on profiles of health-promoting substances in turkey meat.

Materials and Methods

Experimental Birds and Management

The experiment was conducted observing the animal welfare Legislative Decree 116/92, Council Directive 98/58/EC, received in Italy by Legislative Decree 146/2001, Council Directive 2007/43/CE, received in Italy by Legislative Decree 181/2010 and Legislative Decree 267/2003.

A total of 140 1-d-old female turkeys (Nicholas 500) 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. 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 23h light: 1h darkness throughout the experimentation period.

Dietary Treatments

The turkeys were fed for 112 d (16 wk) two experimental diets, a wheat middling-soybean meal (control) and wheat middling-micronized-air classified sunflower meal. Each diet was replicated seven times, with each replicate comprising one pen of 10 birds. The diets (Table 1) were isocaloric and isonitrogenous containing 21.2% CP and 11.9 MJ of ME/kg of diet, designed to meet or exceed the bird's requirements (Larbier and Leclercq, 1994). The metabolizable energy (ME) of the diets was estimated using the Carpenter and Clegg equation (Leeson and Summers, 2001). Feed (pellet form) and water were provided *ad libitum* throughout the whole trial. The BW and cumulative feed intake, from

Table 1. **Ingredient and chemical analysis of the experimental diets**

Ingredient, g/kg	Diets	
	Soybean	Sunflower
Wheat middlings ¹	784.7	754.8
Soybean meal (44% CP)	145.0	—
Sunflower meal ² (42% CP)	—	172.0
Sunflower oil	20.0	24.0
Dicalcium phosphate	20.0	18.0
Calcium carbonate	12.0	11.0
Vitamin-mineral premix ³	5.0	5.0
L-Lys HCl	4.0	6.5
DL-Met	2.4	2.1
Sodium chloride	2.0	1.8
Sodium bicarbonate	2.0	1.8
Thr	1.6	1.7
Enzyme ⁴	0.8	0.8
Choline chloride	0.5	0.5
Chemical analysis, %		
Dry matter	89.8	89.9
Crude protein	21.3	21.2
Crude fibre	4.4	4.7
Crude fat	5.0	5.2
Ash	6.4	6.3
Calculated analysis		
ME (MJ/kg of diet)	11.9	11.9
Ca, %	1.09	1.02
Lys, %	0.96	0.97
Met+Cys, %	0.82	0.83
Thr, %	0.67	0.64
Available P, %	0.43	0.42

¹ Low-fiber wheat middlings obtained from durum wheat (Laudadio and Tufarelli, 2011).

² Low-fiber sunflower meal obtained from micronized and air classified sunflower meal (Laudadio *et al.*, 2013).

³ 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.

⁴ Provided per kilogram of product: Endo-1, 4-beta-glucanase, 800,000 U; Endo-1, 3 (4)-beta-glucanase 1,800,000 U; Endo-1, 4-beta-xylanase 2,600,000 U.

which ADG and feed conversion ratio (FCR) were calculated, were measured. Mortality was recorded as it occurred.

Preparation of Feed Ingredients

The two dietary protein sources evaluated were soybean meal (SBM; 44% CP) and micronized-air classified sunflower meal (SFM; *Heliantus annuus* L.) having 42% CP and 2.4% crude fiber as reported by Laudadio *et al.* (2013). 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, 2010a). The SFM, from commercial supplier, was used as a starting research material. Briefly, the SFM fractionation

was carried out through a turbo-separator and a cyclone which were in series assembled. The apparatus sorted meal into two portions: coarse and fine fractions, respectively. Sunflower meal were micronized in a KMX-300 device (100–200 kg/h; SeparMicroSystem, Brescia, Italy), then the obtained meal was fractioned by air classification with an SX-100 apparatus (SeparMicroSystem).

Sample Collection and Processing Procedures

On d 112 of the trial, three turkeys of average BW were randomly selected from each pen following a 12-h fasting period and weighed individually. Birds were then manually caught and crated in plastic crates, then they were transported less than 0.3 km to the processing facility. Turkeys from each dietary treatment were electrically stimulated with a device consisting of conventional shackles suspended above a 1% NaCl solution bath. The device was wired such that, when the turkeys were hung from the shackles and their heads immersed in the salt water, electric current flowed through the birds from head to feet. Birds were stimulated during bleeding with a fixed voltage of 150 V alternating current intermittently (2 s on, 1 s off) for 1 min. Current during the stimulation phases varied from 115 to 125 mA per bird. Immediately following stunning, the birds were killed by bleeding for approximately 180 s until death from a single unilateral neck cut severing the right carotid artery and jugular vein. After bleeding, turkeys were scalded for 120 s at 63°C in an air-agitated commercial scalding and plucked for 30 s in a commercial inline plucker. After the head, shanks and feet, and feathers were removed, the carcass was eviscerated.

The abdominal fat (consisting of fat surrounding the gizzard, proventriculus and in 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 Analysis

At 24 h after killing, the breast and thigh muscle pH was assayed at 2.0 cm depth below the surface. Measurement was performed using a combined glass-penetrating electrode (Ingold, Mettler Toledo, Greifensee, Switzerland).

The water-holding capacity (WHC) of breast and thigh meat was determined after killing according to Sun and Luo (1993). A total 0.5 g muscle sample was pressed onto an oven-dried Whatman 125-mm filter paper (GE Healthcare, Buckinghamshire, England) 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, USA).

Measurements of color were determined on the carcass surface over the breast muscle 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) CIE scale, as reported by Combes *et al.* (2008). Meat drip loss was measured by the filter paper

method as suggested by Kauffman *et al.* (1986).

Meat samples were analyzed for moisture (945.15), ash (967.05) and crude protein (990.03) by oven, muffle furnace and Kjeldahl methods, respectively, as described in AOAC (2004). Total lipids were extracted according to the method of Folch *et al.* (1957). Phospholipids and total cholesterol content of the meat samples were quantified using the procedures described by Bartlett (1959) and Sperry and Webb (1950), respectively.

Statistical Analysis

Data were analyzed using the ANOVA option of the General Linear Model of SAS/STAT software (SAS Institute, Inc., Cary, NC, USA) as a completely randomized design with the two dietary treatment or crude protein sources (SBM and SFM, respectively) as main effects. When there was a significant *F*-value means were compared by the Student-Newman-Keuls method. Significance level implies $P < 0.05$ unless stated otherwise.

Results

The mean performance parameters of turkeys fed diets containing either SBM or micronized-air classified SFM are presented in Table 2. Mean differences in final BW and ADG of the turkeys fed the SBM based diet were not different ($P > 0.05$) from those of birds fed the micronized-air classified SFM diet. Likewise, mean mortality rate was very low and it was not different between birds fed the SBM based control diet and those fed the micronized-air classified SFM based diet (1.31 and 1.27%, respectively). Conversely, after 16 weeks of feeding period, the turkeys from SFM group were characterized by a significantly lower cumulative FI ($P = 0.047$) and FCR ($P = 0.037$), respectively. The carcass dressing yield, which was determined after the removal of the head, neck, and feet, was approximately 80% and was also not different ($P = 0.089$) between the two dietary treatment groups (Table 3). While differences in mean in breast and thigh plus drumstick yields were different between the treatment groups, in fact turkeys fed the micronized-air classified SFM based diet produced heavier breast ($P = 0.045$) and thigh plus drumstick ($P = 0.039$) cuts. However, a slight reduction in abdominal fat pad content was observed in birds fed the SFM when compared with the SBM based diet (0.57 vs. 0.60 %, respectively; $P = 0.075$). The breast and thigh meat pH was not different among the dietary treatment groups. Also the inclusion of micronized-air classified SFM in the diets of turkeys did not affect ($P > 0.05$) the qualitative parameters of meat in terms of protein, fat and ash as well as meat color, WHC and drip loss. However, an higher saturation index (a*/b* ratio) was observed in breast muscle of the birds fed the micronized-air classified SFM than those fed the SBM based diet (0.39 and 0.35 and, respectively; $P < 0.05$), indicating that feeding the micronized-air classified SFM meal increased the darkness of the muscle.

The effects of diet on the total lipids, phospholipids and cholesterol contents of breast muscles of turkeys are reported in Table 3. The total phospholipids concentration in breast meat of turkeys fed the dehulled-micronized pea based diet

Table 2. Effect of the diets on growth performance of turkeys at 16 weeks of age

Item ¹	Diet			
	Soybean	Sunflower	SEM	P-value
Final BW, g	8,663	8,762	49.11	0.078
ADG, g/day	76.4	77.1	0.29	0.059
Cumulative FI, kg	20.03	19.85	0.32	0.047
FCR, g/g	2.31	2.26	0.03	0.037
Mortality, %	1.31	1.27	—	0.698

¹ BW=body weight;
 ADG=average daily weight gain;
 Cumulative FI=cumulative feed intake;
 FCR=feed conversion ratio.

Table 3. Effect of dietary protein source on carcass yield and meat quality parameters of turkeys at 16 weeks of age (*n*=21)

	Diet			
	Soybean	Sunflower	SEM	P-value
Carcass traits ¹				
Dressing percentage	80.7	81.0	0.17	0.089
Breast	25.3	26.7	0.22	0.045
Thigh+drumstick	22.1	23.5	0.19	0.039
Abdominal fat	0.60	0.57	0.04	0.075
Meat parameters				
Breast				
pH ₂₄ ²	5.75	5.78	0.05	0.158
L* (lightness)	48.92	49.03	0.56	0.193
a* (redness)	4.65	4.88	0.62	0.205
b* (yellowness)	12.98	12.59	0.47	0.114
Drip loss, %	0.79	0.66	0.05	0.109
WHC ³ , %	35.12	36.01	0.25	0.092
Moisture, %	72.03	72.21	0.27	0.288
Protein, %	24.71	24.67	0.39	0.119
Fat, %	2.09	1.94	0.18	0.077
Ash, %	1.17	1.15	0.04	0.366
Thigh				
pH ₂₄ ²	5.86	5.90	0.04	0.202
Drip loss, %	0.69	0.65	0.04	0.185
WHC ³ , %	47.33	46.92	0.31	0.101
Moisture, %	73.31	73.50	0.32	0.301
Protein, %	22.85	22.92	0.28	0.141
Fat, %	2.75	2.47	0.11	0.122
Ash, %	1.09	1.11	0.03	0.323
Lipid quality (<i>Pectoralis major</i>)				
Total lipids, g/kg	0.21	0.19	0.011	0.061
Total phospholipids, mg/g	4.05	5.31	0.129	0.015
Total cholesterol, mg/g	0.51	0.41	0.017	0.032

¹ Percentage of body weight at slaughter;

² pH₂₄=pH at 24 h postmortem;

³ WHC=water-holding capacity.

were higher ($P=0.015$) than those of birds fed the SBM based diet. Moreover, the breast meat of birds on the micro-nized-air classified based diets exhibited lower content of

cholesterol ($P=0.032$) when compared to birds fed the control SBM based diet.

Discussion

The inclusion of dietary processed SFM in turkey rations on their productive performance and meat traits have not been previously reported. Therefore, cross-referencing in discussion of finding in this report will be based on findings from other poultry species such as chickens and laying hens. Earlier studies have shown variable effects of SFM on performance in poultry. The satisfactory growth parameters of turkeys fed diet containing processed SFM was consistent with previous reports conducted on broiler chickens fed diets including sunflower (Igbasan and Guenter 1996; Laudadio *et al.*, 2010).

Sunflower meal in this study had significant positive effect on cumulative feed intake and feed to gain ratio of turkeys for 16 week of feeding period. Jankowski *et al.* (2011) reported that a diet with 21% SFM resulted in lower the body weights and depressed feed utilization in Big 6 turkeys aged 18 weeks. However, the same authors found that an addition up to 14% SFM did not adversely affect performance in turkeys. Pinheiro *et al.* (2002) observed that the inclusion of up to 12% SFM/kg diet had no effect on daily gain, but impaired feed conversion ration of fattening broilers. Further, Homayouni and Shivazad (2003) also reported positive results when broiler chickens were fed rations containing 16% SFM.

In a previous research using laying hens, SFM-containing diets (100 g/kg) did not decrease feed intake and egg production when compared to a control diet containing soybean meal. However, a further increase in the content of SFM (150 g/kg) and crude fiber (~60 g/kg) was found to exercise an undesirable influence (Rezaei and Hafezian, 2007). As a result, it seems that the effects of SFM in the diet may depend on the concentration of sunflower in the diet and the species. It was previously reported that high protein SFM can also replace soybean meal in isocaloric diets with equal levels of lysine (Serman *et al.*, 1997) and up to 85% soybean in a lysine-methionine and energy supplemented diet (El-Sherif *et al.*, 1997).

The results obtained in our study indicate that the substitution of soybean meal with micronized-air classified SFM in the diet had no effect on the carcass dressing percentage of turkeys, whereas the SFM-containing diet improved meat cuts. Moreover, the chemical composition as well as physicochemical properties of meat resulted comparable with soybean-control diet. Similar findings were reported by Jankowski *et al.* (2011) where turkeys were fed diets containing different level of SFM substituted for soybean. In their report, the yield of breast and leg muscle portions of the turkeys carcass fed the SFM diet correspond to the average breast muscle weight of the birds reported recently in Werner *et al.* (2009). The color of muscles were not influenced by the dietary substitution of SBM for treated SFM. Meat color is an indicator of meat quality and one of the first characteristics noted by customers, especially in boneless products. In our study, the inclusion of sunflower in the diet led to lighter breast meat; nevertheless, these data were in the

normal range and therefore these muscles would not be considered to be excessively pale (Woelfel *et al.*, 2002).

Meat total lipid content contributes to both the flavor and, most principally, the nutrient composition of poultry meat. Phospholipids act as essential components of cell membranes and play a key role in their structure and function. Many studies have reported that phospholipids have different health functions, such as improving memory performance of the ageing brain, preventing atherosclerosis, inflammation and hyperlipidaemia (Tian *et al.*, 2010). In the present study, the higher concentration of phospholipids found in the muscle of birds fed the sunflower diets when compared with those fed the soybean-control diet is probably a reflection of the higher total lipid or fat content of turkeys on the sunflower diet as a result of the enhanced fatness of their meat as previously found by Wood *et al.* (2008). 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 muscle of turkeys fed sunflower-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 treated sunflower-based diet may contain biologically active substances able of influencing metabolism of cholesterol in poultry and ultimately altering the cholesterol content in meat of poultry species (Laudadio *et al.*, 2012).

In conclusion, our research demonstrated that total replacement of SBM with micronized-air classified SFM in diets of turkeys had no adverse effect on growth performance and carcass yield. In addition, inclusion of the treated sunflower in the diet enriched the meats of turkeys with healthy components, thereby improving their nutritional value and offering an alternative method for enhancing the quality and marketability of turkey-meat.

References

- AOAC, 2004. Official Methods of Analysis, 17th ed. Association of Official Analytical Chemists, Arlington, VA, USA.
- Bartlett GR. Phosphorus assay in column chromatography. *Journal of Biological Chemistry*, 234: 466-468. 1959.
- Bell DE, Weaver Jr. WD. Feeding commercial egg-type layers. in commercial chicken meat and egg production, DE Bell and WD Weaver, Eds. Cluwer Academic Publishers, The Netherlands. pp. 287-328. 2002.
- Bozzo G, Ceci E, Bonerba E, Desantis S, Tantillo G. Ochratoxin A in laying hens: High-performance liquid chromatography detection and cytological and histological analysis of target tissues. *Journal of Applied Poultry Research*, 17: 151-156. 2008.
- Brenes A, Centeno C, Viveros A, Arija I. Effect of enzyme addition on the nutritive value of high oleic acid sunflower seeds in chicken diets. *Poultry Science*, 87: 2300-2310. 2008.
- Canibe N, Martin-Pedrosa M, Robredo LM, Bach-Knudsen KE. Chemical composition, digestibility and protein quality of 12 sunflower (*Helianthus annuus* L.) cultivars. *Journal of the Science of Food and Agriculture*, 79: 1775-1782. 1999.
- Combes S, González I, Déjean S, Baccini A, Jehl N, Juin H, Cauquil L, Gabinaud B, Lebas F, Larzul C. Relationships between sen-

- sory and physicochemical measurements in meat of rabbit from three different breeding systems using canonical correlation analysis. *Meat Science*, 80: 835–841. 2008.
- El-Sherif KH, Gerendai D, Gippert T. Complete substitution of sunflower meal for soybean meal with or without enzyme supplementation in broiler rations. *Archiv Geflügelk*, 61: 8–14. 1997.
- Ferrari B, Finocchiaro F, Stanca, AM, Gianinetti A. Optimization of air classification for the production of β -glucan-enriched barley flours. *Journal of Cereal Science*, 50: 152–158. 2009.
- Folch J, Lees M, Sloane-Stanley GHA. 1957. A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry*, 226: 497–507. 1957.
- Homayouni V and Shivazad M. Effect of various levels of high and low fibre sunflower seed meal on broiler performance. *Journal of Agricultural Science*, 8: 49–60. 2003.
- Igbasan FA and Guenter W. The enhancement of the nutritive value of peas for broiler chickens: An evaluation of micronization and dehulling processes. *Poultry Science*, 75: 1243–1252. 1996.
- Jankowski J, Lecewicz A, Chwastowska-Siwiecka I, Juskiewicz J, Zdunczyk Z. Performance, slaughter value and meat quality of turkeys fed diets with different content of sunflower meal. *Archiv Geflügelk*, 75: 104–112. 2011.
- Kalmendal R, Elwinger K, Holm L, Tauson R. High-fibre sunflower cake affects small intestinal digestion and health in broiler chickens. *British Poultry Science*, 52: 86–96. 2011.
- Kauffman RG, Eikelenboom G, Merkus SM, Zaar M. The use of filter paper to estimate drip loss of porcine musculature. *Meat Science*, 18: 191–200. 1986.
- Larbier M and Leclercq B. Nutrition and feeding of poultry: intake of food and water. Nottingham, Nottingham University Press, UK. 1994.
- Laudadio V and Tufarelli V. Treated fava bean (*Vicia faba* var. minor) as substitute for soybean meal in diet of early phase laying hens: Egg-laying performance and egg quality. *Poultry Science*, 89: 2299–2303. 2010a.
- Laudadio V and Tufarelli V. 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. *Poultry Science*, 89: 1537–1543. 2010b.
- Laudadio V, Bastoni E, Introna M and Tufarelli V. Production of low-fiber sunflower (*Helianthus annuus* L.) meal by micronization and air classification processes. *CYTA – Journal of Food*, 11: 398–403. 2013.
- Laudadio V, Ceci E and Tufarelli V. 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. 2011.
- Laudadio V, Nahashon SN and Tufarelli V. Growth performance and carcass characteristics of guinea fowl broilers fed micronized-dehulled pea (*Pisum sativum* L.) as a substitute for soybean meal. *Poultry Science*, 91: 2988–2996. 2012.
- Leeson S and Summers JD. Nutrition of the Chicken. University Books, Guelph. 2001.
- Montagne L, Pluske JR, Hampson DJ. A review of interactions between dietary fibre and the intestinal mucosa, and their consequences on digestive health in young non-ruminant animals. *Animal Feed Science Technology*, 108: 95–117. 2003.
- Owusu-Ansah YJ and McCurdy SM. Pea proteins: a review of chemistry, technology of production, and utilization. *Food Review International*, 7: 103–134. 1991.
- Pinheiro JW, Fonseca NAN, Silva CA, Cabrera L, Bruneli FAT and Takahashi SE. Farelo de girassol na alimentação de frangos de corte em diferentes fases de desenvolvimento. *Revista Brasileira de Zootecnia*, 31: 1418–1425. 2002.
- Ponte PIP, Mendes I, Quaresma M, Aguiar MNM, Lemos JPC, Ferreira LMA, Soares MAC, Alfaia CM, Prates JAM and Fontes CMGA. Cholesterol levels and sensory characteristics of meat from broilers consuming moderate to high levels of alfalfa. *Poultry Science*, 83: 810–814. 2004.
- Rezaei M and Hafezian H. Use of different levels of high fiber sunflower meal in commercial leghorn type layer diets. *International Journal of Poultry Science*, 6: 431–433. 2007.
- Rizzello CG, Coda R, Mazzacane F, Minervini D and Gobetti M. Micronized by-products from debranned durum wheat and sourdough fermentation enhanced the nutritional, textural and sensory features of bread. *Food Research International*, 46: 304–313. 2012.
- SAS. SAS/STAT 9.13 User's Guide. Statistical Analysis System Inst, Cary, NC. 2004.
- Serman V, Mas N, Melenjuk V, Dumanovski F and Mikulec Z. Use of sunflower meal in feed mixtures for laying hens. *Acta Veterinaria Brno*, 66: 219–227. 1997.
- Sperry WM and Webb M. A revision of the Schoenheimer–Sperry method for cholesterol determination. *Journal of Biological Chemistry*, 187: 97–106. 1950.
- Sun YM and Luo M. Livestock and Poultry Meat Science. Shandong Science and Technology Press, Jinan. 1993.
- Tian Y, Zhu S, Xie M, Wang W, Wu H and Gong D. Composition of fatty acids in the muscle of black-bone silky chicken (*Gallus gallus domesticus* brissen) and its bioactivity in mice. *Food Chemistry*, 126: 479–483. 2010.
- Tufarelli V, Dario M and Laudadio V. Milk yield and composition of lactating Comisana ewes fed total mixed rations containing nitrogen sources with different ruminal degradability. *Livestock Science*, 122: 349–353. 2009.
- Werner C, Janisch S, Kuembet U and Wicke M. Comparative study of the quality of broiler and turkey meat. *British Poultry Science*, 50: 318–324. 2009.
- Woelfel RL, Owens CM, Hirschler EM, Martinez-Dawson R and Sams AR. The characterization and incidence of pale, soft, and exudative broiler meat in a commercial processing plant. *Poultry Science*, 81: 579–584. 2002.
- Wood JD, Enser M, Fisher AV, Nute GR, Sheard PR, Richardson RI, Hughes SI and Whittington FM. Fat deposition, fatty acid composition and meat quality: A review. *Meat Science*, 78: 343–358. 2008.
- Wu YV and Nichols NN. Fine grinding and air classification of field pea. *Cereal Chemistry*, 82: 341–344. 2005.