Journal of Sustainable Veterinary & Allied Sciences
P-ISSN-2695-2661 e-ISSN: 2811-1346
JoSVAS 2025 March Vol 7 Issue 1: 24-32

Original Research Article

PHYSIOLOGICAL RESPONSES OF FINISHER BROILER CHICKENS TO SUPPLEMENTATION OF *ARTOCARPUS HETEROPHYLLUS* LEAF EXTRACT IN DRINKING WATER

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ABSTRACT

This study investigated the physiological responses of finisher broiler chickens supplemented with *Artocarpus heterophyllus* leaf extract (AHLE) in drinking water. A total of 144 day-old Arbor Acre broiler chicks were divided into four treatment groups (received in drinking water for 16 days AHLE at concentrations of 0, 1, 3, and 5 mL/L) after brooding for 3 weeks. Each treatment contained 3 replicates comprising of 12 birds per replicate. Phytochemical screening of AHLE was determined, while data collected for haemato-biochemical parameters, oxidative markers, and intestinal morphology were subjected to a one-way analysis of variance, and photomicrographs of bone marrow histology were presented. Phytochemical analysis revealed a diverse composition of bioactive compounds in AHLE, including flavonoids, phenols, alkaloids, saponins, tannins, steroids, glycosides, terpenoids, and cardiac glycosides, with phenol and terpenoid being the most abundant. The results showed that AHLE supplementation did not significantly affect haemato-biochemical parameters, oxidative stress markers, or intestinal morphology, indicating no adverse effects on the overall health of the birds. However, bone marrow histology indicated potential benefits of AHLE supplementation on bone marrow health characterized by the presence of adipose tissues and precursor cells, suggesting that AHLE supplementation up to 5 mL/L is safe and may have positive effects on bone health of finisher broiler chickens, without inducing oxidative stress or disrupting metabolic functions.

Keywords: *Artocarpus heterophyllus*, bone marrow histology, finisher broiler, haemato-biochemical parameters, small intestinemorphorlogy

INTRODUCTION

The poultry industry faces daunting challenges in response to the growing concerns over antibiotic resistance and associated human health risks, and environmental contamination. The European Union's ban on antibiotic growth promoters (AGPs) in animal and poultry feed since 2006 has necessitated the identification of effective and sustainable alternatives. Research has demonstrated the potential of phytogenic feed additives, such as essential oils, to enhance growth rate and immune system function in farm animals (Botsoglou *et al*., 2002). Plant extracts (Cimrin *et al*., 2020; Safiyu *et al*., 2024), mushroom-based additives (Sogunle *et al*., 2021), and citrus-coconut electrolytes (Safiyu *et al*., 2023) have also shown promise as alternatives to AGPs, providing health-related benefits

http://doi.org/10.54328/covm.josvas.2025.224

in poultry production. The biological activities of natural bioactive compounds have been reported to mitigate stress in chickens, highlighting the potential benefits of incorporating phytochemical into poultry diets (Shehata *et al*., 2020; Vandana *et al*., 2021). Furthermore, phytogenic additives have been shown to stimulate intestinal secretion, weakening pathogen adhesion and promoting the stability of beneficial microbes in the gut (Jamroz *et al*., 2005). These findings support the hypothesis that phytogenic feed additives have a positive impact on immune responses and intestinal functions in poultry, providing a valuable alternative to AGPs and contributing to a more sustainable and healthy poultry industry.

Artocarpus heterophyllus Lam, commonly known as jackfruit, is a rich natural produce resource, exhibiting diverse biological activities, including antioxidant, anti-inflammatory, antibacterial, and antineoplastic properties (Septama & Panichayupakaranant, 2015; Moke *et al*., 2017). The plant contains an array of bioactive compounds, such as pectin, carotene, flavonoids, volatile sterols, tannins, and polyphenols (Vazhacharickal *et al*., 2015). Specifically, *A. heterophyllus* comprises artocarpusins (A, B, C), artocarpetin, morin, carotenoids, cynomacurin, dihydromorin, norartocarpetin, artocarpanone, cycloartinone, 2-arylbenzofuran derivative, and artocarstilene A (Baliga *et al*., 2011; Di *et al*., 2013). Traditionally, the leaves have been utilized to treat hypertension, diarrhoea, burns, asthma, and cough (Ramalingum & Mahomoodally, 2014), while aqueous leaf extracts have been employed in managing Diabetes mellitus (Chackrewarthy *et al*., 2010). Recent studies have demonstrated the leaves' potent natriuretic and diuretic activities (Fitrya *et al*., 2023) and anti-hepatitis C virus properties (IC_{50} = 1.5 mg/mL) without observed toxicity (Hafid *et al*., 2017). However, despite its huge therapeutic potential, information on the utilization of jackfruit leaf extract and its impact on physiological activities of meat-type poultry is limited in literature. Based on these backgrounds, the present study evaluated the effects of supplemental *Artocarpus heterophyllus* leaf extract administered through drinking water on haemoto-biochemical characteristics, oxidative stress markers, intestinal morphology and bone marrow histology of finisher broiler chickens.

MATERIALS AND METHODS

ETHICS STATEMENT

This study was conducted in accordance with the guidelines and protocols approved by the Animal Use and Care Committee of Michael Okpara University of Agriculture, Umudike, Nigeria, which adheres to the national regulatory frameworks outlined in the Constitution of the Federal Republic of Nigeria. All procedures involving animal subjects were carefully designed to minimize suffering and harm, ensuring the welfare and humane treatment of animals.

STUDY LOCATION AND FACILITIES

The experiment was conducted at the Poultry Unit, Teaching and Research Farm, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria (5°29′N, 7°33′E, elevation 122m). The site lies within Nigeria's tropical rainforest zone, characterized by an annual rainfall of 2177 mm, monthly ambient temperature range of 22-36 ℃, and relative humidity of 50-95%. The *Artocarpus heterophyllus* leaf extract (AHLE) preparation was carried out in the Animal Nutrition Laboratory, while assessment of small intestine and bone marrow were carried out in the Veterinary Pathology Laboratory of the same institution.

PLANT IDENTIFICATION, COLLECTION AND PREPARATION

The plant was identified by Dr. I. A. Ewetola, a Forage and Grassland Agronomist and co-author of this study.

Although no voucher specimen was deposited, the plant was fully validated (http://mpns.kew.org/mpns-portal/?_ga=1.111763972.1427522246.1459077346).

The leaves of *Artocarpus heterophyllus* were harvested on June 20, 2024, from the surroundings of Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Following drying at 50°C using a forced air ventilation oven (Quimis Q317M-12) to achieve constant weight, the leaves were pulverized into a fine powder. A subsequent ethanolic extraction (95% v/v) was performed using 600 g of powdered leaf material and 3 L of ethanol, with intermittent shaking every 12 hours, over a 48-hour period in a dark environment maintained at 25-30°C.

The resultant extract (*Artocarpus heterophyllus* leaf extract (AHLE)) was filtered, concentrated via rotary evaporation, and stored in a refrigerated (4°C), dark glass bottle to preserve it prior to administration to the experimental birds according to predetermined treatment guidelines.

EXPERIMENTAL BIRDS, DESIGN AND MANAGEMENT

A total of 144 day-old Arbor Acre broiler chicks were procured from a reputable source in Umuahia, Abia State, and brooded for 3 weeks. The chicks were allotted to four treatment groups (n=36 per group) in a completely randomized design, with three replicates of twelve birds each. *Artocarpus heterophyllus* leaf extract was administered via drinking water at concentrations of 0, 1, 3, and 5 mL/L for an experiment that lasted for 16 days. All

birds received the same basal diet (Table I) *ad libitum* and were housed in deep litter pens. Vaccinations against infectious bursal disease (days 5 and 24) and Newcastle disease (days 10 and 20) were conducted as part of standard management practices.

DATA COLLECTION

PHYTOCHEMICAL SCREENING OF *ARTOCARPUS HETEROPHYLLUS* LEAF EXTRACT (AHLE)

The phytochemical screening of AHLE was conducted according to standard protocols described by Manjulika *et al*. (2015). The extract was screened for the following bioactive substances: flavonoids, phenols, alkaloids, saponins, tannins, steroids, glycosides, terpenoids and cardiac glycosides.

BLOOD COLLECTION AND ANALYSES

On the last day of the study (37th day-old birds), 4 mL of blood was aseptically drawn from the brachial vein of two randomly selected birds from each replicate, into ethylene diamine tetraacetic acid (EDTA) sample bottle for haematological analysis and another 4 mL blood into plain sample bottle from the same birds for determination of serum biochemical parameters and oxidative biomarkers. All samples were collected in the morning before feeding (between 07:00 to 09:00 am). The sample bottles were kept in ice pack and then transported to the laboratory within 2 hours of blood collection. Haematological parameters were determined using the procedures of Sood (2016). Serum biochemical parameters (Total protein, albumin, globulin, glucose, Total cholesterol, Low Density Lipoprotein (LDL), High Density Lipoprotein (HDL), Very Low Density Lipoprotein (VLDL), triglycerides, Alanine transaminase (ALT) and, Alkaline Phosphatase (ALP)) were analyzed using commercially available test kits by Randox laboratories, United Kingdom (Model BT294QY). Oxidative markers such as glutathione (GSH), glutathione peroxidase (GPX), superoxide dismutase (SOD), catalase (CAT), and malondialdehyde (MDA) were determined as enunciated by Daramola (2019).

SMALL INTESTINE MORPHOLOGY

Two birds (37-day-old broilers) from each replicate were humanely euthanized by cervical dislocation, and then eviscerated. The duodenum was removed, and the content was collected and serially diluted. The intestines were collected and fixed in 10% neutral buffered formalin for 48 hours and prepared for histomorphological studies using the standard techniques as described by Bancroft & Gamble (2002).

Histomorphometric measurements were made using the ×10 objective and photomicrographs were taken at ×100 magnification. The length and width of villi, and depth of crypts for a total of 6 selected individuals and apparently complete, full-sized intestinal villi with minimal damage or bending, were measured for each sample. For the wall thickness, 4 sections along the intersecting plane of rounded intestinal sections were measured. All measurements were in micrometers (µm) by the same individual.

BONE MARROW HISTOLOGY

Left tibiae bone marrow from the sacrificed birds were fixed and stored in 10% neutral buffered formalin. Each of the samples was embedded in paraffin, and a 5-µm section of each sample was placed on a glass slide and stained with haematoxylin and eosin for examination under a light microscope as described by Sogunle *et al.* (2021).

RESULTS

TABLE I: COMPOSITION (%) OF DIET FED TO EXPERIMENTAL BIRDS

Ingredients	**Quantity (%)**
Maize	58.60
Soybean Meal (48% CP)	36.10
Vegetable Oil	1.65
Bone Meal	1.75
Limestone	1.00
Salt (NaCl)	0.35
Lysine	0.10
DL-Methionine	0.20
*Vitamin-Mineral Premix	0.25
Total	**100.0**
Calculated Composition	
Metabolizable Energy (KCal/kg)	3036.26
Crude Fiber (%)	2.98
Crude Protein (%)	20.49
Available P (%)	0.38
Total Calcium (%)	0.88
Ether Extract (%)	3.43
Total Lysine (%)	1.29
Total Methionine (%)	0.52

*Vitamins and minerals premix contains vitamin A, 10,000,000 IU; vitamin D3, 2,000,000 IU; vitamin E, 12,500 IU; vitamin K, 1.30 g; vitamin B1, 1.30 g; vitamin B2, 4 g; D-calcium pantothenate, 1.3 g; vitamin B6, 1.3 g; vitamin B12, 0.01 g; nicotinic acid, 15 g; folic acid, 0.05 g; biotin, 0.02 g; copper, 0.05 g; cobalt, 0.20; iron, 25 g; iodine, 0.06 g; manganese, 48 g; selenium, 0.10 g; zinc, 45 g; choline chloride, 200 g; butylated hydroxytoluene, 50 g

PHYTOCHEMICAL SCREENING

The phytochemical constituents of *Artocarpus heterophyllus* leaf extract revealed a diverse composition of bioactive compounds. As shown in Table II, the extract contained flavonoid (28.55 mg/100 g), phenol (52.19 mg/100 g), alkaloid (14.52 mg/100 g), saponins (28.90 mg/100 g), tannin (39.05 mg/100 g), steroid (23.50 mg/100 g), glycosides (42.58 mg/100 g), terpenoid (51.20 mg/100 g) and Cardiac glycoside (42.71 mg/100 g).

TABLE II: PHYTOCHEMICAL CONSTITUENTS OF *ARTOCARPUS HETEROPHYLLUS* LEAF EXTRACT

Phytochemical	Amount (mg/100 g)
Flavonoid	28.55
Phenol	52.19
Alkaloid	14.52
Saponins	28.90
Tannin	39.05
Steroid	23.50
Glycosides	42.58
Terpenoid	51.20
Cardiac Glycoside	42.71

HAEMATO-BIOCHEMICAL PARAMETERS

The haemato-biochemical parameters of finisher broiler chickens administered varying levels of *Artocarpus heterophyllus* leaf extract are presented in Table III. The results indicated that all parameters measured were not significantly influenced ($p > 0.05$) by the supplementation of AHLE.

OXIDATIVE STRESS MARKERS

The oxidative stress markers of finisher broiler chickens administered varying levels of *Artocarpus heterophyllus* leaf extract are shown in Table IV.

The results revealed that the extract had no significant effect ($p > 0.05$) on all parameters measured.

SMALL INTESTINE MEASUREMENTS

The supplementation of *Artocarpus heterophyllus* leaf extract did not significantly influence ($p > 0.05$) the morphometric of the duodenum, jejunum, and ileum of finisher broilers as presented in Table IV.

BONE MARROW HISTOLOGY

The bone marrow histology of finisher broiler chickens administered through drinking water varying levels of *Artocarpus heterophyllus* Leaf Extract is depicted in Figure I. The results showed that birds in the control group (T1) had compact bones with no observable lesions. Similarly, birds in the treatment groups (T2, T3, and T4) showed no visible lesions, but the presence of adipose tissues (long arrows) and precursor cells (arrow head).

TABLE III: HAEMATO-BIOCHEMICAL PARAMETERS OF FINISHER BROILER CHICKENS ADMINISTERED VARYING LEVELS OF *ARTOCARPUS HETEROPHYLLUS* LEAF EXTRACT

Parameter	T1	T2	T3	T4	SEM	P value
Packed Cell Volume (%)	31.00	29.75	29.87	29.87	1.11	0.647
Haemoglobin concentration (g/dl)	11.07	10.87	10.80	10.70	0.10	0.137
Red Blood Cell count ($\times 10^6$/µl)	3.18	3.077	3.14	3.12	0.08	0.839
White Blood Cell count ($\times 10^3$/µl)	21.45	20.92	20.73	20.52	0.33	0.305
Total protein (g/dl)	3.70	4.31	4.23	3.71	0.38	0.546
Albumin (g/dl)	1.35	1.79	1.74	1.56	0.17	0.316
Globulin (g/dl)	2.35	2.52	2.49	2.14	0.23	0.667
Glucose (mg/dl)	355.67	356.00	350.00	359.00	4.87	0.635
Creatinine (mg/dl)	1.09	1.11	1.11	1.09	0.01	0.723
Urea (mg/dl)	8.98	9.09	9.03	8.98	0.15	0.943
Cholesterol (mg/dl)	45.83	47.85	46.10	47.68	3.63	0.967
Low Density Lipoprotein(mg/dl)	3.04	5.53	4.70	5.11	2.01	0.827
High Density Lipoprotein(mg/dl)	31.60	31.58	30.38	32.07	1.65	0.900
Very Low Density Lipoprotein (mg/dl)	11.19	10.77	11.02	10.51	0.30	0.444
Triglycerides (mg/dl)	55.97	53.84	55.08	52.53	1.50	0.442
Alanine transaminase (u/l)	30.80	25.53	25.57	28.30	2.24	0.349
Alkaline Phosphatase (u/l)	60.23	58.67	58.40	59.67	0.77	0.361

T1 = 0 mL AHLE/litre of water, T2 = 1 mL AHLE/litre of water, T3 = 3 mL AHLE/litre of water, T4 = 5 mL AHLE/litre of water

TABLE IV: OXIDATIVE STRESS MARKERS OF FINISHER BROILER CHICKENS ADMINISTERED VARYING LEVELS OF *ARTOCARPUS HETEROPHYLLUS* LEAF EXTRACT

Parameter	T1	T2	T3	T4	SEM	P value
GSH(mg/dl)	11.39	10.13	10.38	10.19	0.58	0.422
GPx(u/l)	39.17	38.48	38.69	37.15	0.80	0.380
SOD(u/l)	20.44	20.83	20.86	20.84	0.29	0.623
CAT(u/l)	25.04	24.63	24.55	24.51	0.28	0.555
MDA(mμ)	0.17	0.16	0.15	0.15	0.01	0.417

T1 = 0 mL AHLE/litre of water, T2 = 1 mL AHLE/litre of water, T3 = 3 mL AHLE/litre of water, T4 = 5 mL AHLE/litre of water

TABLE V: SMALL INTESTINE MEASUREMENTS OF FINISHER BROILER CHICKENS ADMINISTERED VARYING LEVELS OF *ARTOCARPUS HETEROPHYLLUS* LEAF EXTRACT

Parameter	T1	T2	T3	T4	SEM	P value
Duodenum						
Villus height (μm)	782.60	845.80	811.30	847.20	41.00	0.665
Villus width (μm)	173.30	154.60	145.40	133.90	17.00	0.492
Crypt depth (μm)	251.50	244.80	213.00	244.30	15.40	0.405
Muscle wall thickness	183.70	230.70	190.80	202.50	24.70	0.598
Villus height to crypt depth ratio	3.17	3.45	3.81	3.49	1.12	0.647
Jejunum						
Villus height	800.50	798.40	774.60	895.20	61.50	0.576
Villus width	134.48	162.85	126.09	151.62	9.70	0.163
Crypt depth	205.60	221.70	174.90	260.30	41.70	0.587
Muscle wall thickness	180.80	163.80	188.70	168.00	18.40	0.767
Villus height to crypt depth ratio	3.96	4.24	4.44	3.49	1.03	0.919
Ileum						
Villus height	774.40	839.00	985.60	854.30	46.90	0.126
Villus width	151.90	130.50	140.90	149.20	13.10	0.681
Crypt depth	185.70	228.90	266.20	222.30	39.00	0.593
Muscle wall thickness	175.30	193.00	224.50	257.90	37.90	0.507
Villus height to crypt depth ratio	4.59	3.73	3.74	3.88	0.78	0.838

T1 = 0 mL AHLE/litre of water, T2 = 1 mL AHLE/litre of water, T3 = 3 mL AHLE/litre of water, T4 = 5 mL AHLE/litre of water

DISCUSSION

The phytochemical composition of *Artocarpus heterophyllus* leaf extract (AHLE) revealed a diverse array of bioactive compounds. The bioactive compounds could have imparted antioxidant activity, making it suitable for ethno-veterinary purposes in preventing and treating diseases in poultry. The findings slightly align with a study by Ngbolua *et al*. (2019) on the phytochemical composition of jackfruit leaves where flavonoids, phenolic acids, and terpenoids were present in Jackfruit leaves, while alkaloids were not found. The abundance of phenolic compounds in AHLE indicates its potential for antioxidant activity and immunity improvement in poultry as enunciated by Kumoro *et al*. (2020). Phenolic compounds in Jackfruit have been reported to exhibit antioxidant and antibacterial properties, which can aid the prevention of cardiovascular diseases (Lee *et al.*, 2013) as well as serve as carcinogenic inhibitor (Nansereko & Muyonga, 2021). However, it is worth noting that the cumulative doses of phenol administered to the experimental birds in this study, over the 16-day treatment period, were significantly below the reported lethal dose range of 140 mg/kg to 500 mg/kg for oral phenolic compounds in animals (Wiley–VCH, 2003). The presence of terpenoids in AHLE suggests its potential to inhibit multiple species of bacteria and other microbes (Prabuseenivasan *et al*., 2006; John *et al*., 2007) as well as possesses other biological activities including anticancer, anti-inflammatory, antioxidant, and antiallergic (Masyita *et al*., 2022). Glycosides in AHLE indicate its potential as a biological response modifier and antimicrobial agent (Trease & Evans, 1989).Additionally, the presence of flavonoid in AHLE is an indication of its increased antioxidant activity against carcinogens (Amadi *et al.*, 2018), and the presence of tannins, saponins, and

alkaloids suggests its potential anti-inflammatory (Just *et al*., 1998; Barbosa-Filho *et al*., 2006), antibacterial (Scazzocchio *et al*., 2001), and antioxidant, anti-carcinogenic, and antimicrobial properties (Li *et al.*, 2021; Safiyu *et al.*, 2023), highlighting AHLE's potential as a valuable natural remedy for various health challenges in poultry.

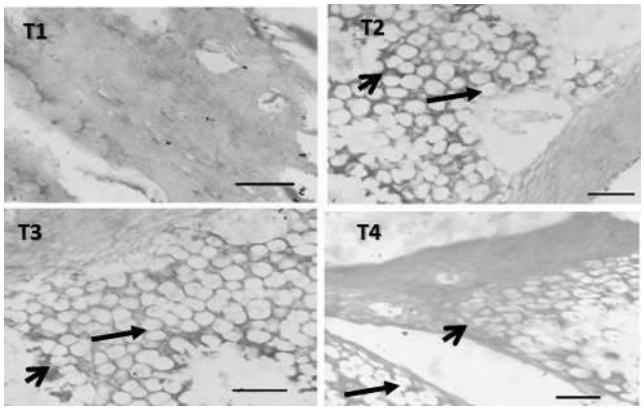

Figure I: Bone marrow Histology of Finisher Broiler Chickens Administered Varying Levels of *Artocarpus heterophyllus* Leaf Extract
T1 = 0 mL AHLE/litre of water, T2 = 1 mL AHLE/litre of water, T3 = 3 mL AHLE/litre of water, T4 = 5 mL AHLE/litre of water

Blood parameters are widely recognized as reliable markers for assessing the health and physiological status of animals (Adeyemi *et al*., 2021). In this study, non-significant difference in haemato-biochemical parameters suggests that the inclusion of AHLE via drinking water of finisher broiler chickens, up to a level of 5 mL/L, did not have any detrimental effects on their health status. The hematological parameters obtained in this study fell within the established ranges for healthy broiler chickens, specifically 29.75-32.38% for packed cell volume (PCV), 21.13-22.13 $\times 10^3$/µl for white blood cell count (WBC), 7.4-14.9 g/dl for hemoglobin concentration (Hb), and 1.28-3.5 $\times 10^6$/µl for red blood cell (RBC) count, as reported by El-katcha *et al.* (2016), Lala *et al*., (2018), Adeyemi *et al.* (2023), and Safiyu *et al.* (2023). That AHLE did not significantly affect serum biochemical parameters in the present study contradicts reports by Sigolo *et al.* (2021), who observed that the supplementation of broiler chickens with plant extracts positively affected blood serum parameters, decreasing the concentrations of total protein, albumin, urea, and total cholesterol. Abd El-Hack *et al.* (2020) also reported that herb supplementation had a beneficial effect on serum cholesterol levels and the distribution of cholesterol lipoproteins. Though the mechanism of AHLE on serum activity is unknown, however, the discrepancy between the findings of this study and those of previous studies may be attributed to differences in the type, dosage, and duration of extract administration. In this study, the birds were supplemented with AHLE for a period of 16 days, whereas in previous studies, the birds had access to plant extracts for longer periods. Nonetheless, the values obtained for total protein, albumin, and globulin were within the normal ranges reported by Okpe & Abdulfatai (2022) for healthy broilers. This implies AHLE supplementation did not compromise thenormal synthetic protein utilization or immune function of finisher broiler chickens.

Although oxidative stress markers in the present study diverged from previous results, which reported reduced MDA and increased SOD levels following herbal plant supplementation (Oke *et al*., 2017; Wan *et al*., 2017), the result provided preliminary evidence of AHLE's safety and efficacy. Notably, the birds exhibited no signs of stress, indicating that AHLE supplementation did not adversely affect their well-being. Additionally, AHLE supplementation did not significantly improve the morphological parameters of small intestinal sections in broiler chickens which is consistent with previous findings by Barreto *et al*. (2008) and Attia*et al.* (2017), which reported no significant changes in the gastrointestinal histomorphology of broiler chickens following plant extract blend supplementation. In contrast, other studies (Garcia *et al*., 2007; Abdullah *et al*., 2010; Yasar *et al*., 2011; Ghazanfari *et al*., 2015; Rafeeq *et al*., 2021) have observed increased villi length following supplementation with different phytogenics.

This study revealed the supplementation of AHLE in drinking water resulted in the presence of adipose tissues in the bone marrow of birds. Although literature is limited on the implication of abundant bone marrow adipose tissues on the health of chicken, existing research in humans suggests that bone marrow adipose tissue functions as a distinct fat depot, influencing bone remodeling and hematopoiesis (Hardouin et al., 2016). Moreover, increased bone marrow adipose tissue often coincides with decreased bone mass, indicating a link between bone formation and marrow adiposity (Cawthorn & Scheller, 2017).It is noteworthy that broiler chickens supplemented with AHLE exhibited optimal health, displaying no signs of severe adiposity or metabolic disorders. Furthermore, the bone marrow histology of these birds revealed the presence of precursor cells, consistent with the findings of Sogunle *et al*. (2021), where aqueous extract of oyster mushroom was shown to enhance precursor cell production in the bone marrow of broiler chickens. This suggests that AHLE supplementation may have a positive impact on bone marrow health and hematopoiesis in broiler chickens.

CONCLUSION

It could be concluded from this study that *Artocarpus heterophyllus* leaf extract is a viable phytogenic additive for replacing antibiotics in broiler production. The abundance of phenols among its bioactive compounds contributes to its potential benefits. Notably, AHLE supplementation at levels up to 5 mL/L did not induce oxidative stress, disrupt metabolic functions, or adversely affect the overall health of finisher broiler chickens. Furthermore, the presence of adipose tissues and precursor cells in the bone marrow histology of AHLE-supplemented birds indicates potential advantages for bone marrow health and hematopoiesis.

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