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Research Article

Leverage of *Matricaria chamomilla* L. Oil Supplementation over Ochratoxin A in Growing Quails

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Ochratoxin A (OTA) is one of the mycotoxins in the agriculture and livestock sectors. The poultry sector suffered from significant economic losses due to the adverse impacts of OTA on the growth rate, feed conversion ratio, and livability. Thus, the present investigation aimed to determine the impact of chamomile essential oil supplementation against OTA toxicity in growing quails. 360 one-week-old growing quails were distributed into six groups ($n = 60$) with four replicates of 15 birds. The groups were G1 (control negative), G2 (OTA 1 mg/kg diet, control positive), G3 (chamomile oil 0.5 g/kg diet), G4 (chamomile oil 1 g/kg diet), G5 (OTA 1 mg/kg diet + chamomile oil 0.5 g/kg diet), and G6 (OTA 1 mg/kg diet + chamomile oil 1 g/kg diet). Adding OTA significantly ($P < 0.05$) reduced live body weight and weight gain at 5 weeks. Feed intake at 5 weeks was nonsignificantly reduced in G3 and G4 compared to G1. G4 showed a significant ($P < 0.05$) increase in weight gain and the lowest feed conversion ratio. The G2 showed the lowest superoxide dismutase (SOD), total antioxidant capacity (TAC), glutathione transferase (GST) activity, and the highest levels of malondialdehyde (MDA). Moreover, they showed a significant improvement in liver enzymes and kidney function tests and a significant ($P < 0.05$) reduction in the levels of total cholesterol and triglycerides. Chamomile supplementation alone or with OTA significantly ($P < 0.05$) increased immunoglobulin M, G, A, and complement 3 than OTA alone. Chamomile oil with an OTA diet or alone reduced the negative effects of OTA and improved the performance, antioxidant status, lipid profile, and immunological state of growing Japanese quails.

1. Introduction

The prevalence of mycotoxins is a global problem that has negative impacts on humans, animals, and poultry [1–3]. Several researchers have established that ochratoxin A (OTA) is one of the mycotoxins in the agriculture and livestock sectors [4–8]. Certain types of fungi, such as *Aspergillus carbonarius*, *Aspergillus ochraceus*, *Aspergillus niger*, and *Penicillium verrucosum*, are responsible for the production of OTA as a result of improper storage of products under deviated temperature and relative humidity [9, 10].

Ochratoxins have been detected in poultry feed and feed additives worldwide [11], and their immunotoxic, livertoxic, neurotoxic, teratogenic, and mutagenic effects have been extensively documented in several poultry and

mammal species [12–14]. When broilers were fed feed contaminated with OTA, the weight of immune organs was reduced [15], and the responses of humoral and cellular immune systems were suppressed [16]. It was also observed that chicks administered OTA at dosages of 2 and 4 mg/kg feed for 15 days exhibited a decrease in the number of immunoglobulin-bearing cells in both their immune organs and serum [17, 18]. Tinelli et al. [19] reported further detrimental consequences of OTA, which included elevated lipid peroxidation, impairment of mitochondrial function, and reduced synthesis of macromolecules.

Scientific investigations have demonstrated the potential efficacy of various naturally occurring feed additives, including phytochemicals, prebiotics, and probiotics, in ameliorating the severity of ochratoxicosis-related symptoms [20–22]. Broiler chicks supplemented with OTA exhibited a decrease in body weight gain (BWG), suboptimal feed efficiency, atypical relative organ weights, and abnormal serum biochemistry [23]. Due to antibiotics' detrimental effects on human and avian health, medicinal plants have been used as a potential substitute for antibiotics [24–26]. Most active components in medicinal plants are rapidly absorbed, and their half-life is shorter than antibiotics [27]. Consequently, they are completely absent from the animal tissue [28]. For thousands of years, chamomile was used for medicinal treatments in Greece, Rome, and Ancient Egypt [29]. According to several studies, chamomile is effective as an anti-inflammatory, antioxidant, sedative, wound-healing, antibacterial, and antifungal agent [29–31]. Reda et al. [32] suggested that the antimycotic, antibacterial, and anti-inflammatory activities and the antioxidant properties of chamomile could enhance body weight and improve feed conversion. Göger et al. [33] found that chamomile contains sesquiterpenoid compounds with antibiotic-like properties. Chamomile has been observed to donate protons and exhibit antioxidant properties through scavenging or inhibiting the activity of free radicals [34]. To the best of our knowledge, there are some studies on the role of herbal plants as natural additives in reducing the detrimental effects of mycotoxins, but no studies on the role of chamomile oils in growing quail diets. Therefore, we aimed to investigate the augmenting influences of chamomile in reducing the negative impact of OTA and improving performance, antioxidants, liver and renal functions, immunity, and serum biochemical markers of Japanese quails.

2. Materials and Methods

2.1. Preparation of OTA. The strain *Aspergillus ochraceus* (CGMCC 3.4412) was employed to produce OTA. This strain was sourced from the Central Laboratory of Residues of Agricultural Products, located at the Agriculture Pesticides Residues Centre in Dokki, Egypt. To synthesize OTA, the fungal organism was cultured for 8 days in a liquid medium containing 2% yeast extract and 20% sugar. The percentage of OTA in the media was determined according to the Association of Official Agricultural Chemists guidelines [35].

2.2. Tested Oil. Chamomile oil ChO was obtained from Harraz Co., a local supplier based in Egypt. A gas chromatography-mass spectrometry (GC-MS) investigation was used to ascertain the active ingredients in the ChO used in the current investigation [36]. GC-MS analysis detected several active ingredients in the ChO with different peak area % and retention times. Retention times and peak areas (%) of the natural constituent in ChO analyzed by GC-MS were 14.27 mn and 0.47% E-2-undecen-1-ol, 15.63 mn and 0.98% Valeric acid, 15.63 mn and 0.98% -Octanol, 2,7-dimethyl-, 17.45 mn and 0.68% cis-á-Farnesene, 22.23 mn and 0.23% acetic acid, 24.21 mn and 3.83% 2H-Pyran-3-ol, 27.14 mn, and 1.48%1,6-Dioxaspiro[4.4]non-3-ene, 29.18 mn and 14.98% Hexadecanoic acid (CAS), and 32.92 mn and 62.64% 6-Octadecenoic acid, respectively.

2.3. Housing and Animals. The trial was conducted in the poultry farm at the Faculty of Agriculture, Poultry Department, Zagazig University, Zagazig, Egypt. Quails were one week old and had similar average body weights (30.82 g) across all groups. The experiment complies with the Zagazig University Ethics Committee's regulations for using experimental animals (Approval No. ZU-IACUC/2/F/313/2023). The recommendations of the ARRIVE guidelines in animal research were also consulted and considered [37]. Quails were housed in traditional cages with drinking water and mash feed provided ad libitum. The trial conditions were a 23 h light–1 h dark cycle in an open-door building with 24–26°C daily temperature and 60–70% humidity. The medical program was conducted according to the different age stages under veterinarian supervision.

2.4. Experimental Design, Diets, and Treatments. The experimental method used in this research was a randomized complete block design. It consisted of six treatments (4 replicates of 15 birds), resulting in 360 growing quails. The study was designed to last for five weeks. The experimental groups were: G1 (negative control) supplemented with basal diet (BD), G2 supplemented with BD with OTA (1 mg/kg of diet), G3 supplemented with BD with chamomile (0.5 g/kg of diet), G4 supplemented with BD with chamomile (1 g/kg of diet), G5 supplemented with BD with OTA (1 mg/kg of diet) and chamomile (0.5 g/kg of diet), and G6 supplemented with BD with OTA (1 mg/kg of diet) and chamomile (1 g/kg of diet). All bird specimens were raised in identical management and hygienic environments and provided nutritionally balanced diets to meet their dietary needs, as outlined in the National Research Council guidelines (Table 1).

2.5. Growth Performance. Body weight (BW) measurements were taken for all birds at 1, 3, and 5 weeks of age using a Digital Micro Scale (model MAB250, IndiaMART C ompany, India). Additionally, BWG was measured using mathematical calculations. The feed intake was consistently measured throughout the trial periods in a duplicated manner to estimate the feed conversion ratio.

Table 1: Ingredients and nutrient contents of the basal diet of growing Japanese quail.

Item	(%)
Ingredient (%)	
Maize 8.5%	51.80
Soybean meal 44%	36.70
Maize gluten meal 62%	5.21
Soybean oil	2.90
Limestone	0.70
Di-calcium phosphate	1.65
Salt	0.30
Premix[1]	0.30
L-Lysine	0.13
Dl-Methionine	0.11
Choline chloride (50%)	0.20
Total	100
Calculated composition[2] (%)	
ME (Kcal/Kg)	2995
Crude protein	24.00
Calcium	0.80
Nonphytate P	0.45
Lysine	1.30
TSAA	0.92

[1]Provides per kg of diet: Vitamin A, 12,000 I.U; Vitamin D3, 5000 I.U; Vitamin E, 130.0 mg; Vitamin K3, 3.605 mg; Vitamin B1 (thiamin), 3.0 mg; Vitamin B2 (riboflavin), 8.0 mg; Vitamin B6, 4.950 mg; Vitamin B12, 17.0 mg; Niacin, 60.0 mg; D-Biotin, 200.0 mg; Calcium D-pantothenate, 18.333 mg; Folic acid, 2.083 mg; manganese, 100.0 mg; iron, 80.0 mg; zinc, 80.0 mg; copper, 8.0 mg; iodine, 2.0 mg; cobalt, 500.0 mg; and selenium, 150.0 mg. [2]Calculated according to NRC (1994).

2.6. Carcass Traits. At the end of the experiment, quails ($n = 30$; 5 birds randomly distributed per group) were weighed and then were anesthetized by using intramuscular injection with 1 ml/kg of ketamine xylazine mixture (2 : 1), slaughtered by sharp knife to determine carcass traits, and their blood was collected in sterile tubes for blood analysis. The carcass weight, and giblets (gizzard, heart, and liver) were quantified and expressed as a percentage of the total weight at slaughter.

2.7. Blood Parameters. Blood samples were obtained from five quails that had been sacrificed for carcass traits for each group. These samples were collected in sterilized tubes. Subsequently, the samples were allowed to undergo coagulation and centrifuged at 4000 rpm for 10 min. The collected serums were kept until they were ready for analysis. The spectrophotometric analysis of various factors was conducted using kits supplied by the Biodiagnostic Company (Giza, Egypt). These factors included total protein (TP), albumin (ALB), aspartate transaminase (AST), alanine transaminase (ALT), lactate dehydrogenase (LDH), triglycerides, total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol levels and very low-density lipoprotein (VLDL) cholesterol levels. Determining serum globulin (GLOB) levels involves subtracting albumin concentration from the total serum protein concentration. The albumin-to-globulin ratio (A/G) was calculated. The levels of immunoglobulins G (IgG), M (IgM), A (IgA), and complement 3 (C3) were determined using kits manufactured by Spectrum Company in Cairo, Egypt. The concentrations of superoxide dismutase (SOD), malondialdehyde (MDA), total antioxidant capacity (TAC), and glutathione transferase (GST) were measured in plasma samples using commercially available kits and read spectrophotometrically (UV-2600i/2700i, Shimadzu, Japan).

2.8. Microbiological Analysis. Five quails per treatment were randomly selected and slaughtered postexperiment (5 weeks) to estimate the total microbial population in the caecum content. Caecal digesta samples (1 g/quail) were rapidly prepared, placed in bottles, exposed to a stream of CO_2, and transported to the lab for microbiological analysis. According to Xia et al. [38], microbial counts (total bacterial count, lactobacilli count, *salmonella spp*., *E. coli*, and *Coliform*) were performed.

2.9. Statistical Analysis. Data were analyzed using GraphPad Prism8 software (GraphPad Software, Inc., La Jolla, CA, USA) and were first checked for normality using the D'Agostino-Pearson normality test. Differences in performance, carcasses, serum components, and oxidative stress were analyzed by one-way ANOVA (with the diet as the fixed factor) followed by the Newman–Keuls multiple comparison test. $P < 0.05$ was considered significant.

3. Results and Discussion

The findings demonstrated a significant ($P < 0.001$) difference in LBW across groups at 5 weeks. However, LBW was considerably impacted by the various dietary supplements, and G2 had the lowest BW. On the other hand, chamomile-supplemented groups showed the highest BW levels. Moreover, G5 and G6 improved BW more than the OTA-supplemented group. BWG revealed that OTA significantly ($P < 0.001$) reduced between 1 and 5 weeks compared to the control and other groups. G3 and G4 obtained a better improvement. Dietary supplements of chamomile and OTA-chamomile mix enhanced the BWG more than OTA. Moreover, during the 3–5 weeks, there were significant ($P < 0.05$) differences in BWG between the various experimental groups. Data in Table 2 revealed a nonsignificant decrease in feed intake (FI) in G3 and G4 over the experimentation period (1–5 weeks).

FI in the G5 and G6 was similar to the control. While, G2 revealed the highest level of feed intake. Likewise, treatments had a significant ($P < 0.01$) increase in FCR in G2 (1–3 and 1–5 weeks) compared to all other groups, while G4 had the best FCR.

According to the results, there are no significant differences in carcass percentage, and G4 had the lowest carcass percentage when in comparison to the other treatments, followed by G2 (Table 3).

Dietary supplementation revealed a significant ($P < 0.05$) impact on liver weight percentage, and G2 showed the highest levels in comparison to the other groups. Moreover, dietary supplementation with OTA or chamomile to quail

Table 2: Effects of treatments on growth performance of growing quails.

Items	Treatments[1]						SEM	*P* value
	G1	G2	G3	G4	G5	G6		
Body weight (g)								
1 wk	29.08	29.39	29.37	29.35	29.1	29.01	0.399	0.9732
3 wk	104.34^{b}	89.95^{d}	109.66^{a}	113.57^{a}	97.00^{c}	100.67^{bc}	1.685	<0.0001
5 wk	206.10^{b}	185.11^{d}	215.12^{a}	220.65^{a}	193.70^{c}	199.80^{bc}	2.332	<0.0001
Body weight gain (g/day)								
1–3 wk	5.38^{bc}	4.33^{e}	5.74^{ab}	6.02^{a}	4.85^{d}	5.12^{cd}	0.117	<0.0001
3–5 wk	7.27^{abc}	6.80^{c}	7.53^{ab}	7.65^{a}	6.91^{c}	7.08^{bc}	0.121	0.0129
1–5 wk	6.32^{b}	5.56^{d}	6.63^{a}	6.83^{a}	5.88^{c}	6.10^{bc}	0.082	<0.0001
Feed intake (g/day)								
1–3 wk	15.19	15.99	15.12	14.83	14.44	14.65	0.345	0.1308
3–5 wk	21.43	21.96	21.12	21.23	22.56	21.95	0.655	0.7295
1–5 wk	18.31	18.97	18.12	18.03	18.5	18.3	0.501	0.8388
Feed conversion ratio (g feed/g gain)								
1–3 wk	2.83^{b}	3.70^{a}	2.65^{bc}	2.47^{c}	2.98^{b}	2.86^{b}	0.089	<0.0001
3–5 wk	2.95	3.25	2.80	2.79	3.27	3.10	0.135	0.1420
1–5 wk	2.90^{bc}	3.41^{a}	2.73^{c}	2.64^{c}	3.15^{ab}	3.00^{bc}	0.103	0.0034

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or $P < 0.01$). [1]Treatments: G1 = control, G2 = OTA 1 mg/kg diet, G3 = chamomile 0.5 g/kg diet, G4 = chamomile 1 g/kg diet, G5 = OTA 1 mg/kg diet + chamomile 0.5 g/kg diet, G6 = OTA 1 mg/kg diet + chamomile 1 g/kg diet.

Table 3: Effects of treatments on carcass traits of growing quails.

Items	Treatments[1]						SEM	*P* value
	G1	G2	G3	G4	G5	G6		
Percentage of slaughter weight (%)								
Carcass	80.00	79.62	79.99	79.09	81.65	81.32	1.033	0.5975
Liver	2.41^{b}	2.95^{a}	2.25^{b}	2.25^{b}	2.68^{ab}	2.54^{ab}	0.127	0.0203
Gizzard	2.03	1.83	1.95	2.06	2.01	1.84	0.105	0.7529
Heart	0.95	0.81	0.80	0.93	0.81	0.92	0.049	0.1547
Giblets	5.39	5.59	5.00	5.24	5.51	5.30	0.167	0.3663

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or $P < 0.01$). [1]Treatments: G1 = control, G2 = OTA 1 mg/kg diet, G3 = chamomile 0.5 g/kg diet, G4 = chamomile 1 g/kg diet, G5 = OTA 1 mg/kg diet + chamomile 0.5 g/kg diet, G6 = OTA 1 mg/kg diet + chamomile 1 g/kg diet.

diet revealed a nonsignificant impact on gizzard, heart, and giblet percentage. Furthermore, G5 and G6 increased the carcass percentage to be comparable to G1 but insignificant.

The findings revealed that G3 and G4 had a significant ($P < 0.05$) elevation in total protein, albumin, and globulin in comparison to control and other supplements, while G2 showed the lowest levels of total protein, albumin, and globulin. The A/G levels were significantly ($P < 0.05$) increased in the G2 and G4. Furthermore, G2 presented a significant ($P < 0.05$) elevation in levels of ALT and AST, while G4 revealed the lowest ALT and AST levels. In Table 4, G2 represented a significant ($P < 0.01$) increase in LDH level while revealed the lowest level.

Creatinine, urea, and uric acid levels were significantly ($P < 0.05$) impacted in quail when OTA and chamomile were added to their diets. In comparison to the other groups, G4 (1 g/kg) showed the lowest plasma creatinine, urea, and uric acid level, while G2 revealed the highest plasma creatinine, urea, and uric acid. Table 5 shows that the addition of chamomile at a level (1 g chamomile/kg diet) to the diet decreased plasma total cholesterol levels ($P < 0.001$) and raised plasma HDL levels ($P < 0.001$).

Triglyceride, LDL, and VLDL readings in the G4 were significantly less ($P < 0.05$) than in the G1 group. The G5 revealed the highest levels of total cholesterol, triglyceride, LDL, and VLDL and the lowest levels of plasma HDL.

The results of the plasma's antioxidant status are shown in Table 6. There were no statistically significant differences observed between treatments in terms of the activity of SOD in the plasma. The G4 showed the highest level of SOD, while G2 revealed the lowest levels. Compared to the G1 group, the levels of MDA were significantly ($P < 0.001$) reduced in G4 and increased in G2. TAC was higher ($P < 0.001$) in G4 than in G1, while G2 revealed the lowest levels. GSH levels were higher in G4 than in the G1.

As shown in Table 6, there were statistically significant ($P < 0.001$) variations in plasma concentrations of IgM, IgG, IgA, and complement 3 in each group, and G3 revealed a significant ($P < 0.01$) elevation in the plasma concentrations of IgM and IgG, while G4 revealed a significant ($P < 0.01$) elevation in the plasma concentrations of IgA and complement 3 in comparison to the other groups.

The G2 revealed a significant ($P < 0.001$) decrease in IgM, IgG, IgA, and complement 3 plasma concentrations.

Table 4: Effects of treatments on lipid profile of growing quails.

Items[2]	Treatments[1]						SEM	*P* value
	G1	G2	G3	G4	G5	G6		
TC (mg/dL)	158.95^{c}	220.40^{a}	155.97^{c}	148.49^{c}	196.65^{ab}	175.80^{bc}	7.827	0.0006
TG (mg/dL)	161.60^{d}	344.05^{a}	158.35^{d}	144.55^{d}	288.85^{b}	215.25^{c}	9.502	<0.0001
HDL (mg/dL)	51.63^{b}	28.76^{d}	53.42^{b}	62.51^{a}	34.66^{cd}	39.60^{c}	2.702	<0.0001
LDL (mg/dL)	75.01^{c}	122.83^{a}	70.89^{c}	57.07^{d}	104.23^{b}	93.16^{b}	4.184	<0.0001
VLDL (mg/dL)	32.32^{d}	68.81^{a}	31.67^{d}	28.91^{d}	57.77^{b}	43.05^{c}	1.900	<0.0001

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or $P < 0.01$). [1]Treatments: G1 = control, G2 = OTA 1 mg/kg diet, G3 = chamomile 0.5 g/kg diet, G4 = chamomile 1 g/kg diet, G5 = OTA 1 mg/kg diet + chamomile 0.5 g/kg diet, G6 = OTA 1 mg/kg diet + chamomile 1 g/kg diet. [2]TC: total cholesterol; TG: triglycerides; HDL: high-density lipoprotein; LDL: low density lipoprotein; VLDL: very low-density lipoprotein.

Table 5: Effects of treatments on liver and kidney functions of growing quails.

Items[2]	Treatments[1]						SEM	*P* value
	G1	G2	G3	G4	G5	G6		
TP (g/dL)	3.20^{ab}	2.14^{c}	3.68^{a}	3.52^{a}	2.71^{b}	2.93^{b}	0.153	0.0006
ALB (g/dL)	1.35^{cd}	1.20^{d}	1.69^{ab}	1.86^{a}	1.53^{bc}	1.39^{cd}	0.069	0.0011
GLOB (g/dL)	1.86^{a}	0.94^{c}	1.99^{a}	1.67^{ab}	1.18^{bc}	1.54^{ab}	0.142	0.0030
A/G ratio	0.73^{b}	1.31^{a}	0.86^{b}	1.13^{ab}	1.29^{a}	0.96^{ab}	0.097	0.0305
ALT (IU/L)	10.21^{c}	15.05^{a}	9.55^{c}	7.24^{d}	12.73^{b}	11.02^{bc}	0.663	<0.0001
AST (IU/L)	139.45^{c}	210.40^{a}	145.77^{c}	103.90^{d}	173.90^{b}	159.80^{bc}	7.629	<0.0001
LDH (IU/L)	222.65^{b}	372.38^{a}	236.90^{b}	199.25^{b}	335.10^{a}	287.45^{ab}	25.747	0.0040
Creat (mg/dL)	0.61^{b}	0.82^{a}	0.36^{c}	0.35^{c}	0.52^{b}	0.42^{c}	0.031	<0.0001
Urea (mg/dL)	0.96^{c}	3.91^{a}	1.04^{c}	0.94^{c}	2.60^{b}	2.10^{b}	0.238	<0.0001
Uric acid A	9.32^{b}	12.21^{a}	7.36^{c}	6.37^{c}	10.58^{ab}	10.23^{b}	0.510	<0.0001

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or $P < 0.01$). [1]Treatments: G1 = control, G2 = OTA 1 mg/kg diet, G3 = chamomile 0.5 g/kg diet, G4 = chamomile 1 g/kg diet, G5 = OTA 1 mg/kg diet + chamomile 0.5 g/kg diet, G6 = OTA 1 mg/kg diet + chamomile 1 g/kg diet. [2]TP: total protein; ALB: albumin; GLOB: globulin; A/G ratio: albumin: globulin ratio; ALT: alanine aminotransferase; AST: aspartate aminotransferase, LDH: lactate dehydrogenase, Creat: creatinine.

Table 6: Effects of treatments on immunity and antioxidants of growing quails.

Items[2]	Treatments[1]						SEM	*P* value
	G1	G2	G3	G4	G5	G6		
Antioxidants								
SOD (U/mL)	0.17	0.16	0.20	0.19	0.17	0.16	0.029	0.9458
MDA (nmol/mL)	0.52^{c}	1.28^{a}	0.40^{cd}	0.30^{d}	1.05^{b}	0.90^{b}	0.050	<0.0001
TAC (ng/ml)	0.56^{b}	0.24^{c}	1.17^{a}	1.19^{a}	0.54^{b}	0.75^{b}	0.063	<0.0001
GST (ng/ml)	0.17	0.15	0.20	0.21	0.16	0.14	0.016	0.0538
Immunity								
IgM (mg/dl)	0.46^{c}	0.23^{d}	0.79^{a}	0.64^{b}	0.38^{c}	0.43^{c}	0.023	<0.0001
IgG (mg/dl)	0.83^{b}	0.47^{c}	1.15^{a}	1.06^{a}	0.76^{b}	0.70^{b}	0.059	<0.0001
IgA (mg/dl)	0.65^{b}	0.28^{c}	1.14^{a}	1.31^{a}	0.59^{b}	0.63^{b}	0.055	<0.0001
Complement 3 (mg/dl)	131.00^{bc}	105.50^{d}	140.00^{ab}	150.50^{a}	127.00^{c}	122.50^{c}	3.801	<0.0001

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$, or $P < 0.01$). [1]Treatments: G1 = control, G2 = OTA 1 mg/kg diet, G3 = chamomile 0.5 g/kg diet, G4 = chamomile 1 g/kg diet, G5 = OTA 1 mg/kg diet + chamomile 0.5 g/kg diet, G6 = OTA 1 mg/kg diet + chamomile 1 g/kg diet. [2]SOD: superoxide dismutase; MDA: malondialdehyde; TAC: total antioxidant capacity; GST: glutathione transferase; IgG: immunoglobulin G: IgM: immunoglobulin M; IgA: immunoglobulin A.

Data in Table 7 demonstrates the impact of OTA and chamomile on growing quail's gut microbial composition.

G4 showed a nonsignificant reduction in total yeast and mold count levels and a significant ($P < 0.05$) reduction in *E. coli,* coliforms, *Salmonella*, and *Enterococcus* count compared to the other groups. Moreover, the same group revealed a significant ($P < 0.001$) elevation in levels of total bacterial count and lactic acid bacteria. In addition, G2 showed a significant ($P < 0.05$) elevation in *E. coli*, coliforms, *Salmonella*, and *Enterococcus* count compared to G1.

OTAs are the most well-known food and feedstuff pollutants due to their potential to induce adverse health effects and economic losses [39, 40]. The dose rate and the length of exposure both play a role in determining the seriousness of symptoms and the clinical signs associated with OTA toxicity. The most prominent symptoms that birds

Table 7: Effects of treatments on the microbial count of growing quails.

Items	Treatments[1]						SEM	*P* value
	G1	G2	G3	G4	G5	G6		
Microbiological count (log CFU/g)								
Total bacterial count	6.85^{ab}	6.71^{bc}	6.88^{a}	6.92^{a}	6.48^{d}	6.65^{c}	0.047	0.0002
Total yeasts and molds count	4.37	4.35	4.21	4.18	4.25	4.26	0.074	0.4809
E. coli	5.67^{a}	5.75^{a}	5.42^{bc}	5.38^{c}	5.53^{b}	5.45^{bc}	0.033	<0.0001
Coliform	6.73^{a}	6.75^{a}	6.58^{b}	6.53^{b}	6.60^{b}	6.65^{ab}	0.036	0.0078
Salmonella spp.	2.09^{a}	2.19^{a}	1.64^{c}	1.41^{d}	1.83^{b}	2.11^{a}	0.043	<0.0001
Lactic acid bacteria	6.47^{b}	5.20^{e}	6.77^{a}	6.85^{a}	5.93^{c}	5.41^{d}	0.052	<0.0001
Enterococcus spp.	5.54^{c}	5.90^{a}	5.38^{d}	5.18^{e}	5.69^{b}	5.63^{bc}	0.043	<0.0001

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$, or $P < 0.01$). [1]Treatments: G1 = control, G2 = OTA 1 mg/kg diet, G3 = chamomile 0.5 g/kg diet, G4 = chamomile 1 g/kg diet, G5 = OTA 1 mg/kg diet + chamomile 0.5 g/kg diet, G6 = OTA 1 mg/kg diet + chamomile 1 g/kg diet.

display include weakness, a reduced FCR, impaired growth, compromised egg and feather quality, increased mortality rates, and elevated weight of internal organs such as the liver, spleen, pancreas, proventriculus, gizzard, and testes in male birds [41].

Studies displayed that OTA hurts laying hens' ADG, ADFI, and productivity [42]. In the current investigation, quail given a diet that contaminated OTA showed a statistically significant reduction in their LBW and BWG. The reduction in quail body weight caused by ochratoxicosis was consistent with the findings of several earlier studies in broilers that used dietary OTA supplementation at 567 ppb [43], 0.5 to 2 parts/10^6 [44–46]. OTA negatively impacts the digestive tract, causing a decrease in feed absorption and body weight and weight gain [45]. In contrast, Prior et al. [44] revealed that the decrease in body weight observed during ochratoxicosis was not primarily caused by the direct impact of OTA. However, it was attributed to the reduced consumption of feed, which subsequently resulted in a decline in total serum proteins or hypoproteinaemia. Elaroussi et al. [13] reported that broilers' decreased feed consumption, FCR, and body weight may have resulted from their elevated serum T3 and decreased T4. The findings of our study showed that the inclusion of chamomile as a dietary supplement for growing quails resulted in a significant rise in live body weight at 5 weeks of age compared to the control group.

Furthermore, quails in G3 and G4 exhibited increased BWG and reduced feed conversion ratio. Our findings contrast the findings of Dada et al. [47], who noted no positive effects in growing quail at chamomile concentrations of 0.002 and 0.004% in feed and 0.0018 and 0.0036% in water. This lack of favorable effects could be attributed to the low dosages in their study. Moreover, including chamomile at different concentrations (0.25, 0.50, 0.75, and 1%) showed a significant reduction in broiler chickens' final body weight and weight gain [48]. According to McCrea et al. [49], the active constituents in chamomile flowers can potentially prevent the proliferation of unfavorable intestinal microorganisms. These compounds have antimicrobial, antifungal, and anti-inflammatory effects, similar to what probiotics do in the gut, which may improve nutrient absorption, preserve the normal microbiota, and inhibit the excessive spread of disease-causing bacteria in the gut [50]. According to Abaza et al. [51], chamomile's antimicrobial, antifungal, and anti-inflammatory properties can potentially enhance productive efficiency. Moreover, chamomile enhances the activity of thyroxin hormones, which accelerates food metabolism and raises body weight [52]. However, Tenório et al. [53] observed that the performance of the birds was not significantly affected by the chamomile extract.

The current findings indicate that OTA has detrimental effects on carcass traits, as evidenced by a decrease in carcass and giblet percentages and a decrease in the relative weight of some organs, such as the gizzard and heart. The observed reduction in growth may be due to several factors, including a decline in food intake, the redirection of nutrients, and a decrease in the synthesis of proteins necessary for the regeneration of organs affected by OTA poisoning. According to our results, we only observed statistically significant differences ($P < 0.05$) in liver weights among carcass features, and the G2 revealed a significant increase in liver weights compared to the other groups. Our results agree with Stoev [54], who reported many pathological changes were observed in the liver of chicks treated with OTA, including granular deterioration, swelling, and infrequently fatty modifications of the liver cells.

The current study demonstrates that exposure to OTA in a quail diet significantly reduced total protein, albumin, and globulin levels compared to control and other supplements. Moreover, OTA caused a significantly high level of liver enzyme activity (AST and ALT) and LDH, creatinine, uric acid, and urea levels. The increased levels of liver enzymes can be attributed to tissue damage and the subsequent release of enzymes into the bloodstream [55]. Our findings were consistent with Sakhare et al. [56], who documented that OTA elevated uric acid levels and creatinine in broiler chicks. Moreover, exposure to OTA resulted in renal damage and increased uric acid and creatinine levels [45]. Incorporating chamomile as a dietary supplement for growing quails in the current study led to a significant increase in total protein, albumin, and globulin levels compared to control and other supplements.

Furthermore, chamomile supplementation for growing quails resulted in a significant decrease in the levels of liver enzymes (AST and ALT), LDH, creatinine, urea, and uric

acid compared to the other groups. Our result disagrees with Akbari et al. [57], who observed that broilers fed with *Matricaria chamomilla* 0.6% and 1.2% exhibited significantly higher uric acid levels than control. Furthermore, laying Japanese quail that received chamomile supplementation significantly increased total protein and albumin serum levels and reduced glucose levels [58]. There were no variations in the total bilirubin, direct bilirubin, creatinine, and ALT levels compared to the control group. The current findings match El-Galil et al. [24], which examined the impact of including chamomile powder into the diet on serum biochemical markers in laying Japanese quail. Additionally, adding chamomile to the diet of Japanese quails at a concentration of 0.3% led to a significant rise in total protein and globulin levels and a decrease in cholesterol [59].

The current study revealed that when quail were fed a diet containing OTA, total cholesterol, triglyceride, LDL, and VLDL were significantly elevated. Our findings were in contrast with those reported by Abo El-Fetouh et al. [60], which indicated that OTA caused a significant reduction in the levels of serum total fat, cholesterol, and triglycerides in ducks and with the finding reported by Elaroussi et al. [13], who observed that OTA induces a decrease in total lipid, triglyceride, and cholesterol levels in chickens. The trial conducted by Schaeffer et al. [61] showed a decrease in blood total lipid, cholesterol, and triglyceride levels in broiler chickens exposed to OTA. In contrast, chamomile supplementation to the quails' diet revealed a significant decrease in total cholesterol, triglyceride, LDL, and VLDL levels. Our findings demonstrated that OTA exposure in growing quail led to a notable reduction in SOD, TAC, and glutathione transferase (GST) while concurrently causing a significant elevation in the levels of MDA. However, the administration of the chamomile resulted in an increase in SOD activity and TAC, along with a significant decrease in MDA levels, as also observed by other authors [62, 63]. The results of our findings also agree with Sinha [64], who indicated that OTA induced reductions in SOD and CAT activity and an increase in the level of MDA in rats [64], and Sohail et al. [65]; who found a modification in the antioxidant enzyme levels following the supplementation of anti-OTA.

Our findings demonstrated that the administration of OTA revealed a significant reduction in IgM, IgG, IgA, and complement 3 levels. According to Ruan et al. [66], OTA has been found to lower the synthesis of the anti-inflammatory cytokine IL-10 and reduce the IgA concentration in poultry jejunum. Likewise, Tong et al. [67] found that the mRNA expression of IL-1β and tumor necrosis factor α was elevated, and the phosphorylation of nf-kB was induced in one-day-old broiler hens fed 50 μg of OTA/kg body weight. In addition, the administration of OTA to broilers at a concentration of 4 parts/10^6 reduced humoral immunity. Moreover, when OTA was combined with aflatoxin at a concentration of 2 parts/10^6, both humoral and cellular immunity were shown to be lowered [16]. The immunological response of chickens following immunization against the B1 strain of Newcastle disease virus [54, 68] or the Lasota strain [69] is reduced by OTA, leading to immunity suppression at both the humoral and cellular levels. This suppression also creates an opportunity for subsequent bacterial infections [12, 46]. The present investigation showed that either 1 or 0.5 g of chamomile in the OTA diet significantly reduced or prevented certain adverse effects caused by OTA and increased levels of IgM, IgG, and IgA. The immunomodulatory effects observed in chamomile may be due to the activation of immunostimulatory abilities of macrocytes, the stimulation of immunoregulatory cells in peripheral circulation, and the enhanced susceptibility of effector cells to support signals [70].

The present study indicates that the administration of OTA revealed a significant increase in quail gut total yeast and mold count, *E. coli*, coliforms, *Salmonella*, and *Enterococcus* compared to control and other animals. According to Yang et al. [71], introducing OTA in the diet at a concentration of 50 μg/kg BW for 21 days in White Feather Broilers decreased the diversity and abundance of caecal microbiota. Several recent research studies have documented the antibacterial properties of chamomile, showing that the lactobacilli levels in the intestinal digesta were significantly increased in broilers that were administered *Matricaria chamomilla* at concentrations of 0.6 and 0.9% in their diets, in comparison to the control diet [72]. The present investigation demonstrated that including chamomile at doses of 0.5 or 1 g/kg in a growing quail diet containing OTA significantly reduced or prevented certain adverse effects of OTA on the gut microorganisms.

4. Conclusions

The administration of chamomile oil combined with OTA revealed a reduction in the negative impacts of OTA, improving the growth performance, antioxidant capacity, liver and kidney function, immune response, and gut microbiota of growing Japanese quails. Using chamomile oil up to 1 g/kg diet could also be useful in solving the problem of OTA in poultry farms.

Data Availability

The data presented in this study are available from the corresponding authors upon request.

Disclosure

No persons or third-party services were involved in the research and manuscript preparation. Moreover, no AI softwares have been used to prepare the manuscript.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

R.S.M., M.M.A., and M.A. conceptualized the study. A.I.A., M.M.E.-M., and A.S.S. proposed the methodology. A.D.C. and M.N. performed formal analysis. F.S.A.I. and M.M.A. investigated the study. A.D.C. and M.A. provided resources.

M.N., A.I.A., R.S.M., and M.M.A. contributed to data curation. A.D.C., M.N., M.A., and R.S.M. wrote the original draft. A.D.C., R.S.M., and M.A. reviewed and edited the article. A.D.C. and M.A. supervised the study. A.D.C., M.A., and R.S.M. performed project administration. All authors agree to be accountable for the content and conclusions of the article.

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References

[1] A. I. Moussa, "Efficacy of kaolin and bentonite clay to reduce aflatoxin M1 content in contaminated milk and effects on milk quality," *Pakistan Veterinary Journal*, vol. 40, 2019.

[2] X. Lin, M. Mohsin, R. Abbas et al., *Evaluation of Immunogenicity and Protective Efficacy of Eimeria Maxima Immune Mapped Protein 1 with EDA Adjuvant in Chicken*, 2020.

[3] M. M. Awais, U. Mehtab, M. I. Anwar et al., "Mitigation potential of individual and combined dietary supplementation of local Bentonite Clay and Distillery Sludge against Ochratoxin-A induced toxicity in broilers," *BMC Veterinary Research*, vol. 18, no. 1, p. 375, 2022.

[4] M. I. E. Ghonaim, A. M. Eid, M. K. Elmossalami, and H. H. Abdel-Naeem, *Sensory, Deterioration and Bacteriological Assessment of Some Ready to Eat Poultry Products*, 2020.

[5] M. Imran, *Mycotoxins A Global One Health Concern: A Review*, 2020.

[6] A. Khaskheli, M. Khaskheli, A. J. Khaskheli, and A. Khaskheli, *Dietary Influence of Yucca Schidigera on Broilers and Layers: A Review*, International Journal of Veterinary Science, 2020.

[7] Z. Abidin, A. Khatoon, and M. Numan, "Mycotoxins in broilers: pathological alterations induced by aflatoxins and ochratoxins, diagnosis and determination, treatment and control of mycotoxicosis," *World's Poultry Science Journal*, vol. 67, no. 3, pp. 485–496, 2011.

[8] M. Makarski, K. Piotrowska, A. Zbikowski et al., "Silica-calcite sedimentary rock (opoka) enhances the immunological status and improves the growth rate in broilers exposed to ochratoxin A in feed," *Animals*, vol. 14, no. 1, p. 24, 2023.

[9] D. C. Kemboi, P. E. Ochieng, G. Antonissen et al., "Multi-Mycotoxin occurrence in dairy cattle and poultry feeds and feed ingredients from machakos town, Kenya," *Toxins*, vol. 12, p. 762, 2020.

[10] P. Battilani, R. Palumbo, P. Giorni et al., "Mycotoxin mixtures in food and feed: holistic, innovative, flexible risk assessment modelling approach," *EFSA Supporting Publications*, vol. 17, no. 1, p. 1757E, 2020.

[11] G. R. Murugesan, D. R. Ledoux, K. Naehrer et al., "Prevalence and effects of mycotoxins on poultry health and performance, and recent development in mycotoxin counteracting strategies," *Poultry Science*, vol. 94, no. 6, pp. 1298–1315, 2015.

[12] A. Kumar, N. Jindal, C. L. Shukla, R. K. Asrani, D. R. Ledoux, and G. E. Rottinghaus, "Pathological changes in broiler chickens fed ochratoxin A and inoculated with *Escherichia coli*," *Avian Pathology*, vol. 33, no. 4, pp. 413–417, 2004.

[13] M. Elaroussi, F. R. Mohamed, M. S. Elgendy, E. E. Barkouky, A. M. Abdou, and M. Hatab, "Ochratoxicosis in broiler chickens: functional and histological changes in target organs," *International Journal of Poultry Science*, vol. 7, no. 5, pp. 414–422, 2008.

[14] S. A. Khan, E. J. Venancio, M. A. Ono et al., "Effects of subcutaneous ochratoxin-A exposure on immune system of broiler chicks," *Toxins*, vol. 11, no. 5, p. 264, 2019.

[15] P. Dwivedi and R. B. Burns, "Immunosuppressive effects of ochratoxin A in young turkeys," *Avian Pathology*, vol. 14, no. 2, pp. 213–225, 1985.

[16] J. Verma, T. S. Johri, B. K. Swain, and S. Ameena, "Effect of graded levels of aflatoxin, ochratoxin and their combinations on the performance and immune response of broilers," *British Poultry Science*, vol. 45, no. 4, pp. 512–518, 2004.

[17] P. Dwivedi and R. B. Burns, "Effect of ochratoxin A on immunoglobulins in broiler chicks," *Research in Veterinary Science*, vol. 36, no. 1, pp. 117–121, 1984.

[18] M. A. Tahir, A. Abbas, M. Muneeb et al., "Ochratoxicosis in poultry: occurrence, environmental factors, pathological alterations and amelioration strategies," *World's Poultry Science Journal*, vol. 78, no. 3, pp. 727–749, 2022.

[19] A. Tinelli, G. Passantino, A. Perillo, and N. Zizzo, "Anatomopathological consequences of mycotoxins contamination in rabbits feed," *Iranian Journal of Applied Animal Science*, vol. 9, pp. 379–387, 2019.

[20] I. E. Ismail, M. R. Farag, M. Alagawany, H. K. Mahmoud, and F. M. Reda, "Efficacy of some feed additives to attenuate the hepato-renal damage induced by aflatoxin B1 in rabbits," *Journal of Animal Physiology and Animal Nutrition*, vol. 104, no. 5, pp. 1343–1350, 2020.

[21] A. Kihal, M. Rodríguez-Prado, and S. Calsamiglia, "The efficacy of mycotoxin binders to control mycotoxins in feeds and the potential risk of interactions with nutrient: a review," *Journal of Animal Science*, vol. 100, no. 11, 2022.

[22] M. R. Farag, H. S. A. Gharib, K. El-Naggar et al., "Origanum majorana essential oil ameliorated the behavior-al,biochemical, physiological and performance perturbations induced by aflatoxin B1 in growing rabbits," *Annals of Animal Science*, vol. 23, no. 4, pp. 1201–1210, 2023.

[23] P. Thavitiki, M. Varra, S. Tv, and K. Kumar, "Efficacy of *Saccharomyces cerevisiae*," in *Reducing the Effects of Ochratoxicosis in Broiler Chicks*, 2018.

[24] K. Abd El-Galil, H. Mahmoud, A. Hassan, and A. Morsy, "Effect of chamomile flowers meal as feed additives in laying Japanese quail diets on productive and reproductive performance," *Journal of Animal and Poultry Production*, vol. 1, no. 10, pp. 517–533, 2010.

[25] M. Alagawany, E. Ashour, and F. Reda, "Effect of dietary supplementation of garlic (Allium sativum) and turmeric (Curcuma longa) on growth performance, carcass traits, blood profile and oxidative status in growing rabbits," *Annals of Animal Science*, vol. 16, pp. 1–17, 2016.

[26] A. S. Salah, O. A. Ahmed-Farid, M. A. Nassan, and M. S. El-Tarabany, "Dietary curcumin improves energy metabolism, brain monoamines, carcass traits, muscle oxidative stability and fatty acid profile in heat-stressed broiler chickens," *Antioxidants*, vol. 10, no. 8, p. 1265, 2021.

[27] A. Guerrini and D. E. A. Tedesco, "Restoring activity of milk thistle (*Silybum marianum* L.) on serum biochemical parameters, oxidative status, immunity, and performance in poultry and other animal species, poisoned by mycotoxins: a review," *Animals*, vol. 13, no. 3, p. 330, 2023.

[28] J. K. Srivastava and S. Gupta, "Extraction, characterization, stability and biological activity of flavonoids isolated from

chamomile flowers," *Molecular and Cellular Pharmacology*, vol. 1, no. 3, pp. 138–147, 2009.

[29] O. Singh, Z. Khanam, N. Misra, and M. K. Srivastava, "Chamomile (Matricaria chamomilla L.): an overview," *Pharmacognosy Reviews*, vol. 5, no. 9, pp. 82–95, 2011.

[30] J. K. Srivastava, E. Shankar, and S. Gupta, "Chamomile: a herbal medicine of the past with bright future," *Molecular Medicine Reports*, vol. 3, no. 6, pp. 895–901, 2010.

[31] K. Beski, "Delivery route of chamomile on the growth and subsequent physiology of broiler chickens under E. COLI challenge," *The Iraqi Journal of Agricultural Sciences*, vol. 51, pp. 1058–1073, 2020.

[32] F. M. Reda, I. S. M. A. I. L. E. Ismail, M. O. H. A. M. E. D. M. El-Mekkawy, M. R. Farag, H. E. M. A. T. K. Mahmoud, and M. Alagawany, "Dietary supplementation of potassium sorbate, hydrated sodium calcium almuniosilicate and methionine enhances growth, antioxidant status and immunity in growing rabbits exposed to aflatoxin B1 in the diet," *Journal of Animal Physiology and Animal Nutrition*, vol. 104, no. 1, pp. 196–203, 2020.

[33] G. Göger, B. Demirci, S. Ilgin, and F. Demirci, "Antimicrobial and toxicity profiles evaluation of the Chamomile (Matricaria recutita L.) essential oil combination with standard antimicrobial agents," *Industrial Crops and Products*, vol. 120, pp. 279–285, 2018.

[34] W. Helmy, M. Osman, H. Taie, and H. Amer, "Screening for antioxidant, antifungal, and antitumor activities of aqueous extracts of chamomile (Matricaria chamomilla)," *Egyptian Pharmaceutical Journal*, vol. 15, no. 2, pp. 55–61, 2016.

[35] Aoac, "Official method 989.05, fat in milk, modified mojonnier, ether extrac tion method," 2006, https://d163axztg8am2h.cloudfront.net/static/doc/33/39/67e2a818ad56f4785aa08ee21f10.pdf.

[36] K. Smigielski, M. Dolot, and A. Raj, "Composition of the essential oils of ginseng roots of Panax quinquefolium L. and Panax ginseng CA Meyer," *Journal of Essential Oil Bearing Plants*, vol. 9, no. 3, pp. 261–266, 2006.

[37] N. Percie Du Sert, V. Hurst, A. Ahluwalia et al., "The ARRIVE guidelines 2.0: updated guidelines for reporting animal research," *BMC Veterinary Research*, vol. 16, no. 1, p. 242, 2020.

[38] M. S. Xia, C. H. Hu, and Z. R. Xu, "Effects of copper-bearing montmorillonite on growth performance, digestive enzyme activities, and intestinal microflora and morphology of male broilers," *Poultry Science*, vol. 83, no. 11, pp. 1868–1875, 2004.

[39] V. Tsiouris, P. Tassis, J. Raj et al., "Investigation of a novel multicomponent mycotoxin detoxifying agent in amelioration of mycotoxicosis induced by aflatoxin-B1 and ochratoxin A in broiler chicks," *Toxins*, vol. 13, no. 6, p. 367, 2021.

[40] A. R. Varalakshmi, A. Josephine, R. K. Priya, and K. Revathi, "Ameliorating the effect of mycotoxins in poultry feeds using plant extracts," *JPRI*, vol. 33, pp. 334–348, 2021.

[41] J. Nedeljkovic-Trailovic, S. Trailovic, R. Resanovic, D. Milicevic, M. Jovanovic, and M. Vasiljevic, "Comparative investigation of the efficacy of three different adsorbents against OTA-induced toxicity in broiler chickens," *Toxins*, vol. 7, no. 4, pp. 1174–1191, 2015.

[42] M. Denli, J. C. Blandon, M. E. Guynot, S. Salado, and J. F. Perez, "Efficacy of a new ochratoxin-binding agent (OcraTox) to counteract the deleterious effects of ochratoxin A in laying hens," *Poultry Science*, vol. 87, no. 11, pp. 2266–2272, 2008.

[43] A. R. Garcia, E. Avila, R. Rosiles, and V. M. Petrone, "Evaluation of two mycotoxin binders to reduce toxicity of broiler diets containing ochratoxin A and T-2 toxin contaminated grain," *Avian Diseases*, vol. 47, no. 3, pp. 691–699, 2003.

[44] M. G. Prior, J. B. O'Neil, and C. S. Sisodia, "Effects of ochratoxin A on growth response and residues in broilers," *Poultry Science*, vol. 59, no. 6, pp. 1254–1257, 1980.

[45] M. V. Raju and G. Devegowda, "Influence of esterified-glucomannan on performance and organ morphology, serum biochemistry and haematology in broilers exposed to individual and combined mycotoxicosis (aflatoxin, ochratoxin and T-2 toxin)," *British Poultry Science*, vol. 41, no. 5, pp. 640–650, 2000.

[46] A. Kumar, N. Jindal, C. L. Shukla, Y. Pal, D. R. Ledoux, and G. E. Rottinghaus, "Effect of ochratoxin A on Escherichia coli-challenged broiler chicks," *Avian Diseases*, vol. 47, no. 2, pp. 415–424, 2003.

[47] R. Dada, M. Toghyani, and S. A. Tabeidian, "The effect of chamomile flower (Matricaria chamomilla L.) extract and powder as growth promoter on growth performance and digestive organs of broiler chickens," *Research Opinions in Animal and Veterinary Sciences*, vol. 5, pp. 290–294, 2015.

[48] A. Hamada, S. Kadry, and A. T. Ayman, *Impact of Two Herbal Seeds Supplementation on Growth Performance and Some Biochemical Blood and Tissue Parameters of Broiler Chickens*, 2015.

[49] B. Mccrea, K. Macklin, R. Norton, J. Hess, and S. Bilgili, "Recovery of Campylobacter jejuni from broiler house samples during four consecutive flocks: isolate distribution," *Poultry Science*, vol. 84, p. 35, 2005.

[50] R. Kołacz, E. Bodak, M. Świtała, and P. Gajewczyk, "Herb as agents affecting the immunological status and growth of piglets weaned with body weight deficiency," *Journal of Animal and Feed Sciences*, vol. 6, no. 2, pp. 269–279, 1997.

[51] I. Abaza, M. Asar, G. Elshaarrawi, and F. Hassan, "Effect of using nigella seeds, chamomile flowers, thyme flowers and harmala seeds as feed additives," *Egyptian Journal of Agricultural Research*, vol. 81, no. 2, pp. 735–750, 2003.

[52] M. M. Bayliak, T. R. Dmytriv, A. V. Melnychuk, N. V. Strilets, K. B. Storey, and V. I. Lushchak, "Chamomile as a potential remedy for obesity and metabolic syndrome," *EXCLI J*, vol. 20, pp. 1261–1286, 2021.

[53] K. Tenório, S. Sgavioli, B. Roriz et al., "Effect of chamomile extract on the welfare of laying Japanese quail," *Revista Brasileira de Zootecnia*, vol. 46, no. 9, pp. 760–765, 2017.

[54] S. D. Stoev, D. Djuvinov, T. Mirtcheva, D. Pavlov, and P. Mantle, "Studies on some feed additives giving partial protection against ochratoxin A toxicity in chicks," *Toxicology Letters*, vol. 135, no. 1-2, pp. 33–50, 2002.

[55] G. Sawale, R. C. Gosh, K. Ravikanth, S. Maini, and D. S. Rekhe, "Experimental mycotoxicosis in layer induced by ochratoxin A and its amelioration with herbomineral toxin binder 'toxiroak," *International Journal of Poultry Science*, vol. 8, pp. 798–803, 2009.

[56] P. Sakhare, S. Harne, D. Kalorey, S. Warke, A. Bhandarkar, and N. Kurkure, "Effect of polyherbal feed supplement "growell" during induced aflatoxicosis, ochratoxicosis and combined mycotoxicoses in broiler," *Veterinarski Arhiv*, vol. 77, pp. 129–146, 2007.

[57] M. Akbari, S. S. Ashrafi, M. Bouyeh, J. R. Jaber, A. Seidavi, and M. Ventura, "Evaluation of chamomile (Matricaria chamomilla L.) as an alternative growth promoter in broiler chicks," *Animal Nutrition and Feed Technology*, vol. 20, no. 1, p. 71, 2020.

[58] F. Yousseff, *Effects of Chamomile Aqueous Extract on Productive Performance, Egg Quality, and Serum Biochemical Parameters in Laying Japanese Quails*, 2023.

[59] A. Taleb and S. El Afifi, "Effect of using some medicinal plants (anise, chamomile, and ginger) on productive and physiological performance of Japanese quail," *Isotope and Radiation Research*, vol. 40, pp. 1061–1070, 2007.

[60] H. Abo El Fetouh, A. Heba, S. Halla, G. El Kader, and N. kamora, "Pathological and biochemical studies on ochratoxicosis in balady duckling with trail of treatment," *Benha Veterinary Medical Journal*, vol. 31, no. 1, pp. 159–166, 2016.

[61] J. L. Schaeffer, J. K. Tyczkowski, and P. B. Hamilton, "Alterations in carotenoid metabolism during ochratoxicosis in young broiler chickens," *Poultry Science*, vol. 66, no. 2, pp. 318–324, 1987.

[62] S. Dhanalakshmi, S. P. Sivakumar, D. Niyogi, and S. Mukhopadhayay, "Protective effect of Picrorrhiza kurroa on ochratoxin A induced oxidative stress in chickens," *Indian Journal of Veterinary Pathology*, vol. 39, no. 3, p. 232, 2015.

[63] M. Soyoz, N. Ozcelik, I. Kilinc, and I. Altuntas¸, "The effects of ochratoxin A on lipid peroxidation and antioxidant enzymes: a protective role of melatonin," *Cell Biology and Toxicology*, vol. 20, no. 4, pp. 213–219, 2004.

[64] A. K. Sinha, "Colorimetric assay of catalase," *Analytical Biochemistry*, vol. 47, no. 2, pp. 389–394, 1972.

[65] M. U. Sohail, Z. U. Rahman, A. Ijaz et al., "Single or combined effects of mannan-oligosaccharides and probiotic supplements on the total oxidants, total antioxidants, enzymatic antioxidants, liver enzymes, and serum trace minerals in cyclic heat-stressed broilers," *Poultry Science*, vol. 90, no. 11, pp. 2573–2577, 2011.

[66] D. Ruan, W. C. Wang, C. X. Lin et al., "Effects of curcumin on performance, antioxidation, intestinal barrier and mitochondrial function in ducks fed corn contaminated with ochratoxin A," *Animal*, vol. 13, no. 1, pp. 42–52, 2019.

[67] C. Tong, P. Li, L.-H. Yu et al., "Selenium-rich yeast attenuates ochratoxin A-induced small intestinal injury in broiler chickens by activating the Nrf2 pathway and inhibiting NF-KB activation," *Journal of Functional Foods*, vol. 66, Article ID 103784, 2020.

[68] S. D. Stoev, G. Anguelov, I. Ivanov, and D. Pavlov, "Influence of ochratoxin A and an extract of artichoke on the vaccinal immunity and health in broiler chicks," *Experimental & Toxicologic Pathology*, vol. 52, no. 1, pp. 43–55, 2000.

[69] E. Santin, A. C. Paulillo, P. C. Maiorka, A. C. Alessi, E. L. Krabbe, and A. Maiorka, "The effects of ochratoxin/aluminosilicate interaction on the tissues and humoral immune response of broilers," *Avian Pathology*, vol. 31, no. 1, pp. 73–79, 2002.

[70] B. S. Uteshev, I. L. Laskova, and V. A. Afanas'Ev, "[The immunomodulating activity of the heteropolysaccharides from German chamomile (Matricaria chamomilla) during air and immersion cooling]," *Eksperimental'naya I Kilnicheskaya Farmakologiya*, vol. 62, no. 6, pp. 52–55, 1999.

[71] S. Yang, L. Li, L. Yu et al., "Selenium-enriched yeast reduces caecal pathological injuries and intervenes changes of the diversity of caecal microbiota caused by Ochratoxin-A in broilers," *Food and Chemical Toxicology*, vol. 137, Article ID 111139, 2020.

[72] G. Abdelhafez, M. Abdel-Moneim, M. El-Sherbiny, A. El-Shinnawy, H. F. A. Motawe, and G. El-Chaghaby, "Chamomile flower extract as natural dietary growth promoter and antioxidant for broiler chickens," *Journal of Animal and Plant Sciences*, vol. 27, pp. 1479–1487, 2017.

[73] J. Morais, S. Deise, F. Santurio, and P. Franchin, *Atividade antimicrobiana dos óleos essenciais de orégano, tomilho e canela frente a sorovares de Salmonella enterica de origem avícola*, 2007.