Impacts of onion and cinnamon supplementation as natural additives on the performance, egg quality, and immunity in laying Japanese quail

Waleed M. Dosoky,[*] Hassan S. Zeweil,[*] Mohamed H. Ahmed,[*] Soliman M. Zahran,[*] Maher M. Shaalan,[*] Nader R. Abdelsalam,[†] Abdel-Moneim E. Abdel-Moneim,[‡] Ayman E. Taha,[§] Khaled A. El-Tarabily,[#,||,1] and Mohamed E. Abd El-Hack[¶]

[*]*Department of Animal and Fish Production, Faculty of Agriculture, Saba Basha, Alexandria University, Alexandria, 21531, Egypt;* [†]*Agricultural Botany Department, Faculty of Agriculture, Saba Basha, Alexandria University, 21531, Egypt;* [‡]*Biological Applications Department, Nuclear Research Center, Egyptian Atomic Energy Authority, 13759, Egypt;* [§]*Department of Animal Husbandry and Animal Wealth Development, Faculty of Veterinary Medicine, Alexandria University, Rasheed, Edfina 22758, Egypt;* [#]*Department of Biology, College of Science, United Arab Emirates University, Al-Ain, 15551, United Arab Emirates;* [||]*Harry Butler Institute, Murdoch University, Murdoch, Western Australia 6150, Australia; and* [¶]*Department of Poultry, Faculty of Agriculture, Zagazig University, Zagazig 44511, Egypt*

ABSTRACT This study aimed to investigate the effects of dietary dried onion and dried cinnamon supplementation on laying performance, egg quality, serum lipid profile, and immune responses of Japanese quails. A total of 120 laying quails aged 12 weeks were randomly allocated into five groups (24 birds each). Each treatment was replicated 4 times with 6 quails in a completely randomized design. Dietary treatments were as follows: control (basal diet only, without any supplementation); tylosin (basal diet + 100 mg tylosin/kg diet); onion (basal diet + 800 mg dried onion/kg diet); cinnamon (basal diet + 800 mg dried cinnamon/kg diet); and onion + cinnamon (basal diet + mixture of 400 mg each of dried onion and dried cinnamon/kg diet). Cinnamon supplementation improved laying rate, egg numbers, egg mass, and feed conversion ratio of quails compared to the control treatment, followed by tylosin supplementation. Egg shell percentage was higher ($P < 0.05$) in quails that consumed the onion + cinnamon mixture than those fed only the cinnamon supplemented diet. Serum total lipid content, egg yolk lipids and egg yolk cholesterol were lower ($P < 0.05$) in birds fed with the supplemented diets than that of the control group. On the other hand, dietary supplements did not affect levels of triglycerides and high-density lipoprotein levels. The dietary supplementation with onion and/or cinnamon reduced serum malondialdehyde levels compared to control treatment. The foot web index was higher ($P < 0.05$) in the onion treatment than in the other experimental groups. The dried cinnamon and the mixture of dried onion + dried cinnamon treatments showed higher ($P < 0.05$) immunoglobulin M (IgM) levels than the control treatment. In conclusion, dietary supplementation with natural plant materials such as dried onion and cinnamon can be used to improve the laying Japanese quail performance, egg quality, and immunity.

Key words: cinnamon, egg quality, laying performance, immunity, onion, quail

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INTRODUCTION

Allium cepa (onion) has been used since ancient times as a medicinal source and is a common component of the human diet. Recently, onion has attracted much attention due to its antithrombotic, hypolipidemic, hypotensive, diaphoretic, antibiotic, antidiabetic, antiatherogenic, and anticancer properties (Nwogor et al., 2020). The biological action of *A. cepa* products is ascribed to their organo-sulfur and phenolic compounds (Kothari et al., 2019). Several studies conducted in rats have shown that onion contains several exogenous and endogenous antioxidants such as selenium; glutathione; vitamins A, B, and C; and flavonoids such as quercetin (12 mg/100 g onion bulb) (Khaki et al., 2012), and isorhamnetin (Khaki et al., 2009). These antioxidants protect DNA and other important molecules from oxidative damage (Abdel-Moneim et al., 2020; Abdel-Moneim et al., 2021).

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[1]Corresponding author: ktarabily@uaeu.ac.ae

Cinnamomum zeylanicum (cinnamon) is one of the oldest herbal medicines (4,000 years ago). The essential oil of *C. zeylanicum* bark is rich in trans-cinnamaldehyde, which exhibits antimicrobial action against animal pathogens that cause food poisoning, such as spoilage bacteria and fungi (Abd El-Hack et al., 2020). Cinnamon oil and extracts possess antioxidant activity that is attributed to phenolic and polyphenolic compounds (Tomaino et al., 2005), including cinnamaldehyde, eugenol, and carvacrol (Tabak et al., 1999). Cinnamon extract inhibits *Helicobacter pylori* when used at a concentration range of common antibiotics (Tabak et al., 1999).

Aromatic plants and their essential oils have been used as alternatives to antibiotics. Their action is due to their antioxidant and antimicrobial effects, with the advantage of showing also simulative effects on the digestive system (Ertas et al., 2005). Lee et al. (2004) found that the addition of cinnamon into broilers' diet improved their growth performance, with increased body weight gain and decreased feed conversion ratio, which was attributed to the presence of cinnamaldehyde and eugenol.

The present study aimed to investigate the effects of dietary dried onion and cinnamon on the laying performance, egg quality, serum lipid profile, and immune responses of Japanese quail in order to evaluate their potential as growth promoters' equivalent to conventional antibiotics in quail diets.

MATERIALS AND METHODS

Experimental Site and Birds

This study was conducted at the Poultry Research Laboratory, Department of Animal and Fish Production, Faculty of Agriculture (Saba Basha), Alexandria University, Egypt, during the winter season (from December 2016 to February 2017). The average daily low and high temperatures were 17.4°C and 18.8°C, respectively.

One hundred and twenty 12-weeks-old laying quails were randomly allocated into five groups (each consisting of four cages with six quails per cage). All birds were weighed, assigned to experimental groups, and groups were balanced according to body weight.

Experimental Design

Dietary treatments were as follows: control, basal diet without any supplementation; basal diet + the macrolide antibiotic "tylosin" (100 mg tylosin/kg feed; Chemical Industries Development, Giza, Egypt) used as a positive control; basal diet + dried onion (800 mg/kg feed) (commercial product from Imtenan Company, Alexandria, Egypt); basal diet + dried cinnamon (800 mg/kg feed) (commercial product from American Garden, New York, NY); and basal diet + a mixture of dried onion and dried cinnamon (each 400 mg/kg feed) according to Kumar et al. (2003). According to the providers, concentrations of total phenolics (mg gallic acid equivalent/g dry matter) and total flavonoids (mg quercetin/g dry matter) of dried onion and ground cinnamon were 4.25 ± 0.08 and 2.8 ± 0.05, and 27.45 ± 0.84 and 8.97 ± 0.62, respectively.

Each treatment was replicated 4 times, with 6 hens in each replicate, thus using a completely randomized design. Birds were distributed equally and randomly in wire cages (replicate). All quails were reared in wire cages under the same managerial, hygienic, and environmental conditions. All laying hens were exposed to 16 h of continuous light per day during the experimental period. Feed and water were available ad libitum throughout the laying period from 12 to 21 weeks of age. The basal diet was formulated to meet the birds' dietary nutrient requirements, according to NRC (1994). The basal diet composition is summarized in Table 1.

Performance of Laying Quail and Egg Parameters

The feed conversion ratio was calculated as g feed/g egg. Feed intake, laying rate, number of eggs, and egg weight were monitored daily. Egg quality measurements were conducted using an average of 21 eggs from each treatment and were performed over two consecutive days per month.

Shell thickness was determined from measurements of the mean thickness at three locations on the egg (air cell, equator, and pointed end) using a dial pipe gauge (0.01−20 mm; Mitutoyo, Tokyo, Japan; Abd El-Moneim and Sabic, 2019). Yolk cholesterol (mg/dL) was determined using nine eggs (at 21 weeks of age) from each treatment and measured by the method described by Fisher and Leveille (1957) and modified by Washburn and Nix (1974).

Table 1. Composition and calculated analysis of the experimental basal diet.

Ingredients	Content (%)
Yellow corn	49.25
Soybean meal (48%)	32.18
Starch	10.15
Di-calcium phosphate	1.16
Limestone	6.50
Vitamin and minerals mixture*	0.30
Salt (NaCl)	0.30
Calculated analysis*	
Crude protein, %	19.63
ME, Kcal/kg diet	2830
Ether extract, %	2.19
Crude fiber, %	2.21
Methionine, %	0.44
Methionine + cystine, %	0.72
Lysine, %	1.01
Calcium, %	2.82
Available phosphorus, %	0.33

*Each kg of vitamin and minerals mixture contained 10,000 IU vitamin A; 3,500 IU vitamin D3; 35 IU vitamin E; 1.67 mg vitamin K; 1.67 mg vitamin B1; 2 mg vitamin B2; 3.67 mg vitamin B6; 0.012 mg vitamin B12; 16.7 mg nicotinic acid; 6.67 mg pantothenic acid; 0.07 mg biotin; 1.67 mg folic acid; 400 mg choline chloride; 80 mg zinc; 90 mg manganese; 25 mg iron; 1.67 mg copper; 0.8 mg iodine; 0.033 mg selenium; and 133.4 g magnesium. Calculated analysis was carried out according to NRC(1994).

Total lipids content (mg/dL) were extracted with chloroform: methanol (2:1 vol: vol) from 0.8 g of yolk according to the method described by Folch et al. (1957). The measurement of the yolk color score was determined using a yolk color fan with a 1−15 scale, according to Dewanti et al. (2019).

Serum Lipid Profile and Antioxidative Properties

At the end of the experiment, blood samples were collected from the brachial vein of four hens randomly selected from each group. The serum was immediately centrifuged at 2058 x g for 15 min and stored at −18°C until use. The serum contents of lipid profile, total antioxidant potential, and malondialdehyde (**MDA**; measured as thiobarbituric acid reactive substances [**TBARS**]) were calorimetrically determined using commercial kits (Biomerieux, Poains, France; Abd El-Moneim et al., 2019).

Immune Responses Parameters

Serum immunoglobulin (**Ig**) fractions were determined as described by Mancini et al. (1965). The foot web index was used as an index of the cell-mediated response and determined using the methods described by Smits et al. (1999).

Statistical Analysis

Before data analysis, data were firstly subjected to testing the homogeneity of variance using Levene's test. Differences in outcomes between treatments were analyzed by one-way ANOVA using SPSS for windows version 11.0. The experimental unit of the study was the cage with 6 quails in each. Significant differences among treatments were determined using Duncan's multiple-range test, and calculation of sample size was performed using Post hoc analysis. The analysis power was 85% and the error type 1 was 0.05.

RESULTS

Performance of Laying Quail

Laying Japanese quails showed differences ($P < 0.05$) among dietary treatments in terms of body weight, laying rate, egg weight, egg number, egg mass, and feed conversion ratio (Table 2). In general, dietary supplementation with onion or cinnamon increased ($P < 0.05$) body weight compared to the control treatment in laying quails (Table 2).

The highest laying rate, egg number, egg mass, and the lowest feed conversion ratio were observed in quails dietary supplemented with cinnamon, followed by that dietary supplemented with tylosin (Table 2). The highest mean egg weight was observed in hens fed the diet supplemented with tylosin, followed by those fed the diets supplemented with cinnamon (Table 2).

Egg Quality and Egg Yolk Lipid Profile

The effects of tylosin and phytogenic (cinnamon and onion) feed supplements on egg quality are summarized in Table 3. Egg weight, absolute eggshell weight (g), eggshell percentage, egg specific gravity, albumen weight and height, and yolk index were not affected by dietary supplements (Table 3).

The absolute and the percentage yolk weight was the highest in quails that received feed supplemented with tylosin (Table 3). Yolk color showed the best values in quails that received feed supplemented with onion alone or tylosin (Table 3). Eggshell thickness did not differ among onion or/and cinnamon supplemented groups, however, tylosin supplementation resulted in lower values ($P < 0.05$) for eggshell thickness than that of the controls (Table 3).

The total lipid in yolk was lower ($P < 0.05$) in quails that received phytogenic feed supplements and tylosin than that received the basal diet (Table 3). The yolk with the lowest total lipid levels was observed in quails that received both onion and cinnamon (33.5% <

Table 2. Effect of tylosin, dried onion, dried cinnamon, and a mixture of dried onion and dried cinnamon on performance of laying Japanese quail.

Variables	Control	Tylosin	Onion	Cinnamon	Onion + cinnamon
Laying performance					
Body weight change, g	$18.24^{b} \pm 0.79$	$22.93^{ab} \pm 2.18$	$24.44^{a} \pm 1.70$	$24.10^{a} \pm 1.51$	$23.58^{a} \pm 2.05$
Laying rate %, hen-day	$62.70^{b} \pm 1.13$	$67.71^{ab} \pm 0.26$	$63.74^{b} \pm 4.07$	$75.00^{a} \pm 2.63$	$63.14^{b} \pm 4.50$
Egg number, hen/day	$0.627^{b} \pm 0.01$	$0.677^{ab} \pm 0.00$	$0.637^{b} \pm 0.04$	$0.750^{a} \pm 0.03$	$0.631^{b} \pm 0.04$
Mean egg weight, g	$11.92^{c} \pm 0.44$	$13.35^{a} \pm 0.18$	$12.38^{bc} \pm 0.19$	$13.17^{ab} \pm 0.30$	$12.31^{bc} \pm 0.20$
Egg mass/hen/day, g	$7.49^{c} \pm 0.40$	$9.04^{ab} \pm 0.13$	$7.89^{bc} \pm 0.51$	$9.89^{a} \pm 0.47$	$7.79^{bc} \pm 0.64$
Feed consumed /hen /day, g	31.72 ± 0.19	31.58 ± 0.30	31.30 ± 0.26	31.62 ± 0.16	31.27 ± 0.61
Feed conversion ratio	$4.27^{a} \pm 0.22$	$3.49^{bc} \pm 0.05$	$4.02^{ab} \pm 0.26$	$3.22^{c} \pm 0.16$	$4.09^{ab} \pm 0.30$

Body weight change, g: live body weight of each bird was recorded at the beginning and at the end of experimental period and then the change in live body weight was calculated. Experimental diets; control: basal diet alone without any supplementation; tylosin: basal diet + tylosin (100 mg tylosin/kg feed); onion: basal diet + dried onion (800 mg/kg feed); cinnamon: basal diet + dried cinnamon (800 mg/kg feed); and onion + cinnamon: basal diet + a mixture of dried onion and cinnamon (each 400 mg/kg feed).

[a-c]Values with different letters within a row are significantly different ($P < 0.05$) according to Duncan's multiple range test; values are means ± (standard error).

Table 3. Effect of tylosin, dried onion, dried cinnamon, and a mixture of dried onion and dried cinnamon on egg quality of laying Japanese quail.

Variables	Control	Tylosin	Onion	Cinnamon	Onion + cinnamon
Egg quality					
Egg weight, g	13.95 ± 0.12	13.95 ± 0.11	13.90 ± 0.11	13.87 ± 0.06	13.97 ± 0.15
Egg specific gravity	1.068 ± 0.002	1.067 ± 0.002	1.064 ± 0.001	1.063 ± 0.001	1.065 ± 0.001
Albumen height, mm	3.21 ± 0.10	3.01 ± 0.10	3.18 ± 0.13	3.25 ± 0.12	3.16 ± 0.09
Albumen weight, g	7.80 ± 0.13	7.61 ± 0.10	7.65 ± 0.11	7.74 ± 0.09	7.65 ± 0.12
Albumen %	55.83 ± 0.48	54.55 ± 0.47	54.98 ± 0.47	55.75 ± 0.41	54.69 ± 0.36
Yolk weight, g	4.80^{b} ± 0.03	4.96^{a} ± 0.06	4.88^{ab} ± 0.04	4.80^{b} ± 0.03	4.87^{ab} ± 0.03
Yolk %	34.45^{b} ± 0.33	35.60^{a} ± 0.33	35.14^{ab} ± 0.34	34.61^{b} ± 0.28	34.8^{ab} ± 0.27
Yolk color	5.09^{c} ± 0.25	6.45^{ab} ± 0.39	7.00^{a} ± 0.33	5.27^{c} ± 0.19	5.91^{bc} ± 0.37
Yolk index	465.43 ± 5.25	488.44 ± 8.57	483.04 ± 5.25	492.94 ± 8.85	490.76 ± 13.31
Egg shell weight, g	1.35 ± 0.02	1.37 ± 0.03	1.37 ± 0.04	1.34 ± 0.02	1.45 ± 0.04
Egg shell %	9.72^{ab} ± 0.16	9.85^{ab} ± 0.23	9.88^{ab} ± 0.26	9.64^{b} ± 0.17	10.42^{a} ± 0.28
Egg shell thickness, mm	0.255^{a} ± 0.008	0.232^{b} ± 0.005	0.249^{ab} ± 0.005	0.237^{ab} ± 0.007	0.248^{ab} ± 0.006

Experimental diets; control: basal diet alone without any supplementation; tylosin: basal diet + tylosin (100 mg tylosin/kg feed); onion: basal diet + dried onion (800 mg/kg feed); cinnamon: basal diet + dried cinnamon (800 mg/kg feed); and onion + cinnamon: basal diet + a mixture of dried onion and cinnamon (each 400 mg/kg feed).

$^{a-e}$Values with different letters within a row are significantly different ($P < 0.05$) according to Duncan's multiple range test. Values are means ± (standard error).

Table 4. Effect of tylosin, dried onion, dried cinnamon, and a mixture of dried onion and dried cinnamon on egg yolk lipid profile of laying Japanese quail.

Variables	Control	Tylosin	Onion	Cinnamon	Onion + cinnamon
Egg yolk lipid profile					
Total lipids, mg/g yolk	364.33^{a} ± 2.54	335.78^{b} ± 2.92	301.00^{c} ± 6.34	275.78^{d} ± 4.18	242.11^{e} ± 4.56
Total cholesterol, g/100 g yolk	19.15^{a} ± 0.28	18.10^{b} ± 0.03	17.14^{c} ± 0.03	16.71^{d} ± 0.10	16.09^{e} ± 0.01

Experimental diets; control: basal diet alone without any supplementation; tylosin: basal diet + tylosin (100 mg tylosin/kg feed); onion: basal diet + dried onion (800 mg/kg feed); cinnamon: basal diet + dried cinnamon (800 mg/kg feed); and onion + cinnamon: basal diet + a mixture of dried onion and cinnamon (each 400 mg/kg feed).

$^{a-e}$Values with different letters within a row are significantly different ($P < 0.05$) according to Duncan's multiple range test. Values are means ± (standard error).

control), followed by cinnamon alone (24.3% < control), onion alone (17.4% < control), and tylosin (7.8% of control; all $P < 0.05$; Table 4).

Egg yolk cholesterol was lower in quails that received any supplements than quails that received the basal diet, with the lowest cholesterol levels observed in those receiving both onion and cinnamon (16.0% < control), followed by cinnamon (12.7% < control), onion (10.5% < control), and tylosin (5.5% < control; Table 4).

Biochemical Analysis

Serum Lipid Profile Concentration of total serum lipids was lower ($P < 0.05$) in quails fed with the supplemented diets than those of the control group (Table 5). However, the dietary supplements did not affect triglyceride levels (Table 5).

Serum total cholesterol decreased in quails received dietary cinnamon compared to the control while values

Table 5. Effect of tylosin, dried onion, dried cinnamon, and a mixture of dried onion and dried cinnamon on serum lipid profile and antioxidant potential of laying Japanese quail.

Variables	Control	Tylosin	Onion	Cinnamon	Onion + cinnamon
Total lipid (mg/dL)	470.00^{a} ± 30.83	330.03^{b} ± 15.20	375.33^{b} ± 27.02	348.67^{b} ± 24.37	315.33^{b} ± 2.73
Triglycerides (mg/dL)	218.00 ± 8.39	208.67 ± 5.17	215.00 ± 16.26	196.00 ± 7.94	199.67 ± 16.59
Cholesterol (mg/dL)	167.67^{a} ± 6.89	164.67^{a} ± 4.33	152.67^{ab} ± 8.51	133.33^{b} ± 5.36	149.33^{ab} ± 15.30
HDL (mg/dL)	75.00 ± 4.04	65.33 ± 2.33	62.67 ± 3.18	66.00 ± 5.51	75.00 ± 4.04
LDL (mg/dL)	50.33^{ab} ± 3.53	55.33^{a} ± 4.84	54.00^{ab} ± 5.51	40.33^{b} ± 1.76	47.33^{ab} ± 4.256
HDL/LDL (ratio)	1.49^{a} ± 0.055	1.19^{a} ± 0.08	1.18^{a} ± 0.12	1.65^{a} ± 0.21	1.65^{a} ± 0.22
Antioxidant potential					
TAC (mmol/mL)	0.343 ± 0.06	0.370 ± 0.03	0.360 ± 0.02	0.383 ± 0.01	0.377 ± 0.02
MDA (nmol/mL)	17.60^{a} ± 1.14	14.77^{ab} ± 0.91		11.67^{b} ± 0.43	14.13^{b} ± 1.34

Abbreviations: HDL, high-density lipoprotein; LDL, low-density lipoprotein; MDA, malondialdehyde; TAC, total antioxidant capacity.

$^{a-b}$Values with different letters within a row are significantly different ($P < 0.05$) according to Duncan's multiple range test; values are means ± (standard error).

Table 6. Effect of tylosin, dried onion, dried cinnamon, and a mixture of dried onion and dried cinnamon on immune responses of laying Japanese quail aged 18 weeks.

Variables	Control	Tylosin	Onion	Cinnamon	Onion + cinnamon
IgG (mg/dL)	236.67 ± 21.86	236.33 ± 20.09	246.33 ± 19.72	202.00 ± 11.06	290.00 ± 45.90
IgM (mg/dL)	20.61[b] ± 0.95	23.33[ab] ± 0.38	23.80[ab] ± 1.15	26.43[a] ± 0.80	25.05[a] ± 1.29
FWI (mm)	0.193[b] ± 0.02	0.206[b] ± 0.01	0.330[a] ± 0.05	0.240[b] ± 0.02	0.200[b] ± 0.01

Abbreviations: FWI, Foot Web Index; IgG, Immunoglobulin G; IgM, Immunoglobulin M.

[a-b]Values with different letters within a row are significantly different ($P < 0.05$) according to Duncan's multiple range test; values are means ± (standard error).

of the other groups were not different from that of the control (Table 5). Total cholesterol level did not differ considerably between quails that received tylosin supplement and quails that received the basal diet (Table 5).

The high-density lipoprotein (**HDL**) was not affected by any dietary supplement (Table 5). On the other hand, only cinnamon supplementation lowered ($P <$ 0.05) low-density lipoprotein (**LDL**) levels compared to tylosin supplementation.

Antioxidant Potential and MDA Content Data concerning blood serum antioxidant parameters are illustrated in in Table 5. The dietary supplementation with onion and/or cinnamon appeared to have improved oxidative stability as shown by the decrease of serum lipid peroxidation ($P < 0.05$), expressed as serum MDA, in the range of 19.7 to 33.7%, with the lowest value observed with 800 mg cinnamon. This concentration of cinnamon also numerically increased the serum total antioxidant potential.

Immune Response Parameters The effect of tylosin, dried onion, dried cinnamon, and a mixture of onion and cinnamon on immune-related parameters (IgG and IgM) are summarized in Table 6. The feed supplements investigated in the current study did not show a considerable effect on IgG levels (Table 6). IgM level was higher in quails that received all the feed supplements (Table 6).

Cellular immunity, assessed as the foot web index, was compared between different feed supplements, and the results are presented in Table 6. We observed that the foot web index was higher ($P < 0.05$) in hens that received 800 g dried onion supplement than in hens that received other supplements (Table 6).

DISCUSSION

In Japanese quail-fed herbal additives, our results showed significant differences among dietary treatments regarding body weight, laying rate, egg weight, egg number, egg mass, and feed conversion ratio. A study by Şimşek et al. (2015) reported that dietary inclusion of 200 ppm cinnamon extract increased egg production of laying quails (59.40 vs. 50.92 for control), and enhanced intestinal length, intestinal villi depth and width, and nutrient absorption. In another study on laying hens, Torki et al. (2015) revealed that egg production, mass, and weight were higher (89.37 vs. 80.45, 55.45 vs. 51.45, and 62.36 vs. 61.77, respectively) in birds treated with 40 mg/kg cinnamon compared to the control. They also noticed a decrease in the feed conversion ratio of hens fed a diet supplemented with cinnamon than those fed the basal diet.

In contrast, in a study by Vali and Mottaghi (2016), dietary inclusion of cinnamon (1−2%) showed no effect on egg mass in Japanese quail. At the same time, Anand et al. (2010) observed that cinnamaldehyde, the active component of cinnamon, increased insulin release from β cells. Insulin regulates carbohydrate, fat, and protein metabolism and stimulates amino acid uptake, protein synthesis, and glucose utilization (Anand et al., 2010). Furthermore, high insulin levels may improve the feed conversion ratio. Previous studies suggest that antioxidants help prevent nutrient oxidation and modification (Dieber-Rotheneder et al., 1991). Results of the present study regarding onion supplementation are in agreement with those of Damaziak et al. (2017), who observed no effect of dietary supplementation of onion extracts on average egg production rate or feed conversion ratio ($P = 0.078$). Goodarzi et al. (2013) reported that birds fed 10 g onion bulb/kg diet did not differ from those fed a control diet. These effects of dietary supplements on laying productivity may be attributed to their high contents of phenolics and flavonoids compounds. These phytochemicals have numerous biological properties, including hypolipidemic, antioxidant, and anti-inflammatory activities, which directly and/or indirectly contributes in improving birds' laying performance. Liu et al. (2014) observed a positive correlation between egg production and quercetin content in the feed mixture. Nevertheless, the excess flavonoids in feed mixtures of laying hens may produce antagonistic effects on phytoestrogens by reducing their association with the estrogen receptor, resulting in delayed or decreased egg production as compared with cinnamon-supplemented diets (Martin et al., 1978).

The results regarding the effects of tylosin and phytogenic (cinnamon and onion) feed supplements on egg quality showed that egg weight, absolute shell weight, egg specific gravity, albumen weight and height, and yolk index were not affected by these supplements (Table 3). These results are in agreement with those of Sharma et al. (2009), who found that cinnamon supplementation exerted no beneficial or detrimental effects on egg quality traits of White Leghorn hens apart from a decrease in yolk cholesterol (9.5−16.9% < control) from week 8 onward. However, Simsek et al. (2015) demonstrated positive effects of cinnamon supplementation on eggshell quality. Vali et al. (2013)demonstrated that cinnamon supplementation improved all egg quality parameters except yolk weight in Japanese quail. Liu et al. (2014) observed no effect of onion quercetin on the quality traits of eggs in laying hens. Moreover, Damaziak et al. (2017) reported that onion extract in the hen diet was beneficial in terms of increasing the egg weight, yolk weight, yolk weight ratio, and albumen quality (expressed in Haugh units).

The total serum lipids were lower in quails that received feed with supplements than quails that received the basal diet; however, the supplements did not affect triglyceride levels (Table 4). The enzyme 3-hydroxy-3-methylglutaryl coenzyme A (**HMG-CoA**) reductase inhibitor effectively lower plasma cholesterol in most animal species, including humans (Alberts, 1988). Cinnamic acid (0.02%, w/w) and its synthetic derivatives (HPP304, HPP305) inhibit hepatic HMG-CoA reductase activity and decrease serum total cholesterol levels (Lee et al., 2007). Dietary supplementation with cinnamon decreased serum cholesterol levels in broilers (Al-Kassie, 2009) and plasma cholesterol (10−25%), triglycerides, and LDL levels in White Leghorn laying hens (Sharma et al., 2009). In contrast, Torki et al. (2015) observed no effects of cinnamon essential oil on serum cholesterol levels in laying hens. Onion peel extract supplementation to a high-fat diet decreased the serum level of LDL-cholesterol and increased the level of HDL cholesterol in male Sprague Dawley rats. However, total cholesterol and triglyceride levels remained unaffected (Chung et al., 2011).

The effect of onion on lipid profiles has been described as sulfur-containing molecules that oxidize thiol compounds and NADPH, which is necessary for lipid synthesis (Sebastian et al., 1979). The lipid-lowering action of S-methyl cysteine sulfoxide (**SMCS**) isolated from onion was investigated in Sprague Dawley rats fed a 1% cholesterol diet (Kumari and Augusti, 2007). The lipid profiles in serum and tissues showed that cholesterol, triglycerides, and phospholipids were lower in treated rats than in their untreated counterparts (Kumari and Augusti, 2007).

Antioxidative mediators are essential for poultry nutrition as they decrease lipid peroxidation, improve organoleptic characteristics and nutritional value of eggs, and extend egg shelf life (Fellenberg and Speisky, 2006). Apart from being effective antioxidants, flavonoids possess immunomodulatory and, in particular, anti-inflammatory properties (Serafini et al., 2010). The most effective feature of quercetin as an antioxidant agent in onion is its ability to scavenge free radicals (reactive oxygen species), which are associated with cancer, diabetes, and chronic inflammation (Alrawaiq and Abdullah, 2014). However, reactive oxygen species play a major role in promoting cell growth and differentiation, physiological stress, and immune responses and protecting cells from pathogen invasion.

In an *in vitro* study carried out by Pietta (2000), flavonoids acted as preventive, chain-breaking antioxidants by scavenging superoxide, alkoxyl, peroxyl, and hydroxyl radicals; preventing LDL oxidation; and generating large amounts of simple phenolic acids, which positively influenced the scavenging activity of other antioxidants. Another study by Prakash et al. (2007) showed that onion is a rich source of polyphenols with promising antioxidant and free radical scavenging potential and protects against DNA damage induced by reactive oxygen and nitrogen species.

Phenolic content and antioxidant activity were higher in the essential oils of red onion than in garlic essential oils (Abdel-Salam et al., 2014). Peluso et al. (2015) demonstrated that the ethanol extract of onion peel exerts strong antioxidant activity and proposed quercetin and polyphenol as the major components responsible for this effect. Thus, an onion peel supplement improved the immune status. Ciftci et al. (2010) reported that cinnamon oil (1,000 ppm) decreased MDA levels in meat of broilers. This effect resulted from the antioxidant activity of cinnamon oil (Lin et al., 2003).

In the current study, the cellular immunity, assessed as the foot web index, was compared among different feed supplements (Table 6), and we observed that the foot web index was higher in hens that received 800 g onion supplement than in hens that received other supplements (Table 6). A previous study by Song et al. (2013) reported that IgG and IgM levels were higher ($P < 0.05$) in animals fed 5% cinnamon powder than in controls. Cinnamon infusion increased titers of antibodies against Newcastle disease virus (**NDV**; Sadeghi et al., 2012). Goodarzi et al. (2013) noted that dietary supplementation with 10 and 30 g onion bulb/kg diet showed no effect on anti-NDV titers. Moreover, the lymphoid organ weights were heavier in birds fed a diet supplemented with 30 g/kg onion. However, Lee et al. (2014) observed that an onion peel extract supplement at 4, 20, or 100 mg/kg improved the immune status of rats by increasing the number of immune-related cells and specific cytokine levels. The immunomodulating impact of dried onion and ground cinnamon can be attributed to their polyphenols and flavonoids. Abdel-Moneim et al. (2020) reported that polyphenols could regulate the immune response of birds by modulating the function of immune cells via their binding to cell receptors and consequently altering the cellular signaling pathways.

Based on the experimental findings, the effects of dietary dried onion and dried cinnamon on the laying performance, egg quality, serum lipid profile, and immune responses of Japanese quail were promising. Dietary cinnamon improved the laying rate and feed conversion ratio of laying quails. Moreover, these birds had better blood serum parameters, egg yolk lipid profiles, and immune responses than the control birds. Our results also suggested that the dietary inclusion of dried onion plus dried cinnamon could be applied as natural plant materials to enhance the performance, egg quality, and immunity in laying Japanese quail diets without detrimental effects on birds. These results are necessary for the support of global trend toward organic poultry production. However, because of the relatively small sample size used in the present study, examining the results obtained on a large scale is required.

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DISCLOSURES

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

REFERENCES

Abd El-Hack, M. E., M. Alagawany, A. E. Abdel-Moneim, N. G. Mohammed, A. F. Khafaga, M. Bin-Jumah, S. I. Othman, A. A. Allam, and S. S. Elnesr. 2020. Cinnamon (*Cinnamomum zeylanicum*) oil as a potential alternative to antibiotics in poultry. Antibiotics 9:210.

Abd El-Moneim, E. A., and E. M. Sabic. 2019. Beneficial effect of feeding olive pulp and *Aspergillus awamori* on productive performance, egg quality, serum/yolk cholesterol and oxidative status in laying Japanese quails. J. Anim. Feed Sci. 28:52–61.

Abd El-Moneim, E. A., E. M. Sabic, and A. M. Abu-Taleb. 2019. Influence of dietary supplementation of irradiated or non-irradiated olive pulp on biochemical profile, antioxidant status and immune response of Japanese quails. Biol. Rhythm Res. 27:1–16.

Abdel-Moneim, E. A., A. M. Shehata, S. O. Alzahrani, M. E. Shafi, N. M. Mesalam, A. E. Taha, A. A. Swelum, M. Arif, M. Fayyaz, and M. E Abd El-Hack. 2020. The role of polyphenols in poultry nutrition. J. Anim. Physiol. Anim. Nutr. 104:1851–1855.

Abdel-Moneim, E. A., A. M. Shehata, R. E. Khidr, V. K. Paswan, N. S. Ibrahim, A. A. El-Ghoul, S. A. Aldhumri, S. A. Gabr, N. M. Mesalam, A. M. Elbaz, M. A. Elsayed, M. M. Wakwak, and T. A. Ebeid. 2021. Nutritional manipulation to combat heat stress in poultry – a comprehensive review. J. Therm. Biol. 98:102915.

Abdel-Salam, A. F., M. E. Shahenda, and B. A. Jehan. 2014. Antimicrobial and antioxidant activities of red onion, garlic and leek in sausage. Afr. J. Microbiol. Res. 8:2574–2582.

Alberts, A. W. 1988. Discovery, biochemistry and biology of lovastatin. Am. J. Cardiol. 62:10J–15J.

Al-Kassie, G. A. M. 2009. Influence of two plant extracts derived from thyme and cinnamon on broiler performance. Pak. Vet. J. 29:169–173.

Alrawaiq, N. S., and A. Abdullah. 2014. A review of flavonoid quercetin: metabolism, bioactivity and antioxidant properties. Int. J. Pharmtech. Res. 6:933–941.

Anand, P., K. Y. Murali, V. Tandon, P. S. Murthy, and R. Chandra. 2010. Insulinotropic effect of cinnamaldehyde on transcriptional regulation of pyruvate kinase, phosphoenolpyruvate carboxykinase, and GLUT4 translocation in experimental diabetic rats. Chem. Biol. Interact. 186:72–81.

Chung, H. K., M. J. Shin, Y. J. Cha, and K. H. Lee. 2011. Effect of onion peel extracts on blood lipid profile and blood coagulation in high fat fed SD rats. Korean J. Food Nutr. 24:442–450.

Ciftci, M., U. G. Simsek, A. Yuce, O. Yilmaz, and B. Dalkilic. 2010. Effects of dietary antibiotic and cinnamon oil supplementation on antioxidant enzyme activities, cholesterol levels and fatty acid compositions of serum and meat in broiler chickens. Acta Vet. Brno. 79:33–40.

Damaziak, K., J. Riedel, D. Gozdowski, J. Niemiec, A. Siennicka, and D. Róg. 2017. Productive performance and egg quality of laying hens fed diets supplemented with garlic and onion extracts. J. Appl. Poult. Res. 26:337–349.

Dewanti, R., P. Fadilla, and M. Cahyadi. 2019. Egg quality in F1 cross between brown and black lines of Japanese quail. IOP Conference Series: Materials Science and Engineering.

Dieber-Rotheneder, M., H. Puhl, G. Waeg, G. Striegl, and H. Esterbauer. 1991. Effect of oral supplementation with D-alpha-tocopherol on the vitamin E content of human low-density lipoproteins and resistance to oxidation. J. Lipid Res. 32:1325–1332.

Ertas, O. N, T. Guler, M. Çiftçi, B. DalkIlIç, and U. G. Simsek. 2005. The effect of an essential oil mix derived from oregano, clove and anise on broiler performance. Int. J. Poult. Sci. 4:879–884.

Fellenberg, M. A., and H. Speisky. 2006. Antioxidants: their effects on broiler oxidative stress and its meat oxidative stability. Worlds Poult. Sci. J. 62:53–70.

Fisher, H., and G. A. Leveille. 1957. Observations on the cholesterol, linoleic and linolenic acid content of eggs as influenced by dietary fats. J. Nutr. 63:119–129.

Folch, J., M. Lees, and G. H. S. Stanley. 1957. A simple method for the isolation and purification of total lipides from animal tissues. J. Biol. Chem. 226:497–509.

Goodarzi, M., N. Landy, and S. Nanekarani. 2013. Effect of onion (*Allium cepa* L.) as an antibiotic growth promoter substitution on performance, immune responses and serum biochemical parameters in broiler chicks. Health 5:1210–1215.

Khaki, A., A. Farnam, A. D. Badie, and H. Nikniaz. 2012. Treatment effects of onion (*Allium cepa*) and ginger (*Zingiber officinale*) on sexual behavior of rat after inducing an antiepileptic drug (lamotrigine). Balkan Med. J. 29:236–246.

Khaki, A., F. Fathiazad, M. Nouri, A. A. Khaki, H. J. Khamenehi, and M. Hamadeh. 2009. Evaluation of androgenic activity of *Allium cepa* on spermatogenesis in the rat. Folia Morphol 68:45–51.

Kothari, D., W-. D. Lee, K-. M. Niu, and S-. K. Kim. 2019. The genus *Allium* as poultry feed additive: a review. Animals 9:1–21.

Kumar, V. G., K. P. Surendranathan, K. G. Umesh, D. R. G. Devi, and M. R. S. Belwadi. 2003. Effect of onion (*Allium cepa* Linn.) and garlic (*Allium sativum* Linn.) on plasma triglyceride content in Japanese quail (*Coturnix coturnix japonicum*). Indian J. Exp. Biol. 41:88–90.

Kumari, K., and K. T. Augusti. 2007. Lipid lowering effect of S-methyl cysteine sulfoxide from *Allium cepa* Linn in high cholesterol diet fed rats. J. Ethnopharmacol. 109:367–371.

Lee, K. W., H. Everts, H. J. Kappert, H. Wouterse, M. Frehner, and A. C. Beynen. 2004. Cinnamaldehyde, but not thymol, counteracts the carboxymethyl cellulose-induced growth depression in female broiler chickens. Int. J. Poult. Sci. 3:608–612.

Lee, H-. A., S-. J. Han, S. Hong, D-. W. Kim, G-. W. Oh, and O. Kim. 2014. Onion peel water extracts enhance immune status in forced swimming rat model. Lab. Anim. Res. 30:161–168.

Lee, M. K., Y. B. Park, S. S. Moon, S. H. Bok, D. J. Kim, T. Y. Ha, K. S. Jeong, and M. S. Choi. 2007. Hypocholesterolemic and antioxidant properties of 3-(4-hydroxyl) propanoic acid derivatives in high-cholesterol fed rats. Chem. Biol. Interact. 170:9–19.

Lin, C. C., S. J. Wu, C. H. Chang, and L. T. Ng. 2003. Antioxidant activity of *Cinnamomum cassia*. Phytother. Res. 17:726–730.

Liu, H. N., Y. Liu, L. Hu L., Y. Suo L., L. Zhang, F. Jin, X. A. Feng, N. Teng, and Y. Li. 2014. Effects of dietary supplementation of quercetin on performance, egg quality, cecal microflora populations, and antioxidant status in laying hens. Poult. Sci. 93:347–353.

Mancini, G., A. O. Carbonara, and J. F. Heremans. 1965. Immunochemical quantitation of antigens by single radial immunodiffusion. Immunochemistry 2:235–254.

Martin, P. M., K. B. Horwitz, D. S. Ryan, and W. L. McGuire. 1978. Phytoestrogen interaction with estrogen receptors in human breast cancer cells. Endocrinology 103:1860–1867.

National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. Natl. Acad. Press, Washington, DC.

Nwogor, U. A, O. Sandra, and A. Uchenna. 2020. The effects of *Allium sativum* and *Piper nigrum* on the growth performance and packed cell volume of broiler chicks. Int. J. Anim. Sci. Technol. 4:1–5.

Peluso, I., C. Miglio, G. Morabito, F. Ioannone, and M. Serafini. 2015. Flavonoids and immune function in human: a systematic review. Crit. Rev. Food Sci. Nutr. 55:383–395.

Pietta, P. G. 2000. Flavonoids as antioxidants. J. Nat. Prod. 63:1035–1042.

Prakash, D., B. N. Singh, and G. Upadhyay. 2007. Antioxidant and free radical scavenging activities of phenols from onion (*Allium cepa*). Food Chem 102:1389–1393.

Sadeghi, G. H., A. Karimi, S. H. P. Jahromi, T. Azizi, and A. Daneshmand. 2012. Effects of cinnamon, thyme and turmeric infusions on the performance and immune response in of 1-to 21-day-old male broilers. Braz. J. Poult. Sci. 14:15–20.

Sebastian, K. L., N. T. Zacharias, B. Philip, and K. T. Augusti. 1979. The hypolipidemic effect of onion (*Allium cepa* Linn) in sucrose fed rabbits. Indian J. Physiol. Pharmacol. 23:27–30.

Serafini, M., I. Peluso, and A. Raguzzini. 2010. Flavonoids as anti-inflammatory agents. Proc. Nutr. Soc. 69:273–278.

Sharma, R. K., A. V. Elangovan, A. B. Mandal, P. K. Tyagi, and A. K. Shrivastav. 2009. Response of white leghorn hens to certain herbs in diets on production performance, blood and egg cholesterol. Indian J. Poul. Sci. 44:347–351.

Şimşek, Ü. G., M. Ciftci, M. Özçelik, M. A. Azman, F. Tonbak, and N. Özhan. 2015. Effects of cinnamon and rosemary oils on egg production, egg quality, hatchability traits and blood serum mineral contents in laying quails. Ankara Üniv. Vet. Fak. Derg. 62:229–236.

Smits, J. E., G. R. Bortolotti, and J. L. Tella. 1999. Simplifying the phytohaemagglutinin skin-testing technique in studies of avian immunocompetence. Funct. Ecol. 13:567–572.

Song, F., H. Li, J. Sun, and S. Wang. 2013. Protective effects of cinnamic acid and cinnamic aldehyde on isoproterenol-induced acute myocardial ischemia in rats. J. Ethnopharmacol. 150:125–130.

Tabak, M., R. Armon, and I. Neeman. 1999. Cinnamon extracts' inhibitory effect on *Helicobacter pylori*. J. Ethnopharmacol. 67:269–277.

Tomaino, A., F. Cimino, V. Zimbalatti, V. Venuti, V. Sulfaro, A. De Pasquale, and A. Saija. 2005. Influence of heating on antioxidant activity and the chemical composition of some spice essential oils. Food Chem 89:549–554.

Torki, M., M. Akbari, and K. Kaviani. 2015. Single and combined effects of zinc and cinnamon essential oil in diet on productive performance, egg quality traits, and blood parameters of laying hens reared under cold stress condition. Int. J. Biometeorol. 59:1169–1177.

Vali, N., and S. Mottaghi. 2016. The effect of using different levels of cinnamon and thyme powder on egg characteristics and fatty acids profile in Japanese quails. CIB Tech. J. Zool. 5:40–47.

Vali, N., H. Shahin, and M. Vatankhah. 2013. Determination of the effects of *Cinnamomum zeylanicum* Blume and *Thymus vulgaris* on performance and egg quality of Japanese quail (*Coturnix japonica*). Res. Opin. Anim. Vet. Sci. 3:280–284.

Washburn, K. W., and D. F. Nix. 1974. A rapid technique for extraction of yolk cholesterol. Poult. Sci. 53:1118–1122.