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ORGANOLEPTIC PARAMETERS, TIBIA BONE GROWTH AND MINERAL RETENTION OF BROILER CHICKEN FED *MORINGA OLEIFERA* AND *ALLIUM SATIVUM*

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ABSTRACT

Two hundred and forty (240) one-day-old, unsexed cobb 500 broiler chickens were used to determine the organoleptic attributes, tibia bone growth and mineral retention of broiler chicken fed *Moringa oleifera* leaf powder (MLP) and *Allium sativum* bulb powder (ABP) inclusive diets. The birds were randomly assigned to 5 dietary treatments with 4 replicates of 12 birds each in a completely randomized design. The treatments were: T1- control diet, T2 – MLP replaced with soya bean meal at 1 %, T3 – MLP replaced with soya bean meal at 3 %, T4 – MLP replaced with soya bean meal at 1 %, added with 0.1 % ABP and T5 – MLP replaced with soya bean meal at 3 %, added with 0.3 % ABP. The feeding trial lasted for a 28-day starter phase and another 28-day finisher phase. Data were collected on organoleptic parameters, tibia bone growth and mineral retention. Data collected were subjected to General Linear Model Procedure of SAS v9.2. Significant means were separated using Tukey's Procedure tested at a 5 % level of significance. At the 4th week, the colour, taste and juiciness of broiler meat in dietary treatments (T2, T3, T4 and T5) were similar ($P > 0.05$) to T1, while other parameters were not influenced by the dietary treatments. At the 8th week, the taste of broiler meat in T1 was significantly ($P < 0.05$) higher than in T4. The aroma in T1 was similar ($P > 0.05$) to T3 and T5, while tenderness in T1 was significantly ($P < 0.05$) lower than in T3. At week 4, the bone's weight in T2 was significantly ($P < 0.05$) lower than in T1. The diameter and ash weight in T2, T3, T4 and T5 were similar ($P > 0.05$) to those in T1. The calcium content in the dietary treatment (T2, T3, T4 and T5) was significantly ($P < 0.05$) higher than in T1. At the 8th week, the bone's weights in (T2, T3, T4 and T5) were similar ($P > 0.05$) to those in T1. The length was significantly ($P < 0.05$) higher in T3 and T5 than in T1 and T4. The diameter in T1 was lower ($P < 0.05$) than that in T2. Calcium was progressively increased among the dietary treatments from T2 to T5. Therefore, T3 and T5 are, hereby, recommended for use in the livestock industry.

Key words: *Allium sativum*; feed additive; tibia bone; *Moringa oleifera*; organoleptic parameter; phytogenic

INTRODUCTION

Phytogenic feed additives in poultry diets are often considered as safe, easy to use and environmentally friendly (Akdemir *et al.*, 2012). They can be used in the poultry industry due to their ability to enrich poultry products with natural antioxidants and antimicrobial compounds to combat known infectious diseases that could affect productivity of birds (Hajati *et al.*, 2014). Phytogenic plants have received increasing attention as possible natural growth promoters in the poultry industry due to their ability to stabilise feed hygiene and form beneficial effects on gastrointestinal microbes through controlled pathogens. The suitability of various phytogenic plants in the nutrition of poultry birds has been proved by some researchers (Abdel-Wareth and Lohakare 2014, Abdel-Wareth 2016, Liu *et al.*, 2020). There are different kinds of herbs, which can be used as phytogenic feed additives in poultry. The most common herbs that have received research attention are *Moringa oleifera*, garlic, ginger, turmeric and others (Vinus *et al.*, 2018).

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In the pursuit of improved broilers performance and in order to fulfil the consumers' expectation for quality food, poultry producers need to apply natural feed additives like *Moringa oleifera* and *Allium sativum* in their feed formulation. There is evidence suggesting that these herbs and spices have different bioactive substances (Al-kassie and Witwit, 2010), which have positive influence on the general performance of broiler chickens.

Allium sativum (Garlic) is a spice and herb with global recognition. It is one of the common herbs, which have been widely exploited for its value (Puvaca *et al.*, 2013). They contain some bioactive substances such as flavonoids, saponin, tannin, alkaloids, steroids, hydrocyanide and anthocyanin. Flavonoids, saponins and tannin contents of garlic are within the range of 0.04 to 0.36 %, 0.14 to 19.0 % and 0.06 to 6.10 % respectively (Friday *et al.*, 2011). It is also a good source

Figure 1. *Allium sativum* bulb, *Allium sativum* bulb powder

of dietary fibre, vitamin C and folic acid, as it contains calcium, iron and a low level of sodium with high protein quality. Adomeh and Eguaoje, (2019) reported that garlic has ability to soften the meat due to aromatic (organic) compounds it contained. This invariably increases the juiciness of the meat. Bone length, weight and ash percentage are good indicators of the bone health (Ziaie *et al.*, 2011), which in turn depends on its mineral content, especially calcium (Hafeez *et al.*, 2014). The hypocholesterolemic effects of ginger and garlic also reduced fat content in broiler meat for safe human consumption (Kamruzzaman and Khandaker, 2016).

Moringa oleifera is among plants that can be integrated with livestock production to enhance feed quality. It can be used as a cheap protein supplement to improve the protein and level of minerals in animal diet. *Moringa oleifera* is a unique plant due to its enriching minerals with lower anti-nutritional components (Nouman *et al.*, 2014). Rehman *et al.* (2018)

Figure 2. *Moringa oleifera* leaves, *Moringa oleifera* leaf powder

reported that the weight, ash percentage and robusticity index of broiler chicken fed *Moringa oleifera* leaf supplemented diet had tibia bone with linear, quadratic and cubic pattern of increase in response to the inclusion levels with peak values obtained at 12 $g.kg^{-1}$ supplementation. Increase in bone weight and ash percentage is good indictors of mineralization of bone. This was due to the positive effect of *Moringa oleifera* leave bioactive compounds on gastrointestinal tract leading to improved nutrient and mineral absorption (Mbikay, 2012) and decreased excretion of calcium from the body (Parikh *et al.*, 2015). The bioactive compounds in *Moringa oleifera* leaf meal influence the intestinal nutrient utilization, thereby improving tibia integrity and inorganic composition of tibia bones (Nkukwana *et al.*, 2014). They further speculate that the increased tibia Ca and P contents, Ca/P ratio and ash weight of broilers that were fed diet supplemented with *Moringa oleifera* leaf meal indicate its potential use as feed additive in broiler chickens. Therefore, this study aimed at determining the organoleptic attributes, tibia bone growth and mineral retention of broiler chicken fed *Moringa oleifera* leaf powder and *Allium sativum* bulb powder.

MATERIAL AND METHODS

Sample collection and preparation

Moringa oleifera leaves were collected from the Moringa plantation established at the experimental site of the Crop Science Department, Teaching and Research Farm, Federal University, Oye Ekiti, Ikole Campus, Nigeria, while the *Allium sativum* bulbs were purchased from a local market in Ado Ekiti, Ekiti State, Nigeria. The Moringa leaves were spread out on a floor and allowed air-drying for 7 days under shady and aerated conditions. The dried leaves were grounded with mortar and pestle to obtain moringa leaf powder (MLP). The MLP was stored in a separate plastic air-tight container for the experiment. The *Allium sativum* bulbs were de-segmented into cloves, which were cut into chips. The chips were sun-dried neatly for 2 weeks until they became crispy. The flake was then grounded to *Allium sativum* bulb powder (ABP) and stored in an air-tight container for feeding trial.

Management of experimental birds

The experiment was carried out at the Federal University, Oye Ekiti, Ekiti State, Nigeria at Animal Production and Health Research Unit, Ikole Ekiti with coordinates (Global Positioning System, GARMIN GPS72H) on latitude of 7.7982661° N and longitude of 5.514493° E. It has an annual average temperature of 24.2 °C. The dimension of each unit of experimental pen was 1.4 m × 1.8 m. Prior to the arrival of the chicks, the pens were cleaned, fumigated and disinfected with potassium permanganate and Izal. Wood shavings were spread on the floor to a depth of 6 inches as bedding materials for the birds and were changed every two weeks. Charcoal stove was provided to heat up the pens. All visitors to the poultry house were required to sanitise their shoes in a foot dip before entering the building. On the day of arrival, an anti-stress pack (glucose) was infused into the water supply and finely produced starter feed was served in chick's trays. All the replicates received standard management. The experimental area was marked by strict adherence to standards of cleanliness, hygiene and biosecurity.

Feed and supplementation process

The experimental diets were formulated and made into homogenous diets manually with *Moringa oleifera* leaf powder and *Allium sativum* bulb powder incorporated to obtain the fine mash given to the birds. The feed additives were first mixed thoroughly with other microminerals for 1 min, then one kg of grounded maize was added to the mixture and mixed together for another 1 min before they were later added to other ingredients that have been measured. These were then mixed on the floor with spade for another 15 min to obtain a 100 kg of the experimental diet. The conventional ingredients were purchased from Unique Feed mill, a subsidiary of Unique Breed Limited, Km 7, Opposite Great Eagle Hall, Ajebandele, Ikere Road, Ado Ekiti, Ekiti State, Nigeria.

Experimental design

A total of 240 unsexed one-day-old Cob 500 broiler chickens were used for the experiment, which was randomly assigned to 5 dietary treatments with 4 replicates of 12 birds each. Feed and water were offered *ad libitum* for 8 weeks. Feeding of experimental diets started in the first week, while all the vaccination and medication procedures were strictly followed. The birds were given IBDV against Infectious Bursal Disease on the 9th day and Lasota vaccine against Newcastle Disease at the 21st day. Neomycin and Coccifor were administered to the birds against bacterial infections

and coccidiosis, respectively. The design of the experiment was completely randomized (CRD). The treatments were designated as: T1 (control) − standard diet without *Moringa oleifera* leaf powder and *Allium sativum* bulb powder, T2 − *Moringa oleifera* leaf powder replaced with soyabean meal at 1 %, T3 − *Moringa oleifera* leaf powder replaced with soyabean meal at 3 %, T4 − *Moringa oleifera* leaf powder replaced with soyabean meal at 1 % + 0.1 % *Allium sativum* bulb powder and T5 − *Moringa oleifera* leaf powder replaced with soyabean meal at 3 % + 0.3 % *Allium sativum* bulb powder.

Data collection

Organoleptic attributes

Organoleptic (sensory) parameters of meat samples were obtained by collecting fresh samples of breast muscles from each carcass at the end of 4th week and 8th week of the experiment, respectively. The samples were cooked in moist heat to a temperature of 70 °C for 15 min. Thereafter, the cooked meat samples were coded and served at room temperature (27 °C) to each of the ten trained taste panelists to adjudge sensory assessment for color, taste, aroma, juiciness, tenderness and overall acceptability. The trained panelists received each sample separately with water to rinse their mouth in-between samples. Each sample was evaluated independent of the other, and scores were awarded using a 9-point hedonic scale from a maximum of 9-point score assigned to "like extremely" and a least score of 1 point assigned to "dislike extremely", as described by Sanwo *et al.* (2013).

Tibia bone growth and mineral retention

At the end of the 4th week and the 8th week of the experiment, left tibia bone was obtained from the sacrificed birds and the muscles were cleaned by boiling them in deionized water for 10 min. Scissors and forceps were used to ensure the complete removal of muscles and connective tissues from the bone. The tibia bone weight, length and diameter

Table 1. Percentage Composition of the Experimental Diet for Broiler Starter

Diet	T1 (CONTROL)	T2	T3	T4	T5
MLP	-	0.36	1.07	0.36	1.07
ABP	-	-	-	0.10	0.30
Maize	50.00	50.00	50.00	50.00	50.00
Soyabean meal	35.50	35.14	34.43	35.04	34.13
Fish meal 72 %	1.00	1.00	1.00	1.00	1.00
Wheat offal	10.00	10.00	10.00	10.00	10.00
Bone meal	1.00	1.00	1.00	1.00	1.00
Limestone	1.90	1.90	1.90	1.90	1.90
Methionine	0.15	0.15	0.15	0.15	0.15
Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.20	0.20	0.20	0.20	0.20
TOTAL	100.00	100.00	100.00	100.00	100.00
Calculated values					
Energy (kcal/kg)	2891.10	2882.12	2864.40	2882.12	2864.40
Crude protein %	23.04	22.94	22.75	22.94	22.75
Crude fibre %	4.17	4.17	4.17	4.17	4.17
Crude Fat %	3.63	3.63	3.62	3.63	3.62
Lysine %	1.25	1.24	1.22	1.24	1.22
Methionine %	0.49	0.49	0.49	0.49	0.49
Calcium %	1.17	1.17	1.17	1.17	1.17
Phosphorus %	0.47	0.47	0.46	0.47	0.46

ABP: *Allium sativum* bulb powder, MLP: *Moringa oleifera* leaf powder; Treatment 1 (T1): Control; Treatment 2 (T2): MLP replaced with soybean meal at 1 %; Treatment 3 (T3): MLP replaced with soybean meal at 3 %, Treatment 4 (T4): MLP replaced with soybean meal at 1 % + 0.1 % ABP and Treatment 5 (T5): MLP replaced with soybean meal at 3 % + 0.3 % ABP.

were measured according to the method described by Mutus *et al.* (2006) as follows:

Weight: the left tibia bone collected was weighed with a digital sensitive scale (Camry, 0.01), and the weight was recorded in grams.

Length: A digital vernier calliper was used to measure the length; the value was recorded to the nearest cm.

Diameter: A digital vernier calliper was also used to measure the maximum diameter. The bone was put in between the external jaws of the digital vernier calliper at its widest point; the value was recorded to the nearest cm.

Ash: The tibia bones were ashed in the labelled ceramic crucibles loaded in a muffle furnace at 550 °C for 12 hours and later transferred into a desiccator containing active desiccant while still hot to cool. After cooling it was weighed to get the weight of ash.

$$\text{Calculation: \% ash} = \frac{\text{Ash}}{\text{Wt. of sample}} \times 100$$

The bone ash was used to determine the mineralization of calcium and phosphorus contents of the bones. The Dry Ashing AOAC Method 920.117 was used according to Nancy *et al.* (2012).

Calcium: Calcium concentrations in the digested ash samples were determined using a Buck Scientific Atomic Absorption Spectrophotometer (Model: 210VGP) at various wavelengths of the metal and using a calcium cathode lamp. Quantification of the metals was based on calibration curves of standard solutions of metals. Blank in the analysis and certified reference standards were used to evaluate the accuracy of the analytical method (Bisergaeva and Sirieva, 2020).

Phosphorous: 5 ml of 6 N HCl were added with several drops of nitric acid and heated to dissolve the ash. This was cooled and transferred into a 100 ml volumetric flask and made up to the mark. 5 ml were then pipetted into a 100 ml standard flask and 20 ml of molybdo-vanadate reagent were added and made up to the mark with distilled water. This was left to stand for 10 min

Table 2. Percentage Composition of the Experimental Diet for Broiler Finisher

Diet	T1 (CONTROL)	T2	T3	T4	T5
MLP	-	0.29	0.87	0.29	0.87
ABP	-	-	-	0.10	0.30
Maize	52.00	52.00	52.00	52.00	52.00
Soyabean meal	29.00	28.71	28.13	28.61	27.83
Fish meal 72 %	12.40	12.40	12.40	12.40	12.40
Wheat offal	1.80	1.80	1.80	1.80	1.80
Bone meal	4.00	4.00	4.00	4.00	4.00
Limestone	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20
Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
TOTAL	100.00	100.00	100.00	100.00	100.00
Calculated values					
Energy (kcal/kg)	2830.56	2823.32	2808.85	2823.32	2808.85
Crude protein %	20.07	19.99	19.83	19.99	19.83
Crude fibre %	3.98	3.98	3.98	3.98	3.98
Crude Fat %	3.53	3.52	3.52	3.52	3.52
Lysine %	1.05	1.05	1.03	1.05	1.03
Methionine %	0.50	0.49	0.49	0.49	0.49
Calcium %	2.21	2.21	2.20	2.21	2.20
Phosphorus %	0.48	0.48	0.48	0.48	0.48

ABP: *Allium sativum* bulb powder, MLP: *Moringa oleifera* leaf powder; Treatment 1 (T1): Control; Treatment 2 (T2): MLP replaced with soybean meal at 1 %; Treatment 3 (T3): MLP replaced with soybean meal at 3 %, Treatment 4 (T4): MLP replaced with soybean meal at 1 % + 0.1 % ABP and Treatment 5 (T5): MLP replaced with soybean meal at 3 % + 0.3 % ABP.

for color development. The sample was read against a reagent blank at 400 nm UV/VIS spectrophotometer. Standards for the calibration curve were prepared from KH_2PO_4, and sample concentration was read out from the calibration curve (Adelowo and Oladeji, 2016).

Data analysis

Data were subjected to the General Linear Model Procedure of SAS v9.2 (2009). Significant differences were determined using a Tukey's procedure tested at a 5 % level of significance.

RESULTS

Organoleptic parameters of broiler chicken fed MLP and ABP inclusive diets

Tables 3 and 4 show the effect of *Moringa oleifera* leaf powder (MLP) and *Allium sativum* bulb powder (ABP) inclusion on the organoleptic attributes of broiler chicken meat. The result at the end of the 4th week shows that the colour, taste and juiciness of broiler meat in dietary treatments T2, T3, T4 and T5 were similar ($P > 0.05$) to T1, while other parameters were not influenced by the dietary treatments. At the 8th week, the taste of broiler meat in T1 was significantly higher ($P < 0.05$) than in T4 but similar to T2, T3 and T5 ($P > 0.05$). The aroma of the broiler meat in T1 was similar ($P > 0.05$) to T3 and T5 but higher ($P < 0.05$) than those in T2 and T4. The tenderness in T1 was significantly ($P < 0.05$) lower than T3 and T4 but similar ($P > 0.05$) to T2 and T5. Overall acceptability in T1 was similar ($P > 0.05$) to the values obtained across the dietary treatments (T2, T3, T4 and T4).

Tibia bone growth and mineral retention of broiler chickens fed MLP and ABP inclusive diets

Tables 5 and 6 revealed the effects of *Moringa oleifera* leaf powder (MLP) and *Allium sativum* bulb powder (ABP) inclusive diets on the tibia bone growth and mineral retention of broiler chicken. At week 4, the weight of the tibia bone in T2 was significantly ($P < 0.05$) lower than in T1 but similar ($P > 0.05$) to T3, T4 and T5. The length of the bone in T4 was significantly ($P < 0.05$) lower than those in T1 but similar ($P > 0.05$) to the other treatments. The diameter and ash weight in T2, T3, T4 and T5 were similar ($P > 0.05$) to those in T1. The calcium content in the dietary treatments T2, T3, T4 and T5 was significantly ($P < 0.05$) higher than in T1. The phosphorus level in T2, T3, T4 and T5 groups were comparable ($P > 0.05$) to T1. At the 8th week, the bone's weight in dietary treatments T2, T3, T4 and T5 were similar ($P > 0.05$) to those in T1. The length was significantly ($P < 0.05$) higher in T3 and T5 than in T1 and T4, but comparable to T2. The diameter in T1 was lower ($P < 0.05$) than in T2, but similar ($P > 0.05$) to T3, T4 and T5. Calcium value was progressively increased in the T2 to T5 dietary treatments, which were higher ($P < 0.05$) than in T1.

DISCUSSION

Organoleptic parameters of broiler chicken fed MLP and ABP inclusive diets

The assessment of broiler meat fed dietary treatments revealed that there was no significant improvement in the organoleptic parameters of the meat at the end of the 4th week. However, there was a marked reduction in the meat taste of birds fed T4

Table 3. Organoleptic parameters of broiler chickens fed MLP and ABP inclusive diet at 4 week

Parameter	T1 (CONTROL)	T2	T3	T4	T5	SEM	P value
Colour	6.70^{ab}	6.58^{ab}	6.33^{b}	6.95^{ab}	7.15^{a}	0.09	0.02
Taste	7.13^{ab}	6.35^{b}	6.30^{b}	7.00^{ab}	7.38^{a}	0.14	0.03
Aroma	7.10	6.60	6.88	6.78	7.05	0.06	0.09
Juiciness	6.45^{ab}	6.30^{b}	6.30^{b}	6.60^{a}	6.68^{a}	0.05	0.04
Tenderness	6.78	6.53	6.60	6.45	6.75	0.04	0.05
Overall acceptability	8.05	8.08	7.98	8.00	8.00	0.02	0.80

^{ab}Mean within rows without common superscript are significantly different at $p < 0.05$.
ABP: *Allium sativum* bulb powder, MLP: *Moringa oleifera* leaf powder, SEM: Standard error of mean; Treatment 1 (T1): Control; Treatment 2 (T2): MLP replaced with soybean meal at 1 %; Treatment 3 (T3): MLP replaced with soybean meal at 3 %, Treatment 4 (T4): MLP replaced with soybean meal at 1 % + 0.1 % ABP and Treatment 5 (T5): MLP replaced with soybean meal at 3 % + 0.3 % ABP.

Table 4. Organoleptic parameters of broiler chickens fed MLP and ABP inclusive diet at 8 week

Parameter	T1 (CONTROL)	T2	T3	T4	T5	SEM	P value
Colour	7.35	6.88	7.33	6.90	7.13	0.06	0.03
Taste	7.18^{a}	6.88^{ab}	7.20^{a}	6.65^{b}	6.80^{ab}	0.07	0.01
Aroma	7.05^{a}	6.68^{b}	7.03^{a}	6.63^{b}	6.83^{ab}	0.07	0.0007
Juiciness	6.88	6.85	6.75	6.50	7.05	0.06	0.06
Tenderness	6.43^{c}	6.63^{bc}	7.45^{a}	7.10^{ab}	6.80^{bc}	0.09	0.0006
Overall acceptability	7.53^{ab}	7.08^{b}	7.53^{ab}	7.33^{ab}	7.73^{a}	0.07	0.02

^{abc}Mean within rows without common superscript are significantly different at $p < 0.05$.
ABP: *Allium sativum* bulb powder, MLP: *Moringa oleifera* leaf powder, SEM: Standard error of mean; Treatment 1 (T1): Control; Treatment 2 (T2): MLP replaced with soybean meal at 1 %; Treatment 3 (T3): MLP replaced with soybean meal at 3 %, Treatment 4 (T4): MLP replaced with soybean meal at 1 % + 0.1 % ABP and Treatment 5 (T5): MLP replaced with soybean meal at 3 % + 0.3 % ABP.

Table 5. Tibia bone growth and mineral retention of broiler chickens fed MLP and ABP inclusive diet at 4 weeks

Parameter	T1 (CONTROL)	T2	T3	T4	T5	SEM	P value
Weight (cm)	4.99^{a}	4.35^{b}	4.47^{ab}	4.58^{ab}	4.66^{ab}	0.07	0.03
Length (cm)	6.70^{a}	6.28^{ab}	6.23^{ab}	6.08^{b}	6.28^{ab}	0.06	0.03
Diameter (cm)	1.40^{ab}	1.35^{ab}	1.40^{ab}	1.55^{a}	1.33^{b}	0.02	0.03
Ash weight (%)	37.36^{ab}	34.54^{b}	37.41^{ab}	38.74^{a}	38.92^{a}	0.46	0.006
Ca (mg.100 g^{-1})	293.00^{e}	317.50^{d}	461.00^{c}	516.00^{b}	752.50^{a}	37.97	<.0001
Ph (mg.100 g^{-1})	166.25^{ab}	169.00^{a}	165.50^{ab}	158.00^{b}	168.25^{a}	1.19	0.009

^{abcde}Mean within rows without common superscript are significantly different at $p < 0.05$.
ABP: *Allium sativum* bulb powder, MLP: *Moringa oleifera* leaf powder, SEM: Standard error of mean; Ca: Calcium, ph: Phosphorus; Treatment 1 (T1): Control; Treatment 2 (T2): MLP replaced with soybean meal at 1 %; Treatment 3 (T3): MLP replaced with soybean meal at 3 %, Treatment 4 (T4): MLP replaced with soybean meal at 1 % + 0.1 % ABP and Treatment 5 (T5): MLP replaced with soybean meal at 3 % + 0.3 % ABP.

Table 6. Tibia bone growth and mineral retention of broiler chickens fed MLP and ABP inclusive diet at 8 weeks

Parameter	T1 (CONTROL)	T2	T3	T4	T5	SEM	P value
Weight (cm)	19.10^{ab}	20.63^{a}	19.32^{ab}	17.14^{b}	19.67^{ab}	0.35	0.01
Length (cm)	10.37^{b}	10.45^{ab}	10.85^{a}	10.30^{b}	10.98^{a}	0.08	0.02
Diameter (cm)	2.28^{b}	2.56^{a}	2.35^{ab}	2.30^{b}	2.37^{ab}	0.03	0.02
Ash weight (%)	36.75	38.70	37.52	39.42	40.12	0.73	0.61
Ca (mg.100 g^{-1})	385.00^{e}	417.50^{d}	470.00^{c}	495.00^{b}	640.00^{a}	20.26	<.0001
Ph (mg.100 g^{-1})	170.50	166.00	168.00	167.25	172.50	1.50	0.72

^{abcde}Mean within rows without common superscript are significantly different at $p < 0.05$.
ABP: *Allium sativum* bulb powder, MLP: *Moringa oleifera* leaf powder, SEM: Standard error of mean; Ca: Calcium, Ph: Phosphorus; Treatment 1 (T1): Control; Treatment 2 (T2): MLP replaced with soybean meal at 1 %; Treatment 3 (T3): MLP replaced with soybean meal at 3 %, Treatment 4 (T4): MLP replaced with soybean meal at 1 % + 0.1 % ABP and Treatment 5 (T5): MLP replaced with soybean meal at 3 % + 0.3 % ABP.

and aroma of birds fed T2 and T4 at the 8th week. The inclusion of *Moringa oleifera* leaf powder and *Allium sativum* bulb powder into broiler chicken diet at the lowest level may not have the ability to affect the taste and aroma of the meat. This observation contrasted with the findings of Adomeh and Eguaoje (2019), who reported that high aroma score recorded in chicken thighs spiced with 1.5 % ginger and garlic easily influenced the broiler meat. The meat tenderness at the 8th week was improved in T3 and T4 groups. At this stage, it could be noted that the tenderness of meat among other traits was mostly preferred by the taste panellists. Lomiwes *et al.* (2014) reported that meat tenderness is a property that mainly determines consumer preference. The response in T3 and T4 groups demonstrated a better influence of *Moringa oleifera* leaf powder and *Allium sativum* bulb powder on broiler's meat. Hence, the effects of bioactive substances in *Moringa oleifera* and *Allium sativum* cannot be overemphasised in poultry production. The aforementioned development in meat tenderness can be attributed to the phytochemical components of the plant products. It was also reported that palatability, tenderness, colour, aroma and acceptability are important components that determine consumer preferences and consumption, which may vary from product to product and depending on locality of the meat product (Balarabe *et al.*, 2016). *Moringa oleifera* contains potential antioxidant phytochemicals and characterized by prebiotic effects (Vinus *et al.*, 2018).

Tibia bone growth and mineral retention of broiler chickens fed MLP and ABP inclusive diets

The study at the 4th week shows that the tibia bone weight was decreased in birds fed T2, and length of the bone in T4, while the calcium contents of the dietary treatments T2, T3, T4 and T5 were significantly improved. At the 8th week, it was observed that the lengths of the bone in T3 and T5 were significantly higher than in other treatments, and the bone diameter in T2 was also increased. It could be noted that the dietary treatments (T2, T3, T4 and T5) contribute effectively to mineralization through the increase in calcium retention in the tibia bone. Dietary *Moringa oleifera* leaf powder and *Allium sativum* bulb powder increased the growth of tibia bone (length and diameter) at the 8th week. Hence, they contribute seamlessly to an effective mineralization that leads to strong tibia bone formation as a result of efficient nutrient and mineral absorption through the intestine. Nkukwana *et al.* (2014) reported an increase in tibia calcium content and ash weight of broiler diet supplemented with *Moringa oleifera* leaf meal, what indicates its potential use as a feed additive in broiler production. Higher tibia bone parameters (length, diameter and calcium) were attributed to the presence of flavonoid phytoestrogens in Moringa leaf meal (Rehman *et al.* 2018). Phytoestrogens inhibit the activities of osteoclasts thus promoting mineralization through osteoblast and protein synthesis in bone (Sirotkin and Harrath, 2014) and decrease the excretion of calcium in poultry birds (Parikh *et al.* 2015).

CONCLUSIONS

This study has highlighted the importance of *Moringa oleifera* leaf powder and *Allium sativum* bulb powder in broiler chicken diet as a promising feed additive due to their phytochemical constituents. Their inclusion in broiler chicken diet improved the quality characteristics of the broiler meat, especially at the 8th week of the experiment which invariably increases the acceptability of the meat by the panellists. It was also found that the calcium content and ash weight of the tibia bone was progressively increased, what indicates a strong bone formation and an increased Ca and P contents. These facts are indication of the potential use of *Moringa oleifera* leaf powder and *Allium sativum* bulb powder as a feed additive to broiler chicken diet. Significant growth and mineralization of the tibia bone were achieved much more at the 8th week than at the 4th week. Therefore, *Moringa oleifera* leaf powder replaced with soyabean meal at 3 % (T3) and *Moringa oleifera* leaf powder replaced with soyabean meal at 3 % + 0.3 % *Allium sativum* bulb powder (T5) are hereby recommended.

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AUTHOR'S CONTRIBUTIONS

Conceptuality: Agbetuyi, O. A., Ekeocha, A. H., Aganga, A. A.

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All authors have read and agreed to the published version of the final manuscript.

INFORMED CONSENT STATEMENT

Not applicable.

DATA AVAILABILITY STATEMENT

All datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

CONFLICT OF INTEREST

The authors declare that there are no conflict of interest.

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