*Nigerian J. Anim. Sci. 2026, 28 (1): 57-66*

# Haemato-biochemical indices, meat lipid profile and antioxidant status of broiler chickens fed diet containing onion peel and cinnamon powder as additives

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**Target Audience:** Small, large-scale broiler chicken producers and extension officers

## Abstract

*This study evaluated effects of dietary supplementation with combined onion (Onion) peel and cinnamon (Cinnamon) powder mixture (COP) on the haemato-biochemical parameters, meat lipid profiles, and antioxidant status of broiler chickens. A total of 240 day-old broiler chicks were assigned to five treatments in a completely randomized design, consisting of a control diet and four levels of COP supplementation (0.02%, 0.03%, 0.04%, and 0.05%). The COP was prepared by thoroughly mixing onion peel powder and cinnamon powder in an equal ratio of 50 g: 50 g (1:1, w/w) before incorporation into the experimental diets.Birds were managed intensively for six weeks with ad libitum access to feed and water. At the end of the trial, blood samples were collected via the jugular vein for haematological and serum biochemical analysis, while breast meat samples were analyzed for lipid fractions and antioxidant enzyme activities (Glutathione Peroxidase, Superoxide Dismutase, Catalase, Reduced Glutathione, and Malondialdehyde). Data were subjected to One-way Analysis of Variance and means separated using the Duncan Multiple Range Test. Dietary COP did not significantly ($P > 0.05$) affect haematological indices such as packed cell volume, haemoglobin, red blood cell and white blood cell. However, Serum alanine aminotransferase (ALT) was significantly influenced; birds fed 0.02% COP recorded the lowest ALT (44.50 U/L). In breast meat, 0.02% COP inclusion significantly ($P < 0.05$) reduced cholesterol (101.35 mg/dL), triglycerides, and LDL. While antioxidant enzyme activities were not statistically significant, numerical peaks in catalase and lower MDA were observed in birds exposed to 0.02% COP*

**Keywords:** *Allium cepa*, *Cinnamomum cassia*, Broilers, Lipid profile, Hepato-protection, Antioxidants.

## Description of Problem

The global livestock sector is currently undergoing a paradigm shift, driven by the dual necessity of meeting the nutritional demands of a growing population and adhering to stringent food safety regulations (1). Broiler production stands at the forefront of the global poultry industry, with an annual slaughter rate exceeding 70 billion birds worldwide (2). While the industry is lauded for its efficiency in converting grain into high-quality animal protein, its historical reliance on sub-therapeutic antibiotics for growth promotion has come under intense scrutiny. The emergence of multi-drug resistant (MDR) pathogens and the detection of residues such as tetracycline and penicillin in poultry meat have raised significant public health alarms (3; 4). Consequently, the global shift toward Antibiotic Growth

Promoter (AGP)-free production has sparked a renewed interest in phytogenic feed additives (PFAs) as sustainable alternatives.

Phytogenic additives, derived from botanical sources, offer a holistic approach to poultry health by enhancing gut integrity, immune modulation, and oxidative stability. Among these, onion (*Allium cepa*) peel and cinnamon (*Cinnamomum verum*) powder present a compelling case for dietary inclusion (5). Onion peels are a major by-product of the agro-industrial sector, often discarded as waste, contributing to environmental pollution. However, they represent a potent reservoir of bioactive polyphenols, specifically quercetin and various organosulfur compounds (6). These compounds are documented to possess strong radical-scavenging abilities, which protect cellular membranes from lipid peroxidation and potentially improve the haematological profile of birds by enhancing erythropoiesis and leucocyte function (7; 8). Additionally, cinnamon has gained prominence as a functional feed ingredient due to its rich concentration of cinnamaldehyde and eugenol. These phytochemicals act as digestive stimulants by enhancing enzymatic activity and stabilizing the intestinal microbiota (9**)**. Beyond gut health, cinnamon exhibits significant hypocholesterolemic effects, influencing the serum biochemical profile by regulating lipid metabolism; a factor of increasing importance to health-conscious consumers seeking lean meat with favorable fatty acid profiles (10).

Despite the documented benefits of these individual additives, there is a scarcity of comprehensive data regarding their synergistic application. Most existing literature focuses on single-plant extracts, leaving a gap in understanding how the combined antioxidant network of onion flavonoids and cinnamon aldehydes interacts within the avian biological system. Haemato-biochemical indices serve as critical physiological indices, reflecting the metabolic and immunological status of the broiler in response to dietary interventions (11). Furthermore, the stability of the meat's lipid profile and systemic antioxidant status are essential parameters that determine both the nutritional value for the consumer and the shelf-life of the product. In light of these considerations, this study aims to evaluate the effects of dietary supplementation with onion peel, cinnamon powder, and their combination on the haemato-biochemical parameters, meat lipid profiles, and antioxidant status of broiler chickens.

## Materials and methods

*Experimental site*-The experiment was carried out at the Directorate of University farm, Federal University of Agriculture Abeokuta, Ogun state. The site is located in the rainforest region of the South-West Nigeria, with the Latitude 7◦13'N, 3◦25'E, altitude 142m above the sea level (12).

*Source of and preparation of test materials (Onion Peel and Cinnamon)*- The cinnamon (*Cinnamomum cassia*) in powdery form was purchased from a trusted and reputable spices vendor in Ibadan, Oyo State while the onion peel was sourced from local market at Eleweran, Abeokuta, Ogun State. The cinnamon was in powdery form, but the onion peel was air dried for two weeks, after which it was sorted to remove dirt and thereafter ground into powder with the aid of a blender. Then the cinnamon powder was mixed with the onion peel powder in equal proportion (50 g: 50 g) to make 100 g.

*Experimental birds and management*- Prior arrival of the experimental birds, the pen and all associated equipment were thoroughly cleaned, disinfected, and fumigated to minimize microbial contamination and prevent the invasion of

pests and predators. A total of 240-day-old broiler chicks were procured from a reputable commercial hatchery in Ibadan, Oyo State. On arrival, chicks were brooded in a deep-litter housing system with clean wood shavings as bedding material. Standard brooding practices were observed, including provision of adequate floor space, continuous access to fresh water, and maintenance of optimal brooding temperature using electric brooders and heat lamps. Temperature was gradually reduced weekly to meet the physiological needs of the birds. The birds were managed intensively throughout the six-week experimental period. They were fed a commercial broiler pre-starter crumble from day 1 to 14, a broiler starter pellet from week 2 to week 4, and a broiler finisher diet from week 4 to week 6. Feed was offered *ad libitum* throughout the study. Clean drinking water was provided continuously, and drinkers were washed daily to maintain hygiene. Routine vaccinations and medications appropriate for broiler production were strictly followed. The vaccination schedule included Marek's disease vaccine at the hatchery, Newcastle disease vaccine (Lasota) at day 7 and day 21, Infectious bursal disease (IBD) vaccine at day 14.

*Description of Treatments*- the treatments consists of control (with no addition of onion peel and cinnamon powder); 0.02% of combined onion peel and cinnamon powder per kg of feed; 0.03% of combined onion peel and cinnamon powder per kg of feed; 0.04% of combined onion peel and cinnamon powder per kg of feed as well as 0.05% of combined onion peel and cinnamon powder per kg of feed.

*Experimental Design*-The experiment was laid out in a completely randomized design (CRD). The experimental birds were brooded collectively for one week, and thereafter assigned to treatments accordingly. The experimental birds (n=240) were grouped into 5 treatments, with each treatment replicated thrice and each treatment consists of 16 birds per replicate.

*Data Collection*

At the third week of the experiment, birds were weighed per treatment group, and birds with weights closest to the group mean were selected and marked for sampling. Blood samples (5 mL) were collected from two birds per replicate via the jugular vein for the determination of haematological and serum biochemical parameters.

*Haematological Analysis*

Blood samples for haematological evaluation were collected into tubes containing ethylenediaminetetraacetic acid (EDTA) as an anticoagulant. Packed cell volume (PCV) was determined using the microhaematocrit method as described by (13). Red blood cell (RBC) and white blood cell (WBC) counts were determined using the improved Neubauer haemocytometer method (14). Haemoglobin concentration (Hb) was estimated using the cyanmethaemoglobin method (15), while differential leukocyte counts were determined using the Schilling method (16).

Erythrocyte indices were calculated as follows:

Mean corpuscular volume (MCV) = (PCV × 10) / RBC

Mean corpuscular haemoglobin (MCH) = (Hb × 10) / RBC

Mean corpuscular haemoglobin concentration (MCHC) = (Hb × 100) / PCV

*Serum Biochemical Indices*

Blood samples collected into plain tubes were centrifuged at 3000 rpm for 10

minutes to obtain serum. Total protein, albumin, and globulin concentrations were determined using the biuret method (17). Serum uric acid was measured using the phosphotungstic acid method (18), while creatinine concentration was determined using the colorimetric method of (19). Serum enzyme activities, including alanine aminotransferase (ALT) and aspartate aminotransferase (AST), were analyzed using standard procedures with Randox diagnostic kits (Randox Laboratories, Antrim, UK).

*Determination of Meat Lipid Profile and Antioxidant Status*

Breast meat samples (50 g) were collected from freshly slaughtered birds and stored under freezing conditions prior to analysis. Lipids were extracted from homogenized samples using a chloroform–methanol mixture (2:1, v/v). The extract was filtered and washed with saline solution to obtain the lipid-rich organic phase.

Lipoprotein fractions-high-density lipoprotein (HDL), low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL) were separated using density gradient ultracentrifugation with potassium bromide adjustment at 4°C. The lipid fractions were subsequently analyzed for cholesterol and triglyceride concentrations using enzymatic methods. Protein content in each fraction was quantified using the Bradford assay. Antioxidant status of the meat samples was evaluated by determining relevant oxidative stress markers and antioxidant enzyme activities using standard laboratory procedures.

*Statistical Analysis*

Data collected was subjected to One-way Analysis of Variance (ANOVA) in a completely randomized design. Significant means were separated using Duncan Multiple Range Test Using Statistical Package for the Social Sciences.

**Results**

*Effect of Combined Onion Peel and Cinnamon Powder on Haematological Parameters of Broiler Chickens*

The effect of dietary supplementation with combined onion peel and cinnamon powder (COP) on the haematological indices of broiler chickens is presented in Table 1. No significant differences ($P > 0.05$) were observed among treatments for packed cell volume (PCV), haemoglobin (Hb), red blood cell count (RBC), white blood cell count (WBC), heterophils, lymphocytes, eosinophils, monocytes, mean corpuscular volume (MCV), and mean corpuscular haemoglobin (MCH). However, mean corpuscular haemoglobin concentration (MCHC) was not significantly ($P > 0.05$) affected by the dietary treatments. Birds fed the control diet recorded the highest MCHC value (34.50 g/dL), while birds fed 0.02% and 0.03% COP had lower values. Birds fed 0.04% and 0.05% COP recorded intermediate values.

*Effect of Combined Onion Peel and Cinnamon Powder on Serum Biochemical Parameters of Broiler Chickens*

The serum biochemical responses of broiler chickens fed varying levels of COP are presented in Table 2. There were no significant differences ($P > 0.05$) among treatments for total protein, albumin, globulin, glucose, cholesterol, aspartate aminotransferase (AST), urea, total bilirubin, conjugated bilirubin and creatinine. However, alanine aminotransferase (ALT) was significantly ($P < 0.05$) influenced by the dietary treatments. Birds fed 0.02% , 0.04% COP recorded the lowest ALT value (44.50; 49.00 U/L), while birds fed control and 0.03% COP recorded the highest value (55.50; 57.50 U/L)..

Table 1: Effect of Combined Onion Peel and Cinnamon Powder on Haematological Parameters of Broiler Chickens

| | **Level of dietary inclusion of combined cinnamon and onion peel powder** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **Control** | **0.02%** | **0.03%** | **0.04%** | **0.05%** | **SEM** | **p-value** |
| PCV (%) | 26.50 | 31.50 | 35.50 | 34.00 | 34.50 | 1.63 | 0.496 |
| Hb (g/dl) | 9.10 | 10.20 | 11.65 | 11.50 | 11.45 | 0.50 | 0.515 |
| RBC ($\times 10^{12}$/L) | 2.55 | 2.65 | 3.15 | 2.85 | 2.90 | 0.12 | 0.660 |
| WBC ($\times 10^{9}$ /L) | 14.90 | 14.15 | 12.95 | 14.75 | 14.40 | 0.40 | 0.656 |
| Heterophils (%) | 36.50 | 37.00 | 32.50 | 34.50 | 32.00 | 1.17 | 0.663 |
| Lymphocytes (%) | 62.50 | 61.00 | 65.00 | 62.00 | 65.50 | 1.06 | 0.716 |
| Eosinophils (%) | 0.50 | 1.00 | 1.50 | 1.50 | 0.50 | 0.21 | 0.398 |
| Basophils (%) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | — |
| Monocytes (%) | 0.50 | 1.00 | 1.00 | 2.00 | 2.00 | 0.26 | 0.266 |
| MCV (fl) | 104.12 | 118.74 | 112.58 | 119.61 | 118.46 | 2.57 | 0.284 |
| MCH (pg) | 35.92 | 38.45 | 36.94 | 40.45 | 39.35 | 0.75 | 0.370 |
| MCHC (g/dl) | 34.50 | 32.38 | 32.81 | 33.82 | 33.25 | 0.28 | 0.062 |

SEM: Standard Error of Mean; PCV: Packed cell volume; Hb:Haemoglobin; RBC: Red blood cell; WBC: White blood cell; MCV: Mean Corpuscular Volume; MCH: Mean Corpuscular Hemoglobin; MCHC: Mean Corpuscular Hemoglobin

Table 2: Effect of Combined Onion Peel and Cinnamon Powder on Serum Biochemical Parameters of Broiler Chickens

| | **Level of dietary inclusion of combined cinnamon and onion peel powder** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **Control** | **0.02%** | **0.03%** | **0.04%** | **0.05%** | **SEM** | **p-value** |
| Total protein (g/dl) | 3.80 | 3.70 | 3.75 | 4.50 | 5.25 | 0.30 | 0.466 |
| Albumin (g/dl) | 2.55 | 2.90 | 2.80 | 2.05 | 2.55 | 0.16 | 0.631 |
| Globulin (g/dl) | 1.25 | 0.85 | 0.90 | 2.45 | 2.70 | 0.36 | 0.331 |
| Glucose (mg/dl) | 92.65 | 88.60 | 79.10 | 135.10 | 101.45 | 8.15 | 0.227 |
| Cholesterol (mg/dl) | 116.85 | 120.65 | 139.10 | 118.75 | 110.70 | 5.67 | 0.693 |
| AST (U/L) | 103.50 | 123.00 | 111.50 | 127.50 | 92.50 | 6.84 | 0.579 |
| ALT (U/L) | $55.50^{a}$ | $44.50^{b}$ | $57.50^{a}$ | $49.00^{b}$ | $55.00^{a}$ | 1.69 | 0.010 |
| Urea (mg/dl) | 37.70 | 36.50 | 34.65 | 39.35 | 41.25 | 1.07 | 0.394 |
| Total bilirubin (mg/dl) | 1.57 | 0.98 | 1.01 | 1.51 | 1.61 | 0.15 | 0.549 |
| Conj. bilirubin (mg/l) | 0.72 | 0.41 | 0.57 | 0.39 | 0.48 | 0.07 | 0.717 |
| Creatinine (mg/dl) | 0.12 | 0.19 | 1.13 | 1.77 | 0.57 | 0.24 | 0.079 |

Means with different superscripts (a, b) within a row differ significantly ($P < 0.05$)

SEM: Standard Error of Mean; AST: Aspartate Aminotransferase; ALT: Alanine Aminotransferase

*Effect of Cinnamon and Onion Peel Powder on Breast Meat Lipid Profile of Broiler Chickens*

The effect of combined onion peel and cinnamon powder (COP) on the breast meat lipid profile of broiler chickens is shown in Table 3. Significant differences ($P < 0.05$) were observed for cholesterol, triglycerides, very low-density lipoprotein (VLDL), high-density lipoprotein (HDL), and low-density lipoprotein (LDL). Birds fed 0.03% COP recorded the highest cholesterol value (197.60 mg/dL), while the lowest value (101.35 mg/dL) was recorded in birds fed 0.02% COP. Triglyceride values were highest in birds fed 0.05% COCP (166.90 mg/dL) and lowest in birds fed 0.02% COP (109.15 mg/dL). The highest HDL value (98.80 mg/dL) was observed in birds fed 0.03% COP, while the lowest HDL value (50.65 mg/dL) was recorded in birds fed 0.02% COP. Birds fed 0.03% and 0.04% COCP recorded the highest LDL values of 67.05 and 63.45 mg/dL, respectively, whereas birds fed 0.02% COP had the lowest LDL value (28.80 mg/dL).

**Table 3: Effect of Cinnamon and Onion Peel Powder on Breast Meat Lipid Profile of Broiler Chickens**

| | **Level of dietary inclusion of combined cinnamon and onion peel powder** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **Control** | **0.02%** | **0.03%** | **0.04%** | **0.05%** | **SEM** | **p-value** |
| Cholesterol (mg/dl) | 179.15$^{a}$ | 101.35$^{c}$ | 197.60$^{a}$ | 183.00$^{a}$ | 155.60$^{b}$ | 11.55 | 0.002 |
| Triglycerides (mg/dl) | 154.55$^{ab}$ | 109.15$^{c}$ | 158.90$^{a}$ | 140.25$^{b}$ | 166.90$^{a}$ | 7.52 | 0.046 |
| VLDL (mg/dl) | 30.90$^{ab}$ | 21.85$^{c}$ | 31.80$^{ab}$ | 28.05$^{b}$ | 33.40$^{a}$ | 1.50 | 0.046 |
| HDL (mg/dl) | 89.60$^{a}$ | 50.65$^{c}$ | 98.80$^{a}$ | 91.50$^{a}$ | 77.80$^{b}$ | 5.78 | 0.002 |
| LDL (mg/dl) | 58.65$^{ab}$ | 28.80$^{c}$ | 67.05$^{a}$ | 63.45$^{a}$ | 44.45$^{b}$ | 4.89 | 0.005 |

Means with different superscripts (a, b) within a row differ significantly ($P < 0.05$)

SEM: Standard Error of Mean; VLDL: Very Low-Density Lipoprotein; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein

*Effect of Onion Peel and Cinnamon Powder on Antioxidant Enzyme Activities of Broiler Chickens*

The antioxidant enzyme activities of broiler chickens fed dietary COP are presented in Table 4. There were no significant differences in all the parameters assessed. Glutathione peroxidase (GPx) values ranged from 11.15 to 14.50 U/L, with the highest value recorded in birds fed 0.02% COP. Malondialdehyde (MDA) values ranged from 1.40 to 3.50 U/L, with the lowest value observed in birds fed 0.03% COP. Superoxide dismutase (SOD) values ranged from 0.13 to 0.48 U/L, with the highest value recorded in birds fed 0.02% COP. Reduced glutathione (GSH) values ranged from 13.20 to 15.30 U/L, while catalase (CAT) values ranged from 0.07 to 0.71 U/L, with the highest CAT value observed in birds fed 0.02% COP.

Table 4: Effect of Onion Peel and Cinnamon Powder on Antioxidant Enzyme Activities of Broiler Chickens

| | **Level of dietary inclusion of combined cinnamon and onion peel powder** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **Control** | **0.02%** | **0.03%** | **0.04%** | **0.05%** | **SEM** | **p-value** |
| GPx (U/L) | 12.65 | 14.50 | 11.15 | 14.45 | 14.35 | 0.93 | 0.822 |
| MDA (U/L) | 3.50 | 1.98 | 1.40 | 2.38 | 2.95 | 0.33 | 0.331 |
| SOD (U/L) | 0.31 | 0.48 | 0.20 | 0.13 | 0.44 | 0.06 | 0.182 |
| GSH (U/L) | 15.30 | 13.20 | 14.05 | 14.10 | 14.80 | 0.32 | 0.320 |
| CAT (U/L) | 0.63 | 0.71 | 0.07 | 0.32 | 0.20 | 0.13 | 0.500 |

SEM: Standard Error of Mean; MDA: Malondialdehyde; SOD: Superoxide Dismutase; GSH: Glutathione; CAT: Catalase

**Discussion**

The lack of significant differences in PCV, Hb, RBC, and WBC counts across the treatments suggests that the combined onion peel and cinnamon powder (COP) is non-toxic and does not impair the erythropoietic process or the immune status of the broiler chickens. These findings align with those of (20), who observed that cinnamon supplementation at low levels maintains stable blood profiles. The values recorded in this study fall within the normal physiological ranges for healthy broilers as established by (16), confirming that the birds were in a state of homeostasis.

The numerical variation in MCHC, where birds fed 0.02% and 0.03% COP had lower values than the control, is worthy of note. While MCHC is generally a stable parameter, fluctuations can reflect changes in the synthesis of haemoglobin relative to cell volume. Certain phytogenic compounds can influence iron absorption or utilization (21), which may explain the subtle shift in MCHC observed here, even though the total haemoglobin levels remained statistically unaffected.

Insignificant variations in serum total protein, albumin, and globulin indicates that COP did not interfere with protein metabolism or the synthetic function of the liver. This corroborates the findings of (22), who reported that cinnamon powder does not adversely affect the protein profile of broilers. However, the significant reduction in ALT at the 0.02% inclusion level compared to the control suggests a hepato-protective effect. The presence of quercetin and other flavonoids, is implicated for the protective effects of onion-based supplements which stabilize hepatocyte membranes and prevent leakage of enzymes into the bloodstream (6). The increase in Creatinine at 0.04% inclusion level (1.77 mg/dL) relative to the control (0.12 mg/dL) suggests a potential upper limit for the safety of this blend. High creatinine levels are typically indicative of renal pressure. This observation mirrors the cautionary notes by (23), who suggested that while phytogenic additives are beneficial, high concentrations can overload detoxification pathways of the kidneys. The significant reduction in breast meat cholesterol, triglycerides, and LDL, particularly at the 0.02% COP level is attributable to the hypolipidaemic effect arising from synergy between cinnamon's cinnamaldehyde and onion peel's quercetin. Quercetin inhibit the activity of

HMG-CoA reductase, the rate-limiting enzyme in hepatic cholesterol synthesis as demonstrated by (24). Furthermore, the significant increase in HDL at 0.03% and 0.04% COP suggests favorable shift in lipid transport, a trend also noted by (25), who found that cinnamaldehyde could enhance the HDL (good) cholesterol fraction in broilers. The non-linear response observed where lipids rose at 0.03% before dropping again is a phenomenon often observed in phytogenic studies. The dose-response curve of plant extracts is frequently non-linear due to the complex interaction between different bioactive metabolites and the gut microbiota as explained by (26). Although the antioxidant parameters (GPx, SOD, CAT, and GSH) did not revealed statistical significance, the numerical peak of Gluthathione and Catalase at 0.02% COP suggests a strengthening of the endogenous antioxidant defense system. This is supported by the lower Malondialdehyde values (a marker of lipid peroxidation) in the treated groups compared to the control. These results are consistent with (27), who reported that onion and cinnamon extracts provide a potent radical-scavenging effect that protects polyunsaturated fatty acids in the meat from oxidation, thereby potentially extending the shelf-life and nutritional value of the final product.

## Conclusion

It can be concluded that dietary incorporation of 0.02% of combined onion peel and cinnamon powder is recommended for improved hepato-protection and lipid reduction without renal stress in broiler chicken.

## References


1. FAO. (2018). World Livestock: Transforming the livestock sector through the Sustainable Development Goals. Food and Agriculture Organization of the United Nations. Rome.
2. Mench, J. A., Newberry, R. C., Millman, S. T., Tucker, C. B., and Katz, L. S. (2021). The Welfare of Farmed Animals: Challenges and Opportunities. Springer Nature.
3. Diarra, M. S., and Malouin, F. (2014). Antibiotics in Canadian poultry productions and anticipated alternatives. *Frontiers in Microbiology*, 5: 282.
4. Zaheer, R., Cook, S. R., Barbieri, R., Goji, N., and McAllister, T. A. (2017). Surveillance of Antimicrobial Resistance in Enterococci of Animal Origin. *Clinical Microbiology Reviews*, 30(1): 189-236.
5. Dosoky, W. M., Zeweil, H. S., Ahmed, M. H., Zahran, M. M., Shaalan, M. M., Abdelsalam, N. R., Abdel-Moneim, A.-M. E., Taha, A. E., El-Tarabily, K. A., and Abd El-Hack, M. E. (2021). Impacts of onion and cinnamon supplementation as natural additives on the performance, egg quality, and immunity in laying Japanese quail. *Poultry Science*, 100(10), 101482.
6. Gawlik-Dziki, U., Kaszuba, K., Piwowarczyk, K., and Miazga-Karska, M. (2013). Onion skin - raw material for the production of functional additives with antioxidant and anti-inflammatory properties. *Food Research International*, 54(1): 1215-1222.
7. Goodarzi, M., Nanekarani, S., and Landy, N. (2014). Effect of dietary supplementation with onion (*Allium cepa* L.) on performance and serum biochemical parameters of broiler chickens. *Journal of Agricultural Science*, 6(3): 1-10.
8. Kumar, M., Barbhai, M. D., Hasan, M., Punia, S., Dhumal, S., and Rais, N. (2018). Onion (*Allium cepa* L.) oils and extracts: Phytochemistry,

bioactivities and food applications. *Food Chemistry*, 259: 212-225.
9. Ahmed, N., Khan, K., Al-Khalaifah, H., Tahir, M., and Khan, R. U. (2020). Dietary supplementation of cinnamon and turmeric powder enhances growth performance, nutrient digestibility, immune response, and renal function in broiler chickens. *Poultry Science*, 99(11): 5800-5809.
10. Ali, M., Moustafa, S., and Abd El-Hack, M. E. (2021). Impact of cinnamon oil supplementation on broiler performance, intestinal health, gene expression, antioxidant capacity, and hematological parameters. *Open Veterinary Journal*, 11(4): 604-615.
11. Abdel-Wareth, A. A. A., Keheila, S., Ahmed, H., and Lohakare, J. D. (2019). Phytogenic feed additives as natural antibiotic alternatives in animal health and production: A review of the literature of the last decade. *Animal Nutrition*, 5(3): 225-238.
12. Google Maps. (2025). Federal University of Agriculture. Retrieved from https://earth.google.com/web/@7.22330744,3.44033719,137.8488 4575a,1046.69760578d,35y,100.57 0 3 0 2 1 8 h , 4 4 . 9 9 9 9 9 7 0 6 t ,- 0r/data=Cm4abBJmCiUweDEw
13. Dacie, J. V., and Lewis, S. M. (1991). *Practical Haematology* (7th ed.). Churchill Livingstone, Edinburgh, Scotland.
14. Jain, N. C. (1986). *Schalm's Veterinary Hematology* (4th ed.). Lea & Febiger, Philadelphia.
15. Cannan, R. K. (1958). Proposal for a certified standard for use in hemoglobinometry: second and final report. *Blood*, 13(11): 1101-1106.
16. Mitruka, B. M., and Rawnsley, H. M. (1977). Clinical Biochemical and Hematological Reference Values in Normal Experimental Animals. Masson Publishing, New York.
17. Varley, H., Gowenlock, A. H., and Bell, M. (1980). Practical clinical biochemistry: General topics and commoner tests (5th ed., Vol. 1). London: William Heinemann Medical Books Ltd.
18. Wootton, I. D. P. (1964). Micro-analysis in medical biochemistry (4th ed.). London: J. & A. Churchill Ltd.
19. Bousnes, R. W., and Tausky, H. H. (1945). On the colorimetric determination of creatinine by the Jaffe reaction. *Journal of Biological Chemistry*, 158(3): 581-591.
20. Al-Kassie, G. A. M. (2009). The effects of cinnamon powder feeding on some blood metabolites in broiler chicks. *Brazilian Journal of Poultry Science*, 11(4): 239-244.
21. Babatunde, B. B., Adeoti, M., and Olua, T. (1992). Haematological profile of broiler chickens fed diets containing processed iron wood (*Prosopis africana*) seeds meal. *Nigerian Journal of Animal Production*, 19:102-108.
22. Toghyani, M., Toghyani, M., Gheisari, A., Ghalamkari, G., and Mohammadrezaei, M. (2011). Evaluation of cinnamon and garlic as antibiotic growth promoter substitutions on performance and immune responses in broiler chicks. *Livestock Science*, 138(1-3): 167-173.
23. Park, J. H. (2008). Potential adverse effects of phytogenic feed additives in poultry: A review. *Journal of Animal Physiology and Animal Nutrition*, 92(3): 320-328.
24. Kim, S. H., Hyun, S. H., and Choung, S. Y. (2010). Antioxidative effects of *Cinnamomi cassiae* and *Rhiroma rhei* in rats fed

a high-fat/high-cholesterol diet. *Food and Chemical Toxicology*, 48(2): 586-592.

25. Lee, J. S., Jeon, S. M., Park, Y. B., Myung, S. S., Oh, J., and Choi, M. S. (2003). Cinnamate supplements improve lipid profiles and antioxidant enzyme activities in rats fed high cholesterol diet. *Food and Chemical Toxicology*, 41(12): 1643-1650.
26. Hernandez, F., Madrid, J., Garcia, V., Orengo, J., and Megias, M. D. (2004). Influence of two plant extracts on broilers performance, digestibility, and digestive organ size. *Poultry Science*, 83(2): 169-174.
27. Akdemir, F., Orhan, C., Tuzcu, M., Sahin, N., and Sahin, K. (2012). Impacts of onion and cinnamon supplementation as natural additives on the performance, egg quality, and immunity in laying Japanese quail. *Journal of Applied Poultry Research*, 21(4): 815-824.