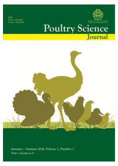

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Effect of Different Levels of Artichoke (*Cynara scolymus* L.) Leaf Powder on the Performance and Meat Quality of Japanese Quail

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Abstract

A total of 240 Japanese quail chicks (1 d old) were used in a 42-d trial to study the effects of Artichoke leaf powder and vitamin E on growth performance and meat quality. This experiment was performed as a completely randomized design with 4 replicates of 15 quails in each, using a 4×2 factorial arrangement with diet and gender as the main effects. Four dietary treatments were formulated by addition of 2 levels (1.5 and 3 percent) of Artichoke leaf powder and 300 mg/Kg vitamin E to the basal diet. Results showed that supplementing the basal diet with Artichoke leaf powder and vitamin E significantly affected growth performance at 21 d of age ($P<0.05$). Dietary treatments significantly affected 2-thiobarbituric acid-reactive substance (TBARS) and water holding capacity (WHC) values of breast meat ($P<0.05$). The value of TBARS in breast meat was not affected by dietary levels of Artichoke leaf powder, whereas the value decreased significantly by vitamin E treatment ($P<0.05$). Quails receiving 1.5 percent Artichoke leaf powder and 300 mg/Kg vitamin E had significantly lower breast meat WHC than those receiving the basal diet ($P<0.05$). Breast meat crude fat and WHC were affected by gender ($P<0.05$). Dietary 3 percent Artichoke leaf powder increased the b* values of thigh meat compared with the control. The lightness of thigh and breast meat and also redness of thigh meat were affected by gender ($P<0.05$). In general, the results indicated that supplementation of diet by Artichoke leaf powder did not improve growth performance of quails, but may have a potential to improve the oxidative stability and meat quality.

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Introduction

Antibiotics, which have been used mainly as growth promoters in farm animals, have been banned or limited in many countries (Hernández *et al*., 2004; Kyprianou, 2005). As a result, there is a growing interest in the feed industry in the identification and evaluation of feed alternatives with less side effects (Hertrampf, 2001; Humphrey *et al*., 2002; Hume, 2011). It has been reported the possibility of growth-promoting and antioxidative effects for some traditional medicinal plants (Park and Yoo, 1999; Liu *et al*., 2006). Moreover, medical plants are being demonstrated to remove not only consumers' concerns regarding antibiotic side effects but also to improve animal performance, quality and shelf life of meat products (Simitzis *et al*., 2008; Vichi *et al*., 2001).

Artichoke *(Cynara scolymus* L.*)* is one of the famous traditional medicinal plants that is widely grown in Mediterranean countries and is rich in natural antioxidants (Mehmetcik *et al*., 2008; Wang *et al*., 2003; Joy and Haber, 2007). The popularity of Artichoke is attributed to phytochemicals, including caffeoylquinic acid derivatives (cynarin and chlorogenic acid) and flavonoids (luteolin, apigenin) (Llorach *et al*., 2002; Wang *et al*., 2003; Joy and Haber, 2007). The Artichoke leaves are higher in medical value than flowers, with antihepathotoxic, choleretic, diuretic, hypocholesterolemic and antilipidemic properties that all are attributed to the phenolic compositions (Sanchez-Rabaneda *et al*., 2003). From a medical point of view, polyphenolic compounds have a great importance as antioxidant, antitumor (Gronbaek *et al*., 1995; Knekt *et al*., 2002) and antimicrobial properties (Zhu *et al*., 2004). The antioxidant and antitumor functions are assumed to result from the radical-scavenging properties of polyphenolic compounds (Wang and Huang, 2004). Nonetheless, owing to the antioxidant capacity of polyphenols and their possible implication in human health in the prevention of cancers, cardiovascular diseases and other pathologies, Artichoke is being subjected to animal feeding. For example, Artichoke extract resulted beneficial when administered to birds challenged with mycotoxins in the diet (Stoev *et al*., 2004). In addition, Azcona *et al*., (2005) demonstrated that a higher metabolizable energy was obtained from the diet, when supplementing with Artichoke extract during the first 21 days of life. These authors documented that this would be explained by a higher lipid digestibility due to an increased bile secretion. Consistent with this explanation, Mariani (1998) reported that the use of Artichoke extract during the first weeks of life may increase the productive response of broilers, as chickens have greater sensitivity to mycotoxins during their first 21 days of life. In addition to this, Mahagna and Nir (1996) documented the fact that during the first days of life, chickens have an immature digestive tract, consequently, bile secretion is insufficient.

In the literature, there are many studies examine using Artichoke extract in rat diets (Mehmetcik *et al*., 2008, Jimenez-Escig *et al*., 2003). However, we could not find in our studies a research regarding the use of Artichoke powder or even extract in Japanese quail feeding. Therefore, we aimed to investigate the effects of using Artichoke leaf powder on growth performance and meat quality in Japanese quail.

Materials and Methods

Plant powder preparation

Artichoke leaves were collected in summer, when the plant was in the vegetative stage, from the research farm (37°00' - 37°30' north latitude and 54°00' - 54°30' east longitude; altitude: 155 m) of Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Golestan, Iran. Collected leaves were shadow dried and ground with a laboratory mill (Iran khodsaz gristmill, ELS 300C, Iran). Nutrient composition of Artichoke leaves was measured (AOAC, 1999) and also total values of phenolic compounds were determined by colorimeter, using Folin- Ciocalteu method (Guo *et al*., 2000) (Table 1).

Table 1. Proximate composition and phenolic compounds of Artichoke leaf powder (As-fed)

Item	Percentage
Moisture	7.70
Protein	11.70
Crude fat	4.49
Crude fiber	23.90
Ash	9.60
NFE	42.61
Ca	0.45
Na	0.22
Total P	0.33
Total polyphenols	7.70
Flavonoids	1.61
Antioxidants	6.92
Gross energy (Kcal/Kg)	3713

Birds and experimental design

A total of 240 Japanese quail chicks (1 d old) were obtained from a local commercial hatchery and raised over a 42-d experimental period. The quails were housed in thermostatically controlled batteries with raised wire floors (60 cm length × 50 cm width × 50 cm height) in an environmentally controlled building. Ambient temperature on d 1 was set at 37±1°C and then gradually reduced to 24°C by d 28 (Nazar *et al*., 2012). A continuous lighting program was provided during the experimental period. The experiment was performed as a completely randomized design with 4 replicates of 15 quails in each, using a 4 × 2 factorial arrangement with diet and gender as the main effects. Four dietary treatments were formulated by addition of 2 levels (1.5 and 3 percent) of Artichoke leaf powder and 300 mg/Kg vitamin E (Niu *et al*., 2009) to the basal diet. Basal diet was formulated to meet or exceed the nutrient recommendations for poultry (Table 2; NRC, 1994). Quails had free access to feed and water throughout the experiment. All experimental protocols were approved by the Animal Care and Use Committee of the College of Animal Science of the Gorgan University of Agricultural Sciences and Natural Resources (Golestan province, Gorgan, Iran).

Table 2. Compositions and calculated analyses of the basal diet[1]

Ingredients (%)	
Corn	48.96
Soybean meal	45.10
Soybean oil	2.89
Dicalcium phosphate	0.75
Calcium carbonate	1.30
Common salt	0.35
Mineral premix[2]	0.25
Vitamin premix[3]	0.25
DL- Methionine	0.15
Calculated analysis	
Metabolize Energy (Kcal/Kg)	2900
Crude protein (%)	24.00
Calcium (%)	0.80
Available phosphorous (%)	0.30
Na (%)	0.15
Lysine (%)	1.39
Methionine (%)	0.50
Methionine + Cystine (%)	0.88

[1]Calculated composition was according to NRC (1994).

[2]Mineral premix (each kg contained): Mn, 50000 mg; Fe, 25000 mg; Zn, 50000 mg; Cu, 5000 mg; Iodine, 500 mg; Choline chloride 134000 mg.

[3]Vitamin Premix (each kg contained): Vitamin A, 3600000 IU; Vitamin D_3, 800000 IU; Vitamin E, 9000 IU; Vitamin K_3, 1600 mg; Vitamin B_1, 720 mg; Vitamin B_2; 3300 mg; Vitamin B_3; 4000 mg; Vitamin B_5; 15000 mg; Vitamin B_6; 150 mg; Vitamin B_9; 500 mg; Vitamin B_{12}; 600 mg; Biotin, 2000 mg.

Traits measured

Body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR) were calculated at the end of wk 3 and 6 for each cage. At the end of the experiment, two birds (one male and one female) from each replicate (8 quails per treatment) were selected and killed by cervical dislocation, and then samples of thigh and breast meat were excised and stored in a freezer (-20˚C) for further analyses after 30 days. Meat quality parameters including crude fat percentage, 2-thiobarbituric acid-reactive substance (TBARS), pH, water holding capacity (WHC), moisture and meat color parameters were measured as follows:

Crude fat and moisture

The moisture and crude fat of the meat samples were determined according to the AOAC (1999) methods.

Thiobarbituric Acid-Reactive Substances (TBARS)

Lipid peroxidation was determined by the modified method of Buege and Aust (1978) by Ahn *et al.*, (1999), as TBARS value. Briefly, a 5-g meat sample was homogenized in 15 mL of distilled water. Meat homogenate (5 mL) was transferred to a test tube. Then 50 µL of butylated hydroxyaniose (7.2%) and 5 mL of TBA-trichloroacetic acid solution (20 m*M* TBA in 15% trichloroacetic acid) were added to the test tube. The mixture was vortexed and then incubated in a boiling water bath for 15 mins to develop color. Samples were cooled in cold water for 10 min and then centrifuged for 15 mins at 966 × *g*. The absorbance of the resulting supernatant was determined at 532 nm, using a spectrophotometer (UV 1600 PC, Shimadzu). The increase in absorbance at 532 nm was taken into consideration to calculate the TBARS values. TBARS numbers were expressed as milligrams of malondialdehyde (MDA) per Kg of meat.

pH

The pH of the meat samples was determined by homogenizing 10 g of meat with 50mL of distilled water. The homogenates were filtered, and the pH of each sample was measured with a pH meter at room temperature (Trout *et al.*, 1992).

Water holding capacity (WHC)

One gram of the sample (minced meat) was placed on a round plastic plate with small holes. The plate with meat sample on it was then fitted into a 2 mL plastic tube. This tube was centrifuged at 1500 × *g* for 4 mins. After centrifugation, the remained water was measured by drying the samples in 70˚C over night (Bouton *et al.*, 1971).

Color

The color of the samples was determined according to CIE system (L*, a*, b*), where: L* = lightness; a* = redness and b* = yellowness (CIE, 1976). Briefly, breast and thigh samples were removed from the freezer, allowed to partially thaw in refrigerator at 2ºC and then the skin of each sample was removed. Then, the color parameters (L*, a*, b*) were measured in breast and thigh meat using a colorimeter (Lovibond CAM-system 500).

Statistical analysis

A completely randomized design was performed with 4 replicates of 15 quails in each, using a 4×2 factorial arrangement with diet and gender as the main effects. Data for growth performance was analyzed based on a completely randomized design, but other parameters were analyzed as a 4 × 2 factorial arrangement of treatments with 4 diets (0, 1.5 and 3 percent Artichoke leaf powder, and 300 mg/Kg Vit. E) and two genders (male and female), using GLM procedure of SAS software (SAS, 2003). The pen mean was an experimental unit for BWG, FI and FCR. Main effect means and the interactions were reported. When significant effects were found, comparisons among multiple means were made by Duncan's multiple range tests. Statistical significance was considered as $P<0.05$.

Results

Growth performance

The effects of different levels of Artichoke leaf powder and 300 mg vitamin E on growth performance of quails are shown in Table 3. The addition of 1.5 percent Artichoke leaf powder did not significantly affect BWG throughout the experiment. Birds treated by 3 percent Artichoke leaf powder and vitamin E treatments showed lower and higher BWG at 21 d of age, when compared with birds fed the basal diet (Table 3). Supplementing basal diet with Artichoke leaf powder and vitamin E did not affect FI at 42 d of age, but vitamin E significantly increased FI at 21 d of age when compared with the birds fed basal and Artichoke supplemented diets. FCR was increased by supplementing the basal diet with 3 percent Artichoke leaf powder at 21 d of age but the effect was not significant at 42 d of age.

Table 3. Influence of supplementation of Artichoke leaf powder and vitamin E in diet on growth performance[1] of Japanese quail from 1-21 and 1- 42 d of age.

Treatments	1 to 21 d			1 to 42 d		
	BWG[1] (g)	FI[2] (g)	FCR[3]	BWG[1] (g)	FI[2] (g)	FCR[3]
Control	99.3^{b}	244^{b}	2.45^{b}	232^{ab}	913	3.93
1.5% Artichoke	96.2^{b}	241^{b}	2.51^{b}	225^{b}	899	4.00
3% Artichoke	87.4^{c}	238^{b}	2.73^{a}	224^{b}	925	4.12
300 mg vitamin E	111.0^{a}	277^{a}	2.50^{b}	242^{a}	976	4.04
SEM	1.96	2.54	0.20	3.46	2.54	0.04
P-value	0.01	0.04	0.01	0.02	0.34	0.45

[1]Body weight gain; [2]Feed Intake; [3]Feed conversion ratio.
[a-c]Means within a column without a common superscript differ significantly ($P<0.05$).

Meat quality parameters

The main effect means of diets and sex and their interactions with crude fat, TBA reactive substances (TBARS), pH, WHC and moisture of thigh and breast meat of quails fed a diet supplemented with 1.5 and 3 percent Artichoke leaf powder and 300 mg/Kg vitamin E are shown in Table 4. Significant interactions between diet and sex on nominated parameters were not observed ($P>0.05$). Diet significantly affected TBARS and WHC of breast meat. Dietary levels of Artichoke leaf powder did not affect breast meat TBARS, whereas vitamin E treatment reduced its value compared to 3 percent Artichoke leaf powder (*P<0.05*). Quails receiving 1.5 percent Artichoke leaf powder and 300 mg/Kg vitamin E had significantly lower breast meat WHC than those receiving the basal diet. Breast meat crude fat and WHC were affected by gender (*P<0.05*). The female quails had higher breast meat crude fat than the males (*P<0.05*), whereas male quails had higher breast meat WHC than females (*P<0.05*).

Table 4. Influence of Artichoke leaf powder and vitamin E on meat quality of thigh and breast meat of Japanese quail

Treatment	Crude fat (%)		TBARS[1] (mg/Kg)		pH		WHC[2] (%)		Moisture (%)	
	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast
Diet:										
Control	16.3	15.5	2.17	2.53^{ab}	6.78	6.16	60.5	57.9^{a}	77.0	73.4
1.5 % Artichoke	17.2	12.4	1.45	2.39^{ab}	6.74	6.19	60.4	55.6^{b}	77.5	74.2
3% Artichoke	13.7	13.6	1.65	3.10^{a}	6.76	6.16	60.2	56.2^{ab}	76.5	73.9
300mg Vitamin E	17.0	15.8	1.67	1.11^{b}	6.70	6.13	58.7	55.4^{b}	77.3	75.3
SEM	0.542	0.417	0.145	0.205	0.017	0.015	0.313	0.258	0.128	0.215
Gender:										
Male	15.7	12.6^{b}	2.00	1.84	6.74	6.14	60.1	57.1^{a}	77.3	73.6
Female	16.4	16.1^{a}	1.47	2.73	6.70	6.11	59.8	55.5^{b}	76.8	74.8
SEM	0.271	0.208	0.072	0.168	0.008	0.008	0.157	0.129	0.064	0.108
Significance:										
Diet	0.366	0.159	0.652	0.128	0.302	0.643	0.460	0.087	0.266	0.185
Gender	0.676	0.008	0.213	0.138	0.366	0.879	0.734	0.033	0.222	0.0503
Diet × Gender	0.938	0.249	0.056	0.505	0.403	0.712	0.148	0.713	0.767	0.700

[1]Thiobarbituric acid reactive substances; [2]Water holding capacity.
[a,b]Means within a column without a common superscript differ significantly (*P<0.05*).

The effect of diets, sex and their interactions with color change of thigh and breast meat of quails fed a diet supplemented with 1.5 and 3 percent Artichoke leaf powder and 300 mg/Kg vitamin E are shown in Table 5. No effect of diet and sex interactions with color change was observed. The main effect of diet was statistically significant only for b* index of thigh meat. In this regard, dietary 3 percent Artichoke leaf powder resulted in higher b* values of thigh meat compared with the control. The lightness of thigh and breast meat and also redness of thigh meat were affected by gender (*P<0.05*). However, a lower L* values was observed in thigh and breast meat of male quails than females (*P<0.05*), whereas thigh meat of male quails showed a higher a* values than female quails (*P<0.05*).

Table 5. Influence of Artichoke leaf powder and vitamin E on color change of thigh and breast meat of Japanese quail

Treatment	L* (lightness)		a* (redness)		b* (yellowness)	
	Thigh	Breast	Thigh	Breast	Thigh	Breast
Diet:						
Control	49.5	40.3	13.5	15.1	3.03[b]	2.82
1.5 % Artichoke	49.0	43.0	14.1	15.6	3.17[ab]	3.51
3% Artichoke	49.4	42.3	14.0	15.4	3.63[a]	3.51
300mg Vitamin E	49.8	43.5	13.8	14.3	3.37[ab]	3.17
SEM	0.655	0.478	0.209	0.173	0.061	0.134
Gender:						
Male	46.5[b]	40.2[b]	15.0[a]	15.2	3.23	2.97
Female	52.3[a]	44.4[a]	12.7[b]	15.0	3.36	3.54
SEM	0.328	0.239	0.105	0.087	0.031	0.067
Significance:						
Diet	0.991	0.372	0.900	0.283	0.109	0.527
Gender	0.005	0.005	0.0007	0.677	0.449	0.150
Diet×Gender	0.416	0.975	0.360	0.410	0.409	0.807

[a,b]Means within a column without a common superscript differ significantly ($P<0.05$).

Discussion

To our best knowledge, this is the first study that evaluates the effects of Artichoke leaf powder in Japanese quail feeding. The results indicated that Artichoke leaf powder did not improve growth performance (BWG, FI, FCR), which is consistent with the findings of Melo and Harkes (2007) who revealed no significant differences among broilers diets supplemented with two levels of Artichoke extract (300 and 600 g/ton) for BWG and FI at the end of studying period. However, our results are in contrast with Melo and Harkes (2007) and Azcona *et al.*, (2005) regarding FCR. Supplementing basal diet with Artichoke extract (600 g/ton) from 1-21 days of age improved feed efficiency of 21 and 42 day-old broilers (Melo and Harkes, 2007). These authors concluded that improved feed conversion may be attributed to the lower feed intake reflected in those birds receiving 600 grams per ton of Artichoke extract. In addition, a better conversion in broilers treated with Artichoke extract was attributed to an improvement in both lipid digestibility and an increase in the metabolizable energy of birds during their first weeks of life (Azcona *et al.*, 2005). These authors explained the better lipid digestibility by an increased bile secretion. Moreover, positive results of Artichoke protection were reported by Stoev *et al.*, (2004) and Mariani (1998). Differences between our results and others may be attributed to the variation of the experimental condition, differences in the type of challenge used (powder *vs.* extract) and probably the environmental stresses including handling, vaccination, and various other instances that lead to a stimulation in bird's immune system and might have negative effects on growth performance (Hevener *et al.*, 1999; Takahashi *et al.*, 2000).

The quality of meat depends on the genetic structure, sex and age of the animal, as well as the environmental temperature at which the animal is reared and the nutrient content of the ration fed which affect post-mortem metabolism (Duclos *et al.*, 2007; Owens *et al.*, 2009; Wang *et al.*, 2009; Imik *et al.*, 2010). The result of crude fat percentage in this study is in agreement with the findings of Onibi *et al.,* (2009), and Sarker *et al.*, (2010). In general, the amount of crude fat in thigh meat is higher than that of breast meat and therefore, and this is the reason why thigh meat is softer and tastier than breast meat. In addition, studies have shown that females of Japanese quails have more fat compared to males (Caron *et al.*, 1990).

The malondialdehyde is an end product of the oxidative degradation of lipids (Del Rio *et al.*, 2005). The results indicated that Artichoke leaf powder did not improve lipid oxidative stability, but vitamin E decreased oxidative degradation of breast lipids as shown by the lower TBARS concentration. Our results are confirmed by the findings of the Bartov and Frigg (1992) and Goni *et al.*, (2007) who reported that vitamin E increases meat oxidative stability. Antioxidants can act by different mechanisms protecting the lipids from the onset of oxidation (Mariutti and Bragagnolo, 2009). In contrast to our findings, Jang *et al.,* (2008) found that using medicinal plants in broiler chickens diet leads to a delay in lipid oxidation. Moreover, there were slight, but not significant, differences between males and females in lipid oxidative indicator with a higher TBARS concentration in male thigh and female breast. A higher TBARS concentration in female breast meat can be attributed to the significantly higher percentage of crude fat in female breast, but a higher concentration of TBARS in male thigh is unknown and needs to be investigated.

The pH value of meat depends on both glycogen content of muscle tissue and the mechanism that converts glycogen into lactic acid (Duclos *et al.*, 2007; Wang *et al.*, 2009; Mikulski *et al.*, 2009). In the present study, the pH value was not statistically significant between experimental treatments, but the lower pH value of the breast meat is an indicator of a better acidification. This could be explained by a higher white fiber in breast muscle. These fibers have a greater glycogen quantity and a higher glycolytic potential which results in lower pH value (Barbut *et al.*, 2008). In the current study, pH values of breast and thigh meat are in a good agreement with the findings of Mikulski *et al.,* (2011) who reported a higher pH value for thigh than breast meat.

The WHC is the capacity of muscle to keep the water bound under specific processing conditions (Almeida *et al.*, 2002). The reduction in the WHC results in poor meat quality such as losses in cooking yield, less tender, less juicy and less tasty (Owens *et al.*, 2000). The WHC is affected by the extent and rate of pH fall post mortem which leads protein denaturation and reduced WHC (Allen *et al.*, 1997). The results indicated that Artichoke leaf powder did not affect WHC of thigh meat, but there was a significant difference between dietary treatments regarding WHC of breast meat. In addition, WHC of breast meat was higher in males than females. Our results coincide with Jang *et al*., (2008) who observed a reduction in WHC in breast meat of broilers treated with a combination of multiple medicinal plants. This reduction is in agreement with the lower breast meat pH which results from glycolytic reaction (Barbut *et al*., 2008). Higher meat pH is more effective for retaining moisture absorption properties (Husak *et al*., 2008; Raach-Moujahed *et al*., 2011). Moreover, a higher intramuscular fat content may also lead to an increase in WHC, which is consistent with our findings.

The findings of this study are confirmed by the results of Onibi *et al*., (2009) who reported that there were no significant differences in moisture percentage values of meat in chickens fed with supplementary raw garlic compared to the control group. Nevertheless, Lahucky *et al*., (2005) reported that adding antioxidants to the diet reduces moisture loss in meat. Moreover, since the higher WHC leads to higher moisture, thigh meat moisture is higher than breast meat moisture in this study.

The natural color of meat depends mainly upon the presence of the myoglobin (muscle pigment) and hemoglobin (blood pigment) pigments. Myoglobin is pink colored and is converted into the red-colored oxymyoglobin as a result of the effect of oxygen. This compound is gradually oxidized into the dull brown-colored metmyoglobin. So, these three compounds define meat color (Barbut, 2002; Mancini and Hunt, 2005). Moreover, poultry meat color is affected by some other factors such as age, sex, strain, diet, intramuscular fat, meat moisture content, preslaughter conditions and processing variables (Santiago *et al*., 2005; Young *et al*., 2001). It has been documented that the older birds have redder meat due to a higher content of myoglobin (Gordon and Charles, 2002). In terms of nutrition, studies showed that the effect of nutrition on meat color is variable. The results of the present study did not demonstrate dietary treatment effect on the color parameters, excluding the b* value of quail thigh meat. In this regards, findings of Leusink *et al*., (2010) indicated that cranberry extract did not have any effect on the color parameters of meat, whereas Karaoğlu *et al*., (2006) reported that probiotics added to the ration influenced the color quality of the carcass. Simitzis *et al*., (2008) explained that dietary oregano essential oil supplementation modifies the meat color, probably by modifying pigment distribution in animal tissues. Moreover, it has been reported that lipid oxidation can stimulate myoglobin oxidation (Erener *et al*., 2011), thereby influencing meat color (Barbut, 1993). An interesting finding here was the lower value of the lightness in breast than thigh meat, which is consistent with the findings of Imik *et al*., (2012) that reported chicken breast meat contains a lower concentration of myoglobin, so its color is lighter than that of chicken thigh. Conley *et al*., (2000) and Obi *et al*., (2010) documented that myoglobin stores oxygen in muscles with higher storage in skeletal and dynamic muscles. The L* value is also under the influence of meat pH. Higher values of L* indicate lighter color, indicating that meat have low pH, whereas lower values indicate that meat are darker and have high pH (Barbut, 1997). When the meat pH is above the isoelectric point of myofibrillar proteins, water molecules are tightly bound, causing more light to be absorbed by the muscle, and meat appears darker in color (Saláková *et al.,* 2009). The pH values of meat is reflected by glycogen reserves of meat (Simitzis *et al.*, 2008), and nutrition is one of the most important factors influencing muscle glycogen levels (Tudor *et al.*, 1996). Therefore, at the present study lower L* values of thigh and breast meat in male quails are partly attributed to higher pH values of thigh and breast meat compared with the female quails. Furthermore, a gender effect on the color parameters (excluding the a* value of breast and the b* value of thigh and breast quail meats) was found in the present study. These findings are in agreement with a previous report (Froning *et al.*, 1968) showing that thigh and breast muscles in male birds are higher in myoglobin content than the females of the same age. Therefore, the redness index in the male quails is higher than the female ones. In terms of b* value, a significant diet effect was observed and also female thigh and breast meat was numerically more yellow than males. The sex effect is likely related to the fat content, as females have more fat content than males (Havenstein *et al.,* 2003; Fanatico *et al.,* 2005).

Conclusion

The data indicate that inclusion of Artichoke leaf powder did not improve growth performance in Japanese quails, but may have the potential to improve oxidative stability and thereby meat quality.

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