The role of aqueous *Cinnamomum cassia* extract on growth performances, gut morphometry, duodenal histomorphometry, organ weight, and blood profiles of broiler chickens

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ABSTRACT

Background and Objective: The utilization of antibiotics as growth promoters in broiler chicken production has been widely accepted due to their impact in enhancing rapid growth and increased broiler chicken production. However, its application has been grossly abused, especially in developing countries, with concomitant effects on the development of resistant strains of bacteria, impacting the productive performance of broiler chicken and having detrimental health implications for consumers. Hence, the need arises to investigate the role of aqueous *Cinnamomum cassia* extract on growth performances, gut morphometry, duodenal histomorphometry, organ weight, and blood profiles of broiler chickens.

Methodology: A total of 240-one-day old mixed sex Cobb 500 broiler chicks were used to investigate the effect of aqueous extract of cinnamon (AEC) on performance indices (such as final body weight, weight gain, feed conversion ratio, blood profiles, gut histomorphometry, and carcass traits) of broiler chickens for a period of 6 weeks. The chicks were equalized for weight at a day old and assigned to six treatments replicated four times (10 birds/replicate) in a completely randomized design. Treatments consist of positive control (enrofloxacin), negative control (no antibiotics/ aqueous cinnamon extracts), 2, 4, 6, and 8% aqueous extract of cinnamon (AEC). The AEC treatments and antibiotics (manufacturer recommendation: 10 mg/litre of water) were administered consecutively thrice a week (from the first day of the week), all through the experimental period.

Main Results: Birds administered 4% AEC had significantly lower total feed intake as well as better feed conversion ratio ($P < 0.05$). At 3rd week of age, broiler chickens under 2% AEC had improved villus height and width; while those exposed to 4% AEC had an enhanced crypt depth ($P < 0.05$). Incorporation of 2, 4, and 6% AEC resulted in relatively better development of the digestive (proventriculus, liver, and gizzard) and lymphoid (spleen and Bursa of Fabricius) organs at 3rd week of age ($P < 0.05$). Most values obtained for the blood profile across the treatments were not significantly different and were within the reference range for healthy chickens ($P > 0.05$).

Conclusions: The study discovered that farmers should utilize aqueous cinnamon extract at the rate of 4% administered thrice consecutively a week to improve productive performance indices (feed conversion ratio, duodenal histomorphometry, organ development) in broiler chickens.

Keywords: Cinnamon, histomorphometry, broiler, digestive, lymphoid organs

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INTRODUCTION

Antibiotic growth promoters (AGP) have been widely and successfully used to promote growth and protect the health of poultry. AGP elicits its actions by reducing or modifying the bacterial population in the gastrointestinal tract (Fairchild *et al.,* 2001) of farm animals. However, their application in feed has risen into a controversial issue worldwide due to the advent of resistant strains of bacteria. Consequently, their use in poultry feed has been banned in many countries. This, in turn, intensified the need to investigate other alternatives to antibiotics in poultry production. As a result, natural growth promoters such as phytobiotics have been investigated as a readily available substitute for antibiotics in animal production. Associated benefits of phytobiotics in poultry production include the fact that they leave no residues in the liver or bone marrow, unlike synthetic antibiotics (Varel, 2002; Hashemi *et al.,* 2008), and comparative reduction in the production cost relative to the use of antibiotics.

Cinnamon is one of the oldest medicinal plants in the genus *Cinnamomum*. It belongs to the *Lauracea* family, native to Sri Lanka and South India (Jakhetia *et al.,* 2010). Cinnamon is known to possess appetite and digestion-stimulating properties (Tabak *et al.,* 1999). Many essential oils isolated from cinnamon, including cinnamic acid, cinnamaldehyde, cinnamate, caryophyllene oxide, eugenol, and L-borneol (Tung *et al.,* 2008) account for its bioactive properties. Cinnamaldehyde possesses antibacterial properties (Chang *et al.,* 2001), antioxidant properties (Singh *et al.,* 2007), antiulcer, anti-diabetic, and anti-inflammatory (Jakhetia *et al.,* 2010).

Furthermore, cinnamon extract increased feed intake, performance, feed efficiency, and health status, increased breast meat yield (Al-Kassie, 2009; Isabel and Santos, 2009), increased pancreatic and intestinal lipase activity (Kim *et al.,* 2010), and meat quality (Sang-Oh *et al.,* 2013) of poultry species. The use of cinnamon in the diet of broiler chicken at various levels had a positive impact on performance in terms of body weight gain, feed intake, feed conversion ratio, overall performance index, carcass characteristics as well as net profit per bird relative to the control group (Chowlu *et al.,* 2018). The inclusion of cinnamon powder in broiler diets led to significantly higher flavor scores for breast and thigh meat, and higher liver and gizzard percentages as compared to birds fed the control diet (Eltazi, 2014). Several previous studies have investigated the utilization of cinnamon as a natural feed additive in animal production with considerable positive outcomes. However, cinnamon application through drinking water in broiler chicken production is relatively rare. Additionally, it is assumed that its incorporation via drinking water, as investigated in this study, may result in improved biological processes that will enhance the positive impact on performance indices. Hence, the study assessed the role of the aqueous extract of *Cinnamomum cassia* on growth performances, gut morphometry, duodenal histomorphometry, organ weight, and blood profiles of broiler chickens.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Poultry Unit of the Teaching and Research Farm, Federal University of Agriculture, Abeokuta, Ogun State. The farm is located in the rainforest region of South-West Nigeria. The climate is tropical and humid, with a mean annual rainfall of 1,037 mm. The procedures used in the experiment complied strictly with the research ethics committee guidelines of the Federal University of Agriculture, Abeokuta (FUNAAB, 2016), with animal use protocol number (APH 07-09/22).

Source of Test Material (*Cinnamomum cassia*) Powder

The test ingredient (*C. cassia*) bark was purchased from a spice market in Abeokuta, Ogun State. Thereafter, the barks ground into a powder with the aid of a hammer mill machine.

Preparation of Aqueous Extract of *Cinnamomum cassia*

The aqueous extract of cinnamon (AEC) was prepared by weighing 60 grams of *C. cassia* powder into an airtight container. Thereafter, one litre of boiled water was poured into the container, and the content was stirred with a rod. The container was covered and allowed to stay for 24 hours. Afterward, the aqueous extract was collected (in a bottle) with the aid of a sieve and thereafter stored in the refrigerator (4 °C) until needed for administration via drinking water.

Experimental Birds and Management

A total of two hundred and forty (240) mixed-sex Cobb 500-day-old broilers were used for the experiment. They were sourced from Zartech Limited, Ibadan, Oyo state, Nigeria. The birds were managed intensively in deep litter housing. The birds were raised indoors with wood shavings litter covered floor and each replicate unit has a dimension of 1.40 m × 1.12 m (0.07 m^2 floor space per bird). The birds were fed commercially formulated starter (2,800 kcal/kg metabolizable energy, 21% crude protein, 4% ether extract, and 5% crude fiber) and finisher (2,900 kcal/kg metabolizable energy, 18% crude protein, 4.28% ether extract, and 4.64% crude fiber) diets and water *ad libitum*. The birds were given access to continuous light for 12 hours during the daytime. The study lasted for six weeks (November 2 to December 14, 2022).

Description of Experimental Treatments

The experimental treatment consists of positive control (birds were administered a broad spectrum antibiotic, i.e., enrofloxacin), negative control (birds were not given any antibiotics or cinnamon extracts), 2% AEC (birds administered 20 mL of cinnamon extracts into 1 liter of drinking water), 4% AEC (birds administered 40 mL of cinnamon extracts into 1 liter of water), 6% AEC (birds administered 60 mL of cinnamon extracts into 1 liter of water), and 8% AEC (birds administered 80 mL of cinnamon extracts into 1 liter of water). The AEC treatments and antibiotics (manufacturer recommendation -10 mg/liter of water) were administered consecutively thrice a week (from the first day of the week), all through the experimental period.

Experimental Design

The experiment commenced from day old as the total of 240 chicks were balanced for weight and assigned to 24 experimental units (six treatment groups with each treatment replicated four times) in a completely randomized design.

Data Collection

Growth performance indices

The chicks were weighed at day old before they were divided into various replicates and were also weighed weekly. The feed intake was deduced by finding the difference between the quantity of offered feed and the leftover. The feed conversion ratio was determined as the ratio of feed consumed to the weight gain. The body weight gain of birds was recorded by weighing them on a replicate basis. This was done weekly, and the values were subtracted from the initial weight of the preceding week. The relation calculated mortality and survivability percents: mortality percent = number of dead birds per replicate / number of stocked birds per replicate; and survivability percent = 100 – mortality percent.

Water was provided for the birds in each replicate group with a bell drinker. Water intake was recorded daily with the aid of a measuring cylinder. A known quantity of water was offered to birds in a replicate daily. The daily water intake per replicate was deduced early in the morning by measuring the leftover water and subtracting it from the initial quantity offered to the birds.

Gut morphometry and duodenal histomorphometry

Gut morphometry and duodenal histomorphometry measurements were carried out on the third and sixth weeks of age for the birds. At the ages, two birds of average weight from each replicate were selected and slaughtered by cervical dislocation, and the gut segments were separated. Thereafter, measurements including weight and length of the duodenum, jejunum, ileum, and caecum were taken according to the procedure described (Sogunle *et al.,* 2018). For histomorphometry, a segment of 2 cm of the duodenum was cut from each of the birds sampled. The intestinal content was cleaned for measurement of villi height, width, and crypt depth, which was based on at least eight complete villi per section/bird, using a microscope and image analysis system (Olympus DP72 microscope digital camera, Olympus NV, Aartselaar, Belgium). Measurements taken include villi height, width, and muscular wall thickness according to the procedure outlined by Dialoke *et al.* (2020)

Digestive and lymphoid organ weight measurement

At 3rd and 6th weeks of age, two birds of average weight were selected per replicate. The selected birds were killed via neck decapitation. Digestive organs (heart, proventriculus, liver, gizzard, and pancreas) and lymphoid organs (thymus, spleen, and bursa) were collected. The organs collected were weighed with the aid of a sensitive scale and expressed as a percentage of the weight.

Evaluation of Blood Profile

At day 42 of age, 3 mL of blood were collected from the brachial vein of 2 selected birds per replicate into ethylene diamine tetra acetic acid (EDTA) bottles. The samples were collected in the morning (between 7 and 8 A.M.) before feeding. The collected blood samples were kept in an ice pack and transported immediately to the laboratory. Hematological parameters (red blood cell, hemoglobin, packed cell volume, white blood cells, and its differentials) and serum biochemical indices (total protein, albumin, globulin, cholesterol, triglyceride, creatinine, aspartate aminotransferase (AST), and alanine aminotransferase (ALT)) were analyzed using commercially available tests kits by Randox Laboratories Limited, Crumlin, County Antrim, BT294QY, UK.

Statistical Analysis

All data collected was subjected to a one-way analysis of variance (ANOVA) in a completely randomized design. Significant means were separated using Duncan's new multiple range test in IBM SPSS Statistics 23.

$$Y_{ij} = \mu + \Upsilon + \varepsilon_{ij}$$

where Y_{ij} represents the j^{th} observation, μ represents the common effect for the whole experiment, and ε_{ij} represents the random error.

RESULTS AND DISCUSSION

Effects of Aqueous Cinnamon Extract on Growth Performances of Broiler Chickens

Table 1 shows the effects of the aqueous extract of cinnamon on the growth performance of broiler chickens. The results show that the aqueous extract of cinnamon had no significant effect ($P > 0.05$) on all the growth performance indices except total feed intake, daily feed intake, and feed conversion ratio. In total feed intake, the significant ($P < 0.05$) higher values were recorded in birds on positive control (3,946.34 g/bird), negative control (3,807.07 g/bird), 2% AEC (3,737.56 g/bird), and 8% AEC (3,780.80 g/bird), while 4% AEC had the lower value (3,287.77 g/bird). Daily feed intake had higher values in positive control (93.96 g/bird), negative control (90.64 g/bird), 8% AEC (90.02 g/bird), and 2% AEC (88.98 g/bird), while lower value was observed in 4% AEC (78.28 g/bird). Also, the feed conversion ratio had a higher value in the positive control (2.22), which is poor, while 4% AEC had a lower value (1.86), which is better.

The effect of the AEC on growth performance resulted in a distinct significant reduction in total feed intake and daily feed intake, as well as better feed utilization with respect to birds on treatment 4% AEC. The presence of bioactive components (essential oils, phenolics cinnamaldehyde, eugenol, and cinnamic acid) in cinnamon makes it a potent antimicrobial, anti-inflammatory, antioxidant as well as a defense agent against oxidative damage in the chicken intestinal tract (Rao and Gan, 2014). Hence, AEC administration at 4% indicates an enhanced optimal gut function in the birds with a direct influence on the feed conversion ratio.

Table 1 Effects of aqueous extract of cinnamon (AEC) on growth performances of broiler chickens

Parameters	Positive control	Negative control	2% AEC	4% AEC	6% AEC	8% AEC	P-value
Initial body weight (g/bird)	53.33 ± 2.92	54.55 ± 0.91	53.33 ± 2.10	55.15 ± 4.67	53.97 ± 2.73	56.97 ± 1.89	0.611
Final body weight (g/bird)	1,840.74 ± 131.74	1,843.70 ± 98.48	1,815.92 ± 57.10	1,823.06 ± 95.59	1,862.50 ± 206.53	1,858.80 ± 70.88	0.995
Total weight gain (g/bird)	1,787.41 ± 131.71	1,789.16 ± 99.34	1,762.59 ± 58.15	1,767.91 ± 92.09	1,808.53 ± 205.77	1,801.82 ± 68.99	0.996
Daily weight gain (g/bird)	42.56 ± 3.14	42.60 ± 2.37	41.97 ± 1.38	42.09 ± 2.19	43.06 ± 4.90	42.90 ± 1.64	0.996
Total feed intake (g/bird)	3,946.34 ± 30.77^{a}	3,807.07 ± 155.04^{a}	3,737.56 ± 191.12^{a}	3,287.77 ± 295.85^{b}	3,639.63 ± 310.73^{ab}	3,780.80 ± 64.41^{a}	0.031
Daily feed intake (g/bird)	93.96 ± 0.73^{a}	90.64 ± 3.69^{a}	88.98 ± 4.55^{a}	78.28 ± 7.04^{b}	86.66 ± 7.39^{ab}	90.02 ± 1.53^{a}	0.031
Feed conversion ratio	2.22 ± 0.15^{a}	2.13 ± 0.09^{ab}	2.12 ± 0.06^{ab}	1.86 ± 0.08^{b}	2.04 ± 0.36^{ab}	2.01 ± 0.04^{ab}	0.026
Survivability	100.00 ± 0.00	100.00 ± 0.00	90.91 ± 15.76	100.00 ± 0.00	96.97 ± 5.25	96.97 ± 5.25	0.605
Total water intake (mL/bird)	9,362.79 ± 182.97	9,220.62 ± 362.57	9,029.51 ± 184.02	8,677.86 ± 930.58	9,099.35 ± 665.02	8,594.07 ± 205.59	0.425
Daily water intake (mL/bird)	222.92 ± 4.35	219.54 ± 8.63	214.99 ± 4.38	206.62 ± 22.15	216.65 ± 15.83	204.62 ± 4.89	0.425

Note: ^{a,b} Means within the same row with differemt superscript differ ($P < 0.05$)

The potential stabilization of the gut microbiota ecosystem owing to the impact of AEC stimulates digestive enzyme secretions, resulting in an improved feed conversion ratio according to previous reports (Lee *et al.,* 2003; Jang *et al.,* 2007; Bento *et al.,* 2013). The reason for the feed utilization index not being reflective of the final body weight and weight gain of the broiler chickens may be adduced to the duration of its administration during the period of the study (thrice a week), which may not be sufficient for impacting significantly on the growth rate of the birds. Several previous reports have affirmed the positive potential of cinnamon's secondary metabolites on the growth indices of poultry, which are consistent with the outcome of this study. Supplementation with 200 ppm oil extract from thyme and cinnamon stimulates the secretion of the salivary gland, improves the activity of pancreatic liver function and intestinal mucosa enzymes, and improves weight gain and feed conversion ratio in growing broiler chickens (Tabak *et al.,* 1999; Al-Kassie, 2009). The addition of cinnamon to the diet of broilers improved their growth performance (Lee *et al.,* 2004). The body weight of the broilers was significantly higher in the group supplemented with a cinnamon diet (Ebrahimi *et al.,* 2012). Also, the incorporation of cinnamon as a dietary additive in broiler chickens leads to enhanced weight gain, feed consumption, and feed conversion ratio (Shirzadegan, 2014). On the contrary, Odutayo *et al.* (2021) observed that dietary additives of cinnamon cassia powder at 0, 2, 4, 6, and 8% in broiler chickens did not significantly impact any growth performance indices at both starter and finishing phases. Dietary addition of cinnamon at 500 to 2,000 mg/kg diet did not affect the growth performance indices of broiler chicken (Koochaksaraie *et al.,* 2011). The inclusion of cinnamon at 2 g/kg in the diet enhanced the body weight of broiler chickens (Toghyani *et al.,* 2011). Growth performance and meat quality were significantly enhanced when broiler diets were incorporated with 3, 5, and 7% cinnamon powder relative to birds on a control diet (Sang-Oh *et al.,* 2013).

Effects of Aqueous Cinnamon Extract on Gut Morphometry and Duodenal Histomorphometry of Broiler Chickens at 3rd and 6th Week of Age

Table 2 shows the effect of AEC on gut morphometry of broiler chickens at 3rd and 6th weeks of age. At 3rd week of age, a significantly ($P < 0.05$) higher colon length of 1.21 cm/100g live weight (LW) was observed in birds subjected to 4% AEC, while a lower colon length of 0.72 cm/100g LW was observed in birds under negative control. The highest colon percentage of 0.19% was observed in birds from positive control as well as 4% AEC, while the lowest colon percentage of (0.11%) was recorded in birds exposed to 8% AEC. Table 3 shows the effect of AEC on duodenal histomorphometry of broiler chickens at 3rd and 6th weeks of age. At 3rd week of age, the inclusion of AEC significantly affected ($P < 0.05$) the villus height. The highest villus height of 1,325.89 μm was observed in birds subjected to 2% AEC, while the lowest villus height of 1,241.19 μm was found in birds under 8% AEC. Significant differences ($P < 0.05$) were also observed in villus width. The highest villus width of 48.92 μm was observed in birds under 2% AEC. In contrast, the lowest value of 28.93 μm was observed in birds subjected to the negative control. The significantly ($P < 0.05$) highest cryptal depth of 173.00 μm was observed in birds under positive control, relative to 93.80 μm in birds subjected to 4% AEC.

At 6th week of age, the inclusion of AEC significantly affected ($P < 0.05$) cryptal width. The significantly ($P < 0.05$) highest cryptal width of 34.06 μm was observed in birds subjected to 2% AEC relative to 26.33 μm, which was observed in birds subjected to 8% AEC inclusion.

Table 2 Effects of aqueous extract of cinnamon (AEC) on gut morphometry of broiler chickens at 3rd and 6th week of age

Parameters	Age (week)	Positive control	Negative control	2% AEC	4% AEC	6% AEC	8% AEC	P-value
Live weight (g/bird)	3rd	668.33 ± 27.53	650.00 ± 0.00	716.67 ± 115.47	616.67 ± 57.73	666.67 ± 28.86	666.67 ± 28.86	0.464
	6th	1,700.00 ± 70.71	1,775.00 ± 106.06	1,825.00 ± 35.35	1,550.00 ± 212.13	1,700.00 ± 212.13	1,800.00 ± 70.71	0.461
Duodenum percent	3rd	1.01 ± 0.20	1.02 ± 0.18	0.93 ± 0.23	1.14 ± 0.30	0.82 ± 0.05	1.02 ± 0.07	0.509
	6th	0.55 ± 0.08	0.59 ± 0.06	0.64 ± 0.01	0.59 ± 0.01	0.58 ± 0.07	0.06 ± 0.07	0.853
Duodenum length	3rd	3.17 ± 0.29	3.64 ± 0.49	3.21 ± 0.97	4.41 ± 1.38	2.95 ± 0.22	3.60 ± 0.26	0.272
	6th	1.57 ± 0.04	1.72 ± 0.00	1.68 ± 0.05	1.66 ± 0.01	1.46 ± 0.02	1.38 ± 0.20	0.044
Jejunum percent	3rd	1.94 ± 0.18	1.81 ± 0.21	2.27 ± 0.75	2.35 ± 0.50	1.85 ± 0.22	2.56 ± 0.41	0.262
	6th	1.46 ± 0.34	1.47 ± 0.17	1.53 ± 0.04	1.60 ± 0.14	1.58 ± 0.32	1.69 ± 0.08	0.891
Jejunum length	3rd	9.10 ± 0.82	8.57 ± 0.56	9.14 ± 2.10	10.04 ± 0.74	8.55 ± 1.02	9.27 ± 1.57	0.724
	6th	4.19 ± 0.43	4.52 ± 0.57	4.45 ± 0.08	4.64 ± 0.11	4.60 ± 0.67	1.58 ± 0.08	0.840
Ileum percent	3rd	2.61 ± 0.13	2.37 ± 0.48	2.74 ± 0.52	2.50 ± 1.01	2.08 ± 0.27	2.89 ± 0.40	0.554
	6th	0.99 ± 0.09	1.27 ± 0.54	1.32 ± 0.42	1.25 ± 0.13	1.13 ± 0.17	1.06 ± 0.21	0.859
Ileum length	3rd	9.87 ± 0.94	8.98 ± 0.85	9.43 ± 1.88	10.30 ± 0.49	8.40 ± 1.11	9.83 ± 1.51	0.486
	6th	3.88 ± 0.26	4.77 ± 0.53	4.97 ± 0.83	4.90 ± 0.26	4.41 ± 0.60	4.27 ± 0.21	0.349
Caecum percent	3rd	1.27 ± 0.57	1.08 ± 0.14	0.90 ± 0.26	0.93 ± 0.14	1.06 ± 0.04	0.96 ± 0.21	0.638
	6th	0.37 ± 0.02	0.61 ± 0.10	0.07 ± 0.30	0.62 ± 0.06	0.49 ± 0.01	0.55 ± 0.09	0.363
Caecum length	3rd	4.26 ± 0.43	4.00 ± 0.13	3.93 ± 0.86	3.97 ± 0.02	3.98 ± 0.26	4.38 ± 0.56	0.788
	6th	1.61 ± 0.33	2.14 ± 0.07	2.20 ± 0.20	1.97 ± 0.67	1.60 ± 0.04	1.90 ± 0.42	0.510
Colon percent	3rd	0.21 ± 0.05	0.28 ± 0.18	0.27 ± 0.12	0.31 ± 0.05	0.32 ± 0.03	0.25 ± 0.05	0.766
	6th	0.19 ± 0.01[a]	0.17 ± 0.01[ab]	0.13 ± 0.00[cd]	0.19 ± 0.01[a]	0.15 ± 0.01[bc]	0.11 ± 0.01[d]	0.004
Colon length	3rd	0.91 ± 0.16[ab]	0.72 ± 0.29[b]	0.88 ± 0.25[ab]	1.21 ± 0.15[a]	0.86 ± 0.07[ab]	0.91 ± 0.15[ab]	0.013
	6th	0.60 ± 0.02	0.53 ± 0.08	0.05 ± 0.05	0.50 ± 0.12	0.41 ± 0.10	0.46 ± 0.03	0.361

Note: [a,b] Means within the same row with differemt superscript differ ($P < 0.05$) The length of the measured segment of the gastrointestinal tract is expressed as cm/100g live weight.

Table 3 Effect of aqueous extract of cinnamon (AEC) on duodenal histomorphometry of broiler chickens at 3rd and 6th week of age

Parameters	Age (week)	Positive control	Negative control	2% AEC	4% AEC	6% AEC	8% AEC	P-value
Villus height (µm)	3rd	1,276.17 ± 2.48^{ab}	1,261.14 ± 24.40^{ab}	1,325.89 ± 67.15^{a}	1,242.86 ± 17.16^{b}	1,251.90 ± 7.79^{ab}	1,241.19 ± 21.11^{b}	0.020
	6th	1,320.75 ± 27.88	1,275.70 ± 61.23	1,261.63 ± 126.84	1,240.00 ± 47.05	1,248.35 ± 47.02	1,327.82 ± 43.10	0.695
Villus width (µm)	3rd	41.22 ± 1.89^{ab}	28.93 ± 14.06^{b}	48.92 ± 4.71^{a}	43.00 ± 3.34^{ab}	31.39 ± 4.80^{ab}	34.52 ± 4.32^{ab}	0.014
	6th	42.13 ± 18.98	29.76 ± 8.61	32.27 ± 3.20	32.10 ± 1.26	31.27 ± 5.66	28.56 ± 0.72	0.712
Cryptal depth (µm)	3rd	173.00 ± 40.01^{a}	110.00 ± 13.25^{ab}	118.05 ± 52.31^{ab}	93.80 ± 1.42^{b}	115.87 ± 9.25^{ab}	107.05 ± 11.05^{ab}	0.022
	6th	195.55 ± 61.57	123.87 ± 0.78	164.02 ± 51.15	117.26 ± 6.07	141.74 ± 12.60	133.91 ± 2.98	0.349
Cryptal width (µm)	3rd	30.22 ± 6.02	30.84 ± 0.76	31.15 ± 3.33	29.64 ± 6.87	26.11 ± 5.73	24.90 ± 1.30	0.225
	6th	28.45 ± 0.80^{b}	26.91 ± 2.95^{b}	34.06 ± 1.85^{a}	29.66 ± 1.96^{b}	30.53 ± 0.34^{ab}	26.33 ± 0.63^{b}	0.030
Muscle wall thickness (µm)	3rd	56.70 ± 19.84	84.23 ± 9.54	65.93 ± 34.11	76.48 ± 18.91	107.47 ± 13.22	71.84 ± 16.60	0.314
	6th	92.53 ± 5.89	66.11 ± 13.22	64.50 ± 19.12	85.49 ± 8.85	69.81 ± 6.07	86.83 ± 13.29	0.193

Note: $^{a,b\ a,b}$ Means within the same row with differemt superscript differ ($P < 0.05$)

The relative improvement observed in the colon length (at 3rd week age) and percent (at 6th week age) of birds subjected to 4% AEC implies a probability of enhanced water, electrolytes, and nutrient absorption by the birds in these treatment groups relative to the others. The growth and health of poultry are reliant on the digestion of feed and absorption of nutrients, which is a result of the structural and functional development of the duodenum, jejunum, and ileum. The crypt and villi of absorptive epithelium play a significant role in the final stage of nutrient assimilation (Liu *et al.,* 2010). Marked improvements in duodenal villi height, width (3rd week of age), and crypt width (6th week of age) in broiler chickens subjected to 2% AEC as well as better cryptal depth (3rd week of age) in birds on 4% AEC can be explained from the growth and several biochemical enhancing properties associated with cinnamon. Although the development of villus height in birds under 2% AEC was more pronounced relative to those subjected to 4% AEC, the rate of turnover of the epithelial cell of the digestive system (utilization of nutrients for productive purposes) represented by comparatively long villi height with shallower cryptal depth signaling enhanced nutrient absorption was noted in birds exposed to 4% AEC and reflected as better feed conversion ratio. Cinnamon possesses the ability to stimulate the secretion of growth hormones and thus promotes the growth and development of tissues in farm animals (Sang-Oh *et al.,* 2013). An increase in villus height was observed in broiler chickens offered diets supplemented with formic acid and phytogenic additives (composed of oregano, cinnamon, and pepper; Jamroz *et al.,* 2005; Garcia *et al.,* 2007). The introduction of a 6% cinnamon dietary additive resulted in significantly higher jejunal villus height and better crypt depth in broiler chickens at six weeks of age relative to other treatment groups (Odutayo *et al.,* 2021). Furthermore, supplementation of combined carvacrol, cinnamaldehyde, and capsicum oleoresin broiler chickens' diet enhanced the development of the villi height and villi/crypt depth ratio (Awaad *et al.,* 2014).

Effect of Aqueous Cinnamon Extract on Organ Weight of Broiler Chickens at 3rd and 6th Weeks of Age

In Table 4, the effect of AEC on the organ weight of broiler chicken at 3rd and 6th week of age is presented. At 3rd week of age, there were significant (P < 0.05) differences in the parameters measured except the heart and thymus percentage. The proventriculus percentage was significantly higher in birds offered 2% AEC (0.76%) relative to lower values (0.52, 0.56, 0.57, and 0.54%) in birds under the positive control, negative control, 4% AEC and 8% AEC, respectively. The liver proportion had the significantly highest value (3.08%) in birds subjected to 4% AEC as against 2.08% recorded in birds under the negative control. Birds offered 2% AEC had improved gizzard (2.50%) relative to other treatment groups. Pancreas shows significant variation with a higher value (0.49%) in birds offered 2% AEC, while lower values were recorded in birds on negative control (0.32%) and 6% AEC (0.28%). For lymphoid organs, the spleen percentage was higher in birds offered 4% AEC (0.10%), and a lower value (0.06%) was found in birds under positive control. The significantly highest bursa (0.28%) was obtained in birds under 6% AEC relative to 0.18% in birds subjected to 8% AEC. At 6th weeks of age. All the parameters were not significant (P > 0.05) varied with respect to the imposed treatment.

Improved digestive organ development for proventriculus, gizzard, and pancreas (at 3rd week of age) in birds under 2% AEC, as well as liver in birds subjected to 4% AEC, is suggestive of enhanced digestive enzyme activities in birds on 2% AEC as well as improved metabolism of proteins, carbohydrates, and lipids in birds under 4% AEC owning to relative increase in absolute liver weight; since increase in liver weight had been related to its higher functional activity of assimilation of nutrients in the early stages of birds as reported by Maher (2019). This outcome is also hinged on the functional bioactive components of cinnamon, which possesses growth-promoting, digestion-stimulant potentials with antioxidant and anti-inflammatory properties (Jakhetia *et al.,* 2010).

The proventriculus is a glandular organ that aids the production of hydrochloric acid, and pepsinogen facilitates the transport of food bolus to the gizzard. The gizzard, due to its muscular layer, grinds, pulverizes, and compresses food bolus to transport it to the intestine. Additionally, it was noted that the relative weights of all the organs measured decreased with age. Similar findings were reported by Iji *et al.* (2001) and Hernandez *et al.* (2004), who affirmed that the relative weights of organs in chickens were higher at 21 days of age than at 42 days of age.

In animals, an increase in the weight of immune organs correlates with enhanced proliferation of immune cells, which represents better immunity (Teo and Tan, 2007). It is known that the study of the variations of lymphoid organs could be a result of the immunological conditions of birds (Perozo *et al.,* 2004). Improved development of the lymphoid organs (spleen and bursa of Fabricius) due to 4 and 6% AEC is an indication that birds in this treatment had enhanced immune systems, as the relative weight of the lymphoid organs is considered a measure of the state of the immune system (Ravis *et al.,* 1988). In avian, the spleen, thymus, and bursa play critical roles in stimulating the production of antibodies against several diseases (Sang-Oh *et al.,* 2013). The ability of cinnamon to exert such influence on the lymphoid organs can be adduced to its constituents' polyphenols, which aid in anti-inflammatory and pro-inflammatory effects on animals' immune cells (Cao *et al.,* 2008; Saied *et al.,* 2022). A similar outcome was found by Saied *et al.* (2022), who administered cinnamon oil at 500, 1,000, and 1,500 mg/kg diet and recorded improved relative weights of the lymphoid organs (spleen, thymus, and Bursa of Fabricius) with high levels of immunoglobulin. Also, Sang-Oh *et al.* (2013) observed that chicks offered dietary cinnamon powder at 3, 5, and 7% levels resulted in enhanced development of the lymphoid organs with higher levels of plasma immunoglobulins (IgG, IgM, and IgA). Improvement in the immune function in laying birds was also observed due to the administration of 300 mg of cinnamon oil/kg diet (Abo Ghanima *et al.,* 2020).

Effect of Aqueous Cinnamon Extract on Blood Profile of Broiler Chicken at 6th Weeks of Age

The effect of AEC on the hematological parameters of broiler chickens at 6th week of age is presented in Table 5. Results from this study indicated that the inclusion of AEC significantly ($P < 0.05$) affected only the white blood cell count in all the parameters collected and observed. The highest white blood cell observed was 12.10 × 10^9/L, which was observed in birds that were subjected to 2% AEC, while the significantly lowest white blood cell of 9.55 × 10^9/L observed were in birds under the negative control.

Blood acts as a pathological reflector of the status of exposed animals to toxicants and other conditions (Olafedehan *et al.,* 2010) and, hence, is an essential tool in the diagnosis and monitoring of diseases (Merck Manual, 2012). The non-significant effect of AEC on most of the hematological indices of the birds indicates that AEC, at the inclusion levels employed in this study, is not detrimental to the formation and function of the blood cells and their constituents. Although reduced white blood cell count was observed in birds administered 8% AEC, the values recorded are within a normal range of healthy birds and similar to that of the study carried out by Mitruka and Rawnsley (1981). This is an indication that the body defense of the birds was strong against infections. White blood cells are an intrinsic body defense system and are found throughout the body, including the blood and lymphatic system (Maton *et al.,* 1993). Values obtained for the hemoglobin and red blood cells are within the normal range reported by Mitruka and Rawnsley (1977), indicating that the chickens had normal metabolic rates. The lymphocyte values obtained in this study are within 47.20–85.00%, reported as reference ranges for lymphocytes in healthy chickens (Mitruka and Rawnsley, 1977).

Table 4 Effect of aqueous extract of cinnamon (AEC) on organ weight of broiler chickens on 3rd and 6th weeks of age

Parameters	Age (week)	Positive control	Negative control	2% AEC	4% AEC	6% AEC	8% AEC	P-value
Liveweight (g/bird)	3rd	668.33 ± 27.53	650.00 ± 0.00	616.67 ± 57.73	616.67 ± 57.73	666.67 ± 28.86	666.67 ± 28.86	0.359
	6th	1,700.00 ± 70.71	1,775.00 ± 106.06	1,825.00 ± 35.35	1,550.00 ± 212.13	1,700.00 ± 212.13	1,800.00 ± 70.71	0.461
Digestive organs								
Heart (%)	3rd	0.56 ± 0.13	0.60 ± 0.10	0.67 ± 0.03	0.67 ± 0.02	0.55 ± 0.01	0.66 ± 0.04	0.246
	6th	0.40 ± 0.00	0.43 ± 0.04	0.43 ± 0.13	0.42 ± 0.08	0.44 ± 0.03	0.39 ± 0.07	0.965
Proventriculus (%)	3rd	0.52 ± 0.08^{b}	0.56 ± 0.08^{b}	0.76 ± 0.17^{a}	0.57 ± 0.04^{b}	0.61 ± 0.03^{ab}	0.54 ± 0.04^{b}	0.037
	6th	0.42 ± 0.04	0.41 ± 0.01	0.40 ± 0.01	0.41 ± 0.01	0.35 ± 0.08	0.43 ± 0.06	0.651
Liver (%)	3rd	2.78 ± 0.30^{ab}	2.08 ± 0.43^{c}	2.97 ± 0.20^{ab}	3.08 ± 0.48^{a}	2.54 ± 0.05^{abc}	2.41 ± 0.30^{bc}	0.025
	6th	2.19 ± 0.40	1.98 ± 0.12	2.03 ± 0.03	2.09 ± 0.22	1.90 ± 0.06	1.85 ± 0.19	0.647
Gizzard (%)	3rd	2.21 ± 0.23^{abc}	2.02 ± 0.21^{c}	2.50 ± 0.08^{a}	2.44 ± 0.28^{ab}	2.08 ± 0.06^{bc}	2.18 ± 0.24^{abc}	0.042
	6th	1.49 ± 0.01	1.56 ± 0.58	1.67 ± 0.39	1.71 ± 0.04	1.74 ± 0.28	1.68 ± 0.23	0.963
Pancreas (%)	3rd	0.35 ± 0.35^{ab}	0.32 ± 0.31^{b}	0.49 ± 0.49^{a}	0.42 ± 0.42^{ab}	0.28 ± 0.28^{b}	0.39 ± 0.39^{ab}	0.026
	6th	0.22 ± 0.07	0.21 ± 0.02	0.20 ± 0.08	0.18 ± 0.03	0.16 ± 0.02	0.21 ± 0.02	0.474
Lymphoid organs								
Spleen (%)	3rd	0.06 ± 0.02^{b}	0.08 ± 0.03^{ab}	0.09 ± 0.03^{ab}	0.10 ± 0.02^{a}	0.09 ± 0.01^{ab}	0.09 ± 0.01^{ab}	0.038
	6th	0.13 ± 0.05	0.10 ± 0.01	0.09 ± 0.03	0.04 ± 0.06	0.10 ± 0.04	0.10 ± 0.04	0.318
Thymus (%)	3rd	0.41 ± 0.21	0.27 ± 0.11	0.36 ± 0.17	0.33 ± 0.08	0.22 ± 0.01	0.22 ± 0.03	0.058
	6th	0.20 ± 0.02	0.20 ± 0.01	0.15 ± 0.05	0.24 ± 0.10	0.16 ± 0.05	0.28 ± 0.06	0.799
Bursa (%)	3rd	0.23 ± 0.23^{abc}	0.20 ± 0.20^{bc}	0.24 ± 0.24^{abc}	0.27 ± 0.27^{ab}	0.28 ± 0.29^{a}	0.18 ± 0.18^{c}	0.046
	6th	0.09 ± 0.13	0.13 ± 0.13	0.09 ± 0.05	0.19 ± 0.02	0.11 ± 0.07	0.12 ± 0.03	0.782

Note: ^{a,b,ca,b} Means within the same row with differemt superscript differ ($P < 0.05$)

Table 5 Effect of aqueous extract of cinnamon (AEC) on blood profile of broiler chicken at 6th weeks of age

Parameters	Positive control	Negative control	2% AEC	4% AEC	6% AEC	8% AEC	P-value
Packed cell volume (%)	29.50 ± 3.53	30.50 ± 0.70	29.50 ± 2.12	28.50 ± 0.71	32.00 ± 2.82	33.50 ± 4.95	0.578
Hemoglobin (g/dL)	9.85 ± 1.20	10.65 ± 0.21	9.80 ± 0.70	9.50 ± 0.28	10.60 ± 0.91	11.15 ± 1.62	0.582
Red blood cell (× 10^{12}/L)	2.75 ± 0.63	2.75 ± 0.35	2.45 ± 0.21	2.35 ± 0.07	2.90 ± 0.56	3.10 ± 0.56	0.607
White blood cell (× 10^{12}/L)	11.30 ± 1.83^{ab}	9.55 ± 1.13^{b}	12.10 ± 0.14^{a}	11.35 ± 0.07^{ab}	10.55 ± 0.07^{ab}	10.60 ± 0.78^{ab}	0.025
Heterophil (%)	26.00 ± 0.00	27.00 ± 1.41	28.50 ± 0.71	27.50 ± 2.12	26.50 ± 2.12	29.00 ± 2.82	0.574
Lymphocytes (%)	72.50 ± 0.71	71.00 ± 0.00	69.00 ± 1.41	70.50 ± 2.12	72.50 ± 3.53	71.00 ± 2.82	0.610
Eosinophil (%)	1.00 ± 0.00	0.50 ± 0.70	0.50 ± 0.70	1.00 ± 0.00	0.50 ± 0.70	0.00 ± 0.00	0.434
Basophil (%)	0.00 ± 0.00	0.50 ± 0.70	1.00 ± 0.00	0.50 ± 0.70	0.00 ± 0.00	0.00 ± 0.00	0.212
Monocytes (%)	0.50 ± 0.71	1.00 ± 0.00	1.00 ± 0.00	0.50 ± 0.71	0.50 ± 0.71	0.00 ± 0.00	0.434
MCV (fL)	108.70 ± 12.30	111.65 ± 11.80	120.45 ± 1.76	121.25 ± 0.64	111.50 ± 12.02	108.40 ± 3.81	0.550
MCH (pg)	36.25 ± 4.03	37.15 ± 4.03	40.00 ± 0.56	40.40 ± 0.00	37.11 ± 4.10	36.05 ± 1.34	0.567
MCHC (g/dL)	33.35 ± 0.07	33.25 ± 0.07	33.20 ± 0.00	33.30 ± 0.14	33.25 ± 0.07	36.05 ± 0.07	0.588
Total protein (g/dL)	5.75 ± 0.49	5.15 ± 0.49	4.95 ± 0.00	4.85 ± 0.28	5.20 ± 0.14	4.90 ± 0.49	0.272
Albumin (g/dL)	3.20 ± 0.28	2.85 ± 0.07	3.50 ± 0.84	2.90 ± 0.14	2.90 ± 0.14	2.85 ± 0.07	0.497
Globulin (g/dL)	2.55 ± 0.21	2.30 ± 0.42	1.45 ± 0.77	1.95 ± 0.07	2.30 ± 0.00	2.05 ± 0.49	0.285
Calcium (mg/dL)	8.35 ± 0.91	10.35 ± 3.60	10.45 ± 1.76	10.95 ± 1.34	9.25 ± 1.06	10.75 ± 0.35	0.699
Cholesterol (mg/dL)	99.30 ± 5.79	101.15 ± 3.46	104.15 ± 4.59	105.80 ± 8.48	97.65 ± 1.90	98.50 ± 9.19	0.747
Triglyceride (mg/dL)	122.90 ± 0.84	127.70 ± 3.81	129.90 ± 2.40	123.05 ± 5.44	120.25 ± 1.20	129.50 ± 9.47	0.887
Creatinine (mg/dL)	1.50 ± 0.28	1.50 ± 0.42	1.60 ± 0.14	1.80 ± 0.14	1.75 ± 0.49	1.90 ± 0.28	0.611
AST (U/L)	132.50 ± 31.82	111.60 ± 21.21	99.00 ± 19.79	113.00 ± 12.72	115.50 ± 45.96	104.50 ± 30.40	0.727
ALT (U/L)	32.50 ± 10.60	27.50 ± 9.19	17.50 ± 3.53	22.00 ± 8.48	23.00 ± 4.24	19.50 ± 13.43	0.355
VLDL (mg/dL)	24.60 ± 0.14	25.95 ± 0.77	25.55 ± 0.49	24.60 ± 1.13	24.05 ± 0.21	25.90 ± 1.83	0.354
HDL (mg/dL)	46.20 ± 3.67	43.70 ± 2.05	48.75 ± 2.26	46.55 ± 3.32	44.75 ± 0.63	41.60 ± 0.84	0.195
LDL (mg/dL)	28.50 ± 2.26	34.50 ± 0.63	26.85 ± 6.36	34.65 ± 4.03	28.85 ± 1.06	31.00 ± 8.20	0.500

Note: $^{\mathbf{a,b}}$ ^{a,b} Means within the same row with differemt superscript differ ($P < 0.05$) MCV = mean corpuscular volume, MCH = mean corpuscular haemoglobin, MCHC = mean corpuscular haemoglobin concentration, AST = aspartate aminotransferase, ALT = alanine aminotransferase, VLDL = very low density lipoprotein, HDL = high density lipoprotein, LDL = low density lipoprotein.

The packed cell volume of the birds was within a normal range of healthy birds and was similar to that of the study carried out by Mitruka and Rawnsley (1981) and Esonu *et al.* (2007). Monocytes are believed to be the white blood differential that fights off viruses and fungi. They form the largest part of the white blood cell. The monocyte reported in this study was within range of the study carried out by Ayoola *et al.* (2015). Serum biochemical indices are important indicators for detecting organ diseases in domestic animals (Malik *et al.,* 2013) and the amount of available protein in the diets.

Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities have been used as indicators of liver function. Elevated levels are monitored in liver malfunction, and it indicates the liver condition of the birds. AST and ALT in the current fell within a range of the study carried out by Obikaonu *et al.* (2011). The rate of AEC administration in this study did not affect the liver conditions in the broiler chickens. Since all parameters measured were within reference ranges reported for healthy domestic chicken this reflects that the administration of AEC up to 4% did not pose any negative influences on hematopoiesis and physiological functions of the birds through the period of the study.

CONCLUSIONS

Broiler chicken producers can adopt the use of 4% AEC (consecutively thrice a week via water) for enhanced feed utilization and improved physiological function of the gastrointestinal tract without deleterious implications for health status.

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