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The role of chamomile oil against ochratoxin A in quail breeders: productive and reproductive performances, egg quality, and blood metabolites

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ABSTRACT This study aimed to evaluate the beneficial role of chamomile essential oil in improving productive and reproductive performances, egg quality, and blood metabolites and reducing the toxic effect of Ochratoxin A (**OTA**) in quail breeder's diets. A total of 144 mature quails, 8 wk old, were divided into 6 groups. The treatments were: G1 (the control), G2 (supplemented with OTA 1 mg/kg diet), G3 (supplemented with chamomile oil 0.5 g/kg diet), G4 (supplemented with chamomile oil 1 G/kg diet), G5 (supplemented with OTA 1 mg/kg diet + chamomile oil 0.5 g/kg diet), and G6 (supplemented with OTA 1 mg/kg diet + chamomile oil 1 g/kg diet). The OTA administration alone significantly decreased egg production and mass in quail breeders ($P < 0.0001$). Moreover, poor feed conversion ratio (**FCR**), fertility percentage ($P < 0.0001$), and hatchability percentage ($P < 0.0009$) were recorded. A significant decline ($P < 0.05$) in the levels of serum protein (total protein and globulin) was also recorded in OTA-contaminated groups, along with elevated serum levels of liver enzymes such as alanine transaminase (**ALT**) and Aspartate transaminase (**AST**) and kidney function test as urea and creatinine levels ($P < 0.05$). Ochratoxin A-contaminated feed resulted in a significant elevation ($P < 0.05$) in total cholesterol (**TC**), triglyceride (**TG**), low-density lipoprotein (**LDL**), and very low-density lipoprotein (**VLDL**), along with a significant reduction ($P < 0.05$) in antioxidant status and immunological response. The supplementation of chamomile essential oil, either 0.5 g/kg or 1g/kg, to the basal diet or OTA-supplemented feed, revealed a significant increase in hatchability %, fertility, egg mass, and egg production and better FCR, egg quality, and immunological status when compared to OTA only. Moreover, chamomile essential oil supplementation improves liver and kidney function markers, decreases LDL, VLDL), TG, and TC. Along with a significant increase ($P < 0.05$) in terms of antioxidant status as glutathione peroxidase enzyme (**GPX**), total antioxidant capacity (**TAC**), and superoxide dismutase (**SOD**) and significantly ($P < 0.05$) improves immunological response as IgM, IgG, lysozyme and complement 3. In summary, chamomile oil supplementation, either separate or combined with OTA, reduced the adverse effects of OTA and led to improved productive and reproductive performance, egg quality, and blood metabolites in Japanese quail breeders.

Key words: quail breeder, Ochratoxin A, chamomile, production, blood metabolite

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INTRODUCTION

Medicinal plants have been considered a suitable antibiotic substitute because of the adverse impacts of antibiotics on human and bird health (Palmieri et al., 2014; Di Cerbo et al., 2014; Destefanis et al., 2016; Mazzeranghi et al., 2017; Di Cerbo et al., 2018b; Di Cerbo et al., 2018a; Di Cerbo et al., 2019; Di Cerbo et al., 2020; Alagawany et al., 2021; Alagawany and Abd El-Hack, 2021). The active ingredients in most medicinal plants are more easily absorbed and have a shorter half-life than antibiotics. Consequently, animal tissue contains no residues (Srivastava and Gupta, 2009; Ismail et al., 2020). Multiple research projects have been conducted to investigate the utilization

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of natural growth enhancers derived from medicinal herbs to enhance quail productivity (Nowaczewski et al., 2010; Guidetti et al., 2016; Reda et al., 2020; Farag et al., 2023).

Chamomile oil, derived from the chamomile plant, has been studied for its potential health benefits and therapeutic properties (McKay, and Blumberg, 2006; Alagawany and Abd El-Hack, 2021; Abd El-Hack et al., 2023). Several studies have proved that chamomile has various beneficial qualities, including anti-inflammatory, antioxidant, antimicrobial, and antifungal effects (Pirzad et al., 2006; Srivastava et al., 2010; Singh et al., 2011; Khishtan and Beski, 2020). Consistent with Ghoniem et al. (2021), the utilization of *Matricaria chamomilla* oil has been suggested as a potential strategy for managing the fungus *Pythium ultimum* in bean plants inside greenhouse environments. Chamomile also has the potential to exhibit strong antioxidant activity due to its composition of numerous substances, including coumarin, anthocyanin, isoflavones, flavonoids, and tannic acid (Svenningsen et al., 2006). Chamomile possesses antibacterial, antifungal, antioxidant, and anti-inflammatory qualities that have the potential to can enhance feed conversion and body weight (Santurio et al., 2007). The sesquiterpenoid compounds found in the chamomile plant have the potential to act similarly to antibiotics by disrupting the typical barrier role of the bacterial cell membrane, thus helping the entry of external solutes into the cell (Göger et al., 2018). The essential oils (**EO**) and extracts derived from *Matricaria chamomilla* possess antioxidant properties, potentially contributing to the prevention and management of many diseases. Chamomile can donate protons and potentially function as an antioxidant through scavenging or suppressing free radicals, as demonstrated in studies conducted by Shimada et al. (1992) and Osman et al. (2016). The anti-inflammatory effects of chamomile have been observed through the inhibition of prostaglandin E2 release (Srivastava et al., 2009). The chamomile flower's flavonoids, essential oils, and chamazulene content have a similar mode of action to probiotics within the small intestine. The potential impact of these actions includes the preservation of the intestinal microbiota's homeostasis and the enhancement of nutrient digestibility (McCrea et al., 2005; Iseppi et al. 2020a; Iseppi et al. 2020b).

Ochratoxin A is a toxin synthesized by specific fungi, namely Aspergillus, and Penicillium species. These fungi can contaminate many agricultural products, like cereals and feed ingredients (Bayman et al., 2002). Saleemi et al. (2017) stated that fungi could generate distinct metabolites or poisons and are commonly linked to certain agricultural commodities. Ochratoxins are mainly found in a lot of agricultural commodities, with a significant body of evidence documenting their presence in mixed feed and cereal grains like rye, barley, oats, hay, and maize (WHO, 2002; EFSA, 2006; Bakr et al., 2019). According to Liuzzi et al. (2016), OTA is the predominant and highly poisonous form of ochratoxin. Previous studies have demonstrated the nephrotoxic, hepatotoxic, teratogenic, and immunotoxic effects of this substance in chickens (Hameed et al., 2017; Wang et al., 2019). Ochratoxin A reduces the feed conversion ratio, decreases growth, damages kidneys, and eventually causes death to birds when fed between 130 μg and 3.9 mg of their food (Stoev et al., 2004; Elaroussi et al., 2006). Khatoon et al. (2016), feeding OTA to birds impacted their growth, likely due to reduced weight and poor feed conversion ratio (**FCR**). The global existence of OTA in poultry feeds has been widely established in an investigation by Zhang et al. (2020). Ochratoxin A absorption begins in the stomach and predominantly occurs in the jejunum (Grenier and Applegate, 2013). The OTA exhibits characteristic symptoms in chicken, including a notable decline in body weight, slowed growth, decreased egg production, a lower-quality eggshell, suppression of immunity, a lower feed conversion ratio, reduced efficacy of immunization, and liver and kidney damage (Bailey et al., 1989). The inclusion of OTA (at concentrations of 3.2 or 6.4 mg/kg food) in a broiler diet caused a notable drop in glutathione peroxidase and superoxide dismutase levels in a variety of organs, including the kidney and liver (Hameed et al., 2017). In this context, Xue et al. (2010) examined the immunopathological impact of co-exposure to T-2 toxin and ochratoxin. Their findings revealed that applying T-2 toxin with ochratoxin reduced antibody titers for New Castle disease by 10.4%. However, data regarding feeding quail breeders with chamomile oil and its role in reducing the negative effects of OTA exposure are rare. This study aimed to examine the potential effects of chamomile oil in mitigating the negative effects of OTA exposure and enhancing the production and reproductive performances, blood metabolites, and egg quality in breeders of Japanese quail.

MATERIAL AND METHODS

Birds, Experimental Design, and Diets

The experiment was designed at the Poultry Department, Faculty of Agriculture, Zagazig University, Zagazig, Egypt. One hundred forty-four, 8-wk-old quails were divided into 6 groups, each including 4 replicates of 6 quails (4 females and 2 males). Dietary treatments were: G1 (the control-basal diet), G2 (supplemented with OTA 1 mg/kg diet), G3 (supplemented with chamomile oil 0.5 g/kg diet), G4 (supplemented with chamomile oil 1 g/kg diet), G5 (supplemented with OTA 1 mg/kg diet + chamomile oil 0.5 g/kg diet), G6 (supplemented with OTA 1 mg/kg diet + chamomile oil 1 g/kg diet). The birds were raised in conventional-type cages measuring ($90 \times 40 \times 40$ cm^3), with unrestricted access to consuming food and water. The birds had been raised in uniform management and hygienic conditions and were given nutritionally balanced diets to fulfill their dietary requirements, as specified in the recommendations established by the National Research Council (NRC) (1994). Table 1 displays the basal diet. The experiment complies with the Zagazig University Ethics

Table 1. Ingredient and nutrient contents of experimental diets of quail breeders.

Ingredient	%
Yellow corn	58.70
Soybean meal 44%	27.50
Corn gluten meal 62%	4.60
Vegetable oil	1.8
Limestone	5.54
Di-calcium phosphate	1.20
Salt	0.30
Premix[1]	0.30
L-Lysine%	0.06
Dl-Methionine%	0.00
Calculated composition[2]	
ME, Kcal /kg	2901
Crude protein%	20.00
Calcium %	2.50
Nonphytate P%	0.35
Lysine%	1.00
TSAA %	0.70

[1]Layer Vitamin-mineral Premix Each 1 kg consists of vit. A, 8000 IU; vit. D3, 1300 ICU, vit. E 5 mg; vit. K, 2 mg; vit B1, 0.7 mg; vit. B2, 3 mg; vit. B6, 1.5 mg; vit. B12, 7 mg; Biotin 0.1 mg; Pantothenic acid, 6 g; Niacin, 20 g; Folic acid, 1 mg, manganese, 60 mg; Zinc, 50 mg, Copper, 6 mg; Iodine, 1 mg, Selenium, 0.5 mg; Cobalt, 1 mg.

[2]Calculated according to NRC (1994).

Committee's regulations for using experimental animals (Approval No. ZU-IACUC/2/F/313/2023).

Data Collection

Production Performance Data collection started 4 wk after the introduction of the studied diets, specifically when the quail breeders reached the age of 12 wk. The feed intake of quail breeders was recorded every 2 wk, along with the calculation of the feed-to-egg mass ratio. The egg mass, determined by multiplying the number of eggs by their respective weights, has been documented to study egg weight and egg number.

Fertility and Hatchability In the 4th week of each experimental period (8−12 and 12−16 wk), 15 eggs from each replicate/treatment were collected and incubated to assess their reproductive characteristics. After hatching, the counting of the newly hatched quails was conducted. The hatchability percentages and fertility were determined by collecting and breaking the unhatched eggs. The hatchability percentage was determined by measuring the proportion of hatched chicks to the total number of eggs laid and the proportion of hatching chicks to viable eggs.

The percentages of fertility and hatchability were assessed according to the following formulas:

$$\text{Fertility}\ \% = \text{number of fertile eggs x100/total eggs set}$$

$$\text{Hatchability}\ \% = \text{number of hatched chicks x100/} \\ \text{total number of fertile eggs}$$

$$\text{Hatchability}\ \% = \text{number of hatched chicks x100/} \\ \text{total eggs set}$$

Egg Quality Criteria Three eggs from each replicate were used to determine monthly egg quality parameters. The egg quality parameters, including exterior and inner characteristics (egg shape index, yolk index, unit surface shell weight (USSW), egg length, egg width, shell weight and thickness, and Haugh unit), were determined according to Romanoff and Romanoff (1949).

Blood Metabolites A total of 30 quails were selected at 16 wk of age to assess various biochemical blood parameters. Heparinized tubes were utilized for the collection of blood samples. A centrifuge was used at a rotational speed of 3,500 rpm per minute for 15 min to facilitate plasma separation. This separation assessed biochemical blood parameters, including lipid profiles, renal and liver function tests, and immunology. The plasma parameters, comprising immunoglobulins A and G, urea, creatinine, aspartate aminotransferase (**AST**), alanine aminotransferase (**ALT**), plasma protein fractions, and plasma lipid fractions, were assessed using commercially available kits and a spectrophotometer manufactured by Shimadzu in Japan.

Statistics The trial was examined using a completely randomized methodology. The study assessed many parameters, including reproductive and productive indices, egg characteristics and quality, hepatic and renal functions, immunity, and lipid profile. The GLM procedure of SPSS (SPSS® (2008) statistical software program v.11.0 was employed for all data analyses.

RESULTS AND DISCUSSION

Productive and Reproductive Parameters

Chamomile oil, derived from the chamomile plant, is known for its potential health benefits and therapeutic properties. While there is limited research specifically focusing on the role of chamomile oil against OTA in quail breeders, in this work, we can discuss the general properties of chamomile oil and its potential effects on the production and reproductive performances, blood metabolites, and egg quality. According to data in Table 2, chamomile oil supplementation to quail breeder diet at a rate of 0.5 g/kg diet or 1 g/kg diet revealed a significant increase ($P < 0.0001$) in egg number and egg mass from 8 to 16 wk and nonsignificant increase in egg weight ($P = 0.2793$) compared to control and other groups. In contrast, OTA-contaminated feed groups revealed a significant reduction ($P < 0.0001$) in egg number and egg mass from 8-16 wk and a nonsignificant decrease in egg weight ($P = 0.2793$). Moreover, data in Table 3 showed that the group that consumed OTA either alone or in combination with chamomile oil as a supplement revealed a nonsignificant increase ($P = 0.3454$) in feed intake when compared to control and other groups; these groups presented a significant increase in feed conversion ratio ($P < 0.00$) and the OTA supplemented group presented the worst level (4.11), while group supplemented with chamomile oil either 0.5 or 1 g/kg diet presented the best feed conversion value (2.82). Our finding is consistent with the observations of Ezeldien et al. (2023), wherein it was discovered that at 8 wk of age, the Japanese quail fed a

Table 2. Effects of chamomile oil against ochratoxin toxicity on egg production of quail breeders.

Items	Control	Ochratoxin 1 mg/kg diet (Och1)	Chamomile 0.5 g/kg diet (Cha0.5)	Chamomile 1 g/kg diet (Cha1)	Och1+ Cha0.5	Och1+ Cha1	SEM	P value
Egg number/bird								
8–12 wk	25.37^{b}	19.89^{d}	28.01^{a}	27.32^{a}	23.43^{c}	22.55^{c}	0.347	0.0011
12–16 wk	22.00^{b}	17.80^{c}	25.35^{a}	25.31^{a}	20.97^{b}	21.47^{b}	0.612	<0.0001
8–16 wk	23.68^{b}	18.85^{d}	26.68^{a}	26.31^{a}	22.20^{c}	22.01^{c}	0.374	<0.0001
Egg weight (g)								
8–12 wk	12.53	11.87	12.57	12.53	12.07	12.32	0.192	0.3295
12–16 wk	12.59	12.13	12.92	13.03	12.49	12.61	0.463	0.8252
8-16 wk	12.56	12.00	12.74	12.78	12.28	12.46	0.201	0.2793
Egg mass (g/bird)								
8–12 wk	317.72^{b}	235.81^{d}	351.95^{a}	342.34^{a}	282.88^{c}	277.73^{c}	5.512	<0.0001
12–16 wk	277.38^{b}	216.02^{c}	327.96^{a}	330.00^{a}	261.16^{b}	270.99^{b}	14.666	0.0021
8–16 wk	297.55^{b}	225.92^{c}	339.96^{a}	336.17^{a}	272.02^{b}	274.36^{b}	7.602	<0.0001

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or 0.01).

Table 3. Effects of chamomile oil against ochratoxin toxicity on feed intake and feed conversion ratio of quail breeders.

Items	Control	Ochratoxin 1 mg/kg diet (Och1)	Chamomile 0.5 g/kg diet (Cha0.5)	Chamomile 1 g/kg diet (Cha1)	Och1+ Cha0.5	Och1+ Cha1	SEM	P value
Feed intake (g/bird)								
8–12 wk	956.7	967.1	958.32	952.1	968.25	963.28	8.935	0.7755
12–16 wk	954.25	950.64	953.4	945.4	963.73	965.83	8.754	0.5891
8–16 wk	955.48	958.87	955.86	948.75	965.99	964.56	4.841	0.3454
Feed conversion ratio (g feed/g egg)								
8–12 wk	3.01^{c}	4.11^{a}	2.72^{d}	2.78^{d}	3.43^{b}	3.47^{b}	0.056	0.0031
12–16 wk	3.48^{bcd}	4.43^{a}	2.94^{cd}	2.88^{d}	3.70^{b}	3.58^{bc}	0.197	0.0020
8–16 wk	3.22^{c}	4.24^{a}	2.82^{d}	2.82^{d}	3.56^{b}	3.52^{b}	0.087	<0.0001

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or 0.01).

chamomile aqueous extract had a larger body weight than the control group.

Furthermore, compared to the control, quails fed with chamomile aqueous extract exhibited a significant increase in egg mass and a reduced feed conversion ratio. These findings align with El-Galil et al. (2010), who observed that incorporating higher quantities of chamomile flower in the laying Japanese quail diets improved live body weight and egg production. Chamomile extract has been found to have antibacterial, antifungal, and anti-inflammatory functions, which may potentially contribute to improved productivity (Abaza et al., 2003). Conversely, according to the level of tannins, chamomile extract could lead to decreased feed consumption and conversion (Dada et al. 2015). Chamomile supplementation was found to positively impact various physiological parameters, including an increase in growth rate, carcass weight, and ovarian relative weight (Abu-Taleb et al., 2008). The potential positive impact of chamomile on quail productivity could be attributed to several factors, including increased feed intake, enhanced digestibility of diets, and accelerated bird sexual maturation. The findings presented in this study are corroborated by the research undertaken by Skomorucha and Sosnowka Czajka (2013). Their results showed that adding 1.0% fennel powder or 0.75% chamomile to the diet significantly increased growing rabbits' body weight gain and feed intake.

Moreover, Nasr et al. (2022) reported that rabbits fed a basal diet + 0.5 mL g/kg chamomile exhibited better feed intake during the entire duration of the study in comparison to the other groups. Similarly, Hameed et al. (2017) and Hameed et al. (2017) studied that giving OTA-contaminated feed to quail breeders impaired FCR. The effect was dose-dependent. When chamomile oil was added at a rate of 0.5 or 1 g/kg of feed, the FCR was higher than in the only fed OTA group. Moreover, a significant ($P < 0.001$) improvement was shown in Table 4 in fertility and hatchability percentage in the group supplemented with chamomile oil from 8 to 16 wk of age, while the group contaminated with OTA recorded a significant decrease in fertility and hatchability percentage ($P < 0.05$). Our finding aligns with Abd El-Galil et al. (2010), who stated that supplementing quail at 0.50 g/kg chamomile flower meal (**CFM**) level revealed higher fertility and hatchability values. A level of 0.5 g/kg could result from improved sperm concentration, total motile sperm, live spermatozoa, and semen quality. On the other hand, the fertility and hatchability percentages were negatively impacted in birds fed with a concentration of 16 ppm of OTA in their diet (Prior et al., 1978). Also, chamomile oil supplementation to OTA-contaminated groups significantly ($P < 0.05$) ameliorates the toxic impact of OTA and improves fertility and hatchability percentage in these groups.

Table 4. Effects of chamomile oil against ochratoxin toxicity on fertility and hatchability of quail breeders.

Items	Control	Ochratoxin 1 mg/kg diet (Och1)	Chamomile 0.5 g/kg diet (Cha0.5)	Chamomile 1 g/kg diet (Cha1)	Och1+ Cha0.5	Och1+ Cha1	SEM	P value
Fertility %								
8−12 wk	92.96[a]	72.22[d]	91.57[ab]	89.50[abc]	86.51[bc]	85.56[c]	1.777	0.0031
12−16 wk	93.56[a]	81.41[b]	92.14[a]	93.24[a]	89.93[a]	90.19[a]	1.798	0.0052
8−16 wk	93.26[a]	76.82[d]	91.85[a]	91.37[ab]	88.22[ba]	87.87[c]	1.003	<0.0001
Hatchability %								
8−12 wk	82.52[a]	63.56[d]	84.23[a]	81.81[ab]	76.39[bc]	73.67[c]	1.805	0.0021
12−16 wk	84.00[a]	69.94[c]	86.28[a]	84.05[a]	80.75[ab]	76.07[bc]	2.104	0.0016
8−16 wk	83.26[ab]	66.75[d]	85.25[a]	82.92[ab]	78.57[bc]	74.87[c]	1.397	0.0009

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or 0.01).

Egg Quality Measurements

Table 5 presents the impact of chamomile oil against OTA toxicity on the egg quality of quail breeders, and the data showed that the group supplemented with chamomile oil and OTA recorded a significant elevation ($P = 0.0008$) in albumin percentage in comparison to the control and other groups. While chamomile oil-supplemented groups with either 0.5 or 1 g/kg diet showed a significant (p<0.05) improvement in yolk % and Haugh unit and a non-significant development in shell %, shell thickness, yolk index, egg shape index in comparison to the control. Results on shell thickness and yolk percentage recorded a nonsignificant elevation between the tested groups. In contrast, yolk indices and albumen were reduced ($P < 0.05$) by increasing CFM) in comparison to the control, egg shape, and eggshell, was significantly ($P < 0.05$) elevated by increasing CFM in comparison to the control (Abd El-Galil et al. 2010). This study agrees with the research conducted by Haddad (2012), which showed that the inclusion of chamomile flower powder in the diets of poultry layers led to a notable enhancement in various egg quality metrics, including yolk index, Haugh unit, albumen height, albumen index, and yolk height. According to a study by Giannenas et al. (2021), the addition of chamomile to the diet of birds caused a significant enhancement in both shell thickness and strength of their eggs. In addition, eggs exhibited elevated levels of tyrosine and phenylalanine and enhanced resistance to yolk oxidation. Given the abundance and affordability of eggs as a good source of animal protein, it is worth noting that chamomile can enhance the nutritional content of eggs by elevating the combined weight of the albumen and the egg. The potential positive impact of chamomile on egg quality indicators may be attributed to several factors, including heightened feed consumption, enhanced diet digestibility, and greater absorption of nutrients in avian species (Ezeldien et al., 2023). According to a study by Shirley and Tohala (1983), laying hens fed diets containing OTA exhibited substandard eggshell quality with blood spots in their eggs. Observations were made regarding thin rubbery shells that exhibit increased susceptibility to breakage during instances of ochratoxicosis epidemics in the field (Jewers, 1990). Hermann (2002) stated that OTA is responsible for stains on the surface of shells and a decrease in shell strength. Furthermore, reduced egg production rate, egg mass production, and egg weight were all reported when feeding laying chickens 2 to 3 mg of OTA/kg (Verma et al., 2003; Denli et al., 2008).

Liver and Kidney Functions

The finding in Table 6 recorded the effect of chamomile oil against OTA toxicity on hepatic and renal functions tests of quail breeders and reported that the chamomile oil 1 g/kg diet supplemented group revealed a significant ($P < 0.05$) decline in total protein levels and globulin. This study showed that adding chamomile oil could partially stop the changes in blood biochemical parameters, but it couldn't completely protect against the negative effects caused by OTA. Our finding agreed with a study by Abu Taleb et al. (2008), who observed that adding 0.3% of chamomile to the diet of Japanese

Table 5. Effects of chamomile oil against ochratoxin toxicity on egg quality of quail breeders.

Items	Control	Ochratoxin 1 mg/kg diet (Och1)	Chamomile 0.5 g/kg diet (Cha0.5)	Chamomile 1 g/kg diet (Cha1)	Och1+ Cha0.5	Och1+ Cha1	SEM	P value
Albumin %	52.88[b]	56.92[a]	52.93[b]	52.80[b]	54.03[b]	53.61[b]	0.510	0.0008
Yolk %	31.76[a]	28.06[b]	31.61[a]	31.38[a]	30.61[a]	30.59[a]	0.491	0.0021
Shell %	15.36	15.02	15.46	15.83	15.36	15.80	0.828	0.9832
Shell thickness	0.23	0.20	0.23	0.24	0.21	0.19	0.013	0.1337
Egg shape index	78.22	76.89	80.09	78.64	77.71	78.37	1.221	0.6230
Yolk index	44.87	44.53	48.17	46.19	45.11	48.03	1.242	0.3200
Haugh unit	82.64[abc]	79.69[c]	85.69[a]	83.47[ab]	80.98[bc]	80.72[bc]	0.997	0.0162
USSW	47.73	47.08	47.95	47.76	47.91	47.90	0.451	0.8046

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or 0.01).

Table 6. Effects of chamomile oil against ochratoxin toxicity on liver and kidney functions of quail breeders.

Items	Control	Ochratoxin 1 mg/kg diet (Och1)	Chamomile 0.5 g/kg diet (Cha0.5)	Chamomile 1 g/kg diet (Cha1)	Och1+ Cha0.5	Och1+ Cha1	SEM	P value
TP (g/dL)	3.97^{b}	4.70^{a}	4.28^{ab}	4.80^{a}	4.35^{ab}	4.45^{ab}	0.111	0.0453
ALB (g/dL)	2.27^{b}	3.27^{a}	1.73^{c}	1.78^{c}	2.45^{b}	2.56^{b}	0.121	<0.0001
GLOB (g/dL)	1.70^{cd}	1.43^{d}	2.55^{b}	3.02^{a}	1.91^{c}	1.89^{c}	0.122	0.0031
A/G (%)	1.36^{b}	2.33^{a}	0.68^{c}	0.59^{c}	1.29^{b}	1.37^{b}	0.106	<0.0001
ALT (IU/L)	8.65^{b}	14.05^{a}	3.84^{c}	4.18^{c}	7.42^{b}	7.63^{b}	0.639	<0.0001
AST (IU/L)	169.65^{b}	281.05^{a}	75.50^{c}	83.73^{c}	155.30^{b}	141.81^{b}	7.948	0.0008
Creatinine (mg/dL)	0.29^{b}	0.49^{a}	0.19^{c}	0.19^{c}	0.28^{b}	0.30^{b}	0.015	<0.0001
Urea (mg/dL)	2.92^{b}	5.18^{a}	2.63^{bc}	2.14^{c}	3.13^{b}	2.93^{b}	0.204	0.0021

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or 0.01).
Abbreviations: ALB, albumin; ALT, alanine aminotransferase; AST, aspartate aminotransferase; TP, protein.

Table 7. Effects of chamomile oil against ochratoxin toxicity on lipid profile of quail breeders.

Items	Control	Ochratoxin 1 mg/kg diet (Och1)	Chamomile 0.5 g/kg diet (Cha0.5)	Chamomile 1 g/kg diet (Cha1)	Och1+ Cha0.5	Och1+ Cha1	SEM	P value
TC (mg/dL)	384.84^{b}	436.84^{a}	264.25^{c}	273.93^{c}	285.41^{c}	347.72^{b}	13.386	<0.0001
TG (mg/dL)	159.17^{b}	219.17^{a}	98.26^{d}	101.75^{d}	120.71^{c}	131.99^{c}	5.122	0.0008
HDL (mg/dL)	41.03^{c}	33.03^{c}	92.18^{a}	85.88^{a}	71.35^{b}	61.20^{b}	4.142	<0.0001
LDL (mg/dL)	311.98^{b}	359.98^{a}	152.42^{d}	167.70^{d}	189.92^{d}	260.12^{c}	12.602	<0.0001
VLDL (mg/dL)	31.83^{b}	43.83^{a}	19.65^{d}	20.35^{d}	24.14^{c}	26.40^{c}	1.025	0.0008

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or 0.01).
Abbreviations: CHOL, total cholesterol; HDL, high density lipoprotein; TRG, triglycerides.

quail resulted in a significant rise in the birds' levels of globulin and total protein. The group that received chamomile supplementation had a notable elevation in albumin and serum total protein values, accompanied by a decrease in glucose levels. There were no observed variations in the total bilirubin levels, direct bilirubin, creatinine, and ALT in comparison to control (Ezeldien et al., 2023). The findings of this research agreed with the research conducted by El-Galil et al. (2010), which examined the impact of including chamomile powder into the diet on serum biochemical markers in Japanese quail. The serum protein levels in the blood of quail breeders who ate a diet supplemented with OTA were significantly reduced in this study.

Similarly, previous research revealed that broilers fed a feed polluted with OTA had lower blood protein levels (Santin et al., 2002; Kumar et al., 2003). The lowered blood protein levels may be because OTA is toxic and stops protein synthesis, which is one of its main negative impacts (Hameed et al., 2017). The experimental group of birds fed a diet contaminated with OTA exhibited lower serum globulin than the control and other groups throughout the trial. Huff et al. (1988) also recorded reduced serum globulin levels due to ochratoxicosis. In the current study, elevated serum urea, creatinine, AST, and ALT values were associated with OTA feeding in quail breeders. Hepatic deterioration within the liver cells is indicated by elevated serum levels of ALT and AST (Kumar et al., 2003). Serum creatinine and urea levels may have increased in OTA-fed birds because of the nephrotoxic effects of OTA, which leads to renal damage via the degeneration of renal tissue. In the presence of chamomile oil, which decreases the OTA's toxic effect, there was a significant ($P < 0.05$) decrease in serum creatinine and urea levels in groups G5 and G6 in comparison to the group contaminated by OTA (G2).

Lipid Profile

The study's findings, which are displayed in Table 7, indicate that the chamomile oil 0.5 g/kg diet-supplemented group had a significant ($P < 0.05$) increase in high-density lipoprotein (**HDL**) cholesterol and a significant ($P < 0.05$) decrease in triglycerides (**TG**), total cholesterol (**TC**), low-density lipoprotein (**LDL**) cholesterol, and very low-density lipoprotein (**VLDL**) cholesterol, while The group supplemented with OTA exhibited a significant ($P < 0.05$) rise in TG, LDL and VLDL cholesterol, as well as a significant ($P < 0.05$) reduction in HDL cholesterol. Our finding agreed with Abu Taleb et al. (2008), who noted that adding chamomile to the Japanese quail's diet at a concentration of 0.3% resulted in a considerable decrease in cholesterol levels. Furthermore, feeding birds OTA at a 1 to 5 mg/kg diet lowers their levels of TG and TC (Tahir et al., 2022).

Immunological Parameters

The current study demonstrated the impact of chamomile oil against OTA toxicity on quail breeders' antioxidant status and immunity, as recorded in Table 8. The result reported that the chamomile oil 1 g/kg diet-supplemented group showed a significant ($P < 0.05$) decrease in malondialdehydes levels and a significant

Table 8. Effects of chamomile oil against ochratoxin toxicity on antioxidants and immunity of quail breeders.

Items	Control	Ochratoxin 1 mg/kg diet (Och1)	Chamomile 0.5 g/kg diet (Cha0.5)	Chamomile 1 g/kg diet (Cha1)	Och1+ Cha0.5	Och1+ Cha1	SEM	*P* value
Antioxidants								
SOD (U/mL)	0.35^{d}	0.28^{e}	0.79^{b}	0.87^{a}	0.42^{d}	0.52^{c}	0.023	0.0005
MDA (nmol/mL)	0.34^{b}	0.59^{a}	0.11^{d}	0.14^{d}	0.21^{c}	0.31^{b}	0.019	<0.0001
TAC (ng/mL)	0.36^{d}	0.26^{d}	1.14^{a}	1.01^{ab}	0.62^{c}	0.89^{b}	0.055	0.0008
GPX (ng/mL)	0.44^{e}	0.38^{e}	0.86^{b}	0.95^{a}	0.55^{d}	0.63^{c}	0.024	<0.0001
Immunity								
IgM (mg/dL)	0.89^{cd}	0.75^{d}	2.00^{b}	2.40^{a}	0.90^{cd}	1.13c	0.070	<0.0001
IgG (mg/dL)	1.12^{bc}	0.98^{c}	1.93^{a}	2.05^{a}	1.24^{b}	1.16^{bc}	0.072	<0.0001
Lysozyme	0.36^{b}	0.18^{b}	1.30^{a}	1.37^{a}	0.48^{b}	0.35^{b}	0.081	<0.0001
Complement 3	112.00^{d}	100.50^{d}	190.00^{b}	219.50^{a}	140.50^{c}	150.50^{c}	5.677	<0.0001

Means in the same column within each classification bearing different letters are significantly different ($P < 0.05$ or 0.01).
Abbreviations: GSH, reduced glutathione; IgM, immunoglobulin M; IgG, immunoglobulin G; MDA, malondialdehyde; SOD, superoxide dismutase.

($P < 0.05$) rise in glutathione peroxidase activity (**GPX**), total antioxidant capacity (**TAC**), and superoxide dismutase (**SOD**). Meanwhile, the OTA-contaminated group reported a significant ($P < 0.05$) rise in malondialdehydes levels but a significant ($P < 0.05$) decline in glutathione peroxidase levels (GPX), SOD, and TAC. The main field of application of natural products is in enhancing birds' antioxidant status and immunity (Arif et al., 101AD; Rafeeq et al., 2022). A study conducted by Cemek et al. (2008) demonstrated that chamomile positively impacts pancreatic tissue by mitigating the impact of oxidative stress induced by increased blood glucose levels. Our results agree with Hameed et al. (2017), who reported that adding OTA to chicken feed (3.2−6.4 mg/kg diet) significantly decreased the glutathione peroxidase and superoxide dismutase levels in different organs like the liver and kidneys.

Furthermore, the chamomile oil 1 g/kg diet-supplemented group revealed a significant ($P < 0.05$) elevation in the immunological state of quail breeders represented in increasing IgM, IgG, lysozyme, and complement 3 levels in quail breeders blood. In contrast, the OTA-supplemented group revealed a significant ($P < 0.05$) lowering in IgM, IgG, lysozyme, and complement 3 levels in quail breeders' blood. Our findings concur with Zahoor-ul-Hassan et al. (2012), who revealed that the progeny of chickens that were fed OTA-supplemented diets exhibited a substantial decrease in the frequency of cells containing IgG, IgA, and IgM in the bursa of Fabricius and spleen. The study's findings are consistent with earlier investigations conducted on various species of mammals and birds exposed to OTA. Concerning avian species, Harvey et al. (1987) observed a decline in IgG-carrying cells within the bursa of Fabricius among recently hatched chicks originating from eggs injected with OTA.

Furthermore, Tahir et al. (2022) revealed that the immunosuppressive effects of OTA in poultry feed are responsible for the decreased size of the thymus and bursa of Fabricius. Moreover, Xue et al. (2010) examined the mixed immunopathological impact of T-2 toxin and ochratoxin. They discovered that giving T-2 toxin and ochratoxin together lowered the levels of antibodies by 10.4% for New Castle disease.

CONCLUSION

The results of the present study showed that OTA has adverse effects on productive and reproductive performances, immunity, lipid profile, antioxidant biomarkers, and kidney and liver functions. The utilization of chamomile oil has shown the capability to mitigate OTA-induced toxicity and improve the production and reproductive performances, egg quality, and blood metabolites in quail breeders, hence indicating its viability for commercialization. Using herbal oils such as chamomile oil in quail diets could also help solve the problem of ochratoxin in poultry farms.

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DISCLOSURES

There were no conflict of interests

REFERENCES

Abaza, I. M. K., M. A. Asar, G. E. Elshaarrawi, and M. F. Hassan. 2003. Effect of using nigella seeds, chamomile flowers, thyme flowers, and harmala seeds as feed additives on performance of broiler. Egypt. J. Agric. Res. 81:735–750.

Abd El-Galil, K., H. A. Mahmoud, A. M. Hassan, and A. S. Morsy. 2010. Effect of chamomile flowers meal as feed additives in laying Japanese quail diets on productive and reproductive performance. J. Anim. Poultry Prod., Mansoura Univ. 1:517–533.

Abd El-Hack, M. E., I. E. Ismail, Q. A. W. Khalaf, A. F. Khafaga, N. E. Khalifa, H. Khojah, W. F. Abusudah, A. Qadhi, N. H. Almohmadi, and M. S. Imam. 2023. Chamomile: functional-properties and impacts on poultry/small ruminant health and production. Ann. An. Sci., doi:10.2478/aoas-2023-0062.

Abu-Taleb, A. M., S. J. Hamodi, and S. F. El-Afifi. 2008. Effect of using some medicinal plants (anise, chamomile, and ginger) on productive and physiological performance of Japanese quail. Isotope Radiat. Res. 40:1061–1070.

Alagawany, M., and M. E. Abd El-Hack. 2021. Natural Feed Additives Used in the Poultry Industry. Bentham Science Publishers Pte. Ltd, Singapore, doi:10.2174/97898114884501200101.

Alagawany, M., M. T. El-Saadony, S. S. Elnesr, M. Farahat, G. Attia, M. Madkour, and F. M. Reda. 2021. Use of lemongrass essential oil as a feed additive in quail's nutrition: its effect on growth, carcass, blood biochemistry, antioxidant and immunological indices, digestive enzymes and intestinal microbiota. Poult. Sci. 100:101172.

Arif, M., A. ur Rehman, K. Naseer, S. H. Abdel-Hafez, F. M. Alminderej, M. T. El-Saadony, M. E. Abd El-Hack, A. E. Taha, S. S. Elnesr, H. M. Salem, and M. Alagawany. 2022. Effect of Aloe vera and clove powder supplementation on growth performance, carcass and blood chemistry of Japanese quails. Poult. Sci. 101:101702.

Bailey, C. A., R. M. Gibson, L. F. Kubena, W. E. Huff, and R. B. Harvey. 1989. Ochratoxin A and dietary protein.: 2. Effects on hematology and various clinical chemistry measurements. Poult. Sci. 68:1664–1671.

Bakr, A. F., S. S. Abdelgayed, O. S. El-Tawil, and A. M. Bakeer. 2019. Assessment of ginger extract and ginger nanoparticles protective activity against acetaminophen-induced hepatotoxicity and nephrotoxicity in rats. Pak. Vet. J. 39:479–486.

Bayman, P., J. L. Baker, M. A. Doster, T. J. Michailides, and N. E. Mahoney. 2002. Ochratoxin production by the Aspergillus ochraceus group and Aspergillus alliaceus. Appl. Environ. Microbiol. 68(5):2326–2329.

Cemek, M., S. Kağa, N. Şimşek, M. E. Büyükokuroğlu, and M. Konuk. 2008. Antihyperglycemic and antioxidative potential of *Matricaria chamomilla* L. in streptozotocin-induced diabetic rats. J. Natl. Med. 62:284–293.

Dada, R., M. Toghyani, and S. A. Tabeidian. 2015. The effect of chamomile flower (*Matricaria chamomilla* L.) extract and powder as growth promoter on growth performance and digestive organs of broiler chickens. Res. Opin. Anim. Vet. Sci. 5:290–294.

Denli, M., J. C. Blandon, M. E. Guynot, S. Salado, and J. F. Perez. 2008. Efficacy of a new ochratoxin-binding agent (Ocratox) to counteract the deleterious effects of ochratoxin a in laying hens. Poult. Sci. 87:2266–2272.

Destefanis, S., D. Giretto, M. C. Muscolo, A. Di Cerbo, G. Guidetti, S. Canello, A. Giovazzino, S. Centenaro, and G. Terrazzano. 2016. Clinical evaluation of a nutraceutical diet as an adjuvant to pharmacological treatment in dogs affected by Keratoconjunctivitis sicca. BMC Vet. Res. 12:214.

Di Cerbo, A., S. Canello, G. Guidetti, F. Fiore, L. Corsi, N. Rubattu, C. Testa, and R. Cocco. 2018b. Adverse food reactions in dogs due to antibiotic residues in pet food: a preliminary study. Vet. It. 54:137–146.

Di Cerbo, A., S. Canello, G. Guidetti, C. Laurino, and B. Palmieri. 2014. Unusual antibiotic presence in gym trained subjects with food intolerance; a case report. Nutr. Hosp. 30:395–398.

Di Cerbo, A., F. Pezzuto, G. Guidetti, S. Canello, and L. Corsi. 2019. Tetracyclines: insights and updates of their use in human and animal pathology and their potential toxicity. Open Biochem. J. 13:1–12.

Di Cerbo, A., F. Pezzuto, A. Scarano, G. Guidetti, and S. Canello. 2020. The contradictory world of tetracyclines. Panminerva Med 62:116–117.

Di Cerbo, A., V. Rubino, F. Morelli, G. Ruggiero, R. Landi, G. Guidetti, et al. 2018a. Mechanical phenotyping of K562 cells by the Micropipette Aspiration Technique allows identifying mechanical changes induced by drugs. Sci. Rep. 8:1219.

Elaroussi, M. A., F. R. Mohamed, E. M. El Barkouky, A. M. Atta, A. M. Abdou, and M. H. Hatab. 2006. Experimental ochratoxicosis in broiler chickens. Avian Pathol 35:263–269.

El-Galil, A., H. A. Mahmoud, A. M. Hassan, and A. S. Morsy. 2010. Effect of chamomile flowers meal as feed additives in laying Japanese quail diets on productive and reproductive performance. J. Anim. Poult. Prod. 1:517–533.

European Food Safety Authority (EFSA). 2006. Opinion of the Scientific Panel on Contaminants in the Food Chain [CONTAM] Related to Ochratoxin A in Food. EFSA J 4:365.

Ezeldien, S., F. Dramou, F. M. Youssef, A. A. Nikishov, and S. B. Seleznev. 2023. Effects of chamomile aqueous extract on productive performance, egg quality, and serum biochemical parameters in laying Japanese quails. Adv. Anim. Vet. Sci. 11:878–885.

Farag, M. R., H. S. A. Gharib, K. El-Naggar, B. M. Hendam, E. A. M. Ahmad, M. Alagawany, and H. M. El-Ghazali. 2023. Origanum majorana essential oil ameliorated the behavioral,biochemical, physiological and performance perturbations induced by aflatoxin B1 in growing rabbits. Ann. Anim. Sci. 23:1201–1210.

Ghoniem, A. A., K. M. Abd El-Hai, A. Y. El-Khateeb, N. M. Eldadamony, S. F. Mahmoud, and A. Elsayed. 2021. Enhancing the potentiality of *Trichoderma harzianum* against Pythium pathogen of beans using chamomile (*Matricaria chamomilla*, L.) flower extract. Molecules 26:1178.

Giannenas, I., K. Grigoriadou, E. Sidiropoulou, E. Bonos, A. Cheilari, A. Vontzalidou, C. Karaiskou, N. Aligiannis, P. Florou-Paneri, and E. Christaki. 2021. Untargeted UHPLC-MS metabolic profiling as a valuable tool for the evaluation of egg quality parameters after dietary supplementation with oregano, thyme, sideritis tea, and chamomile on brown laying hens. Metabolomics 17:1–15.

Göger, G., B. Demirci, S. Ilgın, and F. Demirci. 2018. Antimicrobial and toxicity profiles evaluation of the Chamomile (*Matricaria recutita* L.) essential oil combination with standard antimicrobial agents. Ind. Crops Prod. 120:279–285.

Grenier, B., and T. Applegate. 2013. Modulation of intestinal functions following mycotoxin ingestion: meta-analysis of published experiments in animals. Toxins 5:396–430.

Guidetti, G., A. Di Cerbo, A. Giovazzino, V. Rubino, A. T. Palatucci, S. Centenaro, E. Fraccaroli, L. Cortese, M. G. Bonomo, G. Ruggiero, S. Canello, and G. Terrazzano. 2016. In Vitro effects of some botanicals with anti-inflammatory and antitoxic activity. J. Immunol. Res. 2016:5457010.

Haddad, H. A. 2012. Effect of supplementing *Anthemis nobilis* (Chamomile) flower powder to the diet of commercial layers on some egg quality traits. Tikrit J. Agric. Sci. 12:35–40.

Hameed, M. R., M. Z. Khan, M. K. Saleemi, A. Khan, M. Akhtar, and Z-u. Hassan. 2017. Study of ochratoxin A (OTA)-induced oxidative stress markers in broiler chicks. Toxin Rev 36:270–274.

Hameed, M. R. M., M. Khan, A. Kashif, M. Khan, Z. Akhtar, and Z. H. Hassan. 2017. Study of ochratoxin A (OTA)-induced oxidative stress markers in broiler chicks. Toxin Rev 36:1–5.

Hermann, T. 2002. Mycotoxins in feed grains and ingredients. Technical Bulletin No. MF-206 on Feed Manufacturing. Agricultural Experiment Station and Extension, Kansas State University, Manhattan, KS.

Huff, W. E., L. F. Kubena, and R. B. 1988. Harvey progression of ochratoxicosis in broiler chickens. Poult. Sci. 67:1139–1146.

Iseppi, R., A. Di Cerbo, P. Aloisi, M. Manelli, V. Pellesi, and C. Provenzano. 2020b. In vitro activity of essential oils against planktonic and biofilm cells of extended-spectrum β-lactamase (ESBL)/carbapenamase-producing gram-negative bacteria involved in human nosocomial infections. Antibiotics 5:272.

Iseppi, R., A. Di Cerbo, P. Messi, and C. Sabia. 2020a. Antibiotic resistance and virulence traits in vancomycin-resistant enterococci (VRE) and extended-spectrum β-lactamase/ampc-producing (ESBL/AmpC) *Enterobacteriaceae* from humans and pets. Antibiotics 4:152.

Ismail, I. E., M. R. Farag, M. Alagawany, H. K. Mahmoud, and F. M. Reda. 2020. Efficacy of some feed additives to attenuate the hepato-renal damage induced by aflatoxin B1 in rabbits. J. Anim. Physiol. Anim. Nutr. (Berl) 104:1343–1350.

Jewers, K. 1990. Mycotoxins and their effect on poultry production. Options Méditerranéennes: Série A 7:195–202.

Khatoon, A., M. Z. Khan, A. Khan, and I. Javed. 2016. Toxicopathological and serum biochemical alterations induced by ochratoxin A in broiler chicks and their amelioration by locally available bentonite clay. Pak. J. Agr. Sci. 53:977–984.

Khishtan, A. T. M., and S. S. M. Beski. 2020. Delivery route of chamomile on the growth and subsequent physiology of broiler chickens under *E. coli* challenge. Iraqi J. Agri. Sci. 51:1058–1073.

Kumar, A., N. Jindal, C. L. Shukla, Y. Pal, D. R. Ledoux, and G. E. Rottinghaus. 2003. Effect of ochratoxin A on *Escherichia coli*−challenged broiler chicks. Avian Dis 47:415–424.

Liuzzi, V. C., F. Fanelli, M. Tristezza, M. Haidukowski, E. Picardi, C. Manzari, C. Lionetti, F. Grieco, A. F. Logrieco, M. R. Thon, G. Pesole, and G. Mulè. 2016. Transcriptional analysis of *Acinetobacter sp.* neg1 capable of degrading ochratoxin. A, Front. Microbiol. 7:2162–2170.

Mazzeranghi, F., C. Zanotti, A. Di Cerbo, J. P. Verstegen, R. Cocco, G. Guidetti, and S. Canello. 2017. Clinical efficacy of nutraceutical diet for cats with clinical signs of cutaneus adverse food reaction (CAFR). Pol. J. Vet. Sci. 20:269–276.

McCrea, B. K., J. H. Macklin, R. Norton, and S. Bilgili. 2005. Recovery of Campylobacter Jujunum from Broiler House Samples

During Four Consecutive Flocks. Dendrogram, Auburn University, Auburn, AL.

McKay, D. L., and J. B. Blumberg. 2006. A review of the bioactivity and potential health benefits of chamomile tea (*Matricaria recutita* L.). Phytother. Res. 20:519–530.

Nasr A.M., Salah El-Din S.A.E., Ismail I.E., Aldhahrani A., Soliman M.M., Alotaibi S.S., Bassiony S.S. and Abd El-Hack M.E., Comparative study among dietary supplementations of antibiotic, grape seed, and chamomile oils on growth performance and carcass properties of growing rabbit, *Saudi J. Biol. Sci.*, **29**, 2022, 2483−2488.

National Research Council (NRC). 1994. Nutrient Requirements of Poultry. 9th rev. ed National Academy Press, Washington, DC.

Nowaczewski, S., H. Kontecka, A. Rosiński, S. Koberling, and P. Koronowski. 2010. Egg quality of Japanese quail depends on layer age and storage time. Folia Biol 58:201–207.

Osman, M. Y., H. A. Taie, W. A. Helmy, and H. Amer. 2016. Screening for antioxidant, antifungal, and antitumor activities of aqueous extracts of chamomile (Matricaria chamomilla). Egypt. Pharm. J. 15:55.

Palmieri, B., A. Di Cerbo, and C. Laurino. 2014. Antibiotic treatments in zootechnology and effects induced on the food chain of domestic species and, comparatively, the human species. Nutr. Hosp. 29:1427–1433.

Pirzad, A., H. Alyari, M. R. Shakiba, S. Zehtab-Salmasi, and A. Mohammadi. 2006. Essential oil content and composition of German chamomile (*Matricaria chamomilla* L.) at different irrigation regimes. J. Agron. 5:451–455.

Prior, M. G., J. B. O'neil, and C. S. Sisodia. 1978. Effects of ochratoxin A on production characteristics and hatchability of Japanese quail. Can. J. Animal Sci. 58:29–33.

Rafeeq M., Bilal R.M., Alagawany M., Batool F., Yameen K., Farag M.R., Ali S., Elnesr S.S. and El-Shall N.A., The use of some herbal plants as effective alternatives to antibiotic growth enhancers in poultry nutrition, *World's Poult. Sci. J.*, **78**, 2022, 1067−1085.

Reda, F. M., I. E. Ismail, M. M. El-Mekkawy, M. R. Farag, H. K. Mahmoud, and M. Alagawany. 2020. 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. J. Anim. Physiol. Anim. Nutr. 104:196–203.

Romanoff, A. L., and A. J. Romanoff. 1949. Pages 1−918 in Avian Egg. John Wiley and Sons, Hoboken, NJ.

Saleemi, M. K., M. Z. Khan, A. Khan, M. R. Hameed, A. Khatoon, Z. U. Abadin, and Zahoor Ul Hassan.. Study of fungi and their toxigenic potential isolated from wheat and wheat bran. Toxin Rev 36:80–88.

Santin, E., A. C. Paulillo, P. C. Maiorka, A. C. Alessi, E. L. Krabbe, and A. Maiorka. 2002. The effects of ochratoxin/aluminosilicate interaction on the tissues and humoral immune response of broilers. Avian Pathol 31:73–79.

Santurio, J. M., D. F. Santurio, P. Pozzatti, C. Moraes, P. R. Franchin, and S. H. Alves. 2007. Atividade antimicrobiana dos óleos essenciais de orégano, tomilho e canela frente a sorovares de Salmonella enterica de origem avícola. Ciência Rural 37:803–808.

Shimada, K., K. Fujikawa, K. Yahara, and T. Nakamura. 1992. Antioxidative properties of xanthan on the autoxidation of soybean oil in cyclodextrin emulsion. J. Agric. Food Chem. 40:945–948.

Shirley, H. V., and S. H. Tohala. 1983. Ochratoxicosis in laying hens. Annual Science Progress Report 83-08. University of Tennessee, Agricultural Experiment Station, Knoxville, TN.

Singh, O., Z. Khanam, N. Misra, and M. K. Srivastava. 2011. Chamomile (*Matricaria chamomilla* L.): an overview. Pharmacogn. Rev. 5:82–95.

Skomorucha, I., and E. Sosnowka-Czajka. 2013. Effect of water supplementation with herbal extracts on broiler chicken welfare. Ann. Anim. Sci. 13:849–857.

SPSS Inc. 2008. SPSS Statistics for Windows, Version 17.0. SPSS Inc, Chicago, IL.

Srivastava, J. K., and S. Gupta. 2009. Extraction, characterization, stability, and biological activity of flavonoids isolated from chamomile flowers. Mol. Cell. Pharmacol. 1:138.

Srivastava, J. K., M. Pandey, and S. Gupta. 2009. Chamomile, a novel and selective COX-2 inhibitor with anti-inflammatory activity. Life Sci. 85(19−20):663–669.

Srivastava, J. K., E. Shankar, and S. Gupta. 2010. Chamomile: a herbal medicine of the past with a bright future (review). Mol. Med. Rep. 3:895–901.

Stoev, S. D., M. Stefanov, A. M. Domijan, A. M. Domijan, M. Peraica, and M. Peraica. 2004. Experimental mycotoxicosis in chickens induced by ochratoxin a and penicillic acid and intervention with natural plant extracts. Vet. Res. Comm. 28:727–746.

Svenningsen, A. B., K. D. Madsen, T. Liljefors, G. I. Stafford, J. van Staden, and A. K. Jäger. 2006. Biflavones from Rhus species with affinity for the GABA (A)/benzodiazepine receptor. J. Ethnopharmacol. 103:276–280.

Tahir M.A., Abbas A., Muneeb M., Bilal R.M., Hussain K., Abdel-Moneim A.E., Farag, K. Dhama M.R., Elnesr S.S. and Alagawany M., Ochratoxicosis in poultry: occurrence, environmental factors, pathological alterations and amelioration strategies, *World. Poult. Sci. J.*, **78**, 2022, 727−749.

Harvey R.B., Kubena L.F., Naqi S.A., Gyimah J.E., Corrier D.E., Panigrahy B. and Phillips T.D., Immunologic effects of low levels of ochratoxin A in ovo: utilization of a chicken embryo model, *Avian Dis.*, **31**, 1987, 787−791.

Verma, J., T. S. Johri, and B. K. Swain. 2003. Effect of varying levels of aflatoxin, ochratoxin and their combinations on the performance and egg quality characteristics in laying hens. Asian-Australas. J. Anim. Sci. 16:1015–1019.

Wang, W., S. Zhai, Y. Xia, H. Wang, D. Ruan, T. Zhou, Y. Zhu, H. Zhang, M. Zhang, H. Ye, W. Ren, and L. Yang. 2019. Ochratoxin A induces liver inflammation: involvement of intestinal microbiota. Microbiome 7:151.

World Health Organization (WHO). 2002. Evaluation of Certain Mycotoxins in Food: Fifty-sixth Report of the Joint FAO/WHO Expert Committee on Food Additives. (p. 62).

Xue, C. Y., G. H. Wang, F. Chen, X. B. Zhang, Y. Z. Bi, and Y. C. Cao. 2010. Immunopathological effects of ochratoxin A and T-2 toxin combination on broilers. Poult. Sci. 89:1162–1166.

Zahoor-ul-Hassan, M. Z. Khan, M. K. Saleemi, A. Khan, I. Javed, and S. A. Bhatti. 2012. Toxico-pathological effects of In ovo inoculation of Ochratoxin A (OTA) in chick embryos and subsequently in hatched chicks. Toxicol. Pathol. 40(1):33–39.

Zhang, K., X. Li, C. Na, A. Abbas, R. Z. Abbas, and M. A. Zaman. 2020. Anticoccidial effects of *Camellia sinensis* (green tea) extract and its effect on blood and serum chemistry of broiler chickens. Pak. Vet. J. 40:77–80.