Carcass Yield, Bone Morphometry and Mineral Concentration in Tissues of Broilers Fed Nano Zinc Fortified Diet

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Summary

Dietary zinc is a potential growth promoter essential for bone development with the possibility of influencing mineral retention in broiler chickens. This 42-day trial was conducted to evaluate the carcass yield, bone morphometry and mineral retention (calcium, zinc and copper) in some organs and muscles of broiler chickens fed diet supplemented with nano zinc oxide (N-Zn) powder. One hundred and eighty (180) Arbor acre broiler chicks were used for this study. The birds were divided into five groups and assigned to the five dietary N-Zn supplementation groups which are; 0 (control), 40, 60, 80 and 100 mg kg^{-1} N-Zn. Each treatment was replicated thrice to consist of 12 birds each. Vaccination and medication were adhered so that only birds in the control groups received antibiotics. Data collected were subjected to general linear model as contained in SPSS version 23. Dressing percentage did not vary significantly with dietary supplementation of zinc. However, thigh and heart weight varied, with the highest recorded in 40 and 60 mg kg^{-1} N-Zn supplemented groups, respectively. Copper concentration increased significantly in heart, kidney, liver and muscle of broiler chickens fed dietary N-Zn while calcium and zinc showed no difference. N-Zn supplementation increased tibio-tarsal length and weight in birds, but the bone and robusticity index were statistically similar. This study has concluded that dietary supplementation of nano N-Zn gives a similar carcass yield as those administered antiobiotics, it increased copper retention in organs and muscles and also increased the length and width of tibio tarsal bones.

Key words

nano zinc, mineral retention, carcass yield and bone morphometry

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Introduction

Broiler chickens remain one of the abundant sources of meat, particularly white meat in Nigeria. The reasons include the fast growth, ease of production and general acceptability of this bird. Broiler farmers are concerned about raising fast growing strains with good carcass yield as this determines the profit of the production. To realize this, different growth promoters have been supplemented in feed or drinking water for broiler chickens. Significant improvement has been recorded owing to the use of various growth promoters especially antibiotics. However, their use has generated issues of concern such as health risk to consumers because of antibiotic residue, increased resistance to antibiotics and development of new strain, as well as a high cost of antibiotics. Another problem related to the use of growth promoters in broiler production is the leg problem resulting from overweight. It therefore becomes imperative to adopt alternatives that will also improve the growth without compromising the health of consumers as well as the bone integrity of the broiler chickens.

Studies have evaluated many minerals as a better alternative, but the forms and levels of supplementation of these minerals also influence the efficacy of this minerals. Nano minerals in the diet of poultry have proven to be better absorbed because of the smaller particle size and hence reducing negative environmental impact when compared to other forms.

Zinc oxide nanoparticles represent a product of one such nano technological approach and are characterized by their high catalytic efficiency and high adsorbing ability (Bouwmeester et al., 2009). Zinc (Zn) is a nutritionally essential trace mineral that requires a regular supply in poultry diets for normal appetite, growth, skeletal development, skin and feather integrity, reproduction, immune competence and many metabolic processes (O'Dell, 2000). All of these contribute to the maintenance of growth (Liu et al., 2011), skeletal development (Ao et al., 2007; Tomaszewska et al., 2017), and immune function (Kidd et al., 1996) of broiler chickens.

Zinc has been said to affect broilers differently based on their sources, which can be organic, inorganic or nano technological sources and on their production performance (Zhao et al., 2014). Zinc from conventional sources is less available to the body and thus mostly excreted to the environment causing environmental pollution so in comparison with other sources, nano ZnO has been said to be readily available to the body due to the particle size which makes it have a stronger chemical activity and participate in oxidation reactions with a variety of organic compounds. Supplementation of some of these minerals can also influence the absorption and retention of other minerals (Underwood and Suttle, 1999). Dukare et al. (2020) reported that supplementation of 80 mg/kg of Nano-Zn increased Zn, Ca and P levels in the liver and muscle. This study therefore investigated the carcass yield, bone morphometry and mineral concentrations in some organs and tissues of broiler chickens fed diet fortified with varying levels of nano zinc oxide particles.

Materials and Methods

Experimental Site

The experiment was carried out at the poultry unit of the Teaching and Research Farms of the Federal University of Agriculture, Abeokuta, Southwest, Ogun State, Nigeria. The farm area is located within latitude 7°10''N, longitude 3°2''E and altitude 76 m above sea level (Google Earth, 2021). The climate of its area of location is characterized with that of the derived savannah zone of South-Western Nigeria. It also has a humid climate with mean annual rainfall of 1037 mm and temperature of about 34.7 °C.

Source of Test Ingredients

The zinc oxide nano particles (80 nm) used for this study were imported from Lolo store, China via Aliexpress online platform. These particles were prepared from secondary zinc oxide-zinc calcine containing 78% of ZnO as a raw material and a $(NH_4)2SO_4$ solution and a NH_3H_2O solution serving as a lixivium.

Experimental Birds and Management

One hundred and eighty (180) day-old broiler chicks were sourced from a reputable hatchery in Ibadan for this study. The pen and its surrounding were cleared, cleaned, and disinfected prior to the arrival of the day-old chicks. The birds were brooded for two weeks with light to aid their feeding and heat source (charcoal and pot) and to help maintain their body temperatures. All of this was adequately provided for the birds during brooding. Commercial feed broiler starter (0-4 weeks) and broiler finisher (4-6 weeks) were provided *ad libitum*, as well as fresh clean water daily.

The brooding pen was covered with black polythene bags to conserve the heat generated for brooding the birds. As the birds aged in weeks, the polythene bag was removed gradually to help the birds acclimatize as they grow and develop feathers that will aid the maintenance of their body temperature. The broiler chicks were raised on deep litter with wood shavings as bedding material. The experiment was carried out within a period of 6 weeks (42 days). *Gumboro* vaccine was administered on the 7th and 21st day while Lasota vaccine was administered on the 28th day of the experiment to prevent Newcastle disease. Coccidiostat and vitamin were also administered when due. Birds given antibiotics (the control group) were administered enrofloxacin in water when necessary.

Experimental Design

The birds were distributed randomly and equally into 5 treatments /36 birds each. The treatment consisted of 3 replicates of 12 birds each. The treatments included supplementation at 0, 40, 60, 80 and 100 mg kg^{-1} nano particles.

Data Collection

Carcass Characteristics

On the 42nd of the study, two birds with weight relatively equal to the average of the birds in each replicate were selected for the evaluation of carcass. Birds were starved for 8 hours and slaughtered via the jugular vein and allowed to bleed for 2 minutes.

This was immediately followed by scalding (60 °C), defeathering and evisceration.

The head and shank were removed and weighed. Carcass was weighed and the dressed weight determined. The weight of the cuts (thigh, wings, drumstick, neck, back and breast), organs (lungs, liver, gizzard and kidney) and abdominal fat were determined and expressed as a percentage of the live weight.

Mineral Content Analysis

Three birds per treatment (one per replicate) were selected and sacrificed for the collection of organs (liver, heart and kidney) and breast muscle. The mineral concentrations of zinc, calcium and copper in the selected parts were determined by inductively coupled plasma atomic emission spectroscopy. Triplicate samples of the selected parts were weighed (0.5 g each), then digested with 10 mL of HNO_3 and 0.4 mL of HCl at 200 °C in a 50 mL flask according to Huang et al. (2009). The solution was allowed to evaporate to dryness and diluted to 1:20 (vol/ vol) with 2% HNO_3 before analysis.

Bone Morphometry

The left drumsticks were chosen from the birds sacrificed. They were labeled and soaked in boiling water (100 °C) for 10 min to facilitate defleshing of the bones. The bones were air dried for 24 hours. The tibio-tarsal length, width and weight were determined. The tibia bone index was calculated as the ratio of tibia weight (g) to the body weight (kg) of the chicken. Tibia bone robusticity was calculated as the ratio of tibia length (cm) to the cube root of bone weight (g).

Statistical Analysis

Data collected were subjected to one-way analysis of variance in a completely randomized design using SPSS version 23. The significant means were separated using Duncan multiple range Test at 5% level of significance.

Table 1. Nutrient composition of commercial diet (%)

Nutrient	Broiler Starter	Broiler Finisher
Crude protein	22.0	18.00
Fat and oil	6.00	6.00
Crude fibre	6.00	5.00
Calcium	1.00	1.00
Available phosphorus	0.45	0.40
Lysine	1.20	0.85
Methionine	0. 55	0.34
Salt	0.30	0.30
Metabolisable energy (Kcal kg^{-1})	2500	2900

Results

Carcass Characteristics

Effect of dietary supplementation of zinc oxide nanoparticles supplementation on carcass characteristics of broiler chickens is presented on Table 2. All measured parameters for effect of dietary nano zinc supplementation did not vary significantly ($P > 0.05$). Dressing percentages across treatment were 70.96, 72.06, 71.08, 70.64 and 69.36 in birds supplemented nano zinc at 0, 40, 60, 80 and 100 mg kg^{-1}, respectively. Significant differences were observed in thighs, shank and heart percentages.

Concentration of Some Minerals in the Heart, Kidney, Liver and Muscle

Table 3 shows the concentration of selected minerals in organs of broilers chickens fed diet supplemented with nano zinc oxide. Dietary nano zinc oxide had no significant ($P > 0.05$) effect on the retention of calcium in the heart, kidney, liver and muscle. Zinc retention varied significantly ($P < 0.05$) in the liver only. Nano zinc oxide supplementation influenced copper retention in the considered organs.

The variation in copper content observed in the heart, liver, muscle and kidney had similar pattern and the values observed were significantly ($P < 0.05$) higher in birds supplemented with 40 mg kg^{-1}, 80 mg kg^{-1} and 100 mg kg^{-1} nano zinc oxide while they were the lowest in birds not supplemented with nano zinc oxide. However, values observed in birds supplemented with 60 mg/kg are comparable to other groups.

The values of zinc content observed in the liver were significantly ($P < 0.05$) the same and higher in birds supplemented with 40 mg kg^{-1} nano zinc oxide (218.63 mg dL^{-1}), 80 mg kg^{-1} nano zinc oxide (227.00 mg dL^{-1}) and 100 mg kg^{-1} (176.33 mg dL^{-1}) zinc oxide nanoparticles compared to values obtained in birds not supplemented with nano zinc oxide (110.90 mg dL^{-1}), which is the lowest, while birds supplemented with 60 mg kg^{-1} (171.40 mg dL^{-1}) had values that are comparable to both, the highest and lowest values.

Calcium content in the heart, kidney, liver and muscle ranged from 8.37 mg dL^{-1} to 14.07 mg dL^{-1}, 7.47 mg dL^{-1} to 14.67 mg dL^{-1}, 7.10 mg dL^{-1} to 18.10 mg dL^{-1} and 8.63 mg dL^{-1} to 13.67 mg dL^{-1}, respectively.

The zinc content observed in the heart, kidney and muscle ranged from 116.83 mg dL^{-1} to 190.53 mg dL^{-1}, 109.97 mg dL^{-1} to 154.00 mg $dL^{-1}$and 61.23 mg dL^{-1} to 119.07 mg dL^{-1}, respectively.

Bone Morphometry

The tibia bone morphometry of broiler chickens fed diet supplemented with nano zinc oxide is shown in Table 4. Dietary nano zinc oxide had significance ($P < 0.05$) influencing the length and width of the bones while no significance ($P > 0.05$) was observed in the bone weights.

The length of bones was statistically the same ($P < 0.05$) in birds fed diet supplemented with nano zinc oxide at inclusion level of 60 mg kg^{-1} (9.63 cm), 80 mg kg^{-1} (9.70 cm), and 100 mg kg^{-1} (9.63 cm) and significantly ($P < 0.05$) higher than other groups. Birds with no inclusion of nano zinc oxide in their diet had the least value (9.30 cm) while birds which were supplemented with 40 mg/kg of nano zinc had values (9.53 cm) that are comparable to both, the highest and lowest values.

Tibia width was significantly ($P < 0.05$) widest in birds fed diet supplemented nano zinc oxide at 60, 80 and 100 mg kg^{-1} (9.24, 8.70 and 9.20 mm, respectively). However, the control group had values comparable to those supplemented at the rate of 40 mg kg^{-1} and the other groups.

There was no significant ($P > 0.05$) difference in the weight and robusticity of tibia bones of birds fed with or without nano zinc supplementation. Values, however, were increasing numerically with increasing supplementation of nano zinc.

Discussion

The economic value of broiler chickens can be assessed in terms of relative carcass yield (dressed weight, cut-up parts and organs) and on some occasions, leanness of the meat. Similar dressed weights, cut-up parts and internal organs weights observed among birds fed diet with nano zinc and the control are an indication that dietary supplementation of nano zinc (without any use of antibiotics) can improve carcass yield in broiler chickens. This is in accordance with Khah et al. (2015) as they reported from their experiment that dietary nano zinc led to increase in the dressing percentage of birds. There has been no variation found with respect to nano zinc levels in this study and this corroborates the earlier report of Collins and Moran (1999) who stated that feeding broiler chickens with inorganic zinc at levels beyond the recommended level by NRC did not influence the carcass yield at 7weeks.

Table 2. Effect of dietary supplementation of nano zinc oxide on carcass characteristics of broiler chickens

	Levels of dietary Nano Zinc supplementation(mg kg^{-1})						
Parameter	0	40	60	80	100	SEM	*P*-value
Live weight (g)	1920.67	1887.33	1932.33	1827.00	1841.00	28.33	0.76
Eviscerated weight (g)	1583.33	1560.67	1580.00	1485.00	1482.00	22.24	0.43
Eviscerated weight (%)	82.49	82.73	81.78	81.31	80.53	0.37	0.36
Dressed weight (%)	70.96	72.06	71.08	70.64	69.36	0.38	0.27
Cut-up Parts (%)							
Head	2.05	2.29	2.49	2.16	2.44	0.09	0.55
Neck	4.35	4.82	4.23	4.86	5.05	0.14	0.33
Wings	6.86	8.63	8.73	8.54	8.16	0.26	0.11
Thighs	12.10^{ab}	12.77^{a}	10.77^{b}	11.63^{ab}	11.41^{ab}	0.24	0.02
Drumsticks	9.97	10.42	10.21	10.23	10.64	0.14	0.69
Breast	22.64	24.17	24.01	24.13	22.92	0.50	0.84
Back	15.50	15.46	16.02	15.22	14.84	0.37	0.93
Shank	3.29^{b}	3.42^{ab}	3.81^{ab}	3.48^{ab}	3.97^{a}	0.10	0.02
Internal Organs (%)							
Liver	1.98	2.24	1.92	2.06	2.01	0.08	0.79
Lungs	0.49	0.48	0.61	0.54	0.53	0.02	0.51
Heart	0.39^{ab}	0.31^{b}	0.41^{a}	0.32^{b}	0.38^{ab}	0.01	0.03
Gizzard	1.94	1.71	1.75	1.80	1.77	0.04	0.50
Abdominal fat	1.18	0.88	0.89	0.97	0.94	0.08	0.83

Note: ^{abc} Means within row with different superscript differ significantly

Table 3. Concentration of some minerals in organs and muscles of broiler chickens fed diet supplemented with nano zinc oxide

		Levels of dietary Nano Zinc supplementation(mg kg^{-1})						
Parameter	Minerals (mg dL^{-1})	0	40	60	80	100	SEM	*P*-value
Heart	Ca	10.70	8.37	10.93	14.07	10.93	1.39	0.84
	Zn	116.83	190.53	139.10	176.27	140.53	12.31	0.34
	Cu	50.20^{b}	108.97^{a}	89.50^{ab}	106.23^{a}	108.23^{a}	7.96	0.06
Kidney	Ca	13.43	7.47	14.67	12.27	8.67	1.19	0.26
	Zn	154.00	144.80	144.13	131.80	109.97	13.40	0.90
	Cu	51.40^{b}	101.63^{a}	92.97^{ab}	106.17^{a}	106.00^{a}	7.62	0.09
Liver	Ca	13.97	18.10	7.10	13.83	8.30	2.37	0.63
	Zn	110.90^{b}	218.63^{a}	171.40^{ab}	227.00^{a}	176.33^{a}	16.74	0.02
	Cu	49.83^{b}	110.57^{a}	95.23^{ab}	117.30^{a}	96.83^{a}	8.55	0.04
Breast Muscle	Ca	10.10	8.63	13.67	12.47	11.00	1.15	0.73
	Zn	61.23	119.07	93.93	81.87	77.33	10.03	0.50
	Cu	52.33^{b}	106.27^{a}	93.17^{ab}	100.10^{a}	102.90^{a}	7.48	0.01

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

Table 4. Tibia morphometry of broiler chickens fed diet supplemented with nano zinc oxide

	Levels of dietary Nano Zinc supplementation(mg kg^{-1})						
Parameter	0	40	60	80	100	SEM	*P*-value
Tibia weight	8.00	8.00	8.67	9.33	10.00	0.37	0.38
Tibia length	9.30^{b}	9.53^{ab}	9.63^{a}	9.70^{a}	9.63^{a}	0.05	0.04
Tibia width	8.33^{ab}	7.74^{b}	9.24^{a}	8.70^{a}	9.20^{a}	0.19	0.02
Tibia bone index	4.17	4.23	4.49	5.10	5.43	0.34	0.27
Robusticity index	4.65	4.77	4.69	4.60	4.47	0.31	0.24

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

Reduced abdominal fat among birds supplemented dietary nano zinc agrees with the report of Liu et al. (2011) stating that nano zinc oxide has the tendency to influence fat metabolism in the liver and enhance lipid synthesis resulting in more lean meat and reduced fat level of broilers.

Nano minerals have the capability to move into the blood, lung, heart, kidney, liver and stomach after absorption in the small intestine (Hillyer and Albrecht, 2001) but the rate of assimilation substantially differs in body tissues (Janer et al. 2014) due to interactions among minerals and that has an impact on their availability in the diet (Underwood and Suttle, 1999). The retention of zinc in this study is in consonance with the report of Kim and Patterson (2004) that dietary Zn levels did not influence Zn concentration in breast muscles of broilers, but in contrast with Sandoval et al. (1998) and Sunder et al. (2008) who observed linear increase in the zinc content of liver and kidneys of broilers.

The general low copper residue found in the organs of the control birds shows that the supplementation of zinc in diet of broiler chickens increases the absorption and retention of copper in organs of birds. Similar concentration of copper and zinc in organs of broiler chickens irrespective of the level of supplementation of nano zinc contradicts previous studies (O'Dell, 1984; Cousins, 1985; Ao et al., 2009) that zinc uptake and absorption are enhanced at lower levels of zinc supplementation. The range of the levels of supplementation adopted in this study might not be large enough to yield significant variation.

Morgan et al. (1969) observed that calcium retention increased with Zn supplementation in pig diets. This negates no variation in calcium retention in tissues of broiler chickens observed in this study. It also contradicts Underwood (1981) report that excess zinc interferes in the utilization and absorption of both calcium and phosphorus.

In broiler chickens, deficiency of Zn could induce shortening and thickening of tibia bones (Scott et al.,1982), though if dietary Cu and Fe are sufficient, Zn deficiency may not influence tibia bone breaking strength due to the shortening and thickening of the tibia bone (Bao et al., 2009).

Significant effect observed in the length and width of tibia bones in this study is in consonance with the studies carried out by Wang et al. (2002) and Scrimgeour et al. (2007) that zinc improved mechanical traits of bones with an assertion that reduction in bone integrity, bone density and bone length is associated with lower zinc dietary supplementation.

Though bone weight and robusticity did not significantly vary due to the supplementation of nano zinc in the diet of broiler chickens, the values increased numerically, which indicates the tendency of nano zinc to improve the weight and robusticity of tibia bones in broiler chickens. This could be a reflection of the role of zinc in bone development. According to Ma and Yamaguchi (2000), zinc functions in the synthesis of DNA in osteoblast and increases bone weight.

Conclusions

It can be concluded that carcass yield, particularly components of economic value were not influenced by dietary nano zinc supplementation. Calcium and zinc in broiler organs were equally not significantly affected by the supplementation of nano zinc. However, copper retention significantly increased in organs of broiler chickens supplemented nano zinc oxide. Higher dosages (60, 80 and 100 mg kg^{-1}) of nano zinc supplementation in the diet of broiler chickens improved the tibia bone morphometry.

This study therefore recommends 60 mg kg^{-1} dietary supplementation of nano zinc for improved bone morphometry while supplementation at the rate of 80 mg kg^{-1} is suggested for better copper retention in organs and muscles of broiler chickens.

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