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Effect of dietary organic selenium on growth performance, antioxidant status and carcass characteristics of broiler chicken reared in the tropics

N W ANIZOBA[1]✉, N E IKEH[1], C EZENWOSU[1], F U UDEH[1] and N S MACHEBE[1]

Department of Animal Science, Faculty of Agriculture, University of Nigeria, Nsukka, Enugu State, 410001, Nigeria

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ABSTRACT

An experiment was conducted to determine the effect of dietary organic selenium inclusion on growth performance, antioxidant capacity, selenium retention and carcass characteristics in broiler chicken. Day-old broiler birds (160) were distributed randomly into four equal groups (T_1, T_2, T_3 and T_4) comprising of four replicated pens with ten birds in each. Different treatment groups of birds were designated as T_1 (Basal diet without selenium-enriched yeast), T_2 (Basal diet with 0.50 mg/kg selenium enriched yeast), T_3 (Basal diet with 1.00 mg/kg\ selenium enriched yeast) and T_4 (Basal diet with 1.50 mg/kg selenium enriched yeast) for 56 days. The results revealed that final body weight, weight gain and feed conversion ratio were significantly enhanced for birds in T_2 at both stages than other groups. T_4 group showed highest glutathione peroxidase, catalase, superoxide dismutase and selenium concentration with lower malondialdehyde concentration compared to birds receiving other treatments. Carcass traits such as live weight and dressed weight significantly improved in T_2 whereas relative weights and lengths of organs increased as level of organic selenium increased. Therefore, it can be concluded that adding 1.50 mg/kg selenium yeast enhanced growth, oxidative status, selenium deposition, carcass and organ traits without having a negative impact on the birds' physiological state.

Keywords: Antioxidant, Broiler chicken, Carcass characteristics, Growth performance, Mineral nutrition

In poultry production, heat stress is quite prevalent and becoming more severe in both tropical and subtropical locations (Wasti *et al.* 2020). In view of these, animal nutritionists have seen the need to supplement trace minerals in diet of poultry chickens, as a management strategy to alleviate the impact of environmental stressors on birds and to increase production (Shakeri *et al.* 2020). Selenium is essential for several metabolic processes that occur in animals, including antioxidant defense, cellular turnover and thyroid metabolism (Kieliszek and Bano 2022). In a recent human study by Ju *et al.* (2017), it was found that selenium has positive health benefits in the development of coronary heart disease by reducing oxidative stress and inflammation and improving the protection of coronary arteries in cardiac disease. Researchers are now interested in boosting the selenium content in human diets by changing the dietary selenium sources and amounts supplied to livestock (Pecoraro *et al.* 2022). More so, higher quantities of selenium are anticipated to be needed to provide high-quality chicken meat given that fast-growing genotypes currently being bred have faster metabolic rates and may, therefore, be more prone to reactive oxygen species formation (Wasti *et al.* 2020).

Present address: [1]Department of Animal Science, University of Nigeria, Nsukka, Nigeria. ✉Corresponding author email: nnenna.nnajiofor@unn.edu.ng

Available literatures on the effect of selenium inclusion in diet of broiler chicken in the tropics are inconsistent (Suchý *et al.* 2014) and available results remain inconclusive. The maximum selenium content permitted in chicken feed cannot exceed 0.5 mg/kg, as per European Union standards, in order to assure the safety of the feed. Michalczuk *et al.* (2021) suggested that supplementing the feed of chicken more than this limit (from 0.7 to 1 mg/kg diet) may still have some positive effects or not have a negative effect on the poultry. However, conducting further research will inform on the benefits of selenium-enriched organic broiler meat as a functional organic food for human consumption and also offer a theoretical basis for selenium supplementation in poultry diets, especially in humid tropical environments. Thus, this study aimed to ascertain effects of organic selenium on broiler chicken growth performance, serum antioxidant levels and carcass characteristics.

MATERIALS AND METHODS

Experimental management, birds and diets: This research was carried out in accordance with the recommendations of research ethics for scientific researchers involving animal subjects. The animals used were handled (No: UNN/C026ARO12.07.02.2023) in line with the principles of Animal Experimentation Ethics Committee of University of Nigeria, Nsukka (Research

Ethics Committee Recommendations, 2013).

A total of 160 broiler chicks were distributed at random into four treatments groups of 40 birds each and replicated four times with 10 birds per replicate. The dietary treatments were $T_{1:}$ Basal diet without selenium-enriched yeast, T_2: Basal diet with 0.50 mg/kg selenium enriched yeast, $T_{3:}$ Basal diet with 1.00 mg/kg selenium enriched yeast and T_4: Basal diet with 1.50 mg/kg selenium enriched yeast. All the standard management practices, including vaccination were followed during the experimental period. Chicks had unlimited access to feed and water throughout the feeding trial. Feeding was done in two-phased manner, viz. starter (0 to 28 days) and finisher (29 to 56 days). The diets were formulated to meet the nutrient requirements of broiler chicken according to NRC recommendations (NRC 1994) except for selenium (the NRC's selenium requirement is 0.15 mg/kg).

Chemical analyses of experimental diets: The representative samples of feed were analyzed for chemical composition using standard procedures. For dry matter determination, samples were analyzed according to the procedure of AOAC (method 930.15) (AOAC 2016). Gross energy was determined in an adiabatic bomb calorimeter (Gallenkamp Autobomb, Weiss Gallenkamp Ltd., UK) using benzoic acid as a calibration standard. Crude protein was analyzed according to the procedure of AOAC (method 954.01) (AOAC 2016). Ash content was determined by method 942.05 of AOAC (AOAC 2016) using a muffle furnace at 600°C for 16 h. Ether extract was analyzed according to the procedure of AOAC (method 920.39) (AOAC 2016). Crude fibre was analyzed by following the standard procedure (method 2002.04) (AOAC 2016). For mineral analysis, samples were first ashed and digested with HCl, phosphorus and calcium contents were determined by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) using a Thermos Jarrell instrument (method 968.08D) (AOAC 2005). The ingredient and nutrient composition of basal diet fed to experimental birds are shown in Tables 1 and 2.

Growth performance indices: Performance indicators such as body weight (BW), feed intake (FI) were recorded at weekly interval up to 8th week. The feed consumed per kg of body weight gain was used to compute the feed conversion ratio (FCR). The growth performance of the broiler starter was assessed at 28 d while that of the finishers was assessed at the end of 56 d of growth of birds with 28 d as 0 d of finisher growth phase.

Analysis of blood oxidative enzymes parameters: At 28 and 56 d of the experiment, five birds from each pen were selected randomly (total of 20 birds per treatment) for blood analysis. Blood samples (3 ml) were collected from each bird at slaughter into 15 ml anti-coagulant free vial bottle. Serum was harvested by centrifugation of the blood at 1800 × g. The serum was analyzed for the concentrations of catalase (CAT) (Cohen *et al.* 1970), superoxide dismutase (SOD) (Madesh and Balasubramanian 1998), malondialdehyde (MDA) (Suleiman *et al.* 1996), reductase

Table 1. Ingredients composition (g/kg) of basal diet of broiler chicken

Ingredient (g/kg)	Starter (0 to 28 d)	Finisher (29 to 56 d)
Maize	460	570
Soybean	160	140
Wheat	50	50
Groundnut cake	200	120
Palm kernel cake	50	50
Fish meal	30	20
Bone meal	40	40
Salt	2.5	2.5
Vitamin and mineral premix*	2.5	2.5
Methionine	2.5	2.5
Lysine	2.5	2.5
Total	1000	1000

*Calculated values; Vitamin and mineral premix per kg of diet: vitamin A: 1000 IU; vitamin D_3: 2500 IU; vitamin B_1: 0.90 g; vitamin B_2: 10 g; Nicotinic acid: 20 g; vitamin B_{12}: 0.025 g; K_3: 2 g; vitamin E: 30 g; Biotin: 0.020 g; Folic acid: 0.5 g; Calcium pantothenate: 10.5 g; Choline chloride: 300 g; Manganese: 80 g; Cobalt: 0.5 g; Copper: 6 g; Iron: 40 g; Zn: 60 g; Iodine: 0.5 g; DL-methionine: 80 g and Lysine: 160 g.

Table 2. Chemical composition of basal diet of broiler chicken

Chemical composition (%)	Starter (0 to 28 d)	Finisher (29 to 56 d)
Dry matter (%)	89.25	90.11
Protein (%)	22.60	18.23
Ether extract (%)	4.55	5.65
Crude fibre (%)	5.00	6.00
Ash (%)	4.00	6.00
Calcium (%)	0.93	0.90
Phosphorus (%)	0.45	0.35
Selenium (mg/kg)	0.02	0.03
Gross energy (MJ/kg)	11.29	12.14

(Lin *et al.* 1988), gluthathione peroxidase (GSH-Px) (Paglia and Valentine 1967) using Randox Laboratories Systems Commercial Kit (County Antrim, UK). Selenium concentrations in the blood samples were determined by inductively coupled plasma emission spectrometry (Optima 4300 DV Dual View ICPOE spectrometer, Perkin-Elmer, Beaconsfield, UK), as described by Tanner *et al.* (2002).

Carcass and organ traits assessment: At 28 and 56 d of the experiment, four representative birds from each replicate (total of 16 birds per treatment) were sacrificed for evaluation of carcass yield parameters and organ characteristics. After subjecting them to water dietary regimen for 12 h, the birds were humanely slaughtered by rupture of the jugular vein and after bleeding and deplumation, were eviscerated and carcass and organs weighed on a digital scale to the nearest 0.01 g. The weights of different organs (heart, liver, spleen, kidney, gizzard, small intestine and large intestine) were recorded by separating them from carcass and expressed as a percentage by the following formula:

Relative weight of organ = [(Organ weight/Live weight)× 100]

Statistical analysis: The experimental data obtained were subjected to one-way analysis of variance (ANOVA) for completely randomized design (CRD) using Statistical Analysis Systems (SAS/STAT Version 20.0, 2012 edition SAS Institute, Cary, NC, USA) using the following model:

$$Y_{ij} = + T_i + e_{ij}$$

where, $Y_{ij,}$ observation associated with each parameter; μ, overall mean; $T_{i,}$ effect of i^{th} treatment group (i=1, 2, 3 & 4); and $e_{ij,}$ random error.

Significant treatment effects were detected by Duncan's multiple range tests. Differences were considered statistically significant at $p<0.05$. The results were presented as mean values with standard error.

RESULTS AND DISCUSSION

Growth performance: The effect of dietary organic selenium on growth performance of broilers were summarized in Table 3. In both phases, final BW and WG were better in selenium treated groups compared to the control group ($p<0.05$) while in the finisher phase, FCR was significantly lower ($p<0.05$) in the selenium treated groups compared to the control group. Improved performance in average final BW, WG and FCR observed in broilers fed supplementary selenium diet were in agreement with Arnaut *et al.* (2021) who found that organic Se increased daily WG and FI in broiler chicken after 42 days of feeding. The effect of selenium on growth rate may be due to its action in the expression of selenoprotein P and selenoenzyme type 1 iodothyronine deiodinase, which are necessary for the synthesis of thyroid hormone and Se transport (Santos *et al.* 2018). Furthermore, our results of increased growth performance with organic selenium could possibly be due to an increased thyroid hormone regulating the body's energy metabolism and increased digestibility of protein (Saleh 2014).

At the starter phase, FI was significantly ($p<0.05$) higher for the selenium treated groups compared to the untreated group of birds confirming other reports by Khan *et al.* (2023). Their findings concur with our current report in this study and this could be that selenium in the form of selenocystein is known to play an important role in feather formation (Choct and Naylor 2004) and acts on the mechanisms involved in thyroid hormone stimulation, secretion and release (Song *et al.* 2006). The higher feathering and increased activity of thyroid hormone stimulation led to increased growth of birds and higher protein turnover in the treated birds compared to the untreated groups of birds during early growth. Previous researchers (Downs *et al.* 2000, Naylor *et al.* 2000) reported that basal metabolic rate increases during periods of feather growth to provide energy for feather production to keep the animal warm and thus birds would increase FI to maintain their physiological balance and growth during this period.

Whereas at the finisher phase, FI was significantly ($p<0.05$) lower for the selenium treated groups compared to the untreated group. This may be due to the fact that as feather cover grows, the basal metabolic rate declines and less heat is produced as a result of a decline in oxidative metabolism, which leads to a lower FI. Huang *et al.* (2022) reports indicate that as an antioxidant agent, selenium

Table 3. Effect of organic selenium on growth performance of broilers

Parameter	Treatment					
	T_1	T_2	T_3	T_4	SEM	p-value
Starter phase (1-28)						
N.160						
Initial body weight (g)	43.7	43.5	42.8	42.5	0.46	0.910
Final body weight (g)	730.6^{b}	828.1^{a}	851.1^{a}	787.1^{ab}	10.2	0.020
Average daily gain (g)	42.6^{b}	48.8^{a}	48.5^{a}	44.5^{ab}	1.57	0.021
Average feed intake (g)	76.0^{c}	88.2^{a}	81.3^{b}	80.3^{b}	1.23	0.023
Feed conversion ratio	1.78	1.80	1.67	1.81	0.03	0.612
Finisher phase (29-56)						
N.96						
Initial body weight (g)	824.1	828.1	825.1	822.1	8.87	0.280
Final body weight (g)	2267.4^{c}	3092.1^{a}	2889.8^{b}	2454.6^{bc}	11.9	0.001
Average daily gain (g)	70.3^{c}	88.9^{a}	80.7^{ab}	77.5^{bc}	2.37	0.002
Average feed intake (g)	161.2^{a}	142.2^{b}	158.6^{ab}	141.2^{b}	0.72	0.040
Feed conversion ratio	2.29^{a}	1.59^{bc}	1.96^{b}	1.82^{b}	0.21	0.002
Global (1-56)						
Initial body weight (g)	43.7	43.5	42.7	42.5	0.46	0.131
Final body weight (g)	2265.7^{c}	3092.8^{a}	2887.9^{b}	2483.6^{bc}	11.8	0.015
Average daily gain (g)	112.9^{c}	137.7^{a}	129.2^{b}	122.1^{b}	4.34	0.020
Average feed intake (g)	237.2^{a}	230.4^{ab}	239.9^{a}	221.5^{b}	2.68	0.005
Feed conversion ratio	2.10^{a}	1.67^{c}	1.86^{b}	1.81^{bc}	0.43	0.002

$^{a-c}$, Means with different superscripts in a row differ significantly ($p<0.05$).

Table 4. Effect of organic selenium on serum antioxidant indices of broilers

Parameter	Treatment					
	T_1	T_2	T_3	T_4	SEM	p-value
Starter phase (1-28)						
N.80						
Catalase (U/L)	11.6	11.7	11.7	11.6	0.15	0.062
Superoxide dismutase (U/L)	0.64^{c}	0.68^{c}	0.76^{b}	0.79^{a}	0.06	0.042
Malondialdehyde (U/L)	1.16^{a}	1.10^{a}	0.92^{b}	0.86^{b}	0.71	0.038
Reductase (U/L)	0.64	0.53	0.53	0.58	1.18	0.110
Selenium (U/L)	1.60	2.03	1.83	1.98	0.19	0.106
Gluthathione peroxidase (U/L)	8.50	8.78	8.46	8.61	1.99	0.061
Finisher phase (29-56)						
N.80						
Catalase (U/L)	11.8^{c}	11.9^{bc}	12.1^{b}	12.3^{a}	0.07	0.004
Superoxide dismutase (U/L)	1.09^{b}	1.11^{b}	1.12^{b}	1.15^{a}	0.05	0.009
Malondialdehyde (U/L)	2.71^{a}	2.08^{ab}	1.38^{b}	0.75^{c}	0.29	0.019
Reductase (U/L)	1.21	0.60	0.70	0.80	0.16	0.102
Selenium (U/L)	1.98^{c}	3.92^{b}	4.23^{ab}	4.95^{a}	0.71	0.020
Gluthathione peroxidase (U/L)	8.21^{b}	10.7^{a}	10.7^{a}	10.7^{a}	0.45	0.048

$^{a-c}$, Means with different superscripts in a row differ significantly ($p<0.05$).

protects nutrient from oxidation and play a crucial role in the maintenance of homeostatic body conditions resulting in greater feed utilization and muscular growth in animals as witnessed in our study.

Blood profile: MDA and SOD activity were significantly ($p<0.05$) improved at 28 d while the remaining parameters were found to differ non-significantly ($p>0.05$) among all treatment groups. There was no significant ($p>0.05$) difference for reductase in both stages (Table 4). At 56 d, a high variation ($p<0.05$) in CAT, SOD, MDA, and GSH-Px levels were shown among treatments. Serum selenium concentrations was significantly ($p<0.05$) improved with increased levels of selenium. In line with our study, documented evidence (Liu *et al.* 2023, Milinkovic Tur *et al.* 2009) showed that dietary supplementation with selenium impacts on the blood concentration of oxidative enzymes (CAT, SOD, MDA, reductase, and GSHPx) and selenium in broiler birds. Higher concentration of SOD and CAT were observed in birds exposed to higher amount of selenium supplementation (1.50 mg/kg) which reduced the oxidative stress in chicken, most likely by scavenging superoxide ions and preventing the generation of oxygen-free radicals by reacting with hydrogen peroxide to produce water and molecular oxygen (Milinkovic Tur *et al.* 2009, Timur and Utlu 2020) while, catalase reacts with generated hydrogen peroxide to form water and molecular oxygen thereby protecting the cells against hydrogen peroxide toxicity and lipid peroxidation (Yamaguchy 1991).

A significantly improved GSH-Px concentration at 56 d was observed in the supplemented groups than that in the control groups of broilers indicating the presence of higher oxidative stress in mature broiler chicken. This may be attributed to the ability of selenium to confer adequate antioxidant protection against lipid peroxidation during thermal heat. GSH-Px fundamental task is removal of excessive peroxide and hydrogen peroxides of fatty acids produced from oxidative removal of lipids (De Almeina *et al.* 2012). The initial line of defense against free radical damage is comprised of GSH-Px, SOD, and CAT activities. These activities are critical in shielding cells and tissues from the damaging effects of these radicals. Therefore, higher levels of these enzymes in blood or tissues indicate a strong antioxidant capacity (Surai 2015).

Endogenous malondialdehyde (MDA) is a reflection of lipid peroxidation, which leads to a decrease in antioxidant defense when reactive oxygen species (ROS) concentration rise. (Suchy *et al.* 2014). There was significant ($p<0.05$) decrease in MDA levels in the blood with increased levels of selenium at both phases which showed the presence of Se. methionine and Se. cysteine which are more bioavailable and can increase the levels of antioxidants and lower the production of lipid peroxidation products (Zoidis *et al.* 2018).

No significant ($p>0.05$) effect of organic selenium on GSH-Px and selenium concentrations were observed at starter phase indicating that young chicks are less vulnerable to oxidative stress compared with broilers at slaughter age. At 56 d, the improved serum Se levels observed indicates accumulation of minerals in the tissues which is considered an indicator for mineral utilization (Liu *et al.* 2023). However, inclusion levels of organic Se increased the serum Se blood concentration which caused an increase in production of GSH-Px activity to counter the activities of ROS and lipid peroxidation in the animal body thereby maintaining homeostasis needed for adequate growth and production of the birds.

Carcass and organ characteristics: In the early stage (0 to 28 d), no significant ($p>0.05$) effect were recorded on the carcass and organ traits of broiler birds supplemented with selenium (Table 5) Selenium supplementation in diets as a

Table 5. Effect of organic selenium on carcass and organ traits of broilers

Parameter	Treatment					
	T_1	T_2	T_3	T_4	SEM	p-value
Starter phase (1-28)						
N.64						
Live weight (g)	830.3	888.2	875.2	878.3	14.8	0.113
Dressed weight (g)	532. 1	570. 2	549.3	561.3	25.4	0.327
Dressing (%)	64.1	64.2	62.8	63.9	0.69	0.117
Kidney weight (%)	0.12	0.12	0.11	0.11	0.05	0.101
Liver weight (%)	1.43	1.44	1.54	1.40	0.04	0.143
Heart weight (%)	0.35	0.36	0.36	0.36	0.06	0.122
Gizzard weight (%)	2.02	2.13	2.07	2.05	0.04	0.111
Small intestine weight (%)	1.62	1.65	1. 63	1. 65	0.14	0.143
Large intestine weight (%)	2.42	2.56	2.47	2.55	0.29	0.664
Small intestine length (cm)	168.4	172.1	171.4	170.8	1.89	0.192
Large intestine length (cm)	7. 44	8.76	8.81	8. 55	0.47	0.159
Finisher phase (29-56)						
N.64						
Live weight (g)	2276.6^{c}	3226.7^{a}	2700.1^{b}	2373.3^{c}	62.4	0.001
Dressed weight (g)	1832.3^{c}	2669.3^{a}	2217.7^{b}	1937.1^{c}	65.2	0.001
Dressing (%)	80.5^{b}	82.3^{a}	82.2^{a}	81.6^{ab}	0.41	0.040
Kidney weight (%)	0.14^{c}	0.14^{c}	0.16^{b}	0.20^{a}	0.03	0.001
Liver weight (%)	2.29	2.38	2.47	2.51	0.06	0.102
Heart weight (%)	0.36^{b}	0.37^{b}	0.38^{b}	0.43^{a}	0.01	0.001
Gizzard weight (%)	2.61	2.69	2.71	2.74	0.03	0.120
Small Intestine weight (%)	2.71^{b}	2.79^{b}	2.84^{ab}	2.94^{a}	0.04	0.002
Large intestine weight (%)	4.46^{b}	4.65^{a}	4.68^{a}	4.75^{a}	0.05	0.004
Small intestine length (cm)	242.1^{c}	252.1^{bc}	255.3^{ab}	265.7^{a}	1.85	0.002
Large intestine length (cm)	10.1^{b}	11.3^{b}	13.7^{a}	12.9^{a}	0.92	0.001

$^{a-c}$, Means with different superscripts in a row differ significantly ($p<0.05$).

positive means of improving carcass and organ attributes in broilers has been documented (Ibrahim *et al.* 2011, Arnaut *et al.* 2021). The earlier reports and our findings may not have been consistent since their basal diet was lacking in Se, whereas in the current study, birds received the minimal amount of selenium needed in the basal diet though a little below the NRC 1994 level which affirms that 0.1 mg/kg of selenium in the feed is the minimum necessary for broiler development and performance. The Se concentration in our basal diet was 0.02 at starter phase and this might be the reason our control group did not exhibit any signs of Se deficiency.

In harmony with reports by these workers, our finding shows that selenium supplementation ($p<0.05$) improved carcass traits namely, final body weight, feed efficiency and dressed weight in finisher broilers. Antioxidant properties of Se may have enhanced development in carcass characteristics since production data show improved FI and FCR in selenium treated birds and this is in consonant with report by Khan *et al.* (2023) which observed an improved feed efficiency in broilers fed 0.2 mg/kg selenium diet. Conversely, Heindl *et al.* (2010) reported that selenium supplementation positively influenced carcass weight but not dressing %, liver and heart weights. These differences may be accounted for by variation in body weights, sex, age and nutrition. Naji *et al.* (2007) noted that dressed weight differs according to the live body weight of broiler, sex, and age of broiler at marketing, and generally would increase by increases in live body weight and by advancing age of broiler.

While the liver and gizzard weights were not affected by the selenium supplements, other organs characteristics (kidney, heart, small and large intestine weights and length) were higher from 1.00 to 1.50 mg/kg. It may be gathered from these results that selenium has a direct stimulatory effect on the kidney, heart and the gastrointestinal tract thereby enhancing proliferation of vital cells in these organs (Zhang *et al.* 2023). Earlier research reports in literature (Minich 2022) indicate that the immediate action of selenomethionine (organic selenium) upon absorption in the digestive tract is that the fraction not immediately used for the synthesis of specialized selenoprotein is incorporated non-specifically into the structural proteins of muscles, heart, kidney and other organs.

Altogether, the current findings clearly show that the addition of selenium in diet of broilers during production increased growth performance, oxidative enzyme status, selenium retention and carcass and organ characteristic of the broiler chickens. Our results suggested that supplementation of organic Se up to 1.50 mg/kg in the

basal diet of broiler chickens during production could be utilized as a nutritional management practice to increase Se content in human food 'functional foods', reduce stress and increased growth and carcass attributes in broilers particularly in environments in which the birds are vulnerable to stress.

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