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Original Article

Improving the Carcass Characteristics, Chemical and Organoleptic Quality of Japanese Quail Meat Using Native Iranian Chicory Extract

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ABSTRACT

Background and Objectives: Poultry meat is considered a perishable product due to its carbohydrates, protein, lipid and water content. The aim of this study was to improve the carcass characteristics, the chemical and organoleptic quality of Japanese quail meat using Iranian native chicory water extract.

Materials and Methods: Ninety Japanese quails were divided into 3 treatment groups including Control: basic diet, F1: basic diet + chicory extract (1%), and F2: basic diet + chicory extract (2%).

Results: Supplementation of diet with chicory water extract improved the whole body, breast, and thigh weight along with an increase in the nutritional value (fat, protein, mineral content (the total ash), vitamin B_{12}, and carotenoids) of breast meat of Japanese quails. In addition to achieve good water holding capacity (WHC) and minimum drip loss and cooking loss in treated samples, the breast meat earned high acceptability score by panelists because of its better odor, color (L*, a*, and b*), and texture (firmness). The higher total phenolic contents in F1 and F2, reduced TBARS value of breast meat that shows chicory extract improves the oxidative stability without exerting any negative effect on chickens' growth performance.

Conclusions: The results indicated that supplementation of diet with chicory water extract improved the nutritional value, oxidative stability, and sensory acceptability of Japanese quail breast meat.

Keywords: *Cichorium intybus*, Growth promoter, Meat quality, Quail

Highlights

- Diet supplementation with chicory extract improved the growth performance in quails
- Diet supplementation with chicory extract improved nutritional value in quail's meat.
- Breast meat of chicory treated quails had lower drip loss and cooking loss.
- Meat of chicory treated quails showed higher oxidative stability and sensory scores compared to control.

Introduction

Poultry meat is considered a perishable product due to its carbohydrates, protein, lipid and water content; therefore, the methods applied to maintain the quality and safety must provide products quality assurance to the point of final consumption (1). The quality and composition of the poultry meat are affected by various factors such as the genotype of the bird, the age at the time of slaughter and the feeding method. Lipid oxidation and microbial degradation are two important factors affecting the shelf life of meat. Due to the presence of unsaturated fatty acids with several double bonds, poultry meat is one of the most vulnerable meats against lipid oxidation (2). In recent years, breeding broiler chickens of various species has become the fastest and most efficient way to produce poultry meat. The consumption of poultry meat has increased due to the relatively low cost of production, low fat content and high nutritional value

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compared to the meat of other animals such as pigs, sheep, and cattle. During the years 1960 to 2010, the world's population increased from 3 billion to 7 billion people and poultry production increased 10 times during the same period (3).

Japanese quail (*Coturnix japonica*) is one of the poultry species bred for meat and eggs, especially in Asia, Europe, and the United States (4). The average weight of an adult bird is approximately 200 grams (5). This bird reaches sexual maturity quickly and has resistance and adaptability to high or low environmental temperatures (6). The growth cycle in quail is fast (3 or 4 generations per year) and also, it is the smallest type of poultry, which makes it easy to manage and can keep a large number of birds in a small space. For this reason, Japanese quail is considered an important laboratory animal model in biological and genetic studies (7). In comparative studies on the physicochemical characteristics of meat obtained from quail, broiler, and duck, it was confirmed that quail meat has the lowest calories and cholesterol content with the highest protein level (8). Quail meat (breast and thigh) is an important source of many essential nutrients for human health, including essential amino acids (lysine, methionine, isoleucine, leucine, phenylalanine, threonine, and valine) as well as polyunsaturated, monounsaturated (palmitoleic, C16:1), oleic acid, C18:1) and polyunsaturated fatty acid (linoleic acid, C18:2; and linolenic acid, C18:3), which are vulnerable to oxidation. Oxidative deterioration of polyunsaturated fatty acid (PUFA) in muscles is one of the main causes of quality loss in any type of meat and leads to color change, loss of nutrients, formation of toxic compounds and shortening of the shelf life (9).

Oxidation of lipids is a very destructive chemical reaction that can cause the oxidation of myoglobin and thus change the color of meat (10). The use of artificial antioxidants such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), tert-butyl hydroquinone (TBHQ) and propyl gallate (PG) is a common solution for meat preservation. However, the use of synthetic antioxidants has shown potential health risks (*e.g.* carcinogenicity) and strict regulations have been determined to monitor the use of these chemicals in food (7). The adverse effects of chemical preservatives on human health have caused them to be replaced by natural additives. Therefore, one of the most important goals of using natural antioxidants is to reduce the oxidation of meat and thus improve its sensory properties and nutritional value. Essential oils and phenolic extracts of various plants have been used as antioxidants or antimicrobial compounds (11). Medicinal plants have anti-stress, anti-bacterial, anti-fungal, and anti-viral properties so they can be used in different forms, for example, dried, extract, and essential oil in the diet of animals. In addition to the mentioned properties, medicinal plants are appetizing and increase the secretion of digestive enzymes (12).

Chicory, a perennial plant of the genus *Cichorium*, is cultivated all over the world. The origin of this species is Europe (Mediterranean region), but it may also be cultivated in other temperate and semi-arid regions (Central Asia, North Africa, Eastern USA, Australia) (13). In Iran, this plant is known as chicory, desert chicory and hendiba. This biennial plant has a tuberous root and consists of 30 to 70 leaves. Its stem grows 30 to 120 cm (1) and has mucus and resin as effective substances. *Cicurium Intibas* has antioxidant, antibacterial, anti-inflammatory, digestive, bitter tonic, diuretic, anti-clostremia, and laxative properties without causing side effects. All parts of this plant, especially the root, contain important medicinal compounds such as alkaloids, fructo-oligosaccharides, inulin (about 98%), flavonoids, and various terpenoids (14). The active compounds of the chicory induce the growth of intestinal beneficial bacteria (lactobacilli, bifidobacteria and butyrate-producing bacteria) and the growth inhibition of pathogenic bacteria (*Escherichia coli* and *Salmonella*) (15). Based on current applications, chicory products can be classified into four types: 1- industrial chicory or chicory root, which is used to produce n-inoleic fructans ((LA, ω−6 18:2), the most common ω−6 polyunsaturated fatty acid in the Modern Western diet) and is used as a substitute for coffee, 2- chicory Brussels sprouts to produce etiolated leaves, 3- chicory leaves for human consumption (fresh or cooked in salad), and 4- chicory fodder for animal feed (16). In different studies, essential oils or extracts of different medicinal plants have been used to improve the quality of poultry meat, and in some studies, the positive effects of these compounds have been proven (4,17,18). Based on the previous studies, the effect of chicory extract on carcass characteristics and quality of quail meat has not been investigated. Therefore, the aim of this study is to improve the carcass characteristics, the chemical and organoleptic quality of Japanese quail meat using Iranian native chicory root extract.

Materials and Methods

Chemicals and materials

All the chemicals and biopolymers were obtained from Scharlau Chemical Co. (Barcelona, Spain). Chicory root extract (*Cichorium intybus*) was purchased from Barij Essence Pharmaceutical Co. (Kashan, Iran).

Determination of Total phenolic content

The total phenolic content (TPC) of chicory eel extract was determined by Folin–Ciocalteu method using a UV/VIS spectrophotometer (T-80 model, PG Instrument Co., Australia) at the 765 nm. (20). The data were reported as mg gallic acid equivalents (GAE) per gram (g) of the peel.

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Determination of flavonoid content

Flavonoid compounds were measured through aluminum chloride colorimetric method at a wavelength of 510 nm according to Kamali et al. Quercetin was used to prepare the standard curve (19).

Experiment design

In this experiment, the treatments were carried out on 90 pieces of Japanese quail as follows: I- basic diet (control), II- diet including 1% (v/v) of chicory (F1), and III- diet including 2% (v/v) of chicory extract (F2). After the breeding period (35 days), live weight, carcass weight, chest and thigh muscle weight were recorded. Then, the chest muscles were kept in polyethylene bags at refrigerator temperature in order to perform the relevant tests.

Determination of pH

Five grams of meat sample was homogenized with 25 ml of distilled water and upon filtering, the pH of each sample was measured at room temperature with a pH meter (model 913, Metrohm, Switzerland) (20).

Determination of moisture, ash, protein, and fat content

On day zero, moisture, ash, protein, and fat content of Japanese quail breast meat were measured according to the methods explained by AOCS (21).

Determination of growth performance and carcass characteristics

At the end of the trial (after 5 weeks), the average live weight of each group was determined. Quails were starved for 12 hours before normal slaughter. The weight of the main parts of the carcass (neck, back, thigh, chest, wings) was measured and reported as the proportion of the weight of that part to the weight of the whole carcass. Breast meat samples were taken from each group of slaughtered quails to determine the carcass characteristics.

Determination of carotenoids content

The carotenoids content of the samples was determined using UV-Vis spectrophotometric method explained by Biswas et al (22).

Determination of vitamin B_{12}

Determination of active vitamin B12 (cobalamin) in quail breast meat samples was carried out by reversed-phase liquid chromatography (23).

Evaluation of meat color

The color of the quail breast meat samples was measured with a colorimeter (Ultrospec 35c Colorimeter, Biochrom, Austria) taking into account the parameters a* (redness), parameter b* (yellowness), and parameter L (lightness) (24).

Texture evaluation

Evaluation of breast meat texture was conducted using a texture analyzer instrument to analyze the softness/firmness of the fillet samples (TA.XTplusC, Stable Microsystems Co., Surrey, UK). Samples with an approximate thickness of 1 cm and a diameter of 3 cm were compressed to 50% of their original thickness at room temperature. The force and time deformation curve were drawn using a 25 kg load cell and a speed of 2 mm/s (25).

Determination of drip loss

Drip loss is water escaping from raw poultry meat during storage. To determine the drip loss, fifty-gram chicken breast samples were suspended in polyethylene bags (without any touch with the sides of the bags), for 24 h at 4℃. Then they were dried with paper and weighted. Drip loss was calculated according to Pastorelli et al. (26):

Drip loss (%): ((sample weight (g) − sample weight after 24 h (g)) / sample weight (g)) × 100

Determination of cooking weight loss

Cooking weight loss is considered as the weight loss of meat caused by cooking at 75 °C in a water bath for 1 h, then cooling the meat for 30 minutes, followed by drying. In this study, cooking weight loss was measured according to the method provided by Pastorelli et al. (26):

Cooking weight loss (%): ((raw sample weight (g) – cooked sample weight (g)) / raw sample weight (g)) × 100

Measurement of thiobarbituric acid index

This assay measures malondialdehyde (MDA), which is a split product of an endoperoxide of unsaturated fatty acids resulting from oxidation of lipid substrates. The MDA reacts with thiobarbituric acid (TBA) forming a pink chromogen (TBARS), which is measured at 532–535 nm. TBARS assay was conducted according to the method applied by Ghani et al. (27).

Sensory tests

On the first day, a panel of 10 trained people evaluated the sensory quality of quail breast meat. Sensory evaluation including color, odor, and overall acceptance was conducted using a 9-point pleasure scale (28).

Statistical Analysis

This experiment was conducted using a completely randomized design with 90 pieces of Japanese quail with 3 repetitions for each treatment and 10 birds in each repetition. All tests were performed in triplicate and the data were presented as mean ± standard deviation. Data analysis was conducted using one-way analysis of variance (ANOVA). Kruskal-Wallis test was used to compare sensory evaluation data. The statistical tests are performed with a confidence level of 99% and 95%.

Results

In the current study, TPC of water extract of *C. intybus* root was 40.55 mg GAE/g and it contained 31.80 mg Que/g of flavonoids. The effects of the diet supplementation with

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Citrus aurantium on the carcass characteristics of Japanese quail is presented in Table 1. The live weight of the broilers fed with treated diet was higher than that of the control (p <0.05). The weight of the breast and thigh of the treated broilers was also higher than control and this difference was statistically significant (p <0.05). It should be noted that the weight of the live weight and whole carcass weight in F1 samples were higher than F2 samples (p <0.05) but breast and thigh weights showed no significant difference in F1 and F2 (p <0.01).

Results of pH measurements (Fig. 1) indicated that the pH of control was similar to the pH the treated samples (p > 0.01) and supplementation of the diet with chicory extract has no effect on pH. In regard to the dry matter, significant differences were detected between the treatments containing chicory extract (F1 and F2) and the control (p < 0.01) (Fig. 1). Moreover, F2 (containing 2% extract) showed higher value of dry matter in comparison to F1 (containing 1% extract) (p < 0.01). Significant increases were seen in ash content of F1 and F2 compared to control upon adding chicory extract to the diet but there was no significant difference between ash content of F1 and F2 (p > 0.01). All the treatments showed significant differences in the protein content (p > 0.01). Fat content of the F1 and F2 was significantly higher than that of the control and the highest percentage of fat was obtained for F2 (2.19%). No significant difference was observed for fat content of F1 and F2 (p >0.01).

Table 1. Effect of dietary supplementation with *C. intybus* extract on carcass characteristics of Japanese quail

	Control	F1 (1% chicory extract)	F2 (2% chicory extract)
Live weight(g)	194.66±3.25[a*]	212.66±5.82[b]	207.00±3.59[c]
Whole carcass weight(g)	124.00±4.11[a]	136.66±2.75[b]	125.66±2.02[c]
Breast weight(g)	30.33±1.79[a]	31.46±1.42[b]	31.66±1.72[b]
Thigh weight(g)	15.66±0.82[a]	16.33±0.58[b]	16.00±0.55[b]

*Data are presented as mean ± SD.
[a]represents a statistically significant difference (p < 0.05) between means of the treatments in each row.

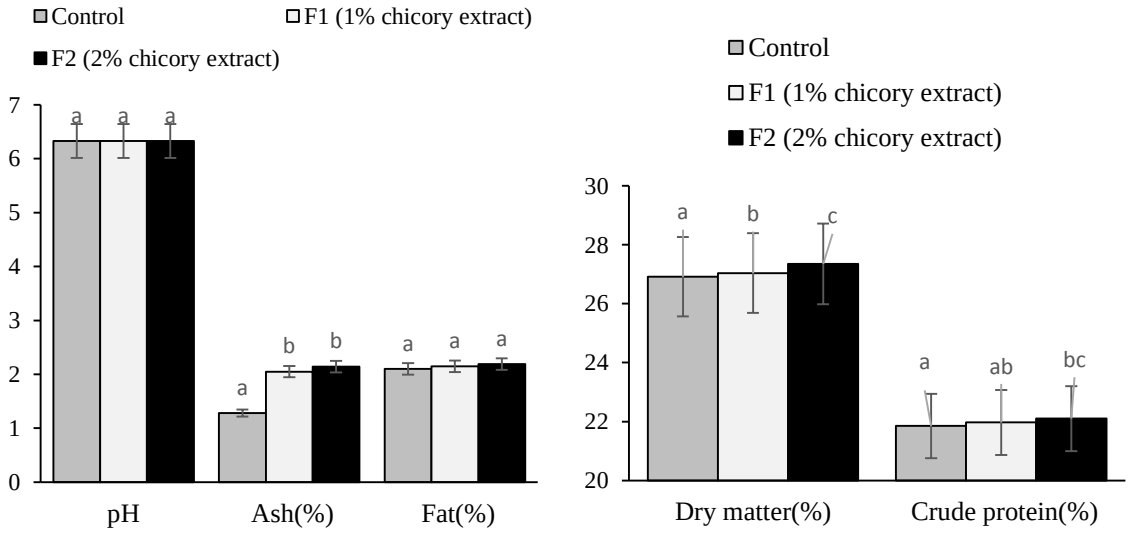


Figure 1. Effect of dietary supplementation with *C. intybus* extract on carcass chemical composition of Japanese quail, Data are presented as mean ± SD. [a] represents a statistically significant difference (p < 0.01) between means

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Based on the results (Table 2), significant differences were reported in drip loss of treated samples and control ($p < 0.01$). The drip loss decreased in treated samples and F2 showed lower drip loss in comparison to F1 ($p < 0.01$). In regard to cooking loss, lower weight loss was observed in chicory extract treated samples compared to control (Table 2) ($p < 0.01$). Treatment with 2% chicory extract decreased weight loss showing higher efficiency than that of F1 ($p < 0.01$).

According to data presented in Table 3, no significant difference was found in vitamin B_{12} content of treated samples and control ($p < 0.01$). The carotenoids content increased in treated samples and there was a statistically significant difference between control and extract-treated samples ($p < 0.05$). Also, F2 had the highest amount of carotenoids in comparison to F1 and control ($p < 0.05$).

Data of TBARS for breast samples demonstrated that the value of malondialdehyde (MDA) decreased upon treating diets with chicory extract ($p < 0.01$). The control had the highest thiobarbituric acid reactive substances (0.18±0.003 mg MDA/kg) and this value decreased along with increasing the amount of chicory extract in the diet, 0.01±0.001 and 0.07±0.001 for F1 and F2, respectively ($p < 0.01$).

Texture average firmness of the control samples was 9.75 N, which decreased in treated samples upon increasing the amount of chicory extract ($p < 0.01$) (Table 4). The L* index in the samples treated with F1 (1% chicory extract) was lower than that of control and F2 (2% chicory extract)-treated samples showed the lowest L* ($p < 0.01$). Also, a* and b* indices that indicate the redness and yellowness increased by adding chicory extract in the diet. As seen in the results in table 5, control had the lowest and F2 had the highest a* and b* ($p < 0.01$). According to the sensory analysis data, color, odor, and overall acceptability of the treated samples showed statistical difference for color, odor, and overall acceptability with control ($p < 0.05$).

Table 2. Effect of dietary supplementation with *C. intybus* extract on drip loss and cooking loss of breast meat of Japanese quail

Treatment	Control	F1 (1% chicory extract)	F2 (2% chicory extract)
Drip loss (%)	2.85±0.17[a*]	2.52±0.10[b]	2.40±0.21[c]
Cooking loss (%)	2.33±0.05[a]	2.25±0.26[b]	2.05±0.11[c]

*Data are presented as mean ± SD.
[a] represents a statistically significant difference ($p < 0.01$) between means of the treatments in each row.

Table 3. Effect of dietary supplementation with *C. intybus* extract on cobalamin (vitamin B_{12}) and carotenoid contents of breast meat of Japanese quail

Treatment	Control	F1 (1% chicory extract)	F2 (2% chicory extract)
vitamin B_{12} (mg/kg)	37.13±0.05[a*]	37.22±0.00[a]	37.20±0.10[a]
carotenoid (mg/kg)	93.05±1.20[a]	94.10±6.09[b]	99.25±5.14[c]

*Data are presented as mean ± SD.
[a] represents a statistically significant difference ($p < 0.01$) and ($p < 0.05$) between means of the treatments in each row.

Table 4. Effect of dietary supplementation with *C. intybus* extract on qualitative features of breast meat of Japanese quail

Treatment	Control	F1 (1% chicory extract)	F2 (2% chicory extract)
Texture firmness (N)	9.75±0.35[a*]	8.51±0.63[b]	7.82±0.02[c]
Color			
L*	59.61±0.11[a*]	59.32±0.20[b]	59.25±0.09[c]
a*	17.01±0.45[a]	17.56±0.10[b]	18.26±0.33[c]
b*	9.75±0.27[a]	9.81±0.15[a]	9.92±0.35[b]
Sensory scores			
Appearance color	8±0.10[aa]	9±1.38[aa]	9±0.42[a]
Odor	8±0.26[aa]	9±0.00[a]	9±0.86[a]
Overall acceptability	8±0.15[aa]	9±045[a]	9±1.03[a]

*Data are presented as mean ± SD.
[a] represents a statistically significant difference ($p < 0.01$) and ($p < 0.05$) between means of the treatments in each row.

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Discussion

In the recent studies, extract and essential oil of plants are extensively used for formulating treatments for animals' diet to improve the growth performance. The presence of phenolic compounds and flavonoids exerts antioxidant effects as the result of hydrogen donating moieties such as hydroxyl groups in their molecular structure; therefor, they act as inhibitors against autoxidation and oxidative stress (29). In our study, chicory roots water extract contained 40.55 mg GAE/g of phenolic compounds and 31.80 mg Que/g of flavonoids. Presence of phenolic compounds in food and feed plays a crucial role in reinforcing the immune system. Previous studies have demonstrated that **C. intybus** possesses a great medicinal importance due to the high content of phenolic compounds, reducing potential, and radical scavenging power (30,31).

The live, breast, and thigh weight of the samples fed with chicory extract-treated diet was higher than that of the control. The positive effect of herbs in appetite stimulation and improving the function of probiotics leads to digestion betterment, health, growth performance, and welfare of the animals. (32). These beneficiaries could be attributed to the antioxidant and antimicrobial activities of phenolic compounds in *C. intybus* that inhibit oxidative stress and growth of harmful bacteria in the gastrointestinal tract, respectively; therefor, prevent physiological malfunctions, such as breakdown and malabsorption of amino acids and essential fatty acids. On the other hand, phenolic compounds increase the permeability of cell membranes that results in weight gain of animals (33,34). Similarly, Sheikhsamani et al. (3) and Sarmad et al. (35) showed that dietary supplementation with *Mentha pulegium* and *Rosmarinus officinalis* increased the live, breast, and thigh weight of Japanese quails. Fathi et al. showed that dietary supplementation with *C. intybus* wastewater improved growth performance and weight gaining of broiler chicks (36).

The pH higher than 5.8 is considered as normal for meat quality purpose. According to our results, pH of control was similar to the pH the treated samples and in normal range and diet supplementation with chicory extract has not significant effect on pH. Same results were reported by Sheikhsamani et al. that adding *M. pulegium* and *R. officinalis* extracts to Japanese quail diet had no significant effect on meat pH (3). Also, Yang et al. showed that water supplementation with *M. arvensis* and *Geranium thunbergii* extracts did not change the pH of broiler leg meat (37).

Significant differences were detected between the dry matter of chicory extract treated samples and control. F2 (containing 2% extract) had higher value of dry matter in comparison to F1 (containing 1% extract) and control. Also, significant increase was observed in ash content of F1 and F2 compared to control upon adding chicory extract to the diet. In a study by Sheikhsamani et al., dry matter of treated broilers with diet containing *M. pulegium* and *R. officinalis* extracts was higher than control but the difference was not significant, it should be noted that no considerable difference was seen in ash content between the samples in their study (3). However, the increase in dry matter and ash content could be due to higher absorption and accumulation of organic and mineral matters in meat.

F1 and F2 showed significantly higher protein and fat content in comparison to control. Similarly, Sheikhsamani et al. (3), Yang et al. (37), and Pirmohamammadi et al. (38) demonstrated that dietary supplementation with *M. pulegium*, *R. officinalis*, *M. arvensis*, *G. thunbergii*, *Thymus vulgaris*, and *M. pulegium* extracts significantly enhanced the protein and fat compared to control due to increase of amino acids and fatty acids absorption through gastrointestinal tract. In our work, dry matter content and crude fat content were highest in bird 's meat supplemented with F2. This might have been due to the inverse relationship between meat moisture and fat content which is linked directly with meat juiciness (39). In an experiment by Dzinic et al. (40), a significant improvement was found in the protein content of chicken meat upon dietary supplementation with pepper and garlic. Totally, it seems supplementation of the diet with herbal extracts exerts positive effects on the chemical composition of poultry meat and improves its nutritional value.

Based on our findings, there was a significant difference between the drip loss of treated samples and control. The drip loss in treated samples was lower than the control and F2 showed the lowest drip loss. Also, in regard to cooking loss, lower weight loss was observed in F1and F2 compared to control. In a previous study, the chickens fed with *R. officinalis* and *M. pulegium* showed lower drip loss than control while cooking loss was not affected (3). Abdel-Wareth et al. demonstrated that supplementing broiler diet with jojoba seed oil resulted in a decrease in the drip loss of leg and breast meat (41). In another study, feed supplementation with lycopene increased the water holding capacity of meat and reduced the drip loss (42). Sosnówka-Czajka et al. reported higher WHC ratio, lower drip loss and cooking loss of breast muscles of broiler chickens receiving dried fruits pomace extract in diet, compared to the control (43). Džinić, et al. (40) announced the lowest cooking loss and drip-loss of muscle upon feeding animals with hot red pepper extract. According to the studies above, the improvement in reducing drip loss and cooking loss upon treatment with extracts is due to the water binding activity of the moieties of the herbal extracts 'compounds and increase in water holding capacity and retention of nutrients and water molecules which leads to better quality of meat.

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Vitamin B12 is synthesized by only certain bacteria and archaeon, but not by plants or animals (44). Our hypothesis was that chicory extract may possess the potential of stimulating intestinal bacteria to produce higher amount of vitamin B_{12}. As shown by our findings, there was no significant difference in vitamin B_{12} content of treated samples and control. It seems that chicory extract has no promoting effect on vitamin B12 production in quails; therefore, our hypothesis in this regard was not accepted. In regard to carotenoids content, significant increase was observed in treated samples and there was a statistically significant difference between control and extract-treated samples. Also, F2 had the highest concentration of carotenoids in comparison to F1 and control. The same results were reported by Partovi et al. (25) and Sepp at al. (45), they reported that absorption of carotenoids decreases during the presence of invading bacteria and enteric infections due to production of nitric oxide by macrophages and decrease in the absorption of fat-soluble compounds; this matter leads to oxidative damage in tissues. Obviously, the presence of antimicrobial compounds such as compounds in herbal essential oils or extracts in the supplemented diet improves the population of intestinal microbiota, inhibits the growth of harmful bacteria, and increases the absorption of healthful compounds like carotenoids and tocopherols (7).

In the present work, the concentration of thiobarbituric acid reacting substances in breast samples demonstrated that treating diets with chicory extract had a significant inhibitory effect on oxidative process. The control showed the highest MDA and this value decreased upon increasing the amount of chicory extract in the diet. Many herbs contains considerable amounts of phenolic compounds and other hydrogen-donating molecules act as antioxidants (46). Similarly, Sheikhsamani et al. showed that diet supplementation with *M. pulegium* and *R. officinalis* improved the oxidative stability of Japanese quail breast meat (3). Also, Rostami et al. (47) and Naimati et al. (4) reported that including of *R. officinalis* extract and quinoa extract, respectively, in chickens diet reduced TBARS and increased the oxidative stability. The same result as ours were announced by Asghar et al. (17) that adding black cumin powder to the feed of the Japanese quail made a considerable improvement in rendering oxidation in this type of meat.

Texture average firmness of the breast in chickens fed with chicory-supplemented diet was significantly lower than control and obviously decreased upon increasing the concentration of chicory extract. The same results have been reported by previous studies that showed diet supplementation with mint, rosemary, and garlic decreased texture firmness of chicken breast and thigh meat (3,48). Yang et al. demonstrated that adding *M. arvensis* and *G. thunbergii* to drinking water caused a decrease in texture hardness and increase the texture acceptability of broiler leg meat which is considered a positive effect of diet supplementation with herbs. In their study, the leg meat was found highly acceptable by the consumers due to its pleasant juiciness and texture (37). It is proven that diet supplementation using herbal essential oils and extracts results in integrity loss of muscle fiber (due to lytic activity of organic acids and other compounds on muscular protein); therefor, decrease in its shear force and mechanical strength and increase in tenderness of chicken meat in comparison to control (49).

The L*color value of meat is associated with visual color observation (50). The L* value in the chicken breast in group F1 (1% chicory extract) was lower than that of control. Group F2 (2% chicory extract showed the lowest L*. According to the cut off values of L* determined for poultry meat, Petracci et al. (51) suggested $L^* < 50$ was considered dark, $50 \leq L^* \leq 56$ as normal and $L^* > 56$ as pale. In our experiment, the L* values of the samples were > 56 and control had the highest L* that shows adding chicory extract reduced the paleness and improved the L* value of quail meat.

The a* value is linked to pigment content, intramuscular fat, and oxidation state, and the b* value is related with intramuscular fat content and redox state (50). Thus, higher a* value shows lower rate of fat deposition and intramuscular fat, fat decrease in the blood vessels and brighter meat (52).

In this work, a* and b* values that indicates the redness and yellowness increased by adding chicory extract in the diet. According to Nabih et al. (2007), chicory extract contains considerable amounts of carotenoids (53); therefor, since there was a higher concentration of carotenoids in diets containing chicory extract in comparison to control diet, finding higher amounts of carotenoids and thus higher a* and b*indices in muscles were expected. In a study by Yang et al. on investigating effect of adding *M. arvensis* and *G. thunbergii* to broilers' diet, the L* color value was 51.24 to 58.50, the a* color index 5.82-9.13 and the b* color index 15.75-17.45. Sheikhsamani et al. showed that a*, b*, and carotenoid contents of all herbal treatments were significantly higher than control in Japanese quail meat (3). These findings in meat color are in accordance with the results of previous researches that reported the including phytogenics such as herbal powder, essential oils or extracts in poultry diets influences the meat color (40). According to the color analysis data discussed above and sensory analysis data, panelists gave the highest scores of color, odor, and overall acceptability to F1 and F2.

Conclusions

Supplementation of diet with chicory water extract improved the whole, breast, and thigh weight along with an

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increase in the nutritional value (fat, protein, mineral content (the total ash), vitamin B_{12}, and carotenoids) of breast meat of Japanese quails. In addition to achieve good WHC and minimum drip loss and cooking loss in treated samples, the breast meat of treated chickens earned high acceptability score by panelists because of its better odor, color, and texture. The higher total phenolic contents in treated diet, reduced TBARS value of breast meat shows that chicory extract improves the oxidative stability without exerting any negative effect on chickens' growth performance.

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