Effects of cashew kernel waste meal on growth performance, flock uniformity, economic indices, hematological parameters, and serum biochemistry of Noiler chicken

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ABSTRACT

Background and Objective: Noiler chickens, a dual-purpose breed developed from broilers and local chickens, are known for thriving on low-quality feed while producing high-quality meat and eggs. This study investigated the effects of different levels of cashew kernel waste meal (CKWM) on growth performance, flock uniformity, economic indices, hematological parameters, and serum biochemistry in Noiler chickens. The aim was to evaluate CKWM's potential as a dietary ingredient.

Methodology: The study used 270 unsexed, one-week-old Noiler chicks, divided into five dietary groups with six replicates of nine birds each. The groups received diets with CKWM incorporated at 0% (K1), 5% (K2), 10% (K3), 15% (K4), and 20% (K5) over eight weeks. A completely randomized design (CRD) was employed. Data were analyzed using one-way ANOVA, followed by Duncan's multiple range test, for post-hoc analysis.

Main Results: Significant variations ($P < 0.05$) were observed in body weight parameters and flock uniformity across the inclusion levels during both the starter and grower phases. Flock uniformity was highest in the Noilers offered diet K2. Economic indices were significantly affected ($P < 0.05$) during the starter phase, with all recorded parameters being influenced. At the grower phase, only feed cost and income differed significantly ($P < 0.05$) with better performance in birds fed K5 and worst in birds fed K3. Hematological parameters, including mean corpuscular volume, mean corpuscular hemoglobin concentration, white blood cell count, and basophil count, were significantly influenced ($P < 0.05$). Serum biochemistry outcomes indicated significant effects ($P < 0.05$) on all parameters except for urea and triglyceride levels.

Conclusions: The findings highlight the potential of cashew kernel waste meal as a dietary ingredient, with implications for optimizing growth, uniformity, and economic performance in Noiler bird production at up to a 15% inclusion level. The study underscores the potential of CKWM to contribute to sustainable and efficient Noiler chicken production, thereby addressing food insecurity and unemployment among smallholders.

Keywords: Noiler, cashew waste, food insecurity

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INTRODUCTION

Noiler chicken was introduced to small-scale farmers to solve problems attributed to food insecurity and the provision of financial independence in rural communities, particularly among women (Oyebanji *et al*., 2018). The significance of providing resource-constrained chicken producers with birds whose genotypes are well suited to the tropics and perform well has been emphasized. Noiler is a dual-purpose chicken species that can thrive on low-quality feedstuffs while producing excellent meat and eggs for smallholders to combat food insecurity (Oyebanji *et al.,* 2018). Noiler is a crossbreed between a broiler and a local chicken.

Nigerian local chickens take a long time to develop. These native birds' growth rates and egg production are underwhelming (Sowunmi *et al*., 2022), necessitating genetic modification. To increase production and guarantee that chickens can be grown by farmers on wide-ranging systems, albeit practiced by the vast majority of rural farmers, the indigenous breed of chicken was modified to create Noilers (Sowunmi *et al*., 2022). Furthermore, Noiler was created to help smallholder farmers in Sub-Saharan Africa, including Nigeria, escape poverty (Yakubu *et al*., 2020). In comparison to indigenous chicken, the breed has higher disease resistance, develops quickly, and weighs better (Ajayi *et al.*, 2020). Studies revealed that native breeds have lower productivity, low weight, reduced egg output, and abject conversion ratio (Manyelo *et al*., 2020). Noiler birds are more able to flourish in a free-range environment than broilers and they lay more eggs. Additionally, the flavor of Noilers is superior and comparable to that of local chicken.

The production of chicken and eggs, which considerably contributes to human nutrition, makes poultry the most significant subsector of the worldwide livestock business. Nigeria presently produces 650 metric tons of eggs annually and 300 metric tons of poultry meat (FAO, 2024). The value of chicken as a source of both income and food for the nation cannot be emphasized as poultry birds provide a substantial contribution to meat production and offer rapid returns on investment.

Economic growth and the price of consuming animal protein are closely related. Humans' urgent demand for high-quality animal protein has become a problem on a national and international scale. The number of poultry farms worldwide has increased because of rising demand for chicken products. The exorbitant feed ingredients crisis, the relative increases in demand for feed ingredients by humans and animals, and the scarcity of traditional ingredients like maize, sorghum, groundnut cake, soybean meal, and fishmeal are the main causes of the high cost of compound feeds for poultry.

Despite producing 45% of the world's cashew nuts, West Africa ships the majority of its crops for processing (Agboola-Adedoja *et al*., 2022). Meanwhile, Nigeria produces 675,266 tons of cashew nuts annually, ranking second in the world, according to figures from the Food and Agricultural Organization (FAO, 2020). However, with local cashew nut processing firms springing up geometrically availability of cashew kernel is on the increase for export and local consumption. The cashew nut kernels that are broken or otherwise unsuitable for human consumption during processing are available for livestock use. Given the nut quality, as much as 30% of the cashew kernel gets wasted in this process (Oddoye *et al*., 2011). Akande *et al.* (2015) stated that early laying pullets and broilers, respectively, were fed on cashew nut meal and waste, even though they are not suitable for human consumption. Ojediran *et al.* (2021; 2022) have also fed it successfully to broilers and pigs respectively. This investigation, therefore, evaluates the effects of cashew kernel waste meal on growth performance, flock uniformity, economic indices, hematological parameters, and serum biochemistry of Noiler birds.

MATERIALS AND METHODS

Experimental Noilers

A total of 270 unsexed Noiler one-old chicks were procured from Amo Farm Sieberer Hatchery Limited in Oyo, and they were acclimatized for seven days before being introduced to the research diets. The birds were fed a commercial diet with 23% crude protein and 3,000 kcal/kg. Their weights were determined at the commencement of the trial and randomly distributed into five dietary groups, with six replicates of nine birds each. They were raised on deep litter (40 mm deep) in an open-sided house with the litter changed every week throughout the experimental period. They were supplied with diet and water *ad libitum*. The experiment lasted for eight weeks (between February and March 2023).

Ingredients and Diets

The test ingredient was procured from a reputable cashew nut processing firm. The discarded kernel was milled using a hammer mill with a 2 mm sieve to achieve the cashew kernel waste meal (CKWM). CKWM was included at 0% for the control diet (diet K1: no CKWM), while it was incorporated at 5%, 10%, 15%, and 20% in diets K2, K3, K4, and K5, respectively (Table 1 and Table 2). Table 1 shows the gross composition of the experimental diet for the starter phase (first 3 weeks), while Table 2 shows the gross composition of the diet fed at the grower phase (4^{th}–8^{th} week).

Data Collection

Feed was offered *ad libitum* daily at around 8:00 a.m. and 4:00 p.m. The leftover feed from the previous day was packed and recorded. The feed and leftovers were weighed. The growth parameters were estimated as described by Ojediran *et al*. (2017a); average daily feed intake (ADFI), average daily weight gain (ADWG), and feed conversion ratio (FCR). The birds were weighed individually, and the data was used to calculate the flock uniformity mathematically as described by Ojediran *et al*. (2017a).

Flock uniformity (%) = 100 – [(Standard deviation (g) / Average body weight (g)) × 100]

The price of the feed components at the time of purchase during the feeding trial was used to calculate the total cost of feed per 100 kg of diet. The variables were evaluated as depicted by Ojediran *et al*. (2017a).

Feed cost per kg (₦) = ∑(Quantity of each ingredient x Unit cost of each ingredient)

Feed cost per kg weight gain (₦) =
(Feed cost × Total feed intake (kg)) / Total weight gain

Income per kg weight gain (₦) =
Selling price per bird / Total weight gain (kg)

Profit per kg weight gain (₦) = Income per kg weight gain – Feed cost per kg weight gain

Economic efficiency of growth (EEG) = (Profit per kg weight gain × 100) / Feed cost per kg weight gain

Table 1 Ingredient and chemical composition of the experimental diet (starter phase)

Ingredients (%)	Diet K1	Diet K2	Diet K3	Diet K4	Diet K5
Maize	52.50	47.50	42.50	36.00	24.00
Fish meal	4.00	3.50	3.00	2.00	3.50
Soya bean meal	32.00	32.00	32.00	32.00	25.00
Cashew kernel waste meal	0.00	5.00	10.00	15.00	20.00
Palm kernel cake	0.00	0.50	0.50	1.50	9.00
Wheat offal	5.50	5.50	6.00	7.50	12.50
Bone meal	3.00	3.00	3.00	3.00	3.00
Limestone	2.00	2.00	2.00	2.00	2.00
L-lysine	0.25	0.25	0.25	0.25	0.25
DL-methionine	0.25	0.25	0.25	0.25	0.25

Table 1 Cont.

Ingredients (%)	Diet K1	Diet K2	Diet K3	Diet K4	Diet K5
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 nutrient composition					
ME (kcal/kg)	2,903.85	2,977.24	3,048.13	3,104.00	3,103.00
Crude protein	22.62	23.00	23.39	23.64	23.94
Ether extract	3.65	3.44	7.23	8.99	11.08
Crude fiber	3.18	3.16	3.14	3.30	4.09
Calcium	1.63	1.68	1.73	1.76	1.85
Phosphorus	0.60	0.82	1.05	1.27	1.50
Lysine	1.47	1.63	1.79	1.91	2.04
Methionine	0.62	0.68	0.73	0.78	0.85

Note: ME = metabolizable energy. *Vitamin premix contained the following vitamins and minerals in 1 kg: 12,500 IU of vitamin A, 2,500 IU of vitamin D3, 40 mg of vitamin E, 2 mg of vitamin K3, 30 mg of vitamin B1, 55 mg of vitamin B2, 550 mg of niacin, 115 mg of calcium pantothenate, 50 mg of vitamin B6, 0.25 mg of vitamin B12, 500 mg of choline chloride, 10 mg of folic acid, 0.08 mg of biotin, 120 mg of manganese, 1,000 mg of Fe, 80 mg of Zn, 8.5 mg of Cu, 1.5 mg of I, 0.3 mg of Co, 0.12 mg of Se, and 120 mg of antioxidant.

Three birds from each replicate were chosen and bled after the trial. Vein blood samples were drawn and placed in pre-labeled EDTA bottles for hematological parameters. The EDTA bottles kept the blood samples from coagulating and ensured that a homogeneous sample was produced during blood analysis. Packed cell volume and hemoglobin were determined using the microhematocrit method and cyanmethemoglobin methods, respectively, as described by Ojediran *et al*. (2018). Red blood cell counts and white blood cell counts were determined using the improved Neubauer hemocytometer after the appropriate dilution as described by Ojediran *et al*. (2018). Mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and mean corpuscular volume (MCV) were calculated using the following formula:

$$MCH = (Hemoglobin / RBC) \times 10$$
$$MCHC = (Hemoglobin / Hematocrit) \times 100$$
$$MCV = (Hematocrit / RBC) \times 10$$

Three birds from each replicate were selected and bled at the end of the trial. Blood samples were collected from the veins and placed in pre-labeled plain serum bottles for serum biochemistry analysis: aspartate aminotransferase (AST), alanine aminotransferases (ALT), alkaline phosphatase (ALP), total protein, albumin, glucose, creatinine, cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL). Serum was obtained by centrifugation and the serum samples were stored in a deep freezer (at -10°C) until required for analysis and were analyzed as described by Ojediran *et al.* (2017b).

Table 2 Ingredient and chemical composition of the experimental diets (grower phase)

Ingredients (%)	Diet K1	Diet K2	Diet K3	Diet K4	Diet K5
Maize	56.00	53.00	48.00	39.00	31.00
Fish meal	1.00	1.00	1.00	1.00	1.00
Soya bean meal	24.00	23.00	21.00	19.00	17.00
Cashew kernel waste meal	0.00	5.00	10.00	15.00	20.00
Palm kernel cake	7.00	6.00	6.00	7.00	10.00
Wheat offal	6.00	6.00	8.00	13.00	15.00
Bone meal	3.00	3.00	3.00	3.00	3.00
Limestone	2.00	2.00	2.00	2.00	2.00
L-lysine	0.25	0.25	0.25	0.25	0.25
DL-methionine	0.25	0.25	0.25	0.25	0.25
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 nutrient composition					
ME (kcal/kg)	2,921.04	3,010.11	3,074.34	3,094.52	3,136.89
Crude protein	18.67	18.87	18.99	19.45	19.86
Ether extract	3.69	5.49	7.31	9.13	11.02
Crude fiber	3.68	3.50	3.51	3.82	4.14
Calcium	1.57	1.62	1.68	1.73	1.79
Phosphorus	0.54	0.77	1.00	1.24	1.48
Lysine	1.10	1.25	1.39	1.53	1.67
Methionine	0.55	0.61	0.66	0.72	0.78

Note: ME = metabolizable energy. *Vitamin premix contained the following vitamins and minerals in 1 kg: 12,500 IU of vitamin A, 2,500 IU of vitamin D3, 40 mg of vitamin E, 2 mg of vitamin K3, 30 mg of vitamin B1, 55 mg of vitamin B2, 550 mg of niacin, 115 mg of calcium pantothenate, 50 mg of vitamin B6, 0.25 mg of vitamin B12, 500 mg of choline chloride, 10 mg of folic acid, 0.08 mg of biotin, 120 mg of manganese, 1,000 mg of Fe, 80 mg of Zn, 8.5 mg of Cu, 1.5 mg of I, 0.3 mg of Co, 0.12 mg of Se, and 120 mg of antioxidant.

Laboratory Examination

The proximate constituents of CKWM and diets were analyzed using the AOAC (2002) recommended techniques. The metabolizable energy (ME; kcal/kg) was calculated using the Pauzenga equation (Ojediran *et al.,* 2024): ME = 37% CP + 81% EE + 35.5% NFE; where CP is the crude protein, EE is the ether extract, and NFE is the nitrogen-free extract.

Statistics

The design of the experiment was completely randomized design (CRD). Statistical package for social science, SPSS, version 16, was used for the analysis. All the data obtained from the experiment were subjected to statistical analysis using one-way analysis of variance. The treatment means were presented with group standard errors and the statistics were compared using

Duncan's multiple range test with a probability of 5% (P = 0.05). The statistical model used was:

$$y_{ij} = \mu + CKWM_i + e_{ij}$$

where y_{ij} is the individual observation, μ is the population mean, $CKWM_i$ is the effect of i^{th} cashew kernel waste meal diets, and e_{ij} is the random error

RESULTS AND DISCUSSION

Table 3 shows the chemical constituents of CKWM. The results showed that the moisture content, crude protein, ether extract, fiber content, ash, nitrogen-free extract, and ME of cashew kernel waste meal were 8.94%, 21.35%, 34.98%, 6.94%, 4.10%, 23.69%, and 4,528.50 kcal/kg, respectively.

According to the study by Ojediran *et al.* (2021), the nutrient value of CKWM reportedly had a moisture content of 8.94%, crude protein content of 21.35%, ether extract content of 34.98%, fiber content of 6.94%, ash content of 4.10%, nitrogen-free extract content of 23.69%, and ME of 4,528.50 kcal/kg. The result is similar to the proximate composition reported in this study, this is because the CKWM was from the same source. The high crude protein content in CKWM makes it a potential source of protein for animal feed production. According to previous studies by Odunsi (2002), the crude protein content in CKWM was 26.06%, which makes it a good source for animal feeding. The high ether extract content in the waste meal could be attributed to the oil content in the cashew kernel, which could contribute to the high ether extract content in the waste meal. The fiber content of CKWM was 6.94%, which is relatively low. This suggests that CKWM could be easily digestible by animals and could be included in animal diets without causing any digestive problems. The ash content in the waste meal indicates the presence of minerals, which are essential for animal growth and health. The nitrogen-free extract content in CKWM could provide a source of energy for animals. However, all the parameters listed in Table 3 are closely related to the work of Ojediran *et al.* (2021).

Table 3 Analyzed chemical constituents of cashew kernel waste meal

Chemical constituents	Composition
Moisture (%)	8.94
Crude protein (%)	21.35
Ether extract (%)	34.98
Crude fiber (%)	6.94
Ash (%)	4.10
Nitrogen-free extract (%)	23.69
Metabolizable energy (kcal/kg)	4,528.50

Table 4 shows the growth response of Noiler chicks fed CKWM. At the starter phase, the final weight (FW), total weight gain (TWG), average daily weight gain (ADWG), average daily feed intake (ADFI), and feed conversion ratio (FCR) were significantly different (P < 0.05), unlike the initial weight (IW; P > 0.05). The FW showed that birds offered diets K1, K2, and K5 had higher FW (448.57, 457.03, and 464.85 g/b respectively) than birds offered diet K3 (396.80 g/b; P < 0.05), while birds on diet K4 compared favorably (442.86 g/b). The FW, TWG, and ADWG followed the same trend. The ADFI revealed that Noilers offered diet K5 had the highest consumption (34.38 g/b/d; P < 0.05), while those offered diets K3 and K4 did not differ significantly (P > 0.05) and were the least. However, those given diets K1 and K2 were in between. The value obtained for FCR showed that birds fed diets K1, K2, and K4 did not differ significantly and were the least (1.88, 1.89, and 1.85, respectively) while birds fed diet K3 was the highest (2.07). Notwithstanding, birds fed diet K5 were comparable (1.95).

The weight gain at the starter phase increased as the CKWM inclusion increased, however, there was a little drop at the 10% inclusion level. This might be ascribed to feed intake and nutrient utilization in the meal; the lower weight gains observed between the birds offered diet with 10% CKWM inclusion, and the control group could be attributed to poor consumption. This agrees with the investigation of Oyewole *et al*. (2017), that broiler starters fed 10% cashew pulp feed gained the least weight. The results obtained for the final and total weight gains were similar and comparable to the findings of Animashahun *et al.* (2022), who examined the response of Noiler chickens given diets with *Parkia biglobosa* folia. This demonstrates that CKWM does not have detrimental effects on the weight gain. The ADFI and ADWG of birds fed diet K5 had the highest value, this may be due to the palatability of CKWM in the feed and the high nutrient composition of diet K5. The observations of FW, TWG, ADWG, ADFI, and FCR were compared favorably with that of Ojediran *et al.* (2022) when broiler starters were fed un-defatted cashew reject kernel meal.

At the grower phase (4–8 weeks), the FW and the FCR were not significantly different ($P > 0.05$). However, it was observed that TWG and ADWG were significantly influenced ($P < 0.05$). From birds fed diet K1, TWG had the value of 847.80 g/b which is the highest, followed by diets K2 and K3 (729.04 and 702.09 g/b), while diets K4 and K5 had the lowest (655.34 and 646.30 g/b) respectively. The ADWG followed the same trend as TWG, which decreased linearly. The IW shows that Noilers fed diets K1, K2, and K5 were significantly the same while those fed diet K3 were the least, and those fed diet K4 compared favorably. Noilers fed diet K1 had the highest feed consumption (83.85 g/b/d), birds fed diet K4 had the lowest consumption (60.44 g/b/d), while birds fed diet 3 compared favorably. The obtained values for ADFI at the inclusion level of 0%, 5%, 10%, 15%, and 20% of CKWM were 83.85, 75.85, 73.31, 60.44, and 64.71 g/b/d, respectively.

At the grower stage (weeks 4–8), there was a reduction in feed intake as the inclusion levels increased compared to the significantly higher control diet. It can be concluded that the lower feed intake, as recorded from the birds fed the diets containing CKWM, was an attempt to regulate their energy-feed intake rate. There was an increase in the final weight of the birds up to diet K5. Birds fed at 15% and 20% CKWM showed lower weight gain. The decline in performance at these higher inclusion levels might be attributed to reduced palatability of the diet. This observation contradicts the outcome obtained by Jaji *et al.* (2011), who substituted CKWM for maize in the growth performance of broiler chicken at 0%, 12.5%, 25%, and 37.5% inclusion levels. The study observed that the feed intake of the birds increases as the level of CKWM is increased from 0% to 25% and slightly decreases as it is further increased from 25% to 37.5%.

The result of flock uniformity of Noilers fed CKWM is presented in Table 4. It showed those fed diet K2 had the highest flock uniformity (93.71%) while those fed diet K5 had the least (89.52). Flock uniformity is an essential performance indicator that is regulated by nutrition and external factors. The birds fed 5% CKWM had the highest uniformity. The lower weight gain could have influenced the decrease in flock homogeneity as the CKWM inclusion level increased. This study's findings contradict those of Ojediran *et al*. (2017a) when low crude protein was supplemented with lysine.

Table 4 Growth performance and flock uniformity of Noiler fed cashew kernel waste meal (starter and grower phases)

Parameter	Diet K1	Diet K2	Diet K3	Diet K4	Diet K5	P-value
Starter phase						
IW (g/b)	94.24 ± 4.38	94.23 ± 2.44	94.37 ± 2.51	94.91 ± 0.80	94.19 ± 1.70	0.99
FW (g/b)	448.57 ± 25.11^{a}	457.03 ± 18.90^{a}	396.80 ± 18.17^{b}	442.86 ± 39.39^{ab}	464.85 ± 27.91^{a}	0.04
TWG (g/b)	354.33 ± 20.73^{a}	356.74 ± 19.41^{a}	302.42 ± 17.01^{b}	347.95 ± 39.03^{ab}	370.66 ± 26.37^{a}	0.04
ADWG (g/b/d)	16.87 ± 0.99^{ab}	16.99 ± 0.92^{a}	14.40 ± 0.81^{b}	16.60 ± 1.86^{ab}	17.65 ± 1.26^{a}	0.04
ADFI (g/b/d)	31.73 ± 1.85^{ab}	32.03 ± 1.22^{ab}	29.79 ± 1.07^{b}	30.57 ± 3.30^{b}	34.38 ± 1.47^{a}	0.04
FCR	1.88 ± 0.13^{b}	1.89 ± 0.03^{b}	2.07 ± 0.14^{a}	1.85 ± 0.07^{b}	1.95 ± 0.06^{ab}	0.02
Grower phase						
IW (g/b)	448.57 ± 25.11^{a}	457.03 ± 18.90^{a}	396.80 ± 18.17^{b}	442.86 ± 39.39^{ab}	464.85 ± 27.91^{a}	0.04
FW (g/b)	1,296.37 ± 131.94	1,180.06 ± 82.93	1,098.89 ± 138.73	1,098.20 ± 132.72	1,111.14 ± 50.70	0.23
TWG (g/b)	847.80 ± 108.82^{a}	729.04 ± 92.58^{ab}	702.09 ± 120.87^{ab}	655.34 ± 93.91^{b}	646.30 ± 29.67^{b}	0.02
ADWG (g/b/d)	24.22 ± 3.11^{a}	20.83 ± 2.65^{ab}	20.06 ± 3.45^{ab}	18.72 ± 2.68^{b}	18.47 ± 0.85^{b}	0.02
ADFI (g/b/d)	83.85 ± 4.05^{a}	75.85 ± 5.25^{ab}	73.31 ± 11.10^{abc}	60.44 ± 9.42^{c}	64.71 ± 4.57^{bc}	0.02
FCR	3.49 ± 0.38	3.66 ± 0.20	3.34 ± 0.29	3.23 ± 0.21	3.50 ± 0.18	0.38
Flock uniformity (%)	93.11 ± 0.86^{ab}	93.71 ± 0.86^{a}	90.65 ± 2.20^{abc}	90.05 ± 1.40^{bc}	89.52 ± 2.59^{c}	0.05

Note: ^{a,b,c} Means accompanied by dissimilar superscripts along the same row differ significantly ($P < 0.05$). IW = initial weight, FW = final weight, TWG = total weight gain, ADWG = average daily weight gain, ADFI = average daily feed intake, FCR = feed conversion ratio. Diets K1, K2, K3, K3, K4, and K5 = dietary treatments with cashew kernel waste meal incorporated at 0%, 5%, 10%, 15%, and 20%, respectively.

The economic indices of Noiler starters offered CKWM are presented in Table 5. The results for the starter phase showed that all parameters differed significantly ($P < 0.05$). A linear decrease in feed cost (FC) from diets K1 to K5 was observed. It was observed that diets K1, K2, and K3 for FC/kgWG had the highest cost value while Noilers offered diets K4 and K5 had the lowest. Nevertheless, those given diets K1, K2, K4, and K5 for the IC/kgWG had the lowest values, while K3 had the towering value. The profit and the economic efficiency gain (EEG) followed the same trend where those fed diets K4 and K5 had the loftiest value while K1, K2, and K3 had the smallest. The economic indices of the finisher phase revealed that FC and IC/kg/WG were remarkably different ($P < 0.05$), while FC/kgWG, profit, and EEG were not notably different ($P > 0.05$). An increase was observed in the IC/kg/WG from K1 to K5. The FC also decreased across the treatment from diets K1 to K5 ($P < 0.05$).

At the starter phase, as the inclusion level of CKWM increased across the groups, the feed cost per unit weight gain decreased at inclusion levels of 5%, 10%, 15%, and 20%, respectively. This demonstrates the economic benefits of including CKWM in the feed for Noilers. The result of this trial at the starter phase showed that at the inclusion of CKWM, there was a linear decrease in the feed cost, which means that the inclusion of CKWM had helped to reduce the feed cost. However, the income, profit, and economic efficiency of gain were higher in those fed the CKWM than in the control diet, similar to the study of Ojediran *et al.* (2016) where broiler chickens were fed crude protein diets supplemented with lysine. The results of this study were in line with that of Abdoulaye *et al*. (2023) who concluded that incorporating CKWM as a feed ingredient for poultry can reduce feed costs and improve economic efficiency. The cost-effectiveness of CKWM can be attributed to its high protein and energy content, which reduces the need for expensive protein sources in poultry diets. Economic benefits at the grower stage revealed that producing Noilers on diet K1 would be more expensive when compared to producing with diet K5.

The hematological indices of Noiler birds fed CKWM are shown in Table 6. The results showed that pack cell volume (PVC), hemoglobin (Hb), red blood cell (RBC), mean corpuscular hemoglobin (MCH), neutrophils, lymphocytes, and platelets were not significantly affected ($P > 0.05$). However, other hematological indices such as mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), white blood cell (WBC), and basophils were significantly influenced ($P < 0.05$). The MCV of the birds fed diet K3 had the highest value (121.00 fL) and was significantly different ($P < 0.05$) from those fed diet K1, but K5 had the lowest value, while K2 and K4 were significantly the same. The MCHC of the birds fed diets K1 and K5 had the highest value and were alike (481.00 and 480.00 g/L, respectively), however, notably different ($P < 0.05$) from K3 and K4 with the lowest value. The WBC of the birds fed diet K5 had the highest value (164.50×10^9/L; $P < 0.05$), the K2, K3, and K4 had the lowest value and were not notably different ($P > 0.05$), while K1 compared favorably. The basophils count of the Noilers given diet K2 was higher (10.00×10^9/L; $P < 0.05$), and those fed diets K4 and K5 had the lowest (3.50 and 4.0×10^9/L respectively), while given diets K1 and K3 compared favorably.

Table 5 Economic indices of Noiler starter fed cashew kernel waste meal

Parameter	Diet K1	Diet K2	Diet K3	Diet K4	Diet K5	P-value
Starter phase						
FC (₦)	341.91 ± 1.00^{a}	331.79 ± 1.00^{b}	321.71 ± 1.00^{c}	300.80 ± 1.00^{d}	288.70 ± 1.00^{e}	0.00
FC/kgWG (₦)	643.98 ± 45.67^{a}	626.03 ± 12.54^{a}	667.02 ± 46.44^{a}	555.42 ± 21.48^{b}	563.22 ± 15.98^{b}	0.01
IC/kgWG (₦)	759.65 ± 1.93^{b}	758.92 ± 10.41^{b}	787.56 ± 9.96^{a}	765.10 ± 19.14^{b}	752.86 ± 8.43^{b}	0.03
P/kgWG (₦)	115.66 ± 44.42^{b}	132.89 ± 2.47^{b}	120.54 ± 42.32^{b}	209.69 ± 23.09^{a}	189.64 ± 7.92^{a}	0.01
EEG	18.34 ± 8.05^{b}	21.24 ± 0.80^{b}	18.43 ± 7.91^{b}	37.86 ± 5.21^{a}	33.72 ± 2.38^{a}	0.00
Grower phase						
FC (₦)	284.00 ± 1.00^{a}	272.50 ± 1.00^{b}	264.00 ± 1.00^{c}	249.18 ± 1.00^{d}	235.55 ± 1.00^{e}	0.00
FC/kgWG (₦)	980.05 ± 257.84	1,122.86 ± 73.03	1,110.62 ± 178.11	1,147.74 ± 77.51	1,112.44 ± 113.34	0.57
IC/kgWG (₦)	$2,145.39 \pm 57.90^{c}$	$2,276.68 \pm 129.33^{abc}$	$2,202.24 \pm 95.49^{bc}$	$2,351.52 \pm 58.49^{ab}$	$2,407.30 \pm 51.51^{a}$	0.02
P/kgWG (₦)	1,165.34 ± 201.62	1,153.83 ± 59.53	1,091.63 ± 82.69	1,203.78 ± 69.23	1,214.87 ± 146.32	0.76
EEG	130.03 ± 63.66	102.85 ± 3.01	101.04 ± 25.77	105.40 ± 12.48	103.20 ± 21.35	0.08

Note: $^{a, b, c, d}$ Means accompanied by dissimilar superscripts along the same row differ significantly ($P < 0.05$). FC = feed cost, FC/kgWG = feed cost per kg weight gain, IC/kgWG = income per kg weight gain, P/kgWG = profit per kg weight gain, EEG = economics efficiency gain. Diets K1, K2, K3, K3, K4, and K5 = dietary treatments with cashew kernel waste meal incorporated at 0%, 5%, 10%, 15%, and 20%, respectively.

Table 6 Serum biochemistry of Noiler birds fed cashew kernel waste meal

Parameter	Diet K1	Diet K2	Diet K3	Diet K4	Diet K5	P-value
PVC (%)	26.00 ± 1.00	27.00 ± 5.00	27.50 ± 1.50	28.00 ± 1.00	29.50 ± 3.50	0.67
Hb (g/dL)	12.70 ± 0.70	12.65 ± 2.15	12.80 ± 0.70	12.90 ± 0.30	14.05 ± 1.85	0.70
RBC (×10^{12}/L)	2.30 ± 0.19	2.23 ± 0.43	2.27 ± 0.18	2.34 ± 0.04	2.57 ± 0.25	0.53
MCV (fL)	115.50 ± 4.50^{b}	120.50 ± 0.50^{ab}	121.00 ± 3.00^{a}	119.50 ± 1.50^{ab}	114.00 ± 2.00^{c}	0.03
MCH (pg)	55.45 ± 1.55	57.05 ± 1.25	56.45 ± 1.35	55.20 ± 0.70	54.70 ± 1.90	0.31
MCHC (g/L)	481.00 ± 5.00^{a}	473.50 ± 8.50^{ab}	465.00 ± 1.00^{bc}	462.00 ± 0.00^{c}	480.00 ± 9.00^{a}	0.00
WBC (×10^{9}/L)	139.50 ± 0.50^{ab}	127.00 ± 9.00^{b}	129.00 ± 1.00^{b}	125.00 ± 5.00^{b}	164.50 ± 35.50^{a}	0.02
Neutrophils (×10^{9}/L)	23.00 ± 3.00	33.00 ± 9.00	26.50 ± 9.50	34.50 ± 7.50	24.00 ± 3.00	0.23
Lymphocytes (×10^{9}/L)	27.50 ± 2.50	55.50 ± 12.50	63.50 ± 11.50	59.50 ± 8.50	71.50 ± 1.50	0.24
Basophils (×10^{9}/L)	7.00 ± 2.00^{ab}	10.00 ± 4.00^{a}	8.00 ± 1.00^{a}	3.50 ± 1.50^{b}	4.00 ± 2.00^{b}	0.03
AST(IU/L)	65.50 ± 31.50^{b}	58.50 ± 11.50^{b}	84.50 ± 14.50^{ab}	100.00 ± 6.00^{a}	88.50 ± 10.50^{ab}	0.02
ALT(IU/L)	2.50 ± 1.50^{ab}	3.50 ± 2.50^{ab}	2.50 ± 1.50^{ab}	4.50 ± 1.50^{a}	1.00 ± 0.00^{b}	0.02
ALP (IU/L)	147.00 ± 5.00^{c}	143.50 ± 6.50^{c}	204.50 ± 5.50^{a}	168.00 ± 27.50^{ab}	184.00 ± 29.00^{ab}	0.01
Total protein (IU/L)	33.00 ± 1.50^{b}	32.50 ± 2.50^{b}	34.50 ± 0.50^{ab}	32.50 ± 0.50^{b}	37.00 ± 3.00^{a}	0.03
Albumin (IU/L)	13.50 ± 0.50^{c}	14.50 ± 0.50^{b}	13.50 ± 0.50^{c}	15.50 ± 0.50^{a}	15.50 ± 0.50^{a}	0.00
Glucose (mmol/L)	1.80 ± 0.20^{ab}	1.85 ± 0.15^{ab}	1.80 ± 0.00^{ab}	1.60 ± 0.00^{b}	1.95 ± 0.15^{a}	0.03
Urea (mmol/L)	2.50 ± 0.20	2.95 ± 0.15	3.65 ± 1.25	2.80 ± 0.40	3.75 ± 1.35	0.36
Creatinine (mmol/L)	74.00 ± 29.00^{a}	46.00 ± 6.00^{b}	47.00 ± 2.00^{b}	63.00 ± 2.00^{ab}	44.50 ± 2.50^{b}	0.03
Cholesterol (mmol/L)	4.95 ± 0.75^{b}	6.05 ± 0.15^{a}	5.75 ± 0.05^{ab}	5.45 ± 0.55^{ab}	4.90 ± 0.50^{b}	0.04
Triglyceride (mmol/L)	0.55 ± 0.35	0.95 ± 0.35	0.80 ± 0.50	1.10 ± 0.20	1.15 ± 0.55	0.43
HDL (mmol/L)	1.35 ± 0.55^{b}	2.10 ± 0.10^{a}	1.45 ± 0.15^{b}	2.50 ± 0.20^{a}	1.40 ± 0.50^{b}	0.01
LDL (mmol/L)	3.40 ± 0.40^{ab}	3.50 ± 0.10^{ab}	3.95 ± 0.45^{a}	2.45 ± 0.25^{b}	3.05 ± 1.25^{ab}	0.02

Note: ^{a,b,c} Means accompanied by dissimilar superscripts along the same row differ significantly ($P < 0.05$). PVC = pack cell volume, Hb = hemoglobin, RBC = red blood cell, MCV = mean corpuscular volume, MCH = mean corpuscular hemoglobin, MCHC = mean corpuscular hemoglobin concentration, WBC = white blood cell, AST = aspartate aminotransferase, ALT = alanine aminotransferase ALP = alkaline phosphatase, HDL = high-density lipoprotein, LDL = low-density lipoprotein. Diets K1, K2, K3, K3, K4, and K5 = dietary treatments with cashew kernel waste meal incorporated at 0%, 5%, 10%, 15%, and 20%, respectively.

Hematological analysis shows the health status of the animals. There was no effect of dietary intake on packed cell volume, hemoglobin content, and eosinophils. These parameters' values were comparable to those presented by Okolo *et al*. (2012). The result for the MCV falls within the normal range showing that there are no underlying health conditions. The birds fed diet K3 had higher MCV, whilst those fed diet K5 experienced the least. This result may be due to the optimal level of CKWM in the diet, which improved the nutritional status and metabolic processes of the birds (Sugiharto, 2022). Moreover, the MCHC and WBC had the highest value in birds fed at 20%, which may be due to allergic reactions, gastrointestinal distress, infection, or inflammation (Siracusa *et al*., 2020). The observed trend of basophil values among those fed CKWM from 5% to 20% may be attributed to the anti-inflammatory response triggered by the higher inclusion level of CKWM (Siracusa *et al*., 2020).

Table 6 also reveals the serum biochemistry of Noilers offered CKWM. All parameters were significantly influenced except urea and triglycerides. Values obtained for AST showed that Noilers given diets K1 and K2 did not differ significantly from each other ($P > 0.05$) but differed from Noilers fed diet K4, while others were comparable. The highest ALT was documented in birds offered diet K4, while the least was noted in Noilers given diet K5. Both were notably dissimilar from one other ($P < 0.05$), while others were in between those values. For ALP, birds fed diet K3 had 204.50 IU/L, while those fed diets K4 and K5 compare favorably. The total protein value ranges from 33.00 IU/L (K1) to 37.00 IU/L (K5). Noilers offered diets K1 and K2 had reduced values not different from one another ($P > 0.05$) but were unlike ($P < 0.05$) those fed diet K5, while those fed diet K3 compared favorably. Observation on albumin showed that birds fed diets K4 and K5 had higher values than the ones presented diets K1-K3. The glucose concentration in the blood revealed that birds offered diet K4 had the minimum value, which was different ($P < 0.05$) compared with the ones offered diet K5, while Noilers given diets K1-K3 were comparable. The creatinine in birds offered diet K1 differed ($P < 0.05$) from those given diets K2, K3, and K5. Those presented diet K4 compared favorably. Those fed diets containing CKWM had reduced creatinine values. Values obtained for cholesterol were 4.95, 6.05, 5.75, 5.45, and 4.90 mmol/L for diets K1-K5, respectively. Birds offered diets K1 and K5 had lower values, while those presented diet K5 had notably higher values ($P > 0.05$). The HDL concentration revealed that Noilers presented rations K2 and K4 had higher values which were not different ($P < 0.05$) from each other but differed notably ($P < 0.05$) from Noiler fed diets K1, K3, and K5, which had lower values. Values obtained for LDL revealed that birds presented diet K3 had towering value while those offered K4 presented the least ($P < 0.05$) while other diets compared favorably.

AST is an enzyme that aids in the metabolism of amino acids. ALT and AST are generally present in modest levels in the blood. A rise in AST values may indicate liver or muscle injury. ALT enzymes, on the other hand, are engaged in the conversion of glucogenic amino acids to make glucose, whereas ALT enzymes aid in the conversion of protein to energy for the liver cells. The increase in AST level birds fed CKWM could be indicative of various factors affecting the bird's liver or other physiological processes. High-fat diets, such as those containing CKWM, can put additional stress on the liver, leading to inflammation or injury (Dhibi *et al*., 2011), and this could be the cause of the observed ALT value. The liver is responsible for metabolizing fats, and excessive fat intake can overwhelm the organ, potentially leading to elevated AST levels (Kalra *et al*., 2022). ALP, liver, and bone-predominant enzymes are significant for protein catalysis (Kuo and Chen, 2017). The increase in the ALP of birds fed diets containing CKWM is attributable to the protein and fat composition of the diet (Ray *et al*., 2017). Higher than normal levels of ALP may indicate liver damage or disease, such as a blocked bile duct or certain bone diseases. However, the values obtained for AST, ALT, and ALP were within the normal range, thus the pattern observed in the values and dietary response invalidated deleterious effects on organs. This is at variance with the work of Ozer *et al.* (2008). The observed total protein values fall within the normal range and are related to the study of Oyebanji *et al.* (2018), who work on the effect of turmeric rhizome (*Curcuma longa*) powder and coconut oil mixture on growth performance, hematological and biochemical parameters of Noiler birds. The observed creatinine level, a kidney marker showed that the kidney was not affected by the CKWM.

Albumin, one of the major proteins found in the blood, increased as the inclusion level increased and this may be due to the protein composition and amino profile of CKWM (Rico *et al*., 2016). The result obtained for HDL, LDL, and cholesterol could be because cashew kernels contain monounsaturated and polyunsaturated fats (Rico *et al*., 2016), which are considered heart-healthy fats. When birds consume these fats in moderation, it can lead to an increase in HDL, as observed in this study (Jenkins *et al*., 2010). The result obtained on HDL is contrary to the work of Toghyani *et al.* (2010).

CONCLUSIONS

In conclusion, cashew kernel waste meal does not exert noxious effects on Noilers' health and growth. The results of this study show that Noilers could tolerate up to 15% inclusion level of CKWM based on the FCR. The economic indices revealed lowered feed costs and increased income, profit, and EEG at both phases. The birds were not anemic. Therefore, it can be concluded that 15% CKWM was well tolerated by the birds.

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