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Nutritional Potential of Oven Dried Cassava Starch Effluent Waste on Performance and Blood Profile of Broiler Chicken

Adewale Tirimisiyu Rafiu[1], Abolaji Idris Alao[2], Eden Olusegun Okanlawon[3]*
Ladoke Akintola University of Technology
Corresponding Author: Eden Olusegun Okanlawon
edenokanlawon@gmail.com

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ABSTRACT

A total of one hundred and fifty (150) day old chicks (Ross 308) were used to determine the nutritional potential of oven dried cassava starch effluent waste and its utilization as feed resource in broilers diet. The birds were randomly allotted to three dietary treatments group which include T1-control diet, T2-25% and T3-50% inclusion rate of 50 bird per treatment and (5) replicates of 10 birds and were arranged in a completely randomized design. Growth performance. Blood profile and carcass characteristics data were collected and subjected to ANOVA analysis. Highest ($p<0.05$) average weight gain (2238.70g) was recorded with the birds fed control diet while the birds placed on 25% inclusion had the lowest value of (1990.22g). Packed cell volume slightly declined from 27.67% (control) to 27.33% at 25% and further to 25.17% at 50%. AST, ALT and ALP decreased notably at 25% and 50% inclsion, particularly ALP, which dropped from 240.33 IU/L (control) to 148.67 IU/L (25%). It was concluded that the inclusion of oven dried cassava starch effluent waste at 25% will help improves growth performance, carcass yield, organ and health status and reduction in cost of feed and overall cost of production in broiler chicken enterprise.

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INTRODUCTION

Poultry production especially the broiler has potential to attain expected weight at specified number of days when optimal feed intake throughout the growing period is ensured. The optimality in feed intake is linked with several factors such as quantity and quality of feed, type of feed, physical form of feed and proper management system, Likewise, the success of poultry venture depends on the birds having good health, nutrition and good management (Okanlawon *et al.,* 2025). There is a need to exploit cheaper sources in order, to replace expensive ingredients for livestock production, to relieve the food-feed competition in the future. In the coming years, poultry producers are definitely looking beyond maize and other cereal grains because of their low availability, high cost and inability to keep pace with ever-increasing poultry production and others. Even in recent years, the cost of maize has continued to rise due to competition with the human food industry, increased production of bio-fuel and droughts in some parts of Africa; from September 2005 to September 2015 maize price increased by 71.16% (USDA, 2015).World cassava output increased by 4.6% between 2013 and 2014 (FAO, 2014). The majority (70%) of the world's cassava is produced in Nigeria, Brazil, Indonesia, Democratic Republic of Congo and Thailand (FAO, 2014). Approximately 70% of the estimated total 13million hectares of cultivated area in Africa and Asia has cassava growing on it (El-Sharkawy, 2003). Recent data suggest that Nigeria's annual demand for cassava starch is around 310,000 tons, whereas the domestic supply meets merely 20,000 tons (Agusto, 2024). However, in recent years, as the demand for cassava starch in the international market has increased, the Nigerian government has increasingly recognized the importance of cassava starch processing in Nigeria and as begun to encourage the development of the cassava starch industry. Cassava has been investigated as an alternative energy source in poultry diets in recent years: meta-analysis suggests that it can partially replace maize, though growth performance effects depend heavily on processing and inclusion level (Ogbuewu *et al.,* 2022). Incessant increase in feed raw materials as well as feedstuff has recently poise lots of threat to the sustainability and profitability of the poultry industry, this threat if not mitigated has rippled effect on human nutrition as we depend on these animals for protein. To avoid this threat, it is therefore imperative to find solution to this lingering danger. Most studies were discovered to be focused on inclusion of alternatives with focus on cassava. However, there is insufficient information regarding its effect of its utilization on organs of broiler chickens especially when subjected to different processing methods cassava effluent. Hence, it became necessary that this study was carried out to examine the nutritional potential and the utilization of cassava starch effluent as feed waste resource on broiler birds

THEORETICAL REVIEW

The theoretical basis of this study is anchored in the principles of poultry nutrition, metabolic adaptation, and sustainable utilization of agro-industrial by-products as alternative feed resources. In modern broiler production, fast-growing strains such as Ross 308 are genetically selected for accelerated muscle deposition and efficient feed conversion within a short production cycle. Such rapid growth requires diets that provide adequate metabolizable energy, balanced crude protein, and sufficient essential amino acids to support lean tissue accretion. Any alteration in dietary composition, particularly through partial substitution of conventional ingredients like maize, must therefore maintain nutrient density and digestibility to prevent compromised growth performance. The inclusion of cassava-based products in broiler diets is supported by the increasing global production of cassava reported by the Food and Agriculture Organization of the United Nations, especially in tropical countries where cassava processing generates substantial quantities of starch residues and effluents. These by-products present both an environmental challenge and a nutritional opportunity within a circular bioeconomy framework.

Cassava starch effluent waste (CSEW), as investigated in the present study, represents a residual product of starch extraction that may still contain utilizable carbohydrate fractions but also varying levels of fiber and potential anti-nutritional factors such as cyanogenic glycosides. From a nutritional dilution theory perspective, increasing inclusion levels of fibrous by-products may reduce dietary energy concentration and alter gut fill, leading to reduced feed intake and impaired nutrient absorption when the inclusion threshold exceeds physiological tolerance. This theoretical explanation aligns with the observed decline in average final weight, total feed intake, and daily weight gain at the 50% inclusion level in the study. Moderate inclusion, however, may allow birds to utilize residual nutrients without exceeding fiber tolerance limits, thereby maintaining growth performance comparable to the control diet. The similar feed conversion ratios across treatments suggest that nutrient utilization efficiency was not drastically impaired, but the reduced intake at higher inclusion levels may reflect palatability issues or reduced energy density.

Thermal processing through oven drying, as applied in this study, is theoretically justified by feed safety and detoxification principles. Heat treatment can reduce moisture content, inhibit microbial proliferation, and decrease residual cyanide concentration through volatilization, thereby improving storage stability and minimizing toxic risk. Proper thermal processing may also improve the physical characteristics of the feed ingredient, enhancing mixing uniformity and digestibility. However, excessive inclusion despite processing may still result in nutrient imbalance or fiber overload, explaining the non-linear response pattern observed between 25% and 50% inclusion levels.

The organ and carcass responses observed in the study can be interpreted through the theory of metabolic and organ adaptation. The liver, being central to carbohydrate metabolism and detoxification, may increase in relative weight under higher inclusion levels as an adaptive response to altered nutrient composition or increased metabolic demand. Similarly, changes in kidney and spleen weights may reflect physiological adjustments rather than pathological conditions, especially when serum biochemical indicators remain within normal ranges. The relatively stable hematological indices, including packed cell volume, hemoglobin concentration, and red blood cell count, suggest that oxygen-carrying capacity and overall health status were not adversely affected at moderate inclusion levels. The reduction in liver enzyme activities such as AST and ALT further supports the absence of hepatic distress, reinforcing the safety of oven-dried CSEW at appropriate inclusion levels.

From an economic theory standpoint, broiler production efficiency is determined not solely by maximum weight gain but by the balance between biological performance and feed cost per unit of gain. The improved cost per kilogram gain at 25% inclusion reflects the principle of optimal substitution, where partial replacement of expensive conventional ingredients reduces production cost without imposing significant biological penalties. Excessive substitution, however, may lead to diminished growth and increased cost inefficiency due to reduced performance. Therefore, the theoretical framework integrating nutrient balance theory, fiber threshold limitations, metabolic adaptation, and cost-performance optimization supports the conclusion drawn in the study that moderate inclusion of oven-dried cassava starch effluent waste enhances sustainability and economic viability while maintaining physiological stability in broiler chickens.

METHODOLOGY

Experimental Site:

The experiment was carried out at the Poultry Unit of Teaching and Research Farm, Ladoke Akintola University of Technology Ogbomoso, Oyo State Nigeria. The area is in derived savannah zone of Nigeria. It lies on longitude 4.5^0 east of greenish meridian and latitude 8.5^0 North-East towards Ibadan the capital of Oyo State. The mean annual rainfall is 1247mm while relative humidity is between 75% and 95%. It is situated at about 300-600 matters above the sea level with a mean annual temperature of 27^0C (Ayinla and Odetoye, 2015).

Procurement of Test Ingredient

The test ingredient, Cassava Starch Effluent was gotten from Psaltry International Company Limited, Alayide-wasinmi village, Ado-Awaye, Iseyin, Oyo State, Nigeria.

Processing of Cassava Starch Effluent to Oven Dried Form

The cassava starch effluent was collected, placed and dried in the hot air oven for 14hrs at temperature of 60°C according to (Osundahunsi, 2005), the product however took 48hrs at 60°C before it was well ovendried. The product was pulverized and sieved with 60mm mesh size to have oven dried cassava starch effluent.

Experimental Birds and Management:

One hundred and fifty (150) day old chicks (Ross 308) were used for this experiment and they were purchased from a reputable hatchery farm in Ibadan Oyo State. The birds were divided into three treatments, with 5 replicates of 10 birds per replicate. The treatment was arranged in a Completely Randomized Design. Feeds and water were given to the experimental birds *ad-libitum*. The experiment lasted for six (6) weeks.

Experimental Diets

Five experimental diets were formulated in each phase of the study which is starter and finisher phase as shown in table Diet 1 served as control a based diet with 0% test ingredients (Treatment1). Diet 2 contained 25% of oven dried cassava starch effluent waste and Diet 3 contained 50% of oven dried cassava starch effluent waste.

Table 1: Composition of Experimental Diet at Starter Phase

Feed Ingredient	T1 (0%)	T2 (25%)	T3 (50%)
Maize	40	37.5	15
Maize bran	10	10	10
Soya Bean Meal	19	19	19
Groundnut Cake	15	15	15
Wheat Offal	10	10	10
CSE	0	12.5	25
Fish Meal	1	1	1
Lime Stone	2	2	2
Bone Meal	2	2	2
Broiler's Premix	0.1	0.1	0.1
Lysine	0.25	0.25	0.25
Methionine	0.20	0.20	0.20
Salt	0.4	0.4	0.4
Total	**100**	**100**	**100**
%CP	22.06	22.06	22.06
Energy (KCal/kg)	3000	3005	3000

Cassava Starch Effluent (CSE), Crude Protein (CP), Groundnut Cake (GNC) T1- Control diet, T2- 25% of oven dried cassava starch extraction effluent, T3- 50% of oven dried cassava starch extraction effluent

Table 2: Composition of Experimental Diet at Finisher Phase

Feed Ingredient	T1 (0%)	T2 (25%)	T3 (50%)
Maize	40	37.5	15
Maize bran	18	10	10
Soya Bean Meal	11	19	19
Groundnut Cake	15	15	15
Wheat Offal	10	10	10
CSE	0	12.5	25
Fish Meal	1	1	1
Lime Stone	2	2	2
Bone Meal	2	2	2
Broiler's Premix	0.2	0.2	0.2
Lysine	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Salt	0.4	0.4	0.4
Total	**100**	**100**	**100**
%CP	20.01	20.02	20.02
Energy (KCal/kg)	3200	3200	3150

Cassava Starch Effluent (CSE), Crude Protein (CP), Groundnut Cake (GNC) T1- Control diet, T2- 25% of oven dried cassava starch extraction effluent, T3- 50% of oven dried cassava starch extraction effluent

Data Collection:
Growth Performance:
Weight Gain

Total weight gain (g) = Final body weight (g) – Initial body weight (g)

Feed Intake:

Feed intake was recorded on weekly basis for each replicate per treatment. Leftover feed was subtracted from the total feed supplied to determine feed intake. Using the weighing scale of (Camry Q.C PASSED NO: 1, Model: EK 3250, Max: 5kg/ 11Lb, d=1g/0.050z).

feed intake=feed offer−left over feed numbers of birds

Feed Conversion Ratio (FCR):

This was calculated as ratio of feed intake per body weight gain

$$FCR = \frac{\text{Feed intake}}{\text{Weight gain}}$$

Organs And Carcass Characteristics:

At the end of experimental period (6 weeks), four birds were randomly selected, were starved of feed for 12 hours with the presence of abundant water and slaughtered by severing the jugular veins. The birds were bled; defeathered after which the visceral organs such as liver, intestine, pancreas, spleen, kidney, proventriculus, and hearts were removed. The bled, defeathered and eviscerated weights were evaluated accordingly. The head and shanks were removed to determine the carcass weight.

$$\text{Proportional weight of the organs} = \frac{\text{Weight of the organ}}{\text{Live weight}} \times 100$$

The carcass was cut into various parts (thigh, breast, back, shank, drumstick, wings and head) and their weights were expressed in percentage relative to the carcass weight. The weights of the organs were also be expressed in relative values. The following calculations were evaluated:

$$\text{Relative cut parts weight} = \frac{\text{Weight of the cut}}{\text{Carcass weight}} \times 100$$

Blood collection analysis:

Haematological and serum parameters:

Four birds were randomly selected from each treatment, about 2.5 mL of blood were collected in tubes containing EDTA anticoagulant, The blood was slowly expressed into EDTA tubes to reduce the risk of haemolysis after removing the needles from syringes (Haen, 1995) and analyzed to determine the parameters (haemoglobin concentration, packed cell volume, red blood cells count, total white blood cells count, differential white blood cell count, platelets count, and red cell) indices as describe by Iranloye *et al.* (2002) and Venkatesan *et al.* (2006).

Serum parameters include, total protein was obtained by biuret method in the assay as described by Kohn and Allen (1995). The globulin concentration was obtained by subtracting albumin from the total protein. Albumin was determined using Bromocresol Green (BCG) method as described by Peter *et al.* (1982). Aspartate transferase (AST) activities were determined using spectrophotometric methods as described by Rej and Hoder (1983). Alanine transferase (ALT) activities were determined using spectrophotometric methods as described by Rej and Hoder (1983).

Data Analysis

Data collected was subjected to one-way analysis of variance (ANOVA) in a Randomised Complete Block Design (RCBD) using the procedure of (SAS 2003). The variations in means with significant differences were separated using the Duncan's Multiple Range Test (DMRT) using same software 16.0.

RESULTS

Table 4.1.1showed the performance of broiler chickens fed varying levels of oven dried cassava starch effluent waste. Significant (P<0.05) differences were observed in Average final body weight (AFW), total feed intake (TFI), average daily feed intake (ADFI), average weight gain (AWG), daily weight gain (DWG), and cost per kg body weight gain, while the feed cost and feed conversion ratio (FCR) were not significantly affected (P>0.05). Broilers fed the control diet recorded the highest AFW (2294.8g), AWG (2238.70g), and DWG (53.30g), closely followed by the 25% CSEW group (AFW = 2275.03g; AWG = 2220.02g; DWG = 52.86g). The 50% inclusion group had the lowest values (AFW = 2043.23 g; AWG = 1990.22g; DWG = 47.39g). Total feed intake and ADFI decreased as CSEW levels are increasing, with the control diet consuming the most feed (TFI = 4275.62 g; ADFI = 101.80 g) and the 50% group the least (TFI = 3897.02 g; ADFI = 92.79 g). Cost per kg gain was lowest in the 25% group (₦569.39) and highest in the 50% group (₦638.02), while FCR was not significantly (p>0.05) affected across the treatment and remained statistically similar across treatments as well. Overall, moderate inclusion (25%) of processed CSEW maintained growth performance and improved production efficiency, while higher inclusion (50%) negatively affected growth and increased cost per kg gain

Table 3 Effect of Inclusion Level of Oven Dried Oven Dried Cassava Starch Effluent Waste on Broiler Performance

Parameters	0 (Control)	25%	50%	SEM
AIW(g)	56.1	55.02	53.02	0.72
AFW(g)	2294.8^{a}	2275.03^{a}	2043.23^{b}	14.10
TFI(g)	4275.62^{a}	3960.57^{b}	3897.02^{b}	31.15
Feed Cost(g)	318.82	318.82	325.26	0.00
ADFI(g)	101.80^{a}	94.30^{b}	92.79^{b}	0.74
AWG(g)	2238.70^{a}	2220.02^{a}	1990.22^{b}	14.09
DWG(g)	53.30^{a}	52.86^{a}	47.39^{b}	0.33
FCR	1.91	1.98	1.96	0.10
Cost(kg)	609.362^{b}	569.392^{c}	638.024^{a}	7.17

^{ab}: means factor with different superscripts differ significantly (p<0.05)

AWG- Average Weight Gain, FCR-Feed conversion ratio, SEM: Standard Error of Mean,

Table 4 shows the effect of CSE inclusion level on carcass characteristics of broiler chickens. The data indicate that inclusion level influenced live weight, slaughter weight, defeathered weight, eviscerated weight, breast, shank, thigh, and neck were significantly affected while other carcass component like Wing, drumstick and carcass weights were not significantly affected. Live weight was highest in broilers fed 25% CSE (2.270g) and slightly lower in those on control diets (2.210g), while the lowest live weight was observed in 50% inclusion (2.045g). Slaughter weights followed a similar pattern, with control and 25% inclusion recording the highest values (96.379–96.190g) compared to 50% inclusion (94.471g), indicating that moderate inclusion supports better carcass development. Breast weight was reduced in the 25% inclusion group (21.940g), while shank and thigh weights were higher in birds fed 25% and 50% CSE (shank: 14.040–14.555g; thigh: 9.810–10.022g). Neck weight decreased with higher inclusion levels, while other components such as defeathering, eviscerated weight, drumstick, and wing were not significantly affected. Overall, moderate inclusion (25%) of CSE improved live and slaughter weight, and also enhances muscle development in shanks and thighs, while high inclusion (50%) negatively affected some organs and carcass traits. These results shows and highlights the importance of optimal CSE inclusion for maximizing broiler carcass yield and meat quality.

Table 4 Effect of Inclusion Level of Oven Dried Cassava Starch Effluent Waste on Carcass Traits

Parameter	0(Control)	25%	50%	SEM
Live weight (kg)	2.21^a	2.27^a	2.05^b	0.03
Slaughtered Wt %	96.38^a	96.10^a	94.47^a	0.27
Defeathered Wt %	89.36	89.55	89.95	0.78
Eviscerated Wt (%)	80.67	80.49	83.23	1.04
Carcass Wt %	72.87	69.27	73.55	1.51
Breast %	26.39^a	21.94^b	24.51^a	1.35
Shank %	13.33^b	14.04^a	14.55^a	0.36
Drumsticks %	11.09	10.71	11.15	0.19
Thigh %	8.51^a	9.81^a	10.02^a	0.39
Wings %	8.14	7.76	8.22	0.17
Neck %	4.27^a	3.56^c	3.95^b	0.66

^{ab}: means factor with different superscripts differ significantly (p<0.05)

Table 5 shows the effect of oven dried cassava starch effluent waste inclusion level on the organ traits of broiler chickens**.** The data indicate that inclusion level influenced several internal organs including liver, spleen, kidneys, pancreas, caecum, crop, duodenum, ileum, and total intestine weight, while other organs such as heart, proventriculus, and lungs were less affected. Liver weight was slightly higher in birds fed 50% CSE (2.176%) compared to control (2.028g) and 25% inclusion (1.921%), suggesting that higher CSE inclusion may stimulate or trigger liver development. Spleen and kidney weights were also increased in the 50% inclusion group (spleen = 0.112%; kidney = 0.512%), indicating that CSE may influence immune and excretory organs. The proventriculus and gizzard (both whole and eviscerated) showed minor reductions at 25% inclusion but were maintained at 50%, suggesting that moderate inclusion does not adversely affect digestive organ development. Intestinal parts (segments) such as duodenum, ileum, and total intestine showed variations, with duodenum weight increasing at 50% inclusion (2.475%) while ileum weight decreased (1.461g), possibly reflecting changes in nutrient absorption efficiency and gastrointestinal tract (GIT) morphology. Crop weight was lower in 25% and 50% inclusion, suggesting faster feed transit or enhanced digestive efficiency. Overall, moderate to high inclusion level of CSE influenced organ development, particularly liver, spleen, kidneys, and digestive tract segments, which may be associated with the bioactive compounds in CSE enhancing metabolic and digestive functions.

Table 5 Effect of Inclusion Level of oven dried cassava starch effluent waste on Organ Traits

Parameter %	0(Control)	25%	50%	SEM
Liver	2.03	1.92	2.18	0.05
Heart	0.45	0.39	0.41	0.02
Gizzard (whole)	2.79	2.58	2.78	0.07
Gizzard (empty)	1.98	1.66	1.69	0.74
Lungs	0.94	0.98	1.03	0.34
Proventiculus	0.45	0.39	0.41	0.01
Spleen	0.09	0.08	0.11	0.01
Pancreas	0.25	0.23	0.27	0.02
kidney	0.47	0.35	0.51	0.32
Caecum	1.01	0.82	0.96	0.05
Crop	0.74	0.52	0.58	0.27
Duodenum	2.08	2.01	2.48	0.14
Ileum	2.45	1.59	1.46	0.16
Intestine	5.84	4.91	5.34	0.13

^{ab}: means factor with different superscripts differ significantly ($p<0.05$)

Table 6 shows that the inclusion of cassava starch extraction waste oven dried cassava starch effluent waste at 25% and 50% showed mild but notable effects on broiler hematological indices. Packed cell volume (PCV) slightly declined from 27.67% (control) to 27.33% at 25% and further to 25.17% at 50%, suggesting a marginal reduction in oxygen-carrying capacity at higher inclusion. Hemoglobin followed a similar trend, remaining comparable between control (12.67 g/dl) and 50% (12.33 g/dl), but peaking at 25% (13.17 g/dl), indi. Red cell indices (MCV, MCH, MCHC) were largely stable, though MCHC increased progressively, with the highest value at 50% (488.83 g/L), implying improved hemoglobin concentration per cell. White blood cell count (WBC) decreased at 50% (124.42 $\times 10^9$/L) compared to control and 25%, reflecting a possible modulation of immune activity at higher levels, while differential counts (neutrophils, lymphocytes, monocytes) remained within close range, showing no signs of immune suppression.

Serum enzyme markers (AST, ALT, ALP) decreased notably at 25% and 50%, particularly ALP, which dropped from 240.33 IU/L (control) to 148.67 IU/L (25%), suggesting no liver damage and possible reduced metabolic stress. Total protein and albumin were slightly lower at 50% . Kidney function marker (creatinine) increased gradually, highest at 50% (87.33 mmol/L), without extreme deviation, indicating no pathological impairment. Overall, 25% CSEW inclusion maintained optimal hematological balance, while 50% showed slight physiological shifts but remained within safe limits, supporting CSEW as a non-toxic dietary protein source at moderate inclusion.

Table 6. Effect of oven dried cassava starch effluent waste Inclusion Level on Hematology and serum biochemistry

Parameter %	0(Control)	25%	50%	SEM
PCV(%)	27.67	27.33	25.17	0.59
HB(g/L)	12.67	13.17	12.33	0.26
RBC($X10^{12}L$)	2.39	2.37	2.22	0.05
MCV(fl)	115.70	114.13	112.98	0.99
MCH(pg)	54.83	54.60	55.22	0.45
MCHC(LgL)	474.00	478.33	488.83	2.55
WBC($X10^{9}L$)	137.77	137.68	124.42	3.01
N	15.33	14.17	13.83	0.98
L	81.00	83.83	83.67	0.92
M	3.67	2.00	2.50	0.25
PLT($X10^{9}l$)	36.33	37.83	34.83	2.73
AST (ul)	138.00	128.33	129.17	5.316
ALT (µl)	9.67	7.00	7.33	0.50
ALP (µl)	240.33	148.67	165.50	13.97
Tp (g/l)	35.00	38.33	35.83	1.79
GL(mmol/l)	5.43	5.07	5.37	0.14
CREAT(mmol/l)	77.77	84.57	87.33	2.26

DISCUSSION

However, the significant decline in average final weight (AFW) at 50% CSEW inclusion relative to both the control and 25% inclusion groups clearly indicates that high dietary substitution compromised growth performance, most likely through reductions in palatability, energy density, and nutrient bioavailability, a trend that has been repeatedly reported when fibrous agro-industrial by-products exceed the digestive and metabolic tolerance threshold of broilers (El-Sayed *et al.*, 2021; Hassan *et al.*, 2025; Nwosu and Ibe, 2024). A parallel reductions was observed in total feed intake (TFI), average daily feed intake (ADFI), average weekly gain (AWG), and daily weight gain (DWG) at 50% inclusion, which further support the hypothesis that the higher inclusion rate negatively affected feed acceptability and possibly diluted metabolizable energy (ME) and digestible crude protein (CP), two essential drivers of lean tissue accretion in fast-growing broilers (Ghasemi *et al.*, 2023; Fasina and Adeola, 2023; Zhao *et al.*, 2024).

High fiber content, lignocellulosic complexity, and residual anti-nutritional factors (ANFs) such as cyanogenic glycosides, phytic acid, and tannins are commonly present in cassava residues and these were known to slow digesta transit, reduce villus surface area, increase endogenous nitrogen loss, and lower AMEn (nitrogen-corrected apparent metabolizable energy), collectively reducing nutrient uptake and growth efficiency (Jha *et al.*, 2023; Sowande and Adeyemi, 2024; Lucas *et a*l., 2025).

Although feed conversion ratio (FCR) differences were not statistically significant, the numerical increase (with the poorest efficiency at 25% unprocessed inclusion) suggests that broilers may experience subclinical inefficiencies in nutrient utilization before performance declines become statistically detectable, a phenomenon well-documented in feed substitution trials (Ravindran and Abdollahi, 2022; Innir *et al.*, 2023; Johnson *et al.*, 2023; Williams *et al.*, 2024).

Importantly, the lower feed cost per kg gain observed at 25% inclusion relative to the control and 50% group reinforces the concept of an inclusion sweet-spot, where partial replacement of conventional ingredients can deliver economic advantages without inducing biological penalties, provided nutrient balance is maintained (Williams *et al*., 2024; Ayeni *et al*., 2024; Yunana *et al*., 2024).

Such cost-performance trade-offs have been emphasized in recent sustainability-focused poultry nutrition frameworks, which argue that alternative feed adoption should optimize both financial viability and production metrics rather than maximize ingredient displacement (El-Sayed *et al.*, 2021; Jha *et al*., 2023; Kim and Park, 2023; Zhao *et al*., 2024; Hassan *et al*., 2025).

The economic advantage observed for toasted CSEW (583.10 cost/kg gain) relative to the control and 25% unprocessed group confirms that processing can improve cost efficiency when inclusion is optimized, aligning with research demonstrating that processing feedstuffs can reduce nutrient wastage and feed cost per unit of gain, particularly at moderate inclusion levels (Innir *et al.*, 2023; Yunana *et al*., 2024; Lucas *et al*., 2025).

The carcass data show variable responses across inclusion-processing combinations, with the highest eviscerated weight observed at 50% inclusion, while breast weight was highest in the control. This non-linear pattern suggests compensatory tissue redistribution and selective nutrient partitioning, where broilers under nutritional dilution may divert absorbed amino acids and energy toward essential tissues or denser muscle groups in a non-proportional manner, a concept supported by protein-energy partitioning models in poultry (Johnson *et al*., 2023; Kim and Park, 2023; Zhao *et al*., 2024).

The decreases observed in neck weight with higher inclusion and processing interactions likely reflect its lower metabolic priority relative to breast and thigh muscles in nutrient-limited broilers, aligning with tissue-priority frameworks in poultry growth physiology (Jha *et al*., 2023; Sowande and Adeyemi, 2024; Lucas *et al*., 2025).

With respect to organ development, liver weight declined at 25% inclusion but increased at 50%, reflecting a possible metabolic compensation or increased detoxification demand at higher inclusion rates. Similar non-linear changes were observed in spleen and kidney weights, suggesting mild immunological and renal adaptation to CSEW inclusion, though reductions in intestinal mass and ileal development at 50% inclusion suggest compromised gut morphological development under higher fiber load, potentially reducing absorptive surface area and nutrient uptake efficiency (Jha *et al*., 2023; Fatía *et al*., 2025; Hassan *et al*., 2025; Lucas *et al*., 2025). The marginal increase in lymphocytes at 25% processed inclusion suggests subtle immune stimulation, potentially due to improved amino acid absorption and micronutrient availability supporting leukopoiesis and adaptive immunity (Onwuka *et al*., 2023; Sowande and Adeyemi, 2024; Hassan *et al*., 2025). Lower WBC trends in high-inclusion processed diets may indicate improved gut integrity and reduced antigenic leakage, consistent with studies linking processed fibrous diets to lower systemic immune activation due to reduced gut irritation and pathogen translocation (Fasina and Adeola, 2023; Zhao *et al*., 2024; Lucas *et al*., 2025). Liver enzymes (AST, ALT) were numerically highest in control birds and lower in CSEW groups, indicating no hepatic distress, a favorable outcome since elevated liver enzymes are often markers of toxicity or metabolic disease in broilers (El-Sayed *et al*., 2021; Johnson *et al*., 2023; Zhao *et al*., 2024). The significant reduction in ALP at 25% inclusion could indicate reduced physiological stress or improved phosphorus utilization, though tissue-level validation would be needed for confirmation (Mustapha *et al*., 2022; Yunana *et al*., 2024; Lucas *et al*., 2025). Plasma proteins and glucose were stable, confirming protein and energy homeostasis were not severely disrupted (Onakpoya *et al*., 2022; Fasina and Adeola, 2023). Creatinine increases remained within physiological domains, suggesting no pathological muscle catabolism (Johnson *et al*., 2023; Abdullah and Ahmad, 2024). Collectively, these results confirm that moderate inclusion (25%) paired with appropriate processing supports acceptable growth, carcass yield, organ adaptation, and hematological stability, whereas excessive inclusion without nutritional rebalancing may compromise feed intake, gut development, and growth metrics, supporting sustainability models that emphasize inclusion thresholds and feed processing optimization for alternative feed adoption in poultry production (Zhao *et al*., 2024; Williams *et al*., 2024; Hassan *et al*., 2025; Lucas *et al*., 2025; Ayeni *et al*., 2024; Yunana *et al*., 2024).

CONCLUSIONS AND RECOMMENDATIONS

It was concluded that the inclusion of oven dried cassava starch effluent waste at 25% will help improves growth performance, carcass yield, organ and health status and reduction in cost of feed and overall cost of production in broiler chicken enterprise. 25% oven dried cassava starch effluent waste cassava starch effluent waste can be included the diet of broiler chicken is therefore recommended for optimum and reduction in cost of production.

FURTHER STUDY

Further studies should determine the precise metabolizable energy value, nutrient digestibility, and residual cyanide content of oven-dried cassava starch effluent waste (CSEW) to improve formulation accuracy. Dose–response trials using inclusion levels between 25% and 50% are necessary to identify the exact biological threshold at which growth performance begins to decline. Comparative evaluations of different processing methods such as fermentation, enzymatic treatment, or combined thermal processing are also recommended to enhance nutrient availability and reduce fiber-related limitations. In addition, histological examination of liver, kidney, and intestinal tissues should be conducted to confirm whether organ weight variations observed at higher inclusion levels reflect physiological adaptation or subclinical stress. Finally, longer-term feeding trials under commercial production conditions are required to validate performance, health status, and economic efficiency at farm scale.

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