Response of finisher broilers to diets containing varying levels of toasted Bambara nut (*Vigna subterranean*) waste

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ABSTRACT

The feeding trial was conducted for twenty-eight (28) days with one hundred and twenty (120) 4-week-old Anak® strain broilers. The feeding trial determined the proximate composition of the Bambara nut waste (BNW) and evaluated the performance, hematology, and serum biochemistry of broilers fed toasted BNW. Five diets were compounded, which contained 0, 5, 10, 15, and 20% of toasted BNW. There were twenty-four birds in each treatment and eight birds per replicate. There were three replicates per treatment. The experimental design was a completely randomized design (CRD). The proximate composition of the experimental diets showed dry matter values 89.21–90.50%, crude protein 20.10–22.32%, crude fiber 4.21–4.40%, ether extracts 5.60–7.95%, ash 5.46–7.78%, and nitrogen-free extract 50.37–51.71%. There were significant differences ($P < 0.05$) among treatments in final body weight (FBW), daily weight gain (DWG), daily feed intake (DFI), and feed conversion ratio (FCR). FBW ranged from 1,432.14 (20% BNW) to 1,594.05 g (0% BNW), DWG from 34.25 (20% BNW) to 39.00 g/day (0% BNW), DFI from 148.51 (0% BNW) to 157.62 g (20% BNW), and FCR from 3.83 (0% BNW) to 4.60 (20% BNW). Significant differences ($P < 0.05$) were found among treatments in packed cell volume, hemoglobin, white blood cell, red blood cell, mean corpuscular volume, mean corpuscular hemoglobin concentration, and mean corpuscular hemoglobin. There were significant differences ($P < 0.05$) among treatments in all serum biochemical parameters. Toasted BNW resulted in lighter birds at 8 weeks than the control except at 5%, but with appreciable live weight and daily weight gains still achieved even at 20% inclusion. However, BNW inclusion did not negatively impact the health status of the birds, even at the 20% inclusion level. BNW diets were cheaper per kilogram but feeding them was not as economical as the control due to higher feed intake. The use of toasted BNW is hereby recommended for broiler production, where it is very cheap.

Keywords: Broilers, Bambara nut waste, serum biochemistry, hematology, anti-nutritional factor

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INTRODUCTION

Rising costs of conventional feedstuffs used in broiler feed composition have led to an increase in the cost of animal protein due to the high cost of production. Therefore, the evaluation of potential alternatives that might replace some of these expensive and competitive conventional feedstuffs has become inevitable. Bambara nut waste (BNW), a by-product from milled and sieved shelled Bambara nut (*Vigna subterranea*) seed during the production of a local staple in Nigeria, may readily come to mind. *Vigna subterranea* seeds contain anti-nutritional factors

such as trypsin inhibitors, phytates, and tannins, including condensed tannins (Heuzé *et al.,* 2016). According to Heuzé *et al*. (2016), tannin content is correlated with coat color, the cream-colored seeds contain less tannin than brown or black seeds. Tannins are known to be deleterious to livestock performance (Hidayat *et al*., 2021). Nwanna *et al.* (2005) reported a high proportion of phytates in *Vigna subterranea* seeds which might reduce cation availability (Ca particularly). Feeding broilers and adult cockerels with raw *Vigna subterranea* seeds depressed feed intake, live weight gains, and feed conversion ratio compared to soybean meal because these indices are negatively correlated with trypsin inhibitors (Akanji *et al.,* 2007), which were deactivated by boiling or roasting (Bello *et al.,* 2005).

The waste (Bambara nut waste) from the milled and sieved seeds also contains these anti-nutritional factors since it also comprises the seed coat. Heat treatments such as boiling, roasting, or toasting are usually effective in destroying trypsin inhibitors (Heuzé *et al*., 2016; Oyewole and Omeje, 2022). According to Heuzé *et al*. (2016), cooking, soaking, milling, hulling, germination, and fermentation may reduce the concentration of anti-nutritional factors.

Feeding toasted BNW to broilers with enzyme supplementation improved its utilization. However, compared to the control, toasted BNW resulted in depressed weight gain, live weight, and feed conversion ratio, while feed intake increased. Economic parameters such as feed cost decreased while the cost of feed/kg gain increased. However, hematological indices were not adversely affected (Oyeagu *et al*., 2016). Toasted BNW was fed to layers at 0, 8, 16, 24, or 32%, and it was observed that it resulted in reduced feed cost/bird, production cost/bird/dozen eggs, and revenue from eggs. A diet containing 16% toasted BNW was the most economical, while the control (0%) was the least. Egg weight and shell weight were significantly ($P < 0.05$) affected by the treatments but not shell thickness, yolk height, yolk diameter, yolk index, yolk color, albumen height, and albumen weight (Oyewole *et al.,* 2016).

Bambara nut waste is readily available in the study location due to the high production of Bambara nut and its use in the preparation of local staples. The waste, if not used for livestock feeding, is of no nutritional use to man and may have to be discarded. The use of BNW for poultry feeding, therefore, became imperative in the generation of wealth and production of meat for man, besides being an avenue to prevent environmental pollution. There was a need to ascertain how safe BNW was through the evaluation of the hematological and serum biochemical profile of the birds (broilers). The feeding trial sought to evaluate the performance, hematology, and serum biochemistry of finisher broilers fed graded levels of toasted Bambara nut waste meal diets.

MATERIALS AND METHODS

The Poultry Unit of the Livestock Teaching and Research Farm of the Department of Animal Production, Prince Abubakar Audu University Anyigba, Kogi State, Nigeria, was used for the feeding trial. Anyigba is located in the derived savanna zone of Nigeria on latitude 7° 30' N and longitude 7° 09' E (Microsoft Encarta Premium, 2009).

Bambara nut waste was obtained from milled seeds of Bambara nut after sieving. The finer particles were used in the preparation of a local staple. The leftover or offal is referred to as BNW. The BNW was then poured into an open fry pan placed over the burning fire and stirred continuously until the color changed to yellowish brown with a nutty aroma. Five experimental diets were compounded for the feeding trial in such a way that toasted Bambara nut was included at 0, 5, 10, 15, and 20% in the finisher broilers' experimental diets (Table 1). The toasted test ingredient (Bambara nut waste) was sieved to pass through a 2 mm sieve after allowing it to cool (Oyewole *et al.,* 2017).

Experimental Birds, Design and Management

One hundred and twenty 28-day-old broilers were randomly assigned to three replicates for each of the five treatments, such that there were eight (8)

birds per replicate and twenty-four (24) birds per treatment. The feeding trial was terminated when the birds were 56 days old. The birds were weighed at the commencement of the experiment. The experiment was laid out in a completely randomized design. The birds were reared on deep litter. The feeding trial was conducted for twenty-eight (28) days between December 2021 and January 2022. Feed and portable clean water were supplied *ad libitum* during the feeding trial.

Proximate Composition of the Experimental Diets

Samples of BNW and the experimental diets were analyzed for proximate composition according to the method of AOAC (2010).

Performance Data Collection

Performance data collected were weight gain and feed conversion ratio (FCR). Weight gain was computed by subtracting the initial weight from the final weight of the bird, dividing weight gain by the product of the number of birds, and the number of days of the feeding trial gave daily weight gain (DWG) per bird. Feed intake was estimated by using feed offered less feed left over. A similar denominator as in DWG was used to divide the feed intake value to arrive at the daily feed intake (DFI) per bird. The FCR was obtained by dividing the quantity of feed consumed by the weight gained.

Table 1 Percentage composition and metabolizable energy of finisher broilers experimental diets (%)

Composition	Toasted Bambara nut waste (%)				
	0	5	10	15	20
Ingredients					
Maize	44.90	39.90	34.90	29.90	24.90
Full-fat soybean	34.00	34.00	34.00	34.00	34.00
Toasted Bambara nut waste	0.00	5.00	10.00	15.00	20.00
Maize offal	17.00	17.00	17.00	17.00	17.00
Bone meal	3.30	3.30	3.30	3.30	3.30
Table salt	0.30	0.30	0.30	0.30	0.30
Methionine	0.20	0.20	0.20	0.20	0.20
Vitamin/mineral premix*	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Crude protein (%)	19.51	19.80	20.09	20.38	20.67
Ether extract (%)	3.28	3.41	3.54	3.67	3.80
Crude fiber (%)	4.10	4.32	4.53	4.75	4.96
Calcium (%)	1.31	1.31	1.31	1.31	1.31
Phosphorus (%)	1.02	1.00	0.99	0.98	0.96
Lysine (%)	1.14	1.12	1.11	1.10	1.09
Methionine (%)	0.55	0.55	0.54	0.53	0.52
Cysteine (%)	1.37	1.39	1.42	1.42	1.44
Metabolizable energy (kcal/kg)	3,113.47	3,093.89	3,074.30	3,054.72	3,035.14

Note: * Vitamin/mineral premix: vitamin A 10,000,000 IU, vitamin D3 2,200,000 IU, vitamin B2 10,000 mg, vitamin K3 2,000 mg, folic acid 500 mg, niacin 15,000 mg, calpain 500 mg, vitamin B12 10 mg, vitamin B1 1,500 mg, vitamin B6 1,500 mg, biotin 20 mg, antioxidant 12,500 mg, selenium 200 mg, iodine 100 mg, iron 40,000 mg, cobalt 200 mg, manganese 70,000 mg, copper 4,000 mg, zinc 50,000 mg, choline/chloride 150,000 mg.

Blood Collection for Hematological and Serum Biochemical Profiles

Blood collection was carried out on the twenty-eighth day of the feeding trial. Broilers, whose body weights were similar to the mean of each group, were selected per replicate, and blood samples were collected via the wing vein using a sterilized disposable needle. The site of blood collection was also sterilized with methylated spirit. Blood samples were delivered into a set of clean labeled bottles containing ethylene diamine tetra acetic acid (EDTA) for hematological evaluation using the procedures of Jain (1986). At the same time, samples for serum biochemical evaluation were delivered into bottles free from EDTA to allow for coagulation. Hematological parameters evaluated were packed cell volume (PCV), hemoglobin (Hb) white blood cell (WBC), red blood cell (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), neutrophils, and lymphocytes. The serum biochemical profile evaluated includes total protein, albumin, urea, creatinine, cholesterol, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and glucose (Ogunsanmi *et al*., 2002). Economic parameters such as feed cost/kg, feed cost/bird/day, total feed cost/bird, and feed cost/kg gain (Oyewole *et al*., 2012) were also estimated.

Data Analysis

Data obtained were subjected to statistical analysis of variance (ANOVA) at 5% probability level while Duncan's new multiple range test was used to separate the means where significant differences were observed using SPSS Version 20 Computer Statistical Software Package.

RESULTS AND DISCUSSION

Proximate Composition and Metabolizable Energy of Bambara Nut Waste, and Experimental Diets Fed to Finisher Broilers

The proximate composition of the BNW and experimental diets for finisher broilers is presented in Table 2. The observed dry matter for BNW was 89.71 ± 1.01%, which indicated sufficient dryness. Crude protein (CP) content was 14.99 ± 1.10%, which is moderate but also indicated that BNW cannot be used as a protein source. The crude fiber (CF) is 2.00 ± 0.54%. This may be due to the milling and sieving of the material before utilization. The observed ether extract (EE) was 3.58 ± 0.56%, while the nitrogen-free extract (NFE) was 67.02 ± 0.98%. These values may indicate the capacity of BNW to supply digestible carbohydrates, which may be a good source of energy. This position is supported by the value of 3,040.35 ± 2.10 kcal/kg metabolizable energy (ME) observed when the method of Pauzenga (1985) was used to estimate this parameter. For the experimental diets, dry matter (DM) ranged from 89.21 to 90.50%, indicating that all the diets were sufficiently dry to store for a long without becoming moldy. The CP ranged from 20.10 to 22.32%, indicating that the experimental diets were adequate in protein needed for body tissue formation and growth and carcass development (Njike and Ndife, 1980; Ofori *et al.,* 2019). Observed CF was 4.21–4.40%, which was adequate for the age of the birds. Hence the diets might be readily digestible and utilizable by the birds. The EE values were between 5.60 and 7.95% and may presuppose that the diets contained sufficient fat, which is required for heat and energy by the birds (Oyewole and Omeje, 2022), which consequently might enhance productivity and feed efficiency (NRC, 1994). Ash ranged from 5.46 to 7.78%, which may suggest the mineral content profile of the diets. The NFE values of 50.37–51.71% may suggest similar and adequate readily utilizable carbohydrates in the diets. Observed ME values ranged from 3,066.71 (10% BNW) to 3,175.79 (20% BNW) kcal/kg. ME values are adequate for finishers in this region (Njike and Ndife, 1980).

Performance of Finisher Broilers Fed Toasted Bambara Nut Waste Meal Diets

Table 3 shows the effects of experimental diets on the performance of finisher broilers. There was a significant difference ($P < 0.05$) among treatments in final body weight (FBW). The FBW

ranged from 1,432.14 to 1,594.05 g. Birds fed the control diet had the highest FBW, which declined as the inclusion of toasted BNW in the diets increased. It seems that this pattern can be attributed to the inclusion of toasted BNW, which was used to replace some quantity of maize. The same trend was observed for daily weight gain. It appears that the nutritional quality of maize in terms of soluble carbohydrates and energy is superior to toasted BNW. It is not likely that the presence of anti-nutritional factors resulted in these observations since the used Bambara nut waste was toasted. Oyewole and Omeje (2022) earlier observed that the inclusion of toasted BNW in a starter broiler diet depressed daily weight gain and live weight. Daily feed intake (DFI) increased ($P < 0.05$) in the toasted BNW groups (from 148.51 to 157.62 g/day), which may indicate that toasted BNW inclusion did not adversely affect acceptability and palatability of the diets nor depress the appetite of the birds. The FCR was significantly affected ($P < 0.05$) and ranged from 3.83 to 4.60. Graded levels 5, 10, and 15% BNW had similar FCR. Birds fed the control diet had the best FCR, a measure of feed utilization for growth that appeared to become poorer as the level of toasted BNW increased in the diet. This might suggest that the ability of the birds to utilize the diets diminished at higher inclusion of toasted BNW. This is not likely due to the fiber level because it was adequate.

Hematology of Finisher Broilers Fed Toasted Bambara Nut Waste Diets

The hematological profile of finisher broilers is shown in Table 4. There was a significant difference ($P < 0.05$) among treatments in PCV. The observed PCV ranged from 28.33 ± 0.57% (15% BNW) to 31.33 ± 1.53% (20% BNW). These values may indicate that toasted BNW diets did not have an adverse effect on the hematopoiesis of finisher broilers. The values observed fall within the range of 22–35% reported by Bounous and Stedman (2000) for healthy birds. Oyewole and Omeje (2022) reported a range of 30.00–31.33% for starter broilers fed toasted BNW diets. PCV is reported to be an index of toxicity in the blood with a high level above the normal range suggesting the presence of toxic factors (Oyawoye and Ogunkunle, 1998) and dehydration, while lower levels may indicate disease condition. However, the inclusion of BNW appeared to elevate PCV values. Hemoglobin was significantly influenced ($P < 0.05$) by the treatments. Values ranged from 9.43 to 10.43 g/dL. Hemoglobin values of the birds, though elevated due to BNW, did not indicate adverse effects on the health status due to the experimental diets. Hemoglobin values obtained fall within the normal range of 7–13 g/dL reported by Bounous and Stedman (2000) and 10.27–11.60 g/dL (Oyewole and Omeje, 2022) in a feeding trial with starter broilers fed toasted BNW diets. Consequently, toasted BNW did not result in anemia nor impair the function of hemoglobin to convey oxygen to different parts of the body and carbon dioxide to the site of expulsion.

The WBC values significantly differed ($P < 0.05$) among the treatments and ranged from 20.50 to 22.28 × 10^9/L. The WBC values obtained in this study were within the normal range of 12–30 × 10^9/L for healthy birds, and 21.06–22.86 × 10^9/L (Oyewole and Omeje, 2022). The observed WBC values, though higher for the control, did not compromise the immune status of birds to fight infection. Observed WBC values may indicate that the birds were healthy and adequately equipped to fight any infection. The observed RBC values were significantly ($P < 0.05$) influenced by the treatments (higher in the control), with values ranging from 2.33 (15% BNW) to 2.63 × 10^{12}/L (0% BNW). These values are similar to 2.33–2.63 × 10^{12}/L (Oyewole and Omeje, 2022) for starter broilers fed toasted BNW-based diets. RBC is also involved in the transport of oxygen, carbon dioxide, and other body nutrients as well as other metabolites. These functions were not adversely affected due to adequate hematopoiesis even in birds fed toasted BNW.

Table 2 Proximate composition and metabolizable energy of the experimental diets and Bambara nut waste

Parameters	Toasted Bambara nut waste (%)					Bambara nut waste
	0	5	10	15	20	
Dry matter (%)	89.56 ± 0.09	89.21 ± 0.06	89.44 ± 0.00	90.11 ± 0.16	90.50 ± 0.06	89.71 ± 1.01
Crude protein (%)	22.32 ± 0.03	21.92 ± 0.03	20.26 ± 0.04	20.15 ± 0.04	20.10 ± 0.01	14.99 ± 1.10
Crude fiber (%)	4.21 ± 0.01	4.22 ± 0.06	4.25 ± 0.00	4.30 ± 0.03	4.40 ± 0.01	2.00 ± 0.54
Ether extract (%)	5.60 ± 0.00	5.89 ± 0.01	6.39 ± 0.03	7.00 ± 0.04	7.95 ± 0.03	3.58 ± 0.56
Ash (%)	5.72 ± 0.06	6.51 ± 0.03	6.65 ± 0.28	5.46 ± 0.01	7.78 ± 0.06	2.12 ± 0.52
NFE (%)	51.71 ± 0.06	50.97 ± 0.03	50.69 ± 0.04	50.40 ± 0.06	50.37 ± 0.04	67.02 ± 0.98
ME (kcal/kg)	3,115.15 ± 1.01	3,097.57 ± 0.65	3,066.71 ± 2.50	3,101.75 ± 1.21	3,175.79 ± 0.45	3,040.35 ± 2.10

Note: NFE = nitrogen-free extract, ME = metabolizable energy: ME = 37% CP + 81 EE + 35.5NFE (Pauzenga, 1985).

Table 3 Performance of finisher broilers fed toasted Bambara nut waste diets

Parameters	Toasted Bambara nut waste (%)				
	0	5	10	15	20
Initial weight (g)	502.32 ± 47.19	500.00 ± 10.68	500.00 ± 27.19	500.08 ± 10.68	506.41 ± 49.03
Final weight (g)	1,594.05 ± 142.50^{a}	1,569.44 ± 118.70^{ab}	1,524.44 ± 66.30^{b}	1,522.38 ± 123.80^{b}	1,432.14 ± 36.20^{c}
Daily weight gain (g/day)	39.00 ± 6.62^{a}	38.19 ± 4.15^{ab}	36.58 ± 4.14^{b}	36.51 ± 4.22^{b}	34.25 ± 1.20^{c}
Daily feed intake (g/day)	148.51 ± 6.62^{b}	155.52 ± 5.98^{a}	154.07 ± 5.66^{a}	156.89 ± 4.64^{a}	157.62 ± 12.98^{a}
Feed conversion ratio	3.83 ± 0.52^{a}	4.07 ± 0.36^{b}	4.21 ± 0.21^{b}	4.30 ± 0.10^{b}	4.60 ± 0.52^{c}

Note: ^{a,b,c} Means on the same row with different superscripts are significantly different ($P < 0.05$).

The MCV was significantly different ($P < 0.05$). All observed values are within 115.53–130.33 fL (Oyewole and Omeje, 2022) reported for starter broilers. Thus, the values of MCV obtained in this study indicated that the toasted BNW diets were adequate in terms of minerals and vitamins required for blood formation. The MCHC was observed to be significantly ($P < 0.05$) different and ranged from 33.27 to 34.00%. The observed range of MCHC is close to 32.40–33.21% (Mitruka and Rawnsley, 1977) and 33.43–35.10% (Oyewole and Omeje, 2022) reported for healthy birds. The experimental birds adequately utilized the diets, and consequently, the birds were healthy, not anemic, and capable of withstanding stress. The MCH significantly ($P < 0.05$) differed due to the treatments. MCH ranged from 39.40 to 42.97 pg and is close to 36.00–41.50 pg reported by Oyewole and Omeje (2022). Since MCH is a measure of hemoglobin amount per blood cell, a low level is an indication of anemia in animals. The result of MCH obtained, therefore indicated that the bone marrows of the birds were functioning normally. Neutrophils values were significantly ($P < 0.05$) different and ranged from 5.00 to 7.33%. Oyewole and Omeje (2022) observed 4.00 to 6.67% of neutrophils for starter broilers offered toasted BNW diets. Furthermore, lymphocytes ($P < 0.05$) ranged from 92.67 to 96.00%, which is close to 93.33 to 96.00% earlier reported by Oyewole and Omeje (2022) for starter broilers fed similar diets. Toasted BNW, therefore, had no adverse effect on the immune vigilance of the birds. All hematological parameters observed therefore indicated that the birds were healthy despite feeding on toasted BNW diets for 28 days.

Table 4 Hematology of finisher broilers fed toasted Bambara nut waste diets

Parameters	Toasted Bambara nut waste (%)				
	0	5	10	15	20
PCV (%)	30.33 ± 1.52^{ab}	31.00 ± 1.00^{ab}	31.00 ± 1.00^{ab}	28.33 ± 0.5^{7}b	31.33 ± 1.53^{a}
Hb (g/dL)	10.33 ± 0.85^{b}	10.33 ± 0.35^{b}	10.43 ± 0.51^{a}	9.43 ± 0.23^{c}	10.43 ± 0.51^{a}
WBC (×10^{9}/L)	22.28 ± 0.47^{a}	22.00 ± 0.55^{b}	20.50 ± 0.28^{d}	21.83 ± 0.40^{c}	21.76 ± 0.18^{c}
RBC (×10^{12}/L)	2.63 ± 0.10^{a}	2.60 ± 0.22^{a}	2.52 ± 0.15^{ab}	2.33 ± 0.08^{c}	2.44 ± 0.20^{b}
MCV (fL)	115.53 ± 5.70^{c}	120.39 ± 7.50^{b}	123.17 ± 5.80^{b}	120.40 ± 4.41^{b}	130.33 ± 11.72^{a}
MCHC (%)	34.00 ± 1.13^{a}	33.30 ± 0.10^{b}	33.63 ± 0.67^{b}	33.27 ± 0.12^{b}	33.30 ± 0.00^{b}
MCH (pg)	39.40 ± 2.63^{b}	39.87 ± 2.80^{b}	41.83 ± 2.73^{a}	40.53 ± 1.70^{b}	42.97 ± 4.65^{a}
Neutrophils (%)	5.67 ± 3.06^{b}	6.33 ± 0.58^{ab}	7.33 ± 4.93^{a}	5.33 ± 1.53^{b}	5.00 ± 2.65^{c}
Lymphocytes (%)	94.33 ± 3.06^{b}	93.67 ± 0.58^{c}	92.67 ± 4.93^{c}	94.67 ± 1.53^{ab}	96.00 ± 2.65^{a}

Note: ^{a,b,c,d} Means on the same row with different superscripts are significantly different ($P < 0.05$). PCV = packed cell volume, Hb = hemoglobin, WBC = white blood cell, RBC = red blood cell, MCV = mean corpuscular volume, MCHC = mean corpuscular hemoglobin concentration, MCH = mean corpuscular hemoglobin.

Serum Biochemistry of Finisher Broilers Fed Toasted Bambara Nut Waste

The serum biochemical indices of finisher broilers are shown in Table 5. There was a significant difference ($P < 0.05$) among treatments in total protein, whose values varied from 3.96 to 4.70 g/dL. Observed total protein values indicated that birds fed the control diet had the highest value which declined with the inclusion of toasted BNW. Total protein value is a measure of dietary protein quality and quantity. Total protein values appeared to diminish when BNW was incorporated. Albumin values (2.20 to 3.20 g/dL) varied significantly ($P < 0.05$) with no clear pattern of variation. However, the highest value was observed in the control group. Globulin (1.47 to 1.57 g/dL) varied significantly ($P < 0.05$) with no clear pattern of variation. Observed

values of all blood proteins did not indicate negative health status due to the inclusion of toasted BNW. Blood protein levels in birds may indicate health status, but also production features and metabolic alterations (Werner and Reavill, 1999; Filipović *et al*., 2007). Creatinine ranged from 0.50 to 0.80 mg/dL and was significantly higher in toasted BNW groups. However, observed values were safe and similar to 0.47 to 0.73 mg/dL (Oyewole and Omeje, 2022) observed for healthy starter broilers fed toasted BNW diets in the same location. Moreover, observed creatinine levels are within the normal range of 0.5–1.5 mg/dL reported by Chineke *et al.* (2006). Creatinine concentrations lower than the reference range are usually caused by decreased muscle mass due to muscle atrophy arising from starvation (Laskin *et al.,* 2014).

Observed serum glucose levels were from 170.67 to 181.00 mg/dL, which is less than 195.33 to 219.67 mg/dL (Oyewole and Omeje, 2022) reported for healthy starter broilers. Aspartate aminotransferase values, though elevated in the toasted BNW group, were between 214.00 and 267.00 µ/L. Observed values were less than 350 µ/L reported as an indicator of liver disease (Oyewole and Omeje, 2022). Alanine aminotransferase values which ranged from 5.60 to 7.14 µ/L, though significantly elevated in the toasted BNW groups, are below 18.99–20.06 µ/L (Abdel-Fattah *et al*., 2008) reported for healthy birds. Hence observed values in this study did not indicate liver and kidney damage due to nutritional distress.

Table 5 Serum biochemistry of finisher broilers fed toasted Bambara nut waste diets

Parameters	Toasted Bambara nut waste (%)				
	0	5	10	15	20
Total protein (g/dL)	4.70 ± 0.20^{a}	4.47 ± 0.25^{a}	4.13 ± 0.59^{ab}	4.00 ± 0.17^{bc}	3.96 ± 0.45^{c}
Albumin (g/dL)	3.20 ± 0.36^{a}	3.00 ± 0.70^{a}	2.90 ± 0.26^{a}	2.20 ± 0.26^{b}	2.90 ± 0.51^{a}
Globulin (g/dL)	1.50 ± 0.15^{b}	1.47 ± 0.05^{b}	1.57 ± 0.10^{a}	1.47 ± 0.06^{b}	1.47 ± 0.15^{b}
Creatinine (mg/dL)	0.50 ± 0.10^{c}	0.63 ± 0.10^{b}	0.70 ± 0.17^{b}	0.70 ± 0.10^{b}	0.80 ± 0.15^{a}
Glucose (mg/dL)	179.33 ± 21.79^{a}	170.67 ± 23.46^{b}	175.00 ± 18.82^{ab}	176.67 ± 11.68^{ab}	181.00 ± 27.73^{a}
AST (µ/L)	214.00 ± 19.00^{c}	227.33 ± 18.15^{bc}	231.00 ± 17.46^{b}	267.00 ± 19.38^{a}	259.33 ± 21.14^{a}
ALT (µ/L)	5.60 ± 1.26^{c}	6.84 ± 1.99^{ab}	6.01 ± 1.46^{b}	7.14 ± 3.85^{a}	5.97 ± 1.14^{c}

Note: ^{a,b,c} Means on the same row with different superscripts are significantly different ($P < 0.05$). AST = aspartate aminotransferase, ALT = alanine aminotransferase.

Economics of Finisher Broilers Fed Toasted Bambara Nut Waste

The economics of the production of finisher broilers fed toasted BNW diets is presented in Table 6. Feed cost/kg was significantly different ($P < 0.05$) among the treatments. Observed values declined (from ₦379.50 to ₦349.50) linearly as the inclusion level of BNW increased in the diet. This is due to the reduction in the cost of BNW relative to maize. Feed cost/bird/day and total feed cost/bird were similar ($P > 0.05$) across the treatments, although numerically lower than the control at 10, 15, and 20%, where linear decreases were observed in that order. The observed values indicated that it was cheaper to feed finisher broilers BNW when at least 10% of maize was substituted. Feed cost/kg gain across the treatments was statistically similar. Observed values range from ₦1,453.50 (0% BNW) to ₦1,607.70 (20% BNW). However, numerically, these values increased linearly with the inclusion level of BNW. This may suggest that the inclusion of BNW in the diet was not economically efficient in terms of the growth performance of the birds.

Table 6 Economics of production of finisher broilers fed toasted Bambara nut waste diets (₦)

Parameters	Toasted Bambara nut waste (%)				
	0	5	10	15	20
Feed cost/kg	379.50 ± 0.00[a]	372.00 ± 0.00[b]	364.50 ± 0.00[c]	357.00 ± 0.00[d]	349.50 ± 0.00[e]
Feed cost/bird/day	56.36 ± 2.51	57.85 ± 2.23	56.07 ± 1.93	56.01 ± 1.66	55.09 ± 4.54
Total feed cost/bird	1,578.10 ± 70.40	1,619.90 ± 62.30	1,570.10 ± 54.10	1,568.30 ± 46.50	1,542.40 ± 127.00
Feed cost/kg gain	1,453.50 ± 197.30	1,514.00 ± 133.90	1,534.50 ± 76.50	1,534.80 ± 35.30	1,607.70 ± 181.70

Note: [a,b,c,d,e] Means on the same row with different superscripts are significantly different ($P < 0.05$).

CONCLUSION

Feeding toasted BNW resulted in lighter birds than the control except at 5%, but appreciable and acceptable (considering this region) live weight and daily weight were still achieved even at 20%. Toasted BNW also enhanced some hematological and serum biochemical parameters of finisher broilers which in turn positively impacted the health status of the birds even at 20% inclusion level. However, some of these parameters, such as WBC, RBC, MCH, AST, ALT, and creatinine, were better with the control. The inclusion of BNW resulted in cheaper feed than the control but lowered economic efficiency as indicated by poorer feed cost/kg gain. Overall toasted BNW is nutritionally safe when fed to finisher broilers for 28 days.

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