Original Research Article

Effect of partial replacement of soybean and corn with dietary chickpea (raw, autoclaved, or microwaved) on production performance of laying quails and egg quality.

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ABSTRACT

This study was conducted to investigate whether adding raw or differently processed and different levels of chickpea into different diets of laying quails affected live weight, feed intake, feed efficiency, egg weight, internal and external egg quality. Chickpea was used as raw, autoclaved or microwave-processed, and it was involved in the diet on two different levels (20% and 40%). The sample was divided into 7 groups including the control, 20% and 40% raw, 20% and 40% autoclaved, and 20% and 40% microwave-processed groups. 336 ten-week-old female laying quails were used in the study and the experiment continued for 9 weeks. In the study, the differences among the groups were insignificant in terms of live weight, feed intake, feed efficiency, egg weight and egg quality characteristics such as shell thickness, shell weight, yolk weight, yolk color and albumin index. The differences were significant in terms of the shape index, Haugh unit ($P<0.05$) and yolk index ($P<0.01$). Consequently, it was observed that different thermal processes on chickpeas did not usually have a significant effect on the yield performance of the quails, and the results that were obtained were similar to the other groups. However, it was determined that some egg quality characteristics were affected by the autoclaving and microwaving processed. Between the thermal processes, it may be stated that autoclaving provided better results.

Key words: Autoclaving, Chickpea, Egg Characteristics, Microwave Process, Productive Performance

INTRODUCTION

Grain legumes are ranked the second after cereals for human nutrition, and they have a special importance in meeting vegetal protein requirements. Their compositions include 18-36% protein, and additionally, their protein digestibility is very high (78%). They are rich in vitamins and minerals, and their proteins have values similar to animal proteins in terms of essential amino acids (Ciftci, 2004). They are also an important food source with their low fat content and high carbohydrate content (Ciftci, 2004). Among the legumes produced in the world, chickpea is ranked the second after beans (FAO, 2016). Chickpea has been widely used in human nutrition, whereas it is also added into animal diets as a source of protein and energy (Bampidis and Christodoulou, 2011). Chickpea would be considered an alternative to soybean meal and corn in animal nutrition. In general, it is recommended to add 300 g/kg of raw chickpeas into the diets of ruminant animals (Bampidis and Christodoulou, 2011). Higher ratios may cause some disadvantages due to the antinutritional factors in chickpea. It was reported that 200 g/kg of raw chickpeas may be added into diet to support growth in poultry or not to cause loss of feed efficiency, and chickpeas should be treated by various thermal processes like boiling, autoclaving, microwave cooking and pressure cooking in order to be used at higher ratios (Bampidis and Christodoulou, 2011). Heat treatment destroys most secondary compounds, thereby improving the utilization of starch, fat and protein in chickpeas.

In addition to high nutritional values, grain legumes also contain various antinutritional factors. These lead to adverse effects on growth, feed conversion and health. These factors are lectins, various proteinase inhibitors, α- amylase inhibitors, non-protein amino acids (neurolathyritic, canavanine, mimosine), carbohydrates (galactomannan gums), polyphenolic compounds (tannins), metal binding agents (phytic acid), goitrogens, saponins, cyanogenetic glycosides, allergens, alkaloids, antivitamins and hemagglutinins (Deshpande and Damodaran, 1990; Huisman and Jansman, 1991; Gatel, 1994; Kaya and Yalcin, 1999). With these factors, legumes protect themselves against the attacks of living creatures such as mice, insects, bacteria and birds in nature. Types and effects of antinutritional factors in legumes vary based on their types, species, variety and different parts of plants, as well as the plant development period. On the other hand, the effects of antinutritional factors are different on different animal species. Leguminous grain usage is limited without any treatment in monogastric animals (Deshpande and Damodaran, 1990; Huisman and Jansman, 1991; Kaya and Yalcin, 1999). Various treatments are performed to remove or reduce the harmful effects of antinutritional factors. These are removal of grain from its shell, deterioration in grain integrity (grinding, crushing), heat treatment (roasting in dry heat, poaching, steam treatment), water and various chemical treatments and fermentation (Sharma and Nicholson, 1975; Deshpande and Damodaran, 1990; Van Der Poel, 1990; Abdelgadir et al., 1996; Kaya and Yalcin, 1999).

Many processes such as boiling, pressure cooking, frying, roasting, germination and fermentation increase in-vitro digestibility of legume starches. This increase in starch digestibility enables starch granules to swell, tear and separate into a wide variety of components during cooking. Additionally, it enables α-amylase inhibitors to activate. Ungerminated legumes may be less digested in comparison to legumes that are germinated and differently processed (Deshpande and Cheryan, 1984; Ertas et al., 2008).

In recent years, microwave radiation began to be used to remove antinutritional factors. In the food industry, microwaves are used for many purposes such as preheating, heating, thickening, drying, freeze drying (technically known as lyophilization), roasting, baking, boiling, pasteurization, sterilization and disinfection of liquid disinfectants (Ercan et al., 1989; Mudgett, 1989; Ozdemir et al., 2003). Recent studies indicated that microwave processes applied to food increase the passage of functional nutrients into the product (Gerard and Roberts, 2004). Heating with microwave energy provides some advantages over other heat sources in some treatments. Converting energy directly into heat inside the material is used to provide opportunity for heat to be controlled immediately and not to produce an electrical stress on the material that would destroy its structure. Mistakes may be made more quickly in process control than other methods. Heating may be controlled immediately by intervening immediately with the degree of heating and by changing the microwave power. Since the control process is performed quickly, the dimensions of heaters that are used are small, and the area they cover is smaller (Gungor and Atalay, 1999; Eskibalci and Ozkan, 2008). Using microwave energy in the food industry has many advantages. These may be listed as quick heating of food, energy saving, obtaining foods with high nutritional value, perfect process control and providing selective heating, if desired (Decareau and Peterson 1986; Seyhun et al., 2004). Among processes of boiling, autoclaving, cooking and germinating with microwave radiation applied to chickpeas, processes of cooking and germinating with microwave radiation lead to loss of less vitamins and minerals than boiling and autoclaving (El-Adawy, 2002).

This study investigated whether adding differently processed chickpea grains (autoclave or microwave) instead of soybean meals and corn into the diets of Japanese quails as a source of protein during the laying period affected feed consumption, feed efficiency and egg quality.

MATERIALS AND METHODS

The animal material of the study consisted of 336 ten-week-old female laying Japanese quails (*Coturnix coturnix japonica*). This study was conducted at a poultry farm of the Department of Animal Science, Faculty of Agriculture, Bingol University. The experiment was designed to have seven treatment groups (1 control) and three replications (16 quails in each replication) according to a randomized block design. The experiment was conducted in May-July, and it was completed in 9 weeks. The experimental quails were housed in 6-fold cage sections with 96 x 42 x 30 cm sizes during the experimental period. A photoperiod of 16 hours of light and 8 hours of dark was applied.

The nutrients of feed materials in the experimental diets were analyzed, and the diets were prepared according to the results of these analyses (Table 1). In the experiment, seven different groups were created as the control group containing no chickpeas (C0) and groups fed on six different diets including 20% raw chickpeas (RC20), 40% raw chickpeas (RC40), 20% autoclaved chickpeas (OC20), 40% autoclaved chickpeas (OC40), 20% microwave-processed chickpeas (MC20) and 40% microwave-processed chickpeas (MC40).

Table 1

The quails in the groups were fed *ad libitum* on isonitrogenic and isocaloric diets containing approximately 20% CP and 3000 kcal/kg ME throughout the laying period.

Crude protein, crude fat and crude cellulose contents of the diets were analyzed according to AOAC (2005), total sugar content was determined according to the method described by Dubois et al. (1956), and analysis of starch content was conducted according to the polarimetric method of Karabulut and Canbolat (2005). The Ca, P, lysine and methionine contents of the diets were calculated according to the NRC (1994). The ME values were calculated as described by Carpenter and Clegg (1956).

The industrial waste feed grain chickpea used in the experiment was supplied from a private company, and it was ground to a size that could pass through a 2 mm diameter sieve in a feed crusher. The ground chickpea was sacked and then autoclaved at 110 ºC for 15 minutes. The autoclaved chickpea was kept until it reached room temperature, and then, it was sacked and taken to the feed mixer.

The grain chickpea was first soaked in a basin filled with 1/4 water (one unit of chickpeas: four units of water) for 12 hours. The water of the soaked chickpea was then filtered. The filtered chickpea was then placed in glass containers, and it was exposed to a microwave process at 900 watts and 8 minutes in a microwave oven. After the microwave process was completed, the chickpeas were dried at 50ºC for 20 hours in an oven. The dried chickpeas were taken to the feed crusher and ground to a size that could pass through a 2 mm diameter sieve, and they were sacked to be taken to the feed mixer.

The changes in the condensed tannin content of the grain chickpea as a result of different heat treatments were determined by the analysis of tannin at the animal feeding and nutrition laboratory of KSU Agricultural Faculty (Makkar, 1995), (Table 2).

Table 2

In the experiment, body weight, live weight changes, feed intake, feed efficiency and egg quality characteristics (shell thickness, shell weight, shape index, yolk weight, yolk ratio, yolk diameter, albumin index, yolk index, Haugh unit and yolk color) were determined for the groups.

In order to determine the external and internal quality characteristics of the eggs obtained from the quails in the control and treatment groups, the necessary measurements of eggs collected every three weeks (5 from each replication) were made at the laboratory.

The body weights of the quails were determined using a scale at the 10^{th}, 13^{th}, 16^{th} and 19^{th} weeks. Feed consumption was determined weekly and calculated by subtracting the remaining feed from the total feed amount. Feed conversion rate was calculated by dividing the total feed consumption per week by the total egg weight per week

After the eggs were collected, they were left at room temperature for 24 hours, and the measurements were made. The eggs were weighed using scales with 0.1mm precision, and egg weights were recorded. The width and length of the eggs were then measured with a digital caliper. To minimize the change in egg structure, the internal quality measurements were made on the eggs placed on a glass surface after 10 minutes from the breaking time of the eggs.

The eggshell was weighed with a precision scale, and its thickness was measured with a digital caliper. The yolk diameters, yolk height, albumen width, albumen length and albumen height of the broken eggs on the glass surface were measured by a digital caliper and a tripod micrometer. The yolk and albumen weights were determined by separating them from each other. Yolk color was measured using a DMS Yolk Color Fan scale.

Shell thickness: A digital micrometer was used to measure shell thickness.

The shape index was calculated using the following formula (Anderson et al., 2004);

$$\text{Shape Index} = \frac{\text{Egg width (mm)}}{\text{Egg length (mm)}} \times 100$$

Albumen index: Albumen height of the broken egg was measured with a three-legged micrometer, and albumen length and width were measured with a digital caliper. Albumen index was calculated using the following formula.

$$\text{Albumen index} = \frac{\text{Albumen height (mm)}}{[\text{Albumen length (mm)} + \text{Albumen width (mm)}]/2} \times 100$$

Yolk index: Egg yolk was measured with a three-leg micrometer, and yolk diameter was measured with a digital caliper. Yolk index was calculated using the following formula.

$$\text{Yolk index} = \frac{\text{Yolk height (mm)}}{\text{Yolk diameter (mm)}} \times 100$$

Haugh Unit: It was calculated using the following formula (Haugh, 1937)

$$HU = 100 \log (H + 7.57 - 1.7 * W^{0.37})$$

H = Albumen height (mm)

W = Egg weight (g)

The data obtained from the study were analyzed by using the SAS 9.1.3 statistical package program (SAS, 2006). Analysis of variance (ANOVA) was performed by using the PROC GLM command, and Duncan's test was used to determine the differences between the significant means. Probability values of $P<0.05$ and $P<0.01$ were considered to indicate significant differences.

RESULTS AND DISCUSSION

Table 3 shows the findings on the live weights of the quails fed on diets prepared by adding raw or differently processed and different levels of chickpea at different periods. It was found that the effects of controlled (C0), raw chickpea 20% (RC20), raw chickpea 40% (RC40), autoclaved chickpea 20% (OC20), autoclaved chickpea 40% (OC40), microwave-processed 20% (MC20) and microwave-processed 40% (MC40) chickpea on live weight changes of quails were insignificant during the experiment, and the mean live weights of all weeks (10^{th}, 13^{th}, 16^{th} and 19^{th} weeks) were close to each other. There was no noticeable change in the live weights of different treatment groups from the beginning to end of the experiment.

Table 3

Similar to the findings obtained from this study, Farrell et al. (1999) reported that the effect of adding 36% raw chickpea into diet on the live weight gain of broiler chickens was insignificant. In their studies on diets containing raw and autoclaved chickpeas (0, 15, 30, 45% chickpea), Viveros et al. (2001) reported that diets containing raw chickpeas had no effect on the live weight gain of broiler chickens in comparison to the control group. Christodoulou et al. (2006) determined that the effect of adding 12% chickpeas instead of soybean meal on the live weight changes of broiler chickens was insignificant; however, 24% chickpeas affected live weight gain negatively. Brenes et al. (2008) found that the effects of diets containing raw chickpeas and extruded chickpeas on the live weight changes of broiler chickens were statistically insignificant. Algam et al. (2013)

stated that the effect of diets containing raw chickpeas at different rates on live weight changes of broiler chickens was insignificant. Obregón et al. (2012) reported that the effect of diets containing 60% raw and heat-treated chickpeas on the weight changes of butchery quails was insignificant.

Table 4

Table 4 shows the daily feed consumption values and feed conversion ratios of the quails, whose diets contained raw or processed chickpeas, in different periods. In feeding on diets containing differently processed chickpeas (autoclaving and microwave processes) and different ratios of chickpeas (20% and 40%), similar results were obtained at all weeks except for the 15th week. In general, there was no significant effect of the treatments on the feed consumption values, and the differences between the feed consumption mean values of the groups (except for the 15th week) were statistically insignificant. The differences in feed consumption between the control and treatment groups at the 15th week was significant ($P<0.05$), and the highest feed consumption was determined in the OC20 group. Similarly, Farrell et al. (1999) reported that the effect of feeding on diets containing different level of raw chickpeas, feed peas, bean and sweet lupines on the feed consumption of broiler chickens was not significant. Brenes et al. (2008) found that the effects of feeding on diets containing raw chickpeas and extruded chickpeas on the feed consumption of broiler chickens were statistically insignificant. Findings on feed consumption in this study showed similar results with those reported by Djeddi (1999), Perez-Maldonado et al. (1999), Fru-Nji et al. (2007), Christodoulou et al. (2005), Torki and Karimi (2007) and Algam et al. (2013) for different poultry animals. Viveros et al. (2001) reported that autoclaving of raw chickpeas significantly affected feed consumption in broiler chickens.

Since raw chickpea contains significant amounts of tannins (5.63 mg/g), and it has trypsin inhibitor activity (107.22 TIU/g), it was reported by Mittal et al. (2012) that it prevents the digestibility of feed proteins and reduces the bioavailability of important minerals (Rehman and Shah, 2001). Similarly, Reed (1995) explained that, since condensed tannins in diet structures are complexed with protein and carbohydrates, they reduce feed consumption of poultry, and they affect performance negatively. However, the usage of raw chickpeas, which was used in this study and contained a condensed tannin content of 3.10 g/kg, in diets by up to 40%, did not cause any adverse effect on feed consumption.

In all weeks, there were no significant differences between the feed conversion ratios in the control and treatment groups. Different heat treatments did not have a significant effect on the feed conversion ratios of the quails. This result was not consistent with the results of Alajaji and El-Adawy (2006) that raw chickpea reduced the performance of poultry. However, findings on feed conversion showed similar results with the results obtained by Algam et al. (2013) for raw chickpea in broiler diets, by Brenes et al. (2008) for extruded chickpea in broiler chickens and by Torki and Karimi (2007) for diets containing raw chickpea (10%) in broilers.

During the experiment, the effect of treatments on egg production was statistically insignificant (Table 5). Addition of raw or heat-treated chickpeas into diets did not significantly affect the egg production of the quails. However, the quails in the OC40 group generally had higher egg production than the other groups during the 9-week experiment period.

Table 5

The results obtained for egg production were similar to the results of the study carried out by Djeddi (1999) that the effect of adding different levels of vetch to quail diets on egg production was insignificant and by Garsen et al. (2007) that the effect of adding 25% to 40% raw chickpeas into diets of laying hens on egg production was insignificant. On the other hand, they differed from the results obtained by Perez-Maldonado et al. (1999) that the effects of diets containing beans and sweet lupines on the egg production of chickens were significant and by Fru-Nji et al. (2007) that the effects of diets containing beans and peas on the egg production of chickens were significant.

The differences between the egg weights of the groups fed on diets containing raw, autoclaved and microwave-processed chickpeas were statistically insignificant (P>0.05), while the differences between the treatments were significant (P<0.05) only in the last week of the experiment (19th week). The RC40, RC20, OC40 and OC20 groups had higher egg weights than the other groups at the 19th week. In general, all treatment groups provided heavier eggs than the control group. The results obtained for egg weight were similar to the findings obtained from studies conducted by Djeddi (1999) on diets containing vetch for quails and by Fru-Nji et al. (2007) on diets containing beans and peas (50%) for egg-laying hens.

The effects of diets containing different levels of chickpeas treated with different heat treatments on the quality characteristics of some egg laying quails were investigated. External and internal quality measurements were made on egg samples collected at the 13th and 19th weeks, and the results that were obtained were statistically analyzed. Table 6 shows the findings on the quality characteristics of eggs.

Table 6

The eggshell thicknesses of the quails in the control and treatment groups were measured at the 13th and 19th weeks, and the data that were obtained were statistically analyzed. The differences between the groups for shell thickness were significant for the 13th week (P<0.01), while they were not significant for the 19th week. At the 13th week, eggshell thickness was affected positively by adding raw and heat-treated chickpeas into the diets. The highest shell thickness values in this period were respectively obtained from the OC40, OC20 and MC20 groups. The eggs of the treatment groups were generally thicker than those in the control group. At the 19th week, the differences between the group's mean values were insignificant. The findings that were obtained were consistent with the results of shell thickness reported by Djeddi (1999) for vetch addition into the diet of quails.

While significant differences (P<0.05) of shell weight were observed between the control and treatment groups at the 13th week, no significant differences were observed at the 19th week. At the 13th week, the highest values for shell weight were respectively obtained from the CO, OC40, RC20, OC20 and MC20 groups, whereas the RC40 and MC40 groups showed lower values than the others. In this period, the heat treatments that were applied reduced the shell weight in some groups. From the 19th week, it was determined that shell weight was not affected by the treatments. In some groups, although there were numerical decreases in shell weight, these decreases were not statistically significant.

It was determined that the differences between the control and treatment groups were insignificant in the statistical analyses applied to the data of the 13th week for the shape index values, but they were significant at the 19th week (P<0.01). Different treatments generally affected the shape indices of the eggs (except for RC20), and lower values were obtained in the treatment groups in comparison to the control group.

The findings on yolk weight indicated that adding raw or processed chickpeas into the diet did not affect egg yolk weight. The measurements showed that differences between the mean yolk weights of the control and treatment groups at the 13th and 19th weeks were not significant. Differences between the control and treatment groups were significant (P<0.05, P<0.01) in the measurements made for yolk rate at the 13th and 19th weeks. The highest ratios for the yolk ratio were obtained from the MC40, MC20 and RC40 groups. Considering the results obtained for yolk diameters, it was seen that the treatments that were applied were effective (P<0.05, P<0.01) in both weeks of measurement. The groups with the highest values in terms of yolk diameter at the 13th and 19th weeks were the OC40, MC20, MC40 and OC20 groups. The microwave and autoclaving processes positively affected the yolk diameter of the eggs.

The albumen index was significantly (P<0.01) affected by different treatments at the 19th week, while it was not affected at the 13th week. At 19th week, RC40, MC20 and MC40 groups had lower albumen index values than the other groups. It was observed that using microwave-processed chickpeas in the diet affected the albumen index negatively. The results obtained from this study for the albumen index were similar to the results obtained by Djeddi (1999) on diets containing vetch for quails and by Fru-Nji et al. (2007) on diets containing beans and peas (50%) for laying hens.

The differences between the yolk index values of the eggs obtained from the control and treatment groups were not significant at the 13th week, but they were significant at the 19th week (P<0.01). The yolk index was significantly influenced by different treatments at the 19th week. The yolk index values of the RC40, OC40, MC20 and MC40 groups were lower than those of the other groups. The microwave process was shown to cause a significant reduction in the yolk index value. This result was similar to Djeddi's (1999) results on vetch addition into diets of quails and different from Fru-Nji et al.'s (2007) results on bean and addition of peas into diets of laying hens.

In the analysis of the 13th week, it was determined that the effect of different treatments on the Haugh unit values of the quail eggs was insignificant (P<0.01), while it was significant at the 19th week. The Haugh unit values of the RC40, MC20 and MC40 groups were lower than the other groups. According to the results obtained, adding microwave-processed chickpeas into the diets affected the Haugh unit of the eggs negatively. This result was in line with Djeddi's report that the effect of quail fed on diets containing vetch on the Haugh unit value of the eggs was significant.

When the eggs from the control and treatment groups were examined in terms of the color of the yolk, significant differences (P<0.05) were observed at the 13th week. The treatments applied at the 13th week affected the yolk color. The yolk color of the RC20, MC20 and MC40 groups was lighter than the other groups. It may be stated that adding microwave-processed chickpeas into diet affected the color of the yolk negatively.

The differences between the 19th week mean values were found to be insignificant. The results on yolk color in this study were similar to the results obtained by Fru-Nji et al. (2007) on diets containing beans and peas for hens.

The most important result of this study was the revelation that industry byproduct chickpea grains, which are rich in protein and energy, may be used to a significant extent in the place of soybean meal and corn which are the two most important elements of poultry diets. In the study, in comparison to the control group, the diets of the treatment groups included chickpea grains to replace 50% of corn and 39% of soybean meal. Usage of 20% and 40% chickpea grains in the diets of laying quails did not create a significant negative effect on the production performance or egg quality of the quails. This result provided hopes that chickpea grains may be used as an alternative product in the feeds of poultry. The condensed tannin contents of the raw, autoclaved and microwaved chickpea grains in the study were found respectively as 3.10, 1.48 and 2.75 g/kg. This result showed that heat processes (especially autoclaving) created significant reductions in the tannin content of chickpeas (up to 52.26%).

The results for the 13th week of the study showed that the yolk color values of the chickpea-containing groups were significantly higher than those in the control group. The lower yolk color value in the microwave treatment group in comparison to the other treatment groups may have been caused by the microwaving process. Thus, more specific studies are needed to determine the effects of chickpea grains on the pigmentation of yolks.

CONCLUSION

It was observed that chickpeas added as raw, autoclaved and microwaved by the ratios of 20% and 40% into the diets of quails did not usually have a significant effect on live weight, daily feed consumption, feed conversion ratio, egg yield and egg weight. However, some significant differences were observed among the groups in terms of some internal and external egg quality characteristics. When the treatment groups were compared to the control group, it was seen that the raw, autoclaved and microwaved treatments did not cause a significant reduction in terms of yield performance. It was a promising outcome that better results were obtained in some heat treatment applications in comparison to the control group. Usage of chickpeas at high ratios (20% and 40%) did not cause a significant reduction in performance. Nevertheless, considering all these treatments together, it was determined that subjecting chickpeas to heat treatments such as autoclaving and microwaving did not show any significant difference to their usage as raw or in comparison to the control group. As a consequence, looking at the effects of the heat treatment processes, it may be stated that the autoclaving process provided partially better results especially in terms of egg quality. It may additionally be stated that, when chickpeas are used by up to 40% in the rations of laying quails, they do not cause a significant negative effect.

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Table 1. The ingredients and chemical compositions of experimental diets (g/kg).

Ingredients	C0	RC20	RC40	OC20	OC40	MC20	MC40
Corn	535.02	401.96	268.90	401.96	268.90	401.96	268.90

Soybean meal	319.70	257.44	195.13	257.44	195.13	257.44	195.13
Chickpea	0	200.00	400.00	200.00	400.00	200.00	400.00
Soybean oil	53.30	49.30	45.30	49.30	45.30	49.30	45.30
Marble powder	66.81	66.60	66.40	66.60	66.40	66.60	66.40
DCP	17.63	17.72	17.83	17.72	17.83	17.72	17.83
Methionine	0.98	1.33	1.67	1.33	1.67	1.33	1.67
Lysine	2.06	1.15	0.27	1.15	0.27	1.15	0.27
Salt	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Vit.-Min.premix	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Total	1000	1000	1000	1000	1000	1000	1000
Nutritional analysis							
Dry matter	899.3	908.4	917.4	908.4	917.4	908.4	917.4
ME (kcal/kg)	2999.96	3000	3000	3000	3000	3000	3000
Crude protein	200	200	200	200	200	200	200
Ether extract	81.3	82.3	83.3	82.3	83.3	82.3	83.3
Crude fiber	18.3	20.9	23.4	20.9	23.4	20.9	23.4
Crude ash	116.6	115.6	114.6	115.6	114.6	115.6	114.6
Calcium	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Phosphorus	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Tannin	16.3	18.7	21.4	15.5	14.9	18.0	20.0

C0: Control, RC: Raw chickpea, OC: Autoclaved chickpea, MC: Microwaved chickpea. Vitamin+Mineral Premix (2.5 kg) =vitamin A 12000000 IU; cholecalciferol (vitamin D_3) 2000000 IU; α-tocopherol acetate (vitamin E) 35000 mg; menadione sodium (vitamin K_3) 5000 IU; thiamine mononitrate (vitamin B_1) 3000 mg; riboflavin (vitamin B_2) 6000 mg; pyridoxine (vitamin B_6) 5000 mg; cyanocobalamin (vitamin B_{12}) 15 mg; ascorbic acid (vitamin C) 50000 mg; D-biotin (vitamin H) 45 mg; niacin 20000 mg, Ca D Pantothenate 6000 mg, folic acid 750 mg, choline chloride 125000 mg, manganese 80000 mg, iron 60000 mg, zinc 60000 mg, copper 5000 mg, iodine 1000 mg, cobalt 200 mg, selenium 150 mg, canthaxanthin 15.000 mg, ß-apo-8'- carotenoic acid ethyl ester 5.000 mg.

Table 2. Analyzed nutrient composition and condensed tannin contents of experimental grain chickpeas treated by different heat-treatments.

		Raw chickpea	Autoclaved chickpea	Microwaved chickpea
Dry matter %		93.48	91.36	94.33
Condense tannin g/kg	Test 1	3.07	1.54	2.91
	Test 2	3.17	1.41	2.35
	Test 3	3.05	1.49	2.99
	Average	3.10	1.48	2.75
Crude protein (%)		20.65	19.04	20.01
Ether extract (%)		5.87	4.90	5.74
Crude fiber (%)		3.32	3.32	3.32
Starch (%)		42.40	38.65	43.72
Total sugar (%)		5.42	5.18	3.86
Metabolizable energy (kcal/kg)		3111.4	2823.0	3085.0

Table 3. Live weight values of quails in control and treatment groups at different periods.

Groups	Live weight, g			
	10. wk	13. wk	16. wk	19. wk
C0	247.4±0.27	257.1±3.35	257.3±4.21	253.3±3.35
RC20	247.9±0.75	250.6±0.24	244.2±4.42	251.5±2.20
RC40	247.5±0.95	255.8±1.15	258.5±0.81	252.3±1.98
OC20	247.7±1.35	256.5±2.20	254.2±2.92	240.1±5.15
OC40	248.2±0.27	254.9±2.63	247.3±8.21	244.7±6.28

MC20	248.0±0.85	254.7±5.03	248.6±3.22	248.9±5.44
MC40	248.5±1.08	258.3±3.66	253.4±6.16	251.0±4.40
P-Values	0.971 NS	0.683 NS	0.348 NS	0.365 NS

C0: Control, RC20: Raw Chickpea 20%, RC40: Raw Chickpea 40%, OC20: Autoclaved chickpea 20%, OC40: Autoclaved chickpea 40%, MC20: Microwaved chickpea 20%, MC40: Microwaved chickpea 40%.
Differences between means in the same column are insignificant. NS: Non-significant.

Table 4. Mean values of daily feed consumption and feed conversion ratios of quails in the control and treatment groups.

Groups	Periods				
	10-11 wk	12-13 wk	14-15 wk	16-17 wk	18-19 wk
	Daily feed intake, (g)				
C0	35.73±0.60	32.54±0.94	30.92±0.79^{b}	30.41±1.08	27.73±1.33
RC20	36.03±1.04	33.13±0.33	30.92±0.41^{b}	31.41±1.05	30.37±0.80
RC40	36.14±0.71	34.77±0.38	33.01±0.56^{ab}	32.36±0.48	29.84±0.71
OC20	34.53±0.30	33.70±0.27	34.12±0.18^{a}	30.00±0.68	28.35±0.87
OC40	36.77±0.49	34.13±1.02	32.96±0.96^{ab}	31.01±1.22	30.79±0.47
MC20	34.30±0.79	32.65±0.45	30.33±1.41^{b}	30.72±0.93	28.90±0.71
MC40	34.70±1.09	33.08±0.88	31.21±0.92^{b}	30.19±1.26	29.62±0.83
P-Values	0.244 NS	0.278 NS	0.047 *	0.677 NS	0.203 NS
	Feed conversion ratio (g:g)				
C0	3.40±0.06	3.14±0.17	3.19±0.20	3.07±0.14	3.19±0.08
RC20	3.42±0.13	3.14±0.05	3.98±0.05	2.99±0.14	2.81±0.10
RC40	3.82±0.07	3.47±0.10	3.31±0.18	3.37±0.17	3.27±0.10
OC20	3.56±0.18	3.12±0.15	3.37±0.01	3.20±0.01	3.18±0.04
OC40	3.55±0.09	3.27±0.19	3.40±0.28	3.43±0.23	3.23±0.22
MC20	3.74±0.05	3.32±0.12	3.55±0.25	3.39±0.18	3.48±0.13
MC40	3.51±0.11	3.10±0.13	3.18±0.14	3.31±0.43	3.08±0.34
P-Values	0.144 NS	0.475 NS	0.389 NS	0.793 NS	0.303 NS

C0: Control, RC20: Raw Chickpea 20%, RC40: Raw Chickpea 40%, OC20: Autoclaved chickpea 20%, OC40: Autoclaved chickpea 40%, MC20: Microwaved chickpea 20%, MC40: Microwaved chickpea 40%.
[a,b] Means with different superscripts in the same column are significantly different. NS: Non-significant. *: P<0.05.

Table 5. Mean weekly egg production and egg weight of quails in the control and treatment groups.

Groups	Periods				
	10-11 wk	12-13 wk	14-15 wk	16-17 wk	18-19 wk
	Egg production, %				
C0	78.87±3.31	78.87±4.87	76.69±6.74	77.74±6.91	73.47±3.71
RC20	82.14±1.03	80.65±2.14	81.25±2.86	81.90±4.29	86.38±3.24
RC40	70.24±2.43	75.59±3.27	76.19±4.64	74.36±4.22	70.46±3.33
OC20	73.22±4.91	80.95±2.97	77.68±1.85	72.92±1.65	71.13±1.29
OC40	78.27±1.29	77.98±3.86	75.00±4.09	69.05±3.50	76.07±5.63
MC20	69.35±3.10	75.89±1.85	66.67±4.64	71.65±5.85	68.71±3.02
MC40	73.51±3.87	81.84±2.97	77.38±4.13	75.00±10.80	79.53±6.39
P-Values	0.090 NS	0.747 NS	0.435 NS	0.803 NS	0.402 NS
	Egg weight, g				

C0	13.35±0.25	13.24±0.25	12.79±0.06	12.86±0.26	11.83±0.24^{c}
RC20	12.83±0.15	13.08±0.09	12.75±0.09	12.88±0.09	12.52±0.16^{ab}
RC40	13.49±0.26	13.29±0.17	13.18±0.10	13.00±0.23	12.99±0.14^{a}
OC20	13.35±0.27	13.38±0.24	13.04±0.27	12.86±0.05	12.55±0.22^{ab}
OC40	13.24±0.14	13.45±0.35	13.00±0.29	13.16±0.22	12.67±0.06^{ab}
MC20	13.26±0.24	12.97±0.18	12.92±0.20	12.77±0.22	12.12±0.25^{bc}
MC40	13.47±0.30	13.08±0.37	12.74±0.34	12.63±0.22	12.32±0.28^{abc}
P-Values	0.561	0.833	0.752	0.664	0.032
	NS	NS	NS	NS	*

C0: Control, RC20: Raw Chickpea 20%, RC40: Raw Chickpea 40%, OC20: Autoclaved chickpea 20%, OC40: Autoclaved chickpea 40%, MC20: Microwaved chickpea 20%, MC40: Microwaved chickpea 40%.
^{a,b,c} Means with different superscripts in the same column are significantly different. NS: Non-significant. *: $P<0.05$.

Table 6. Some quality characteristics of quail eggs in the control and treatment groups.

Weeks	Groups								
	C0	RC20	RC40	OC20	OC40	MC20	MC40	P-values	
	Egg shell thickness, mm								
13	0.19±0.0^{d}	0.20±0.0^{dc}	0.20±0.0^{dc}	0.21±0.0^{abc}	0.22±0.0^{a}	0.21±0.0^{ab}	0.20±0.0^{dc}	0.0001	**
19	0.21±0.0	0.21±0.0	0.21±0.0	0.21±0.0	0.21±0.0	0.22±0.0	0.22±0.0	0.451	NS
	Egg shell weight, g								
13	1.30±0.0^{a}	1.25±0.0^{ab}	1.18±0.0^{b}	1.23±0.0^{ab}	1.27±0.0^{a}	1.22±0.0^{ab}	1.18±0.0^{b}	0.036	*
19	1.10±0.0	1.13±0.0	1.17±0.0	1.11±0.0	1.12±0.0	1.10±0.0	1.10±0.0	0.622	NS
	Shape index, %								
13	77.0±0.8	77.4±1.2	77.2±0.8	75.1±0.8	75.2±1.2	76.5±1.3	77.4±0.9	0.469	NS
19	80.5±2.0^{a}	77.9±0.8^{ab}	75.6±0.6^{b}	75.3±0.9^{b}	76.5±0.6^{b}	77.3±0.6^{b}	76.9±0.5^{b}	0.007	**
	Yolk weight, g								
13	4.17±0.12	4.17±0.09	4.15±0.09	4.24±0.09	4.39±0.08	4.36±0.12	4.36±0.13	0.519	NS
19	3.91±0.12	4.24±0.09	4.49±0.11	4.12±0.14	4.13±0.08	4.24±0.14	4.31±0.12	0.058	NS
	Yolk, %								
13	31.3±0.5^{b}	32.0±0.6^{b}	32.7±0.5^{ab}	31.9±0.4^{b}	31.9±0.4^{b}	32.9±0.6^{ab}	33.8±0.7^{a}	0.026	*
19	32.1±0.5^{c}	32.9±0.5^{bc}	33.5±0.4^{abc}	32.9±0.6^{bc}	32.7±0.4^{c}	34.3±0.5a^{b}	34.5±0.5a	0.005	**
	Yolk diameter, mm								
13	26.7±0.3^{c}	27.1±0.3^{bc}	27.1±0.3^{bc}	27.7±0.3^{abc}	28.1±0.3^{a}	27.9±0.3a^{b}	27.3±0.4^{abc}	0.021	*
19	26.9±0.3c	27.6±0.3bc	28.6±0.3ab	28.1±0.4ab	28.8±0.3a	28.6±0.4^{ab}	28.9±0.4^{a}	0.0002	**
	Albumen index, %								
13	10.65±0.5	11.32±0.5	11.15±0.5	10.07±0.5	10.27±0.5	9.92±0.3	10.44±0.3	0.214	NS
19	9.68±0.3^{ab}	9.52±0.4^{ab}	8.44±0.5^{bc}	9.35±0.4^{ab}	9.94±0.4^{a}	8.46±0.4^{bc}	8.04±0.4c	0.006	**
	Yolk index, %								
13	43.18±0.7	43.21±0.7	43.80±0.7	42.11±0.4	42.70±1.0	41.74±0.7	44.17±0.7	0.151	NS
19	41.49±0.7^{a}	40.81±0.6^{a}	38.65±0.8^{bc}	40.28±0.6^{ab}	36.75±0.5^{dc}	36.65±0.7^{dc}	36.44±0.8^{d}	0.0001	**
	Haugh unit								
13	88.08±1.0	90.59±1.2	90.12±1.0	88.55±1.0	89.04±1.3	88.26±0.7	88.86±0.6	0.466	NS
19	87.42±0.7^{a}	87.17±0.7^{ab}	84.27±1.2^{c}	87.10±0.9^{ab}	88.74±0.7^{a}	84.54±1.0^{bc}	83.58±0.9^{c}	0.0003	**
	Yolk color								
13	9.38±0.4^{abc}	9.28±0.3^{bc}	10.47±0.3^{a}	9.60±0.4^{abc}	10.00±0.4^{ab}	8.87±0.4^{b}c	8.60±0.4^{c}	0.011	*
19	8.73±0.5	9.60±0.4	8.93±0.5	9.27±0.4	8.87±0.2	9.20±0.5	8.40±0.4	0.509	NS

C0: Control, RC20: Raw Chickpea 20%, RC40: Raw Chickpea 40%, OC20: Autoclaved chickpea 20%, OC40: Autoclaved chickpea 40%, MC20: Microwaved chickpea 20%, MC40: Microwaved chickpea 40%.

^{a,b,c,d} Means with different superscripts in the same row are significantly different. NS: Non-significant. *: P<0.05, **: P<0.01.