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IMPACT OF CINNAMON POWDER EXTRACT ON PRODUCTIVE PERFORMANCE, BLOOD PARAMETERS, DIGESTIVE ENZYMES, IMMUNITY, ANTIOXIDANT AND MICROBIAL COUNT OF GROWING JAPANESE QUAILS

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ABSTRACT: This study aimed to investigate the effects of cinnamon powder extract (CPEx) on the intestinal microbial populations, serum indices and growth performance of Japanese quail. A total of 320 Japanese quail, aged ten days, were randomly divided into four treatment groups, each consisting of four replicates of 20 birds, for a feeding study lasting 38 days. The dietary treatments included a control group (a basal diet without CPEx), as well as three other groups that received the basal diet supplemented with CPEx at levels 150, 250 and 500 ppm/ kg, respectively. The results demonstrated that quails receiving diets supplemented with 250 and 500 ppm CPEx/ kg diet exhibited the highest live body weight, body weight gain, growth rate and performance index, with statistical significance ($P \leq 0.01$). Moreover, quails fed 250 and 500 ppm CPEx /kg diet displayed the best feed conversion ratio and the lowest feed intake. Additionally, quails provided 250 and 500 ppm CPEx/ kg diet demonstrated the lowest total cholesterol, LDL, triglycerides, ALT, AST, TBARS, populations of *Escherichia coli* and *Salmonella*, with the highest levels of high-density lipoprotein (HDL), amylase, lipase, trypsin, immunoglobulin A (IgA), immunoglobulin M (IgM) and population of *Lactobacilli* compared with control ($P \leq 0.01$). Lastly, quails received 150ppm CPEx/ kg diet exhibited the highest levels of GSH-PX and immunoglobulin G (IgG). In conclusion, the inclusion of 250 and 500 ppm CPEx/ kg quails' feed resulted in improved growth performance, antioxidant capacity, blood biochemical parameters, immunological indices and intestinal microbiota in growing Japanese quails.

Keywords: Cinnamon Powder Extract; Growth; Antioxidant; Immunity; Quail.

1. INTRODUCTION

Recent years have seen a noticeable advancement in the field of avian husbandry. Which the increasing demand towards chicken meat, which is viewed as a healthier and more practical substitute for beef (Buttar *et al.,* 2022 and Mitra *et al.,* 2022). Feed conversion ratio (FCR), growth rate and economical efficiency can be enhanced by incorporating dietary additives into poultry feed; this could lead to a reduction in feed expenses (Abd El-Hack and Alagawany, 2022 and Rajan *et al*., 2022; 2023). Antibiotic growth promoters (AGPs) have long been used to treat gastrointestinal infections and decrease the harmful impacts of stress on the gastrointestinal tract of chickens. Nevertheless, actions have been taken to limit the use of antibiotics in poultry farming due to increasing understanding of the harmful effects of antibiotics on the health of humans, the emergence of bacterial resistance, and worries about the safety of food (Alagawany *et al.*, 2020; Abd El-Hack and Alagawany, 2022). For these reasons, in the poultry industry, phytogenic feed additives (PFAs) have become a viable substitute for antibiotic (Ali *et al.,* 2021; Prakash *et al.,* 2022 and Rajan *et al.,* 2022; 2023). In this respect, plants and medicinal herbs contain phytochemicals and bioactive ingredients that have been shown to have a number of advantageous that enhancing the health of poultry (Seidavi *et al.*, 2022; El-Sabrout *et al.,* 2023 and Zebeaman *et al.,* 2023). Medical plants can be used as natural alternatives to antibiotics in poultry diets, which have strong immunological characteristics and demonstrate antioxidant, antibacterial properties, that enhanced appetite, increased secretion of enzymes for digestion, increased immunity, antibacterial and viral activity and antioxidant properties (Parham *et al.,* 2020; Kuralkar and Kuralkar 2021 and Uddin *et al.,* 2021). Cinnamon is one of the most potent potential PFAs (Prakash *et al.*, 2021 a, b; Kumar *et al.*, 2022 and Kumari *et al.*, 2022). Cinnamon (*Cinnamomum verum*) one of a popular seasoning in kitchens across the world (Arain *et al.,* 2018). The growth rate of broilers, plus their FI and FCR, are all positively impacted by the addition of cinnamon, even in small amounts (Chowlu *et al.,* 2019). Cinnamon has a wide range of medicinal applications, including improving digestion, eliminating bacteria, scavenging free radicals and reducing inflammation (Taback *et al.,* 1999, Chang *et al.*, 2001, Singh *et al.*, 2007 and Jakhetia *et al.*, 2010). Because of its unique scent, cinnamon is mostly used in poultry feed industry (Abo Ghanima *et al.,* 2020). According to Abd El-Hack *et al.* (2020), the main effects of cinnamon are ascribed to its high concentration of cinnamaldehyde and eugenol, which both have strong antifungal, antibacterial and antioxidant characteristics. From this point, cinnamon may be a natural substitute for antibiotics and have a positive impact on broilers performance (Mehdipour and Afsharmanesh, 2018). It is hypothesized that the dietary supplementation of CPEx will improve the health and performance of broiler chickens based on the previously mentioned studies. Thus, the purpose of this study was to evaluate CPEx as a natural feed additive in growing Japanese quail diets, and its effect on the caecal bacteria count, immunity, blood indices, antioxidant parameters and growth performance.

2. MATERIALS AND METHODS

This study was conducted at the Poultry Research Center, Faculty of Agriculture, Fayoum University, Egypt.

Experimental design and diets:

In this study, birds were housed and cared for throughout the experiment in compliance with the guidelines established by the Institutional Animal Care Committee of Fayoum University (Code No. of the research proposal: AEC 2361). A total number of 500 1-day- old Japanese quail chicks were reared in electrically heated batteries and fed a basal diet containing 24% crude protein with 2900 Kcal ME/ kg diet, from one up to 10 days of age, according to National Research Council (NRC, 1994). At day 10th of age, 320 unsexed quail chicks were randomly distributed to four equal treatments, each treatment containing 80 birds in four replicates of 20 birds each. The first group fed a basal diet without CPEx (control).

While, the second, third and fourth groups will be received the basal diet plus 150, 250 and 500 ppm CPEx/ kg diet, respectively. The newly hatched chicks were wing banded using small size plastic bands at 10 days, individually weighted and reared in cages with dimensions 40 × 60 ×25 cm^3. The ambient temperature of the rearing house in the first 10 days of age will 34−35ºC and then decreased gradually by about 2ºC weekly to reach 30-31ºC at 3 weeks of age after that birds reared under the normal environmental conditions of Fayoum University Poultry Farms. Birds exposed to light 23-24 h/ day, feed and water were provided *ad libitum* all over the experimental period. Cinnamon powder was purchased from a local market in Egypt in powder form. The extract was made by soaking the powder (350 g) with methanol (90%) at 25 °C for 48 h. The extraction was repeated three- times and the solvent was completely evaporated in vacuum, and dried extract was stored at -20 °C until use. Cinnamon Powder Extract (CPEx) will mixed to diets manually with a small amount of the feed, then the quantity was increased with good mixing until reaching the demanded homogeneity, after that the mixing was completed, stored in sealed and labelled bags according to each treatment for the purpose of maintaining the effectiveness of the additives. The composition of the basal diet is presented in Table 1.

Growth performance:

Live body weights of birds (LBW) were individually weighed and feed consumptions per pen were weekly recorded (FC), the uneaten feed discarded, body weight gain (BWG) as a difference between final and initial body weights, and feed conversion ratio (FCR)were calculated. Also, performance index (PI) were calculated based on North (1981) as follows: PI = BW_{kg}/FCR and growth rate was calculated based on Brody (1945) as follows: GR= (LBW_{38}– $LBW_{10)}$ /0.5 (LBW_{10} + LBW_{38}).

Blood biochemical, digestive enzymes, anti-oxidant and immunity:

At the end of the experiment (38 days), a blood sampling will collected from the slaughtered quails using two birds (1 male and 1 female) randomly chosen from each replicate. The birds were initially weighed to the nearest g, and slaughtered by cutting the Jugular vein (Islamic method), and in dry clean centrifugal tubes individual 32 blood, samples were gathered and by centrifugation for 15 minutes at 755 rpm, the serum was isolated then stored at −20℃ in a tube of Eppendorf till analysis. Quantitative determination was done for the following: total cholesterol (TC), LDL, HDL, triglycerides (TG), aspartate aminotransferase (AST) and alanine aminotransferase (ALT). All blood biochemical parameters were calorimetrically determined using commercial diagnosing kits (produced by Spectrum Diagnostics Company, Egypt). Amylase and lipase enzymes were assayed by Friedman and Young (2005) and according to Bovine Trypsin ELISA Kit (MBS706461) trypsin enzyme was determined. The glutathione peroxidase (GPx, EC 1.11.1.9) determined calorimetrically according to Paglia and Valentine (1967) and thiobarbaturic acid-reactive substances' (TBARS) were performed according to Yagi (1998) using commercial diagnosing kits produced by Cayman Chemical Company (USA). The method used for the assay of chicken immunoglobulins isotypes; IgG, IgM and IgA in Sandwich ELISA were described by Erhard *et al.* (1992) as the absorbance measured on an ELISA plate reader set at 450 nm.

Microbial analysis:

After slaughter, intestinal content was immediately collected in sterile glass containers, digesta was evacuated and mixed. At 4°C, the sealed containers were kept in the laboratory till enumeration of microbial population. Samples (1g of the mixed fresh mass) were taken into sterile test tubes, diluted 1:10 in sterile 0.1% peptone solution and homogenized for 3 min in a stomacher homogenizer. Tenfold serial dilutions up to 10^{-7} of each sample were prepared in nine ml of 0.1% sterile peptone solution. Viable counts of *Salmonella spp, Escherichia coli (E.coli)* and *Lactobacilli spp* were performed. One milliliter of the serial dilution was incubated into sterile Petri dishes and sealed with an appropriate medium. *Lactobacillus spp.* colony count was determined using MRS agar (Biokar Diagnostic, France) after incubation in an anaerobic chamber at 37 °C for 72 h. *Salmonella and E. coli* colonies were counted on brilliant green agar plate and incubated at 37°C for 24 h. After cultivation in Petri dishes, the total colony count for *Lactobacilli, Salmonella* and *E. coli* was then calculated as the number of colonies by reciprocal of the dilution. The microbial counts were determined as colony forming units (cfu) per gram of sample.

Statistical analysis

The results obtained studied using the statistics tools (analysis of variance) of Infostat (Di Rienzo, 2017) as the following model:

$Yij = \mu + Ti + eij$

Where: Yij: observation of traits, μ: overall mean, Ti: treatment effect, eij: random error. All means were compared using multiple range test (Duncan, 1955) at significance level of 0.05.

3. RESULTS

3.1 | Growth performance:

Table 2 presents data indicating a significant ($P < 0.001$) effect of the treatments on growth performance during the study period from 10 to 38 days of age. When compared to the control group, quails fed diets supplemented with 250 and 500 ppm CPEx/kg diet showed the best LBW at 38d, BWG (10-38), FCR (10-38), PI (10-38), and faster GR (10-38), while control group and chicks received 150 ppm CPEx recorded significantly the worst values of these parameters. In addition, birds fed 500 and 250 ppm CPEx/ kg diet had significantly ($P < 0.001$) lower feed intake values than control group which recorded the highest value of feed intake.

3.2 | Serum biochemistry:

The results presented in Table 3 displayed that feeding CPEx had a significantly substantial ($P < 0.001$) influence on lipids profile (Total cholesterol, HDL, LDL and TG), liver enzymes (ALT and AST) and digestive enzymes (Amylase, Lipase and Trypsin). Chicks fed diet supplemented with all levels of CPEx had significantly ($P < 0.001$) lower cholesterol, LDL, TG, ALT and AST and the highest HDL, Amylase, Lipase and Trypsin especially 250 and 500 ppm CPEx which enhanced digestive enzymes compared to the control group.

3.3 | Antioxidant capacity and immunity:

Data in Table 4 showed that both antioxidant characteristics (GPx, and TBAR) and immune response index were strongly ($P \leq 0.001$) affected by CPEx therapies compared to the control treatment. Birds fed diets supplemented with CPEx recorded the best IgG, IgA, IgM and glutathione peroxidase, with reduced thiobarbaturic acid-reactive compounds. Moreover, for GPx and IgG, the better impact was proved in the treated group with CPEx at 150 mg, with values of 2042.00 and 1085.00, respectively. Concerning to TBAR, IgA and IgM levels, the best value recorded for group fed 500 ppm CPEx (1.23, 106.93 and 197.30, respectively), while the worst effect recorded for control (1.53, 100.12 and 186.90, respectively). In general, addition CPEx in quail diets enhance values of immune index (IgM, IgA, and IgG) and GPx.

3.4| Intestinal bacteria:

Results found in Table 5 showed the effect of dietary CPEx on intestinal bacteria in Japanese quail at growing period. In the current study, feeding CPEx supplementation enhanced the healthy gut bacterial population *(Lactobacillus population*), while dramatically lowering ($P > 0.001$) the harmful diverse microbial population (*Salmonella and E. coli population*). Also, quails fed diets supplemented by different levels of CPEx had substantially the highest total population of intestinal advantageous *Lactobacilli* bacteria. While, decreasing the population count of small intestine *E. coli and Salmonella*, particularly in treatment fed diet supplemented with 500 mg CPEx, which had the lowest *E. coli and Salmonella* population levels (6.34 and 6.20), respectively, and the highest *Lactobacilli* population number (7.63), compared to control treatment (7.29, 7.54 and 5.81, respectively).

4. DISCUSSION

In the present study, quails that were provided diets containing 250 and 500 mg CPEx/ kg diet exhibited superior performance parameters compared to the control group, which demonstrated significantly inferior results for all performance traits (P < 0.001). The enhanced growth characteristics (BW, BWG and FCR) observed upon the inclusion of CPEx (250 and 500 ppm/ kg) in quail diets can be attributed to the presence of bioactive compounds like cinnamaldehyde and eugenol found in cinnamon plants. These compounds possess antioxidant properties that can enhance digestion by stimulating the secretion of digestive enzymes, maintaining the health of intestinal villi, and positively influencing digestion and absorption processes (Jamroz *et al.*, 2005). Furthermore, the enhanced growth performance could be ascribed to the characteristics of cinnamon, which have the potential to invigorate the broiler's digestive tract, enhance liver function, and elevate pancreatic digestive enzymes (Langhout, 2000 and Mellor, 2000). Baskara *et al.* (2021) showed that the beneficial substances in cinnamon extract are capable adequate to slow down the rate passing food in small intestine, improving digestion efficiency for nutrient. The findings of our study are consistent with those of Ahmed *et al.* (2019), who demonstrated that the inclusion of CPEx at different concentrations (0.5 or 1.0 ml/kg diet) in quail's diet led to a notable enhancement in BWG compared to antibiotic treated group. Mehdipour and Afsharmanesh (2018) discovered that adding 200 mg CPEx/ kg quail feed increased BWG and enhanced FCR in comparison with the control birds. Likewise, Toghyani *et al.* (2011) reported that broiler chickens fed 2 g cinnamon powder/ kg had a higher BW than the control treatment. Furthermore, Ciftci *et al.* (2009) and Al-Kassie (2009) reported that broiler chicks fed a diet containing 500 mg CPEx/ kg and cinnamon essential oil recorded the best BWG and FCR than antibiotic or control groups. Similarly, Shirzadegan (2014) showed that chicks received a diet with 2 g/kg of cinnamon had the highest weight. Saeed *et al.* (2018) and Abo-Ghanima *et al.* (2020) showed that essential oils that found in cinnamon can improve FCR and growth performance, through their effects on regulation of intestinal microflora, stimulation of the immune system, production of gastric enzymes, and promotion of properties that fight against microbes and oxidation. Recently, Saied *et al.* (2022) demonstrated the potential benefits of incorporating cinnamon oil as a dietary supplement for broiler chickens, in lieu of antibiotic growth enhancers and they found that dosages of 500, 1000 and 1500 mg/ kg of cinnamon oil produced positive results on performance. Contrary, Symeon *et al.* (2014) and Lee *et al.* (2003) showed that broilers fed a diet treated with different levels of CPEx (0.5 or 1.0 ml/kg diet) or cinnamon oil and cinnamon byproducts have no significant influence on growth performance. Furthermore, Koochaksaraie *et al.* (2011) demonstrated that the addition of cinnamon at levels varying between 0.5- 2 g/kg had no appreciable impact on broiler growth or body weight.

Concerning to FI and FCR, quails fed diets supplemented with 250 and 500 mg CPEx /kg showed the best FCR and the lowest FI. While control group showed the highest FI and the worst FCR followed by quils fed diet supplemented with 150mg CPEx with significant differences between them. In this respect, adding cinnamon in poultry feed can improve gut ecology and enhance ability to absorb nutrients (Mountzouris *et al.*, 2011). They also stimulate the production of bile acid and digestive enzymes, which aid in the breakdown of fat and food. Additionally, enhancing digestive process by increasing interactions between feed and digestive enzymes (Zhai *et al.*, 2018). Moreover, Devi *et al.* (2018) found that the addition of cinnamon to the broiler diet increased the villus surface area, villus height (VH) in the duodenum and jejunum, and the efficiency of digesting nutrients, all of which contribute to better nutrient absorption. The antioxidant properties of cinnamon oil are responsible for the enhancement of gut heath and digestive enzymes (Mehdi *et al.*, 2018). Recently, Kumar *et al.* (2022) illustrated that cinnamaldehyde, which is present in cinnamon, can stimulates the digestive system by promoting saliva and digestive enzyme production from the pancreas and intestines. Therefore, improves nutrient absorption and digestion. Furthermore, the digestibility of crude fat and amino acids was significantly improved in birds supplemented with cinnamaldehyde. Additionally, Redondo *et al.* (2014) found that supplementing broiler diets with cinnamon oil enhanced protein digestion by encouraging the stomach's production of pepsin and hydrochloric acid. Torki *et al.* (2015) demonstrated that cinnamon enhanced the immune systems of chickens, decreased feed intake with enhancing feed conversion ratio. Furthermore, Al-Kassie (2009) found that FCR and FI were improved for poultry fed 200 ppm of cinnamon oil. Furthermore, broilers given a diet supplemented with 500 ppm of cinnamon oil or different levels powdered cinnamon significantly improves their FCR than those given antibiotics (Ciftci *et al.,* 2009). In contrast, Sim sek *et al.* (2015) and Torki *et al.* (2015) noted that laying hens fed a diet containing cinnamon oil had a worse FCR. According to Hernandez *et al.* (2004), feed conversion efficiency did not change for broilers given 200 ppm of CPEx.

In relation to lipid levels, chicks treated with diet complemented with 150, 250 and 500 mg CPEx have substantially ($P < 0.001$) lower levels of cholesterol, LDL and TG with higher HDL in contrast to control treatment. In this regard, the benefits of using cinnamon oil to lower total cholesterol levels; where the active compounds derived from cinnamon had an impact on total cholesterol levels. The cinnamon active compounds have the potential to reduce cholesterol in consumers' meat, making it more appealing (Krauze *et al.,* 2021; Chandran, 2021 and Kumari *et al.,* 2022). Moreover, the significant decrease in cholesterol associated with supplementation may be explained by cinnamon's inhibitory action on 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase (Goldstein and Brown, 1995). In the current investigation, CPEx treatment resulted in a drop in blood triglyceride levels. Due to triglyceride-rich, lipoproteins transport triglycerides from the liver into the bloodstream, which reduced hepatic lipogenesis that lower plasma triglyceride concentrations (Zhou *et al.,* 2009). Furthermore, CPEx includes active derivatives such cinnamic acid that could inhibit the activity of hepatic HMG-CoA reductase that lowering blood cholesterol levels (Lee *et al.,* 2007). Faghani *et al.,* (2014) reported that broiler feed containing cinnamon essential oil increased HDL and decreased LDL and TG. In addition, when 0.8% of cinnamon is added to chicken feed, it has been shown to reduce LDL and plasma TC in birds (Najafi and Taherpour 2014 and Kumari *et al.,* 2022). In a similar vein, Torki *et al.,* (2015) found that feeding birds with cinnamon and zinc reduced their levels of TG. Gopi *et al.,* (2012) demonstrated that adding cinnamon to broiler feeding at 250 and 500 ppm lowers the levels of TC in blood. Lately, Krauze *et al.* (2023) discovered that the smallest and highest levels of cinnamon (0.1 and 0.25 ml/L) caused a positive increase in acetylcholinesterase and low-density lipoprotein receptor-related protein 1 concentrations, which in turn caused a decrease in TC and LDL levels. Moreover, Sarica *et al.* (2009) and Torki *et al.* (2018) discovered that quail (laying hens) diets supplemented with 500 mg CPEx/kg recorded a decrease in plasma TC and TG levels. In the same trend, Al-Kassie (2009) discovered that broilers given supplements containing cinnamon essential oil had lower cholesterol levels. Recently, Prakash *et al.* (2021a, b) illustrated that birds fed a diet supplemented by cinnamon essential oil at 1000 ppm recorded lower TC and total saturated fatty acid. On the other hand, according to Ali *et al.* (2018), adding 3% of cinnamon powder to a broiler's diets did not significantly influence the animal's plasma TC and TG levels. Furthermore, the addition of cinnamonaldehyde to the broiler feed did not significantly influence plasma lipid concentrations of poultry (Lee *et al.,* 2017).

Concerning liver enzymes, the present findings align with those published by Ahmed *et al.* (2019), which observed that quails given a dose of 0.5 or 1.0 ml/ kg diet recorded lower AST values than other treatments. In a similar vein, Abo Ghanima *et al.* (2020) found that laying hens treated with CO at a dose of 300 mg/kg had significantly lower levels of both ALT and AST. On the contrary, Ali *et al.* (2018) noted that broilers given a diet supplemented with 3% cinnamon powder have higher AST levels in blood. Furthermore, Kanani *et al.* (2016) found that adding 0.5% cinnamon powder to broiler diets had no discernible effect on the levels of AST in the blood.

Regarding digestive enzymes, it was discovered that the groups supplemented with 250 and 500 mg CPEx exhibited higher levels of trypsin, lipase and amylase than other groups. Research on chickens has led to the suggestion that cinnamon may have an impact on the release of digestive enzymes from the pancreas and intestinal mucosa (Zhu *et al.*, 2020). Cinnamon is also thought to help with digestion by encouraging the synthesis of digestive enzymes and making it easier for nutrients to be absorbed by stabilizing the gut microbial environment and promoting the release of digestive enzymes with prevent metabolic and digestive disorders (Garcia *et al.*, 2007 and Bento *et al.*, 2013).

Regarding the antioxidant status, the inclusion of CPEx in chicks diet resulted in the highest glutathione peroxidase activity and a reduction in thiobarbaturic acid-reactive compounds. The group that received CPEx at a dosage of 150 mg demonstrated the most significant effect on GPx. On the other hand, the group that received CPEx at a dosage of 500 mg exhibited the lowest value for TBAR compared to the control group. In this context, the immune response of animals can be influenced by cinnamon polyphenol extract, which possesses both anti-inflammatory and pro-inflammatory effects (Cao *et al.*, 2008). These findings align with the results of Mehdipour and Afsharmanesh (2018), who demonstrated that chickens fed a diet with powdered cinnamon increased their antioxidant capacity and superoxide dismutase activity (SOD). Similarly, Reda *et al.* (2020) found that birds fed diets supplemented with cinnamon oil exhibited increased activities of GSH, SOD and TAC, as well as decreased levels of MDA, indicating that cinnamon oil possesses effective antioxidant properties. It has been discovered that phenolic substances and essential oil combinations enhance CAT activity, which removes hydrogen peroxide and changes lipid hydroperoxides into non-toxic substances (Fki *et al.*, 2005). Additionally, quails fed diets containing 0.5 or 1.0 ml CO/kg diet showed higher levels of TAC, SOD and GSH than other groups (Ahmed *et al.*, 2019). According to Ciftci *et al.* (2010), broilers fed diets supplemented with 500 or 1000 ppm of CO showed substantially higher levels of CAT and GP and lower levels of MDA. A substantial drop for MDA in the liver was observed by Yang *et al.* (2019) in broiler chickens fed diets containing varying concentrations of CO (50, 100, 200, 400, or 800 mg/kg diet). Recently, Abo Ghanima *et al.* (2020) showed that hens fed diets containing 300 mg CO/kg diet reduce MDA levels.

Concerning to immune indicators, the ingestion of diets supplemented with CPEx resulted in the highest levels of IgG, IgA and IgM in birds. This can be attributed to the presence of phenolic components in cinnamon, which possess properties that scavenge free radicals. Consequently, the consumption of cinnamon has the potential to enhance the immune response (Alves-Santos *et al.,* 2020 and Habiba *et al.*, 2021). In this respect, Pannee *et al.* (2014) found that cinnamon aldehyde, known for its anti-inflammatory effects, enhances the resistance of chickens to diseases. Furthermore, Lillehoj *et al.* (2011) demonstrated that cinnamon exerts its immune regulatory actions through the antigen and immune response pathways. Kettunen *et al.* (2006) reported that chickens fed cinnamon essential oil exhibited improvements in intestinal immune competence and an increase in IgA content. Similarly, Sang-Oh *et al.* (2013) observed an increase in serum immunoglobulin levels in broilers fed a cinnamon diet. This aligns with our own findings, as we also observed higher levels of plasma IgG, IgM, and IgA in chicks supplemented with cinnamon powder (3, 5, and 7%) compared to those not supplemented. Additionally, Yang *et al.* (2019) discovered that diets supplemented with cinnamon essential oil at varying levels or mixed with bamboo leaf flavonoids significantly impacted the serum

IgM content in broilers. However, the study did not find any significant influence on serum IgG and IgA levels. Recently, Abo Ghanima *et al.* (2020) observed that the inclusion of 300 mg CO/kg of laying hens diet significantly enhanced the functioning of their immune systems.

Alternate strategies in recent times have focused on enhancing health and immune system function through the reduction of pathogenic bacteria and manipulation of the gut microbiota composition to achieve better outcomes. The current investigation reveals that the administration of CPEx supplementation augments the population of beneficial gut bacteria (specifically *Lactobacillus* population), while significantly reducing the presence of harmful and diverse microbial population (*Salmonella and E. coli* population) ($P > 0.001$). According to Dorman and Deans (2000), CPEx has antibacterial activity towards a variety of bacteria in the gut, which inhibits the colonization of several harmful types in the gastrointestinal tract. In addition, Tiwari *et al.* (2018) reported that the active ingredients derived from medicinal and aromatic plants may change the way entero pathogenic strains' cellular membranes structure, causing the pathogen to be damaged as a result of ion leakage from the cell. These effects are largely attributed to the phenolic substances present in these compounds, which exert negative effects on bacterial cells (Basílico and Basílico, 1999 and Peñalver *et al.,* 2005). Cinnamaldehyde, the main phenolic component of cinnamon plants, that has antibacterial characteristics (Alagawany *et al.,* 2017) which it may result to damage bacteria cell walls and cell contents release, a decrease in intracellular pH that lowers adenosine triphosphate levels, and change of the structure of the membrane, which can impact inorganic equilibrium and pH equilibrium (Oussalah *et al.,* 2006). Hernández *et al.* (2004) found that active components such carvacrol and eugenol that found in cinnamon have been shown to have antimicrobial activity because they have a preventive effect from pathogenic microorganisms. According to Tiihonen *et al.* (2010), CPEx's have a capacity to harm bacterial cellular membranes which inhibits *E. coli* populations from growing. Moreover, cinnamon oil increases the secretion of mucus in the digestive tract, which decreases the adherence of harmful bacteria to the intestinal epithelium (Jamroz *et al.,* 2006). Additionally, Ahmed *et al.* (2019) found that quails given a diet supplemented with CPEx have an increase in lactic acid bacteria and a reduction in *salmonella*. In a similar vein, Chowdhury *et al.* (2018) discovered that broiler chicks' pre-caecal content contained less *E. coli* when CPEx was added to their diet. Furthermore, Zhu *et al.* (2020) found that cinnamon powder and cinnamon oil have antibacterial advantages. Additionally, cinnamon's bioactive compounds can stimulate the growth of useful bacteria in chicken intestines with inhibiting harmful bacteria (Lin *et al.,* 2003). Similarly, Jamroz *et al.* (2005) discovered that the presence of cinnamon decreased *E. coli* and increased *Lactobacillus* in the intestines of broilers. The antimicrobial activity of cinnamon oil may be attributed to its ability to disrupt bacterial cell membranes, thereby reducing *E. coli* populations. Yang *et al.* (2020) demonstrated that cinnamaldehyde, either alone or in combination with citral, can reduce the occurrence of necrotic enteritis. The antioxidant status, immunity, and antibacterial effects of poultry can all be promoted by adding CO as a feed component in their diets (Lee *et al.,* 2017). According to a recent study by Solanki *et al.* (2022), CO may be used in poultry farming rather than chemical enhancers for growth, it dramatically reduces the levels of *Salmonella, E. coli,* and overall microbial count. Thymol and cinnamaldehyde have been suggested in a number of studies due to their ability to improve digestive tract health in poultry (Ouwehand *et al.,* 2010 and Tiihonen *et al.,* 2010). Studies have demonstrated that adding cinnamon to chicken diets may modify gastrointestinal microorganisms and enhance the health of the gut (Mehdi *et al.,* 2018). Consuming a diet including cinnamon stimulates the growth of beneficial bacteria and inhibits the growth of harmful bacteria, where increased the growth of *Lactobacillus* species in the digestive tract of the broilers, while significantly inhibiting the growth of harmful bacteria such as *E. coli*, resulting a healthier gut ecology (Rashid *et al.*, 2020). Where, cinnamon bioactive compounds have antibacterial properties and can effectively eradicate harmful bacteria (Chang *et al.,* 2001).

5 | CONCLUSION

The findings of the current investigation suggest that the incorporation of CPEx into the diet at concentrations of 250 and 500 mg/kg diet exhibited enhanced efficacy concerning productivity, antioxidant potential, blood parameters and immune profiles in quails. Consequently, CPEx may serve as a growth enhancer and a promoter of health in the rearing of Japanese quail at growing period.

Table (1): Composition and calculated analysis of basal diet fed to growing Japanese quail.

Ingredients	**%**
Yellow corn	53.5
Soybean meal (44 %)	30.5
Corn gluten meal (60%)	9.5
Wheat bran	1.5
Vegetable oil	0.5
DL-methionine	0.20
L-Lysine HCl	0.30
Salt (NaCl)	0.50
Vitamin and mineral premix*	0.50
Limestone	1.00
Di calcium phosphate	2.00
Total	**100**
Calculated Analysis**	
Metabolisable energy (kcal/kg)	2900
Crude protein %	24.04
Crude fiber %	3.60
Calcium %	0.89
Available phosphorus%	0.63
Lysine	1.40
Methionine	0.62
Methionine + Cystine	0.89

*Premix provided per kg of diet: vitamin A, 12000 IU; vitamin D3, 2400 IU; vitamin E, 30 mg; vitamin K3, 4 mg; vitamin B1, 3 mg; vitamin B2, 7 mg; vitamin B6, 5 mg; vitamin B12, 15 µg; niacin, 25 mg, Fe, 80 mg; folic acid, 1 mg; pantothenic acid, 10 mg; biotin, 45 mg; choline, 125000 mg; Cu, 5 mg; Mn, 80 mg; Zn, 60 mg; Se, 150 µg

According NRC, 1994.**

Table (2): Effect of dietary cinnamon powder extract on growth performance in growing Japanese quail.

Items / **Treat.**	**Control**	**CPEx 150mg/kg**	**CPEx 250mg/kg**	**CPEx 500mg/kg**	**SE**	**P-value**
Initial LBW(g)	55.46	55.43	55.42	55.44	0.48	0.9999
LBW38d (g)	226.61^{b}	229.49^{b}	235.22^{a}	235.10^{a}	1.46	0.0001
BWG10-38 (g)	171.15^{b}	174.06^{b}	179.80^{a}	179.66^{a}	1.35	0.0001
FI 10-38 (g)	599.78^{a}	582.81^{b}	579.61^{c}	578.73^{c}	0.60	0.0001
FCR 10-38 (g/g)	3.50^{a}	3.35^{b}	3.22^{c}	3.22^{c}	0.03	0.0001
GR_{10-38}	1.21^{b}	1.22^{b}	1.24^{a}	1.24^{a}	0.01	0.0019
PI_{10-38}	6.47^{c}	6.85^{b}	7.30^{a}	7.30^{a}	0.10	0.0001

Abbreviations: CPEx: cinnamon powder extract, LBW: Live Body Weight, BWG: Body Weight Gain, FI: Feed Intake, FC: feed conversion, GR: Growth rate (GR= (LBW_{38}– $LBW_{10)}$ /0.5 (LBW_{10} + $LBW_{38)}$), PI: Performance index (PI = BW_{kg}/FCR) ×100, SE: Standard Error, $^{a-c}$: Means within the same row with different superscript.

Table (3): Effect of dietary cinnamon powder extract on lipid profile, liver functions and digestive enzymes in growing Japanese quail.

Items / **Treat.**	**Control**	**CPEx 150mg/kg**	**CPEx 250mg/kg**	**CPEx 500mg/kg**	**SE**	**P-value**
lipids profile						
Total chol., mg/dL	171.75^{a}	159.41^{b}	156.20^{b}	156.48^{b}	3.11	0.0040
HDL, mg/ dL	57.00^{b}	92.33^{a}	91.52^{a}	91.00^{a}	1.16	0.0001
LDL, mg/ dL	92.00^{a}	46.46^{b}	44.03^{b}	45.43^{b}	1.68	0.0001
TG , mg/dL	134.00^{a}	107.88^{b}	105.02^{b}	105.70^{b}	2.25	0.0001
liver functions						
ALT, IU/L	4.75^{a}	3.58^{b}	3.53^{b}	3.44^{b}	0.21	0.0003
AST, IU/L	218.00^{a}	192.00^{b}	192.00^{b}	190.00^{b}	2.76	0.0001
Digestive Enzymes						
Amylase U/L	560.50^{c}	596.50^{b}	627.25^{a}	628.50^{a}	7.66	0.0001
Lipase U/L	71.15^{c}	91.40^{b}	93.58^{ab}	98.03^{a}	1.85	0.0001
Trypsin U/L	91.50^{b}	109.75^{a}	109.50^{a}	112.75^{a}	2.03	0.0001

Abbreviations: CPEx: cinnamon powder extract, Total Chol: Total Cholesterol, TG: triglycerides, ALT: Alanine Aminotransferase, AST: Aspartate Aminotransferase, SE: Standard Error, $^{a-c}$: Means within the same row with different superscript

Table (4): Effect of dietary cinnamon powder extract on antioxidant parameters and immune response in growing Japanese quail.

Items / **Treat.**	**Control**	**CPEx 150mg/kg**	**CPEx 250mg/kg**	**CPEx 500mg/kg**	**SE**	**P-value**
Antioxidant Parameters						
GSH-PX (nmol/min/ml)	1864.50^{b}	2042.00^{a}	2025.00^{a}	1998.50^{a}	26.06	0.0002
TBARS (nmol /ml)	1.53^{a}	1.45^{ab}	1.25^{b}	1.23^{b}	0.08	0.0232
Immune Indices						
IgG (mg/dl)	972.63^{c}	1085.00^{a}	1075.08^{ab}	1019.30^{bc}	20.12	0.0014
IgA (mg/dl)	100.12^{b}	103.50^{ab}	105.51^{a}	106.93^{a}	1.17	0.0020
IgM (mg/dl)	186.90^{b}	195.78^{a}	195.68^{a}	197.30^{a}	1.95	0.0030

Abbreviations: CPEx: cinnamon powder extract, GSH-PX: Glutathione Peroxidase TBARS: Thiobarbaturic Acid- Reactive Substances, IgG: Immunglobin G, IgA: Immunglobin A, IgM: Immunglobin M, SE: Standard Error $^{a-c}$: Means within the same row with different superscript

Table (5): Effect of dietary cinnamon powder extract on intestinal bacteria count in growing Japanese quail.

Items / **Treat.**	**Control**	**CPEx 150mg/kg**	**CPEx 250mg/kg**	**CPEx 500mg/kg**	**SE**	**P-value**
E.coli log 10 cfug	7.29^{a}	6.94^{ab}	6.89^{b}	6.34^{c}	0.13	0.0002
Salamonella log 10 cfug	7.54^{a}	6.20^{b}	6.24^{b}	6.20^{b}	0.20	0.0001
Lactobacillus log 10 cfug	5.81^{b}	7.30^{a}	7.29^{a}	7.63^{a}	0.12	0.0001

Abbreviations: CPEx: cinnamon powder extract, SE: Standard Error, $^{a-c}$: Means within the same row with different superscript.

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الملخص العربي

تأثير إضافة مستخلص مسحوق القرفة على الأداء الإنتاجي ومقاييس الدم والإنزيمات الهاضمة والمناعة ومضادات الأكسدة والعد البكتيري للسمان الياباني النامى

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هدفت هذه الدراسة إلى التحقق من تأثيرات مستخلص مسحوق القرفة (CPEx) على العد البكتيري في الأمعاء ومقاييس الدم والأداء الإنتاجي لطيور السمان اليابانى خلال مرحلة النمو. في اليوم العاشر من هذه الدراسة والتى استمرت إلى عمر ٣٨ يوما تم تقسيم ٣٢٠ كتكوت من السمان اليابانى عشوائيًا إلى أربع معاملات تجريبية، شملت كل معاملة أربع مكررات وكل مكرر به ٢٠ كتكوت . تم تغذية المعاملة الأولى على عليقة الكنترول (عليقة الكنترول بدون إضافة CPEx) ، بينما المعاملات من ٢ إلى ٥ فقد تم تغذيتها على عليقة الكنترول مضافا إليها مستخلص مسحوق القرفة CPEx بمستويات ١٥٠ و ٢٥٠ و ٥٠٠ مجم / كجم ، على التوالي. أظهرت النتائج أن الطيور التي تلقت علائق مضاف إليها CPEx بمعدل ٢٥٠ و ٥٠٠ جزء في المليون/ كجم عليقة هى الأعلى معنويا$(P \leq 0.01)$ في وزن الجسم الحى ومعدل الزيادة في وزن الجسم ومعدل النمو ومؤشر الأداء. من ناحية أخرى ، أظهرت الطيور التي تم تغذيتها بـعلائق مكملة ب ٢٥٠ و ٥٠٠ جزء في المليون من CPEx كجم/ عليقة أفضل معدل تحويل للغذاء وأقل استهلاك للعلف. بالإضافة إلى ذلك ، أظهرت الطيور التي تم تزويدها بتركيز ٢٥٠ و 500جزء في المليون من CPExكجم/عليقة أقل مستوى من الكوليسترول الكلي و LDL والدهون الثلاثية و ALT و AST و TBARS و عدد لـ *Escherichia coli*بكتيريا القولون و السالمونيلا *Salmonella*، مع أعلى مستويات الدهون العالية الكثافة (HDL) والأميليز والليبيز والتريبسين و IgA و IgM وبكتيريا حامض اللاكتيك *Lactobacilli* ، مقارنة بمجموعة الكنترول $(P \leq 0.01)$. في النهاية، سجلت طيور السمان التي تم إمدادها بـ ١٥٠ ملجم من CPEx أعلى مستويات من إنزيم الجلوتاثيون بيروكسديز IgG GSH-PX,.

وختاما، أدت إضافة CPEx بتراكيز ٢٥٠ و ٥٠٠ مجم / كجم/ عليقة إلى تحسين أداء النمو والقدرة المضادة للأكسدة والمعايير الكيميائية للدم والمؤشرات المناعية والعد البكتيري في الأمعاء للسمان اليابانى النامى.