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Effect of Artichoke (*Cynara scolymus*) Leaf Powder on Performance and Physicochemical Properties of Frozen Meat of Japanese Quail

Research Article

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ABSTRACT

This study evaluated the effects of artichoke leaf powder on growth performance and physicochemical properties of Japanese quail frozen meat after 3 month storage. A total of 240 Japanese quail chicks (1 d old) were raised over a 42-d 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 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 basal diet with artichoke leaf powder and vitamin E significantly affected growth performance parameters at 21 d of age, but body weight (BW) was the only growth performance which was affected by dietary treatments at 42 of age. Dietary treatments significantly affected only thiobarbituric reactive substances (TBARS) value of thigh meat. Vitamin E dietary treatment reduced TBARS value of thigh meat compared with control ($P<0.05$). The main effect of diet was statistically significant only for b* index of breast meat. In this regard, dietary 1.5 percent artichoke leaf powder resulted in higher b* values of breast meat when compared with control. The lightness values of thigh and breast meats and also redness value of breast meat were affected by gender ($P<0.05$). In general, this study showed that supplementing basal diet of Japanese quail with artichoke leaf powder did not improve growth performance, but has potential to improve oxidative stability and meat quality. In addition, vitamin E showed an improvement in growth performance at 21 d of age and oxidative stability of thigh meat at 42 d of age.

KEY WORDS artichoke, growth performance, Japanese quail, meat quality.

INTRODUCTION

A major problem in the meat industry is a reduction in acceptability and nutritional quality of meat as a result of the lipid oxidation. An approach to overcoming lipid oxidation and its related problems is to use antioxidant compounds such as vitamin E. This vitamin is known as a lipid component of biological membranes and plays an important role as a chain-breaking lipid antioxidant and free radical scavenger in the cell membranes (McDowell, 1989). Vitamin E is mainly found in the hydrocarbon part of cell membrane and in close proximity to oxidase enzymes which initiate the production of free radicals (McDowell, 1989; Packer, 1991). Therefore, vitamin E protects cells and tissues from oxidative damage induced by free radicals. Apart from its protective effects on lipid peroxidation, the immunoregulatory and growth stimulatory effects of vitamin E are well known (Brigelius-flohe and Traber, 1991). However, duo to toxicity properties of synthetic antioxidants (Van Esch, 1986), there is an increasing interest to herbs and medical

plants as natural antioxidant sources to improve meat quality (Kraft, 1997; Fellenberg and Speisky, 2006; Choi *et al.* 2010).

Artichoke is one of these medical plants which has highly potential in antioxidant properties. Artichoke (*Cynara scolymus*) is widely cultivated in Europe and the United States of America. Extensive studies on the chemical components of the artichoke have revealed it to be a rich source of the polyphenol compounds, with mono and dicaffeoylquinic acids and flavonoids as the major chemical components (Wagenbreth, 1996). Two major compounds in the artichoke are the salts of chlorogenic acid and cynarin (1,3-dicaffeoylquinic acid), phenolic compounds that are derivatives of caffeic acid. Extracts containing cynarin have been found to be effective on the treatments of hepatobiliary diseases, hyperlipidaemia and cholesterol metabolism (Zaki *et al.* 1991). Pharmacological and pre-clinical research indicates that artichoke leaf extract (ALE) possesses, among others, hypocholesterolemic and antioxidant properties (Mills and Bone, 1999). These properties are thought to operate through a reduction in de novo cholesterol synthesis via the inhibition of 3-hydroxy-3-methylglutaryl coenzyme A reduc (HMG CoA reductase), an increase in cholesterol elimination in bile secretions, and an inhibition of low-density lipoprotein (LDL) oxidation (Kraft, 1997). Nonetheless, owing to the antioxidant capacity of polyphenols and their possible implication in human health in the prevention of cardiovascular diseases and other pathologies, artichoke is being subjected to animal feeding as natural antioxidant source. In the literature, there are many studies examining the use of artichoke powder or its extract in rat diets. However, there is no study investigating the effects of artichoke leaf powder or extract in Japanese quail. Therefore, we aimed to investigate the effects of artichoke leaf powder as natural antioxidant source on growth performance and meat quality during 3 month frozen storage.

MATERIALS AND METHODS

Plant powder preparation

Fresh artichoke leaves were obtained 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 Science and Natural Resources, Gorgan, Golestan, Iran. The artichoke leaves were prepared according to the following procedure; leaves were cut in pieces and shadow-dried for 10-14 days and then heated in an oven at a temperature below 50 ˚C. The dried leaves were then pulverized to form coarse powder in a grinding machine (Iran Khodsaz gristmill, ELS 300 C, Iran). Nutrient compositions of artichoke leaves were measured, using 1-2,2 Diphenyl-1picrylhydrazyl (DPPH) (Alim *et al.* 2009) and also total values of phenolic compounds were measured by colorimeter, using Folin- Ciocalteu method (Guo *et al.* 2000) (Table 1).

Table 1 Proximate compositions and phenolic compounds of artichoke leaf powder

Item	Percentage
Moisture	7.70
Protein	11.70
Fat	4.49
Crude fiber	23.90
Ash	9.60
Ca	0.45
Na	0.22
P	0.33
Total polyphenols	7.70
Flavonoids	1.61
Antioxidants	6.92

Birds and experimental design

A total of 240 one-day-old Japanese quail chicks were used in accordance with animal welfare regulations at the Gorgan University of Agricultural Science and Natural Resources, Gorgan, Golestan, Iran. 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 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. All birds used in the experiment were fed a basal diet according to applicable recommendations of the national research council, Table 2, (NRC, 1994).

The Japanese quail chicks were offered the experimental diets from 1 to 42 d of age. Feed and fresh water were offered *ad libitum* throughout the experimental period. The room temperature was 37 ˚C during the first week, with a weekly decline of 3.0 ˚C until room temperature (24-27 ˚C) was achieved. Light was provided continuously (24 h) throughout the experiment.

Traits measured

Feed intake (FI) and body weight gain (BW gain) were recorded at the morning of 21 and 42 d of ages before giving feed, from which feed conversion ratio (FCR) was calculated. At 42 d of age, 2 birds (1 male and 1 female) from each replicate (8 birds per treatment) were randomly selected and killed by cervical dislocation.

The slaughtered birds had been fasted for 10 h. From the carcasses, samples of thigh and breast muscles were immediately trimmed of excess fat and washed under running tap water. Thigh and breast meat samples were wrapped in plastic bags and stored at -20 ˚C for 3 months. Meat quality parameters including Thiobarbituric Acid-Reactive Substances (TBARS), pH, water holding capacity (WHC), moisture and meat color were measured as follows:

TBARS: lipid peroxidation was assessed as TBARS values in samples by the method of Ahn *et al.* (1999). Briefly, 5 g of meat sample in 15 mL distilled water was homogenized at 1130 × g for 1 min.

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

Ingredients	% (unless noted)
Corn	48.90
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 and Se: 100 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 and Biotin: 2000 mg.

Homogenated sample (1 mL) was transferred to a test tube. Then, 50 µL butylated hydroxyanisol (7.2%) and 2 mL TBA-TCA solution (20 m*M* TBA in 15% TCA) were added to the test tube. Tubes were heated (90 ˚C) in a boiling water bath for 30 min, cooled, and then centrifuged at 2090 × g for 15 min. Absorbance of the supernatant was measured at 532 nm with a spectrophotometer (Beckman). TBARS value was reported as mg malondialdehyde per kg meat.

pH: pH values of the samples were measured by a pH meter (SevenGo, Mettler-Toledo Inti, Inc. Schwerzenbach, Switzerland) equipped with an insertion glass electrode after calibration by buffers at pH 7.00 at room temperature (Trout *et al.* 1992).

WHC: one gram of minced meat sample was placed on a round filter paper (No. 4, Whatman Ltd. Kent, UK). The filter paper with meat was placed into the centrifuge tube and was centrifuged (CR 20B2, Hitachi Koki Co., Ltd. Fukuoka, Japan) at 1500 × g for 4 min. After centrifugation, the remained water was measured by drying the samples in 70 ˚C for one night (Bouton *et al.* 1971).

Moisture: moisture contents of thigh and breast meat were analyzed according to the AOAC (1999).

Color: color intensities (L*, a*, b*) of the cross-sectional areas of the samples were measured with a Lovibond Tintometer Cam-System 500 (Amesbury, UK) using the colored tile provided by the manufacturer as the internal standard and set to use Illuminant D65 and CIE 10˚ standard observer. Four measures were taken on the thigh and breast muscles.

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 main effects. Data for growth parameters was analyzed based on a completely randomized design. As sexing was performed on d 42, other parameters were analyzed as a 4 × 2 factorial arrangement of treatments with 4 diets (0, 1.5 and 3 percent artichoke powder and 300 mg/kg Vit. E) and two gender (male and female), using GLM procedure of SAS software (SAS, 2003).

The pen mean was an experimental unit for BW gain, feed intake and feed: gain ratio. Main effect means and the interactions were reported. For interpretation purposes, main effect means were used when the interaction term was not significant, and individual means were used when the interaction term was significant. 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 AND DISCUSSION

Growth performance

The effect of artichoke leaf powder and 300 mg vitamin E on growth performance of quails is shown in Table 3. The addition of 1.5 percent artichoke leaf powder did not significantly affect BW throughout the experiment, but 3 percent artichoke leaf powder and 300 mg vitamin E reduced and increased BW at 21 d of age, respectively, 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 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.

Meat quality parameters

The main effect means of diets and sex and their interactions on TBA reactive substances (TBARS), pH, WHC and moisture of thigh and breast meats of quails fed a diet supplemented with 1.5 and 3 percent artichoke leaf powder and 300 mg vitamin E during 3 month frozen storage is illustrated in Table 4. Significant interactions between diet and sex on nominated parameters were not observed (P>0.05).

Table 3 Influence of supplementation of artichoke powder and vitamin E in diet on growth performance of Japanese quail from 1 to 42 d of age

Treatments	1 to 21 d			1 to 42 d		
	BW	FI	FCR	BW	FI	FCR
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
Pooled SEM	1.96	2.54	0.200	3.46	2.54	0.040

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
BW: body weight (g); FI: feed intake (g) and FCR: feed conversion ratio (g of feed/g of BW gain).
SEM: standard error of the means.

Table 4 Influence of supplementation of artichoke powder and vitamin E in diet on TBA reactive substances (TBARS), pH, water-holding capacity (WHC) and moisture of thigh and breast meats of Japanese quail during 3 month frozen storage

Treatment	TBARS (mg/kg)		pH		WHC (%)		Moisture (%)	
	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast
Diet								
Control	7.74^{a}	7.88	6.53	5.94	58.2	55.7	75.4	73.5
1.5% artichoke	5.13^{ab}	7.53	6.56	5.95	60.9	55.8	76.2	73.7
3% artichoke	5.96^{ab}	6.84	6.54	5.97	60.0	57.3	76.1	73.9
300 mg vitamin E	4.54^{b}	6.50	6.59	6.02	61.0	58.0	77.1	74.0
SEM	0.348	0.276	0.018	0.014	0.411	0.369	0.332	0.325
Gender								
Male	5.71	7.12	6.57	5.99	61.0	56.9	76.3	74.1
Female	5.97	7.25	6.54	5.95	59.0	56.5	76.1	73.4
SEM	0.174	0.138	0.009	0.007	0.205	0.184	0.166	0.162
Interactions								
Male × control	4.87	7.12	6.52	6.00	56.31	55.94	75.87	73.11
Male × 1.5% artichoke	4.82	7.48	6.57	6.00	60.51	58.20	77.91	72.73
Male × 3% artichoke	6.03	6.65	6.47	6.00	58.29	56.73	76.03	74.82
Male × vitamin E	7.11	7.24	6.59	5.94	61.00	55.29	75.50	72.99
Female × control	4.21	6.56	6.56	5.94	60.05	60.12	76.55	74.61
Female × 1.5% artichoke	5.43	7.57	6.54	6.03	61.41	56.47	76.35	75.28
Female × 3% artichoke	5.89	6.36	6.58	5.89	61.63	54.74	76.20	72.56
Female × vitamin E	8.37	8.51	6.59	5.94	60.84	56.39	75.22	74.00
SEM	0.696	0.552	0.035	0.027	0.821	0.738	0.664	0.650
Significance								
Diet	0.140	0.593	0.814	0.515	0.313	0.340	0.623	0.982
Gender	0.789	0.872	0.556	0.383	0.106	0.711	0.794	0.459
Diet × gender	0.907	0.849	0.792	0.593	0.585	0.154	0.851	0.299

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Diet affected significantly only on thigh meat TBARS. Dietary levels of artichoke leaf powder did not affect on thigh meat TBARS, whereas 300 mg vitamin E reduced its value compared with control (P<0.05). The effect of diets, sex and their interactions on color change of thigh and breast meats of quails fed a diet supplemented with 1.5 and 3 percent artichoke leaf powder and 300 mg vitamin E during 3 month frozen storage is shown in Table 5. No effect of diet and sex interactions on color change was observed. The main effect of diet was statistically significant only for b* index of breast meat. In this regard, dietary 1.5 percent artichoke leaf powder resulted in higher b* values of breast meat when compared with control. The lightness of thigh and breast meats and also redness of breast meat were affected by gender (P<0.05). However, a lower L* values was observed in thigh and breast meats of male quails than females (P<0.05), whereas breast meat of male quails showed a higher a* values than female quails (P<0.05).

The results of this study are in agreement with some research that showed no effect of herbs and medical plants on body weight, feed intake and feed efficiency in broilers (Cross *et al.* 2007; Hernandez *et al.* 2004; Bampidis *et al.* 2005).

Whereas findings of current study is contrary to the of Abu-Dieyeh and Abu-Drawish (2008) who reported that an addition of 1 and 1.5 percent seed powder of *Nigella sativa* to the broiler diet increased body weight gain and improved the feed conversation ratio. These differences can be partly due to the variation of experimental conditions and in particular environmental stresses which lead to a stimulation in bird's immune system and might have negative effects on growth performance (Takahashi *et al.* 2000).

Table 5 Influence of supplementation of artichoke powder and vitamin E in diet on color change of thigh and breast meats of Japanese quail during 3 month frozen storage

Treatment	L* (lightness)		a* (redness)		b* (yellowness)	
	Thigh	Breast	Thigh	Breast	Thigh	Breast
Diet						
Control	51.9	45.3	12.6	12.7	2.95	2.93[b]
1.5% artichoke	49.8	44.4	11.9	11.9	3.25	3.84[a]
3% artichoke	50.1	41.9	10.6	12.6	3.32	3.18[ab]
300 mg vitamin E	46.5	41.8	10.2	11.7	3.77	3.54[ab]
SEM	0.674	0.411	0.283	0.122	0.092	0.076
Gender						
Male	46.8[b]	42.2[b]	12.1	12.8[a]	3.12	3.23
Female	52.4[a]	44.6[a]	10.6	11.7[b]	3.52	3.51
SEM	0.337	0.205	0.142	0.061	0.046	0.038
Interactions						
Male × control	43.41	40.32	13.19	12.94	2.60	2.42
Male × 1.5% artichoke	47.26	42.41	12.68	13.00	3.11	3.37
Male × 3% artichoke	46.96	41.85	11.36	13.04	3.00	3.70
Male × vitamin E	49.49	44.09	11.18	12.10	3.77	3.43
Female × control	49.66	43.33	12.09	12.50	3.31	3.43
Female × 1.5% artichoke	52.28	48.25	11.11	10.86	3.38	4.30
Female × 3% artichoke	53.33	42.04	9.87	12.23	3.63	2.66
Female × vitamin E	54.22	44.67	9.20	11.37	3.77	3.64
SEM	1.347	0.822	0.566	0.244	0.183	0.152
Significance						
Diet	0.280	0.104	0.141	0.133	0.197	0.033
Gender	0.007	0.050	0.067	0.007	0.132	0.212
Diet × gender	0.985	0.312	0.984	0.335	0.752	0.051

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Supplementing diet with vitamin E improved feed intake and body weight at 21 d of age, this is consistent with Konjufca *et al.* (2004) who reported at 21st days of age broilers are not fully immunocompetent and therefore they rely on other immune stimulator mechanisms for defense against environmental pathogens. It seems that enhancement of immune system function by vitamin E supplementation at this age results in better growth performance by diverting energy toward production. In the field of oxidative stability, our results are consistent with the study of Kim *et al.* (2009) who reported that 20 or 40 g/kg garlic bulb and garlic husk decreased TBARS in broilers. The decrease in TBARS could be a result of antioxidant influence of fermented garlic powder (FGP) which protected from lipid oxidation. Garlic has many kinds of antioxidant compounds, mainly such as flavonoid and sulfur-containing compounds (Gorinstein *et al.* 2005). Meanwhile in another study, dietary administration of rosemary and sage essential oil extract to broilers resulted in a decrease in the lipid and cholesterol oxidation of broiler meat (Lopez-Bote *et al.* 1998). Supplementing turkeys with oregano extract increased the oxidative stability and retention of α-tocopherol in long-term frozen-stored turkey meat (Botsoglou *et al.* 2003). Sallam *et al.* (2004) reported that lipid oxidation represented by TBA values was reduced with the higher concentrations of each of the 3 forms of garlic (fresh garlic, garlic power, and garlic oil). In accordance to our results, Ao *et al.* (2011) observed no significant differences in meat pH values in broiler fed 1 g/kg fermented garlic powder compared to the control group. Jang *et al.* (2008) reported that there were no significant differences in pH values of meat in chickens treated with 0.3 and 1.0 percent MHEM (MHEM, consisting of mulberry leaf, Japanese honeysuckle and goldthread) compared to the control group at d 7 of refrigerated storage. Liu (1970) showed that in the pH range of 5.6 to 7.8, the oxidative catalytic activity of metmyoglobin on linoleic acid increased with increasing pH. Conversely, Liu and Watts (1970) reported an increase in the catalytic activity of nonheme iron by decreasing pH. This difference in results between these 2 studies may be due to the different mechanisms between heme and nonheme catalysis of lipid oxidation. Thus, the relationship between meat pH and oxidation rate differ in fresh meat where the heme-myoglobin structure is intact and in cooked meat where the heme has been denatured to form nonheme iron. Aminzade *et al.* (2012) observed no significant differences in WHC values in quails fed with peppermint powder. The mechanism of water-holding capacity is centered in the proteins and structures that bind and entrap water, specifically the myofibrillar protein.

There is a great body of evidence that demonstrates a direct effect of pH, ionic strength and oxidation on the ability of myofibrillar protein and myofibrils and muscle cells to entrap water. Regardless of these effects, it is clear that the same factors, including pH decline, ionic strength and oxidation also affect proteolysis of key cytoskeletal proteins in postmortem muscle.

Variation in water holding capacity at given pH and temperature of storage is proposed to be partially due to variation in proteolysis and the resulting muscle cell shrinkage and mobilization of water to the extracellular space (Huff-Lonergan and Lonergan, 2005).

Results of meat moisture in our study is in agreement with those of Choi *et al.* (2010) who reported that there were no significant differences in moisture percentage values of meat in chickens treated with 5% garlic powder compared to the control group. Adding antioxidants to the diet reduces moisture loss in meat. This reduction can be due to an increase in sarcomere length (Lahucky *et al.* 2005). Artichoke powder have antioxidant role which helps to preserve the integrity of membrane structure and reduces moisture outflow at the storage period. However, the moisture outflow increases with time.

Our finding showed a higher b* value for breast meat of birds treated with 1.5 percent artichoke leaf powder which is consistent with Young *et al.* (2003) who treated broilers with a dietary oregano extract. Regarding the meat color, it has been hypothesized (Liu *et al.* 1995) that certain free radicals produced during lipid oxidation act directly on the pigment, resulting in its oxidation or damaging the pigment's reduction systems.

In addition, toxic metabolites or fatty acid free radicals seem to have degraded some of these pigments, justifying the value of b*. The higher value of b* component in current study can be related to the action of the antioxidant to block the propagation of free radicals, preserving the pigments and giving a yellower color. In addition, Simitzis *et al.* (2008) explained that dietary oregano essential oil supplementation modifies the meat color, probably by decreasing hemoglobin oxidation and activating mechanisms that modify pigment distribution in animal tissues. Fernandez-Lopez *et al.* (2005) suggested that the presence of antioxidant compounds in the natural extracts could retard metmyoglobin formation in meatballs and so L* values decreased. The lower L* values may be related to the higher pH values (Jang *et al.* 2008).

Therefore, at present study a lower L* values of thigh and breast meats in male quails are attributed to higher pH values of thigh and breast meats. Studies showed that meat redness (a*) is under influence of a number of factor, including age and sex. Meat redness (a*) increases with age (Fleming *et al.* 1991).

Froning *et al.* (1968) reported that thigh and breast muscles in male birds are higher in myoglobin content than the female birds of the same age. Therefore, the redness index in the male quails is higher than the female ones.

CONCLUSION

In general, the present study showed that supplementing basal diet of Japanese quail with artichoke leaf powder did not improve growth performance, but may improve oxidative stability and thereby meat quality during 3 months frozen storage, therefore further studies is needed. In addition, quails fed diet supplemented with 300 mg vitamin E showed an improvement in growth performance at 21 d of age and oxidative stability at thigh meat.

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