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Table of Content

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Full Length Research Paper

Fermented mixture of cassava roots and palm kernel cake can substitute for maize in poultry feed formulation

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A feeding experiment was conducted to investigate the effect of feeding fermented cassava-palm kernel cake (PKC) on weight gain in broiler finishers. Twenty-five 25-day-old chicks were used and divided into five groups. Each group was fed a different diet with varying ratios of maize to cassava roots-palm kernel cake (PKC). The study found no significant difference in weight gain between birds fed fermented cassava roots-PKC and those fed maize. The fermented cassava-PKC had no impact on blood AST, ALT, or ALP levels, creatinine, or urea levels. However, there was a significant difference in albumin levels between birds fed fermented cassava-PKC diets and the control group. Blood calcium levels were higher in birds fed fermented cassava-PKC diets, with the highest levels in the 1:1 maize:fCassava-PKC diet. Birds on the control diet had higher cholesterol levels than those on the experimental diets, while serum triglyceride levels were lower in birds fed fermented cassava-PKC diets compared to the control group. The study concluded that fermented cassava roots-PKC can be used as a substitute for maize in broiler finisher diets without affecting performance.

Key words: Broiler, solid state fermentation, cassava roots, palm kernel cake.

INTRODUCTION

The goal of livestock production research is to reduce production costs while preserving animal comfort and enhance performance and products quality. Maize, a key ingredient in animal diets is scarce and expensive, thus alternative sources of energy and protein are required to replace or supplement it. Several maize alternatives have been previously studied (Egbune et al., 2021b; Ojo et al., 2022).

Currently, alternative protein and energy sources are being used to substitute soybean meal and yellow maize in monogastric animal feeds. Some developing nations generate a large volume of agro-waste byproducts that might be beneficial alternative feedstuffs. These by-products, on the other hand, may have non-starch poly saccharides (NSPs) such as xylans and mannans, in addition to anti-nutritional compounds that may hinder avian development (Sathitkowitchai et al., 2022).

Cassava is a native of South America that is botanically known as *Manihot esculanta* and is extensively planted in the tropics for its starchy and tuberous roots that are consumed as food by many households (Tonukari et al., 2015). Researchers have stated that Nigeria's cassava

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production accounts for 20.4% of the world's total production since 2017, making Nigeria the leading cassava producer in the world food market (Barrett et al., 2022). Although cassava has a high nutritional energy content, its incorporation in chicken feed is insufficient due to its limited crude protein content and low amino acid profile, high cyanogenic glucoside content and powdery quality of its dried meals (Tonukari et al., 2016). Cassava blended alongside agricultural byproducts such as palm kernel cake (PKC) has been recommended as a solution to rising chicken product prices caused by high maize prices, predominantly in sub-Saharan Africa (Egbune et al., 2021a, b). A 1:1 combination of cassava root meal (CSM) and PKC would provide a product with a composition comparable to maize; however, due to the physicochemical properties of CSM and PKC, the capability of broilers to consume such a product may be inadequate (Tonukari et al., 2016). The digestive tracts of most agricultural animals, including broilers, are inadequate to produce mannanase. However, solid fermentation is reported to improve ameliorate these objections.

Fermentation is a process that enhances the nutritional value of food by enhancing the quality of proteins, improving the absorption of fiber, and increasing the synthesis of essential amino acids, vitamins, and proteins. It also facilitates the availability of micronutrients while reducing the levels of antinutritional compounds (Ndego et al., 2022; Egbune et al., 2023). To initiate solid state-fermentation (SSF), bacterial and fungal species, such as *Aspergillus niger* and *Saccharomyces cerevisiae*, are commonly employed to produce enzymes and other beneficial by-products. *Rhizopus oligosporus* is a type of filamentous fungus that grows rapidly within a temperature range of 34 to 45°C and is classified as a Generally Recognized as Safe (GRAS) organism. It takes on various hyphal morphological forms and has been successfully utilized in the SSF of tempe, a traditional Indonesian fermented meal made from soybeans (Miszkiewicz et al., 2004).

After 6 days of SSF, Aladi et al. (2013) observed that newly grated cassava roots and PKC had improved crude protein (CP) content while decreasing the crude fiber (CF) content. When sun dried, the product reportedly replaced maize and reduced enteric *Escherichia coli* and *Salmonella* levels in broiler chicken diets (Chukwukaelo et al., 2018; Aladi et al., 2017). Although the increased nutritious content in agro-industrial by-products has been observed during fermentation, little research has been conducted on the use of fermented cassava-PKC as a feedstuff for broilers.

This research aims to investigate the impact of substituting maize with fermented cassava-PKC in broiler diet. The study involves replacing maize in the diet of broiler finishers with fermented cassava-PKC using *R. oligosporus* in different ratios (4:1, 3:1, 1:1, 1:3, and 0:4) to create a healthier and more nutritious feed for broiler finishers. The research also evaluates how the various feed compositions affect the proximate analysis of the compounded feed and serum biochemical parameters.

MATERIALS AND METHODS

Cassava roots and PKC were provided by the cassava unit and palm oil refinery unit of Songhai Delta Ltd., Sapele, Delta State, Nigeria. After thorough washing, the unpeeled roots were grated and pressed for 2 h to remove as much moisture as possible. The filamentous fungi *R. oligosporus* strains (produced by PT Aneka Fermentasi Industri, Bandung-Indonesia) were obtained from the Tonukari Biotechnology Laboratory in Sapele Delta State, Nigeria.

Substrate preparation for solid state fermentation

Five (A, B, C, D, and E) different samples of the cassava roots-palm kernel cake mixture (4:0, 3:1, 1:1, 1:3, and 0:4) were placed in bio-solid-state fermenters as substrates. Sample A served as a control. For samples B, C, D, and E, 1 g of *R. oligosporus* (1.4×10^2 colony forming unit [CFU]) of the fungus per gram calculated as stated by Egbune et al. (2022a) was added to the mixture and mixed very well. Solid-state fermentation was carried out at room temperature for 72 h. The fermented extract was then employed in broilers finisher feed production.

Metabolizable energy

The experimental diets were analyzed following standard laboratory procedures. Metabolizable energy (Kcal/kg) was estimated using the Panzenga (1985) formula from the proximate chemical composition data: Metabolizable energy (Kcal/kg) = 37 × CP + 81.8 × EE + 35.5 × NFE; where CP denotes crude protein (%), CF denotes crude fat (%), and NFE denotes nitrogen-free extract (carbohydrate, %).

Proximate analysis of feeds

Percentage fat determination

To determine the weight of fat as a percentage of the sample being analyzed, the Kirk and Sawyer (1991) method of solvent extraction gravimetric technique was employed, using the following equation:

$$\% \text{ fat} = \frac{W2 - W1}{W} X\ 100$$

where W1 = weight of empty extraction flask, W2 = weight of flask + oil (fat) extract, and W = weight of sample material.

Percentage fibre determination

The weight of fibers as a percentage of the sample weight was determined using the Weende technique (James, 1995), which involved the use of the following formula:

$$\% \text{ fiber} = \frac{W2 - W1}{W} X\ 100$$

where W = weight of sample material, W_2 = weight of crucible + sample material, and W_3 = weight of crucible + ash.

Table 1. Composition by components of broiler finisher's diet (%).

Component	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
	Maize only	**Maize: fCassava-PKC* 3:1**	**Maize: fCassava-PKC 1:1**	**Maize: fCassava-PKC 1:3**	**fCassava-PKC only**
Maize	64	48	32	16	0
fCassava-PKC	0	16	32	48	64
Soybean Cake	30	30	30	30	30
Bone meal	2	2	2	2	2
Limestone	2.9	2.9	2.9	2.9	2.9
Salt	0.5	0.5	0.5	0.5	0.5
Methionine	0.2	0.2	0.2	0.2	0.2
Lysine	0.2	0.2	0.2	0.2	0.2
Premix	0.2	0.2	0.2	0.2	0.2
Total	100	100	100	100	100

*fCassava-PKC: fermented cassava-PKC.
Source: Authors

Percentage ash determination

The percentage of ash content was determined using James' (1995) furnace incineration gravimetric method. The calculation was performed as follows:

$$\% \text{ Ash} = \frac{W2 - W1}{W} X\ 100$$

where W = weight of sample material analyzed, W1 = weight of empty crucible, and W2 = weight of crucible + ash.

Percentage carbohydrate determination

The calculation of this was carried out by following the procedures described by James (1995), and the following equation was utilized:

$$\% \text{ Carbohydrate} = \frac{\%\text{protein} + \%\text{ fat} + \%\text{ fibre}}{\%\text{ash} + \%\text{ moisture content}}$$

Percentage moisture determination

Using the gravimetric method of AOAC (1990) on a fresh weight basis, the weight of moisture lost was determined and expressed as a percentage of the weight of the sample analyzed. Therefore, the percentage of moisture lost in the sample is reported.

$$\% \text{ Moisture content (Mc)} = \frac{W2 - W3}{W2 - W1} X\ 100$$

where W_1 = weight of empty moisture can, W_2 = weight of can + sample before drying, and W_3= weight of can + dried sample.

Percentage dry matter determination

The calculation involved finding the difference between 100 and the percentage of moisture content. Therefore, the formula used to calculate this value is as follows:

% Dry matter = 100 - % MC

where MC = moisture content

Experimental design for feed formulations and trial

Twenty-five broiler chicks purchased from CHI farms, Ibadan were raised from a day old on a commercial starter feed. The chicks were of the classic Cornish white breed (Cornish White × White Plymouth Rock). The recommended medications and vaccines were administered to ensure good health status of the experimental birds. On the 29th day, the birds were weighed and divided into five groups in a completely randomized design. The broiler finisher feed was formulated with fermented cassava-PKC to replace maize in the diets; Diets 1 to 5 were produced using the following maize to cassava ratios: 4:0, 3:1, 1:1, 1:3, and 0:4.

Diet 1: (Control Feed): 100% Maize (control);
Diet 2: 80% fCassava-PKC: 70% Maize and 30% Solid-state fermented cassava roots-PKC;
Diet 3: 40% fCassava-PKC: 50% Maize and 50% Solid-state fermented cassava roots-PKC;
Diet 4: 60% fCassava-PKC: 30% Maize and 70% Solid-state fermented cassava roots-PKC;
Diet 5: 100% fCassava-PKC: 0% Maize and 100% Solid-state fermented cassava roots-PKC.

All other feed ingredients were kept constant (Table 1; details of formulated diets composition). Each diet was fed for three weeks, to a group of five chicks having approximately the same weight. Throughout the experiment, feed and water were provided *ad libitum*. The poultry cage house used for this experiment was located at Tonukari Biotechnology Laboratory Farm located at Sapele, Delta State. The bird pen has a measurement of 100 × 45 × 14 feet. They were brooded in deep litter pen. The broiler chicks were weighed at the end of the sixth week, which marked the completion of the feeding period.

Blood sampling and biochemical analysis from broiler chicks

By the end of the eighth week, pronounced veins in the chicks' wings and/or legs were punctured using a sterile syringe and needle, and the blood was then transferred to a test tube. The blood was dislodged and centrifuged at 2000 × *g* for 10 min to obtain the serum as supernatant after allowing it to coagulate for a while. The supernatants (sera) were utilized for biochemical investigations. The Randox® kits were used to measure serum ALT, AST, and ALP activity. The assay methods were meticulously carried out in accordance with the manufacturer's manual specifications. Approval for the ethical treatment of animals in this study was obtained from the Research and Ethics Committee (Ref: REC/FOS/22/04), which operates under the auspices of the Faculty of Science at Delta State University, Abraka.

Statistical evaluation

The SPSS software was utilized to analyze all the data. The experimental outcomes were evaluated utilizing analysis of variance (ANOVA) and the Fischer test of least significant (LSD) to compare the different group averages. Mean Standard Deviation was used to present the values.

RESULTS AND DISCUSSION

The use of SSF has garnered increased attention from researchers due to its potential to reduce food waste, mitigate environmental risks, and transform agro-industrial waste into valuable materials for human and animal consumption. The results of the proximate analyses conducted on the formulated diets are presented in Table 2. The study of broiler finisher feeds indicated the following composition range: CP 18.70 - 27.45%, CF 4.10 - 4.65%, crude fiber 22.90 - 24.60%, ash 6.40 - 8.50%, carbohydrate 35.10 - 37.25%, moisture 4.09 - 8.33%, and dry matter 89.40 - 97.10%. When compared to the control group, fermented cassava PKC exhibited a significant increase in crude protein content (27.45%) among the prepared diets.

In this study, significant differences ($p<0.05$) were observed in the crude protein content of fermented cassava-PKC compared to the control, emphasizing the importance of proteins and carbohydrates in poultry diets. The fermentation process, facilitated by microbial cells, may have contributed to the increase in CP by releasing enzymes such as cellulases, amylases, and linamarases, which are known to enhance nutrient availability (Egbune et al., 2022a, b; Ezedom et al., 2022). These findings are consistent with the results reported by Anigboro et al. (2022), indicating that using SSF on carbohydrate-rich sources for a specific period can lead to an increase in CP content.

Moreover, the prepared meal samples had a ME value ranging from 2273.33 to 2720.74 Kcal/kg, with a different proximate composition compared to the control diet. Specifically, the experimental feeds had a higher crude protein value and energy level, while the control feed had a lower crude protein content (18.7%) compared to the recommended value of 22 to 24% CP for diets for broiler finisher animals by the National Research Council (NRC). This resulted in a different energy profile between the experimental and control feeds, with the former having higher energy levels ranging from 2800 to 3000 kcal/kg ME (NRC, 1994). These results indicate that SSF can enhance the nutritional value of animal feed, which is crucial for optimal growth and development in animals.

The results obtained for the replacing maize in broiler diet with fermented cassava-PKC in 4:1, 3:1, 1:1, 1:3, and 0:4 ratios on the average weight of broilers' finisher diet between 8 and 12th weeks are as shown in Figure 1. Birds maintained on the formulated diet were not significantly different from the control.

The study showed that the broiler chickens fed the fermented cassava-PKC diets had a similar weight gains with those fed the control diet. This could be attributed to the higher crude protein (CP) and metabolizable energy (ME) contents of the fermented cassava-PKC meals compared to the control diet.

According to the study, the CP content of the fermented cassava-PKC meals ranged from 18.70% to 27.45%, while that of the control diet was 18.70%. CP is essential for muscle development, and higher levels of dietary CP have been shown to increase weight gain in broiler chickens (Chrystal et al., 2020; Saleh et al., 2021).

Furthermore, the ME content of the fermented cassava-PKC meals ranged from 2273.33 to 2720.74 kcal/kg, while that of the control diet was 2273.33 kcal/kg. ME is a measure of the available energy in feed that can be utilized by the bird. Higher levels of dietary ME have also been shown to increase weight gain in broiler chickens (Boontiam et al., 2019; Abu Hafsa et al., 2020).

Therefore, the higher CP and ME contents of the fermented cassava-PKC meals could have contributed to the observed weight gain in the broiler chickens fed these diets compared to the control diet. Several studies have reported improved broiler performance with the use of PKC treated with enzymes, indicating that the broilers were able to consume and digest the fermented cassava-PKC feed efficiently. These findings are consistent with previous research by Avwioroko et al. (2016), Tonukari et al. (2016), and Svihus et al. (2004). SSF of PKC has been shown to produce low levels of hemicellulose and cellulose but significant amounts of protein, and microbial fermentation can enhance the nutritional value of agricultural byproducts by altering their composition. Studies have shown that bacterial and fungal fermentation increases PKC's total protein content while reducing its fiber content (Srivastava et al., 2018; Montagne et al., 2003).

Figure 2 depicts how serum biochemical parameters are affected by dietary mixtures. The blood levels of liver enzymes alanine transaminase (ALT), aspartate transaminase (AST), and alkaline phosphatase (ALP) were similar in both the control group and the experimental groups of birds.

Monitoring AST, ALT, and ALP activity biomarkers is toxicologically important as their elevation in the blood can indicate a loss of hepatic function. However, there was no significant difference in blood AST, ALT, and ALP activity between broiler chicks fed fermented cassava-

Table 2. Composition of the formulated feeds

Composition	Maize only	Maize: fCassava-PKC 3:1	Maize: fCassava-PKC 1:1	Maize: fCassava-PKC 1:3	fCassava-PKC only
Protein (%)	18.70±0.3[a]	21.15±0.1[b]	27.45±0.5[c]	27.45±0.5[c]	27.45±0.5[c]
Fat content (%)	4.10±0.1[a]	4.61±0.2[a]	4.66±0.2[a]	4.67±0.2[a]	4.65±0.2[a]
Fiber (%)	22.90±0.4[a]	23.20±0.4[b]	24.40±0.4[b]	24.60±0.4[b]	24.20±0.4[b]
Ash (%)	8.50±0.2[a]	7.80±0.1[a]	6.40±0.1[b]	6.90±0.1[b]	6.80±0.1[b]
Carbohydrate (%)	35.10±0.3[a]	34.05±0.2[a]	33.15±0.2[b]	37.11±0.2[c]	37.25±0.2[c]
Moisture (%)	8.30±0.2[a]	4.09±0.1[b]	4.35±0.1[b]	4.43±0.1[b]	4.95±0.1[b]
Dry matter (%)	97.10±0.2[a]	91.10±0.3[c]	90.20±0.3[d]	89.40±0.3[d]	93.90±0.3[b]
Metabolizable energy (kcal/kg)	2273.33[a]	2368.43[b]	2573.66[c]	2720.74[d]	2718.40[d]

*fCassava-PKC: fermented cassava-PKC.
Source: Authors

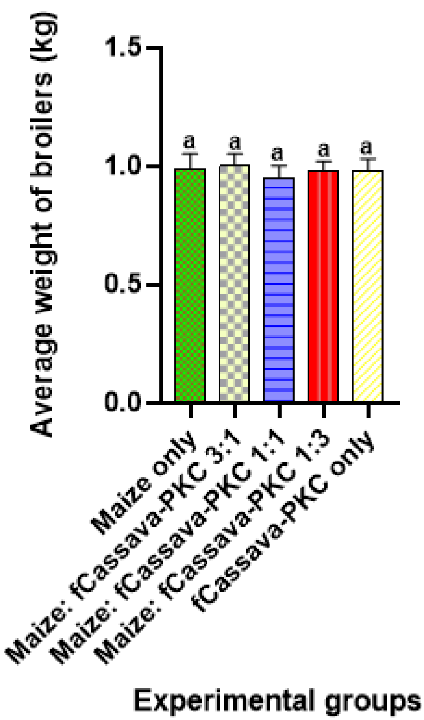

Figure 1. Performance of broilers finisher fed fermented cassava-PKC and maize diets after six weeks Bars not sharing same alphabet differs significantly at (p<0.05).
Source: Authors

PKC diets and healthy controls, suggesting that the hepatic function of the broilers was unaffected. Although serum ALP activity is a significant indicator of hepatobiliary damage and cholestasis, serum AST and ALT activity increases may be considered valid indicators for hepatocellular damage. These results indicate that the use of fermented cassava-PKC as a substitute energy source for the formulation of chicken feeds shows promise, despite the limited information available on its use.

The birds that ate the fermented cassava-PKC diets did not have significantly different blood creatinine levels compared to the control groups (p>0.05), shown in Table 3. Typically, high creatinine levels in the blood may indicate muscle damage and breakdown during metabolic processes, which is common as chicks grow. However, these results are consistent with previous research by Ahamefule et al. (2006), who also found no significant increase in creatinine levels and observed values within the normal range.

The birds that ate the fermented cassava-PKC diets did not have significantly higher urea levels compared to the control group (p>0.05). This suggests that the meal did not cause kidney damage from hydrogen cyanide or other harmful substances, likely because the appropriate amount was produced during fermentation. High levels of serum urea can indicate increased activity of certain enzymes or kidney injury caused by fever or tissue damage (Ibrahim et al., 2020; Natarajan et al., 2023).

Birds that ate fermented cassava-PKC diets had significantly different albumin levels (p<0.05) compared to the control group. This is consistent with a previous study on developing pigs fed cassava peel-based diets supplemented with Avizyme® 1300 (Fashina, 1991). A lack of protein can reduce the formation of blood cells, which are primarily protein-based, leading to lower haematological and serum parameters (Fernandez-Carballo et al., 2021; Abo-Zaid and Hamdi, 2022). Thus, the efficient use of protein by the birds indicates that the protein levels in the diet were sufficient to maintain normal protein stores, suggesting that the nutritional profile of the meal and feed additives was suitable for the birds' overall function (Lamsal et al., 2019; Zaefarian et al., 2019).

Birds fed fermented cassava-PKC diets had significantly higher blood calcium levels (p<0.05) than the control group, with the highest levels observed in birds fed

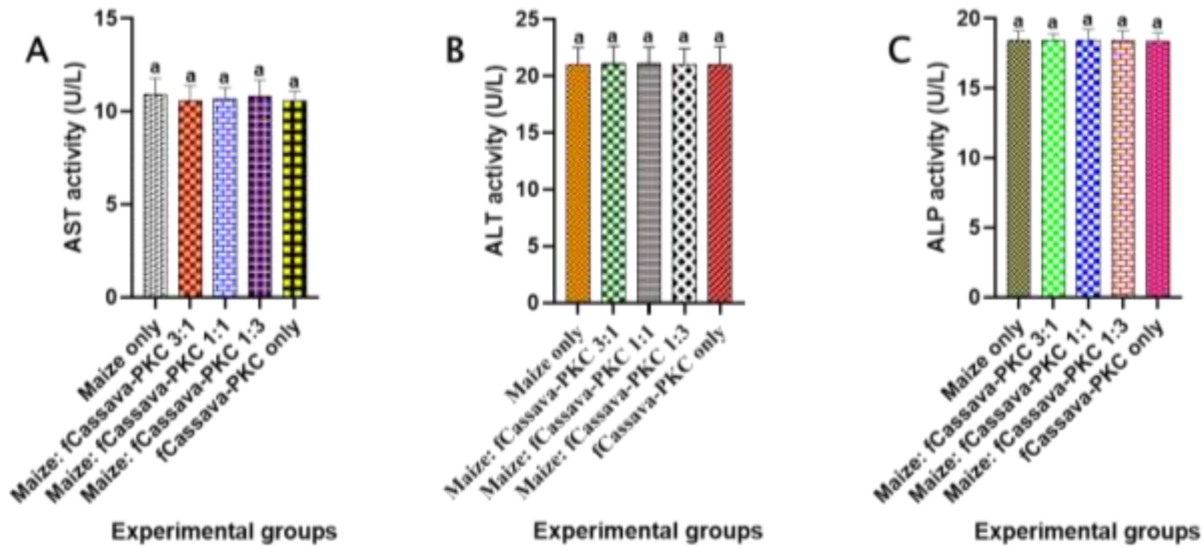

Figure 2. Serum AST, ALT and ALP activity (U/L) of birds (n = 5). Significant variations exist between various superscripts (p<0.05).
Source: Authors

Table 3. Serum metabolites of formulated feeds.

Serum metabolites	Maize only	Maize: fCassava-PKC 3:1	Maize: fCassava-PKC 1:1	Maize: fCassava-PKC 1:3	fCassava-PKC only
Creatinine	2.94[a]	2.90[a]	2.90[a]	2.91[a]	2.91[a]
Urea	3.26[a]	3.30[a]	3.35[a]	3.34[a]	3.35[a]
Albumin	2.24[a]	3.14[b]	3.96[c]	3.57[d]	3.59[d]
Calcium	4.10[a]	4.50[b]	5.23[b]	4.70[b]	4.90[b]
Cholesterol	143.33[a]	131.33[b]	120.67[b]	135.33d	135.99[d]
Triglyceride	57.20[a]	54.60[b]	44.20[c]	51.40	44.30[c]
HDL	93.90[a]	93.40[a]	93.20[a]	93.20[a]	93.70[a]
LDL	153.83[a]	153.47[a]	152.98[a]	154.34[a]	153.42[a]

*fCassava-PKC: fermented cassava-PKC.
Source: Authors

Maize:fCassava-PKC 1:1 diets. Fermenting cassava peel increases the mineral and ash content of the feed, potentially promoting bone formation pathways and leading to strong and healthy bones in the birds (Tonukari et al., 2016; David Troncoso et al., 2022). Serum albumin facilitates the transport of free fatty acids from the bloodstream to cells for energy storage, which may explain why birds fed fermented cassava-PKC diets gained more weight than those on the control diet.

Birds on the control diet had higher cholesterol levels than those on the experimental diets, which is contrary to previous studies reporting an inverse correlation between dietary fiber content and blood cholesterol levels in animals (Sadeghi and Pourreza, 2007). However, the difference could be due to the type and source of fiber used. The significant reduction in cholesterol levels in the experimental diets suggests the presence of hypocholesterolemic properties, possibly linked to decreased lipid mobilization. This suggests that fermented cassava-PKC diets may have the potential to lower cholesterol levels in meat.

Birds fed fermented cassava-PKC diets had lower serum triglyceride levels than the control group (p<0.05). This decrease may be due to enhanced triglyceride hydrolysis and fatty acid oxidation in fermented feed (Sugiharto and Ranjitkar, 2020). However, there was no significant difference in the levels of LDL and HDL in the broiler chicks.

According to the data presented in Table 4, the most cost-effective feed for achieving a 1 kg live weight increase in broiler chickens was Diet 3, which consisted of a mixture of maize and fermented Cassava-PKC in a

Table 4. Cost benefit analysis of maize to fermented cassava PKC in broiler feed formulation.

Ingredient	Quantity (kg)	Unit price (₦/kg)	Diet 1 Maize only	Diet 2 Maize: fCassava-PKC* 3:1	Diet 3 Maize: fCassava-PKC 1:1	Diet 4 Maize: fCassava-PKC 1:3	Diet 5 fCassava-PKC only
Maize	15	300	4500	3375	1125	1125	0
fCassava-PKC	15	250	0	937.5	937.5	2812.5	3750
Soybean	9	350	3150	3150	3150	3150	3150
Wheat offal	3	100	300	300	300	300	300
Palm Kernel Cake	1.5	1000	1500	1500	1500	1500	1500
Bone meal	0.6	20	12	12	12	12	12
Limestone	0.6	20	12	12	12	12	12
Salt	0.09	100	9	9	9	9	9
Premix	0.09	1500	135	135	135	135	135
Lysine	0.09	2000	180	180	180	180	180
Methionine	0.09	3000	270	270	270	270	270
Rhizopus oligosporus	0.003	200	0.6	0.6	0.6	0.6	0.6
Total cost of feeding (₦)	0	0	10068.6	9881.1	7631.1	9506.1	9318.6

*fCassava-PKC: fermented cassava-PKC.
Source: Authors

1:1 ratio, costing ₦7631.1. On the other hand, the control diet was the most expensive, costing ₦10068.6. Other diets such as Diet 2, consisting of maize and fermented Cassava-PKC in a 3:1 ratio, Diet 4, consisting of maize and fermented Cassava-PKC in a 1:3 ratio, and Diet 5, which only contained fermented Cassava-PKC, were priced at ₦9881.1, ₦9506.1, and ₦9318.6, respectively.

The cost of compounding 1 kg of feed and the cost of feed used per bird were significantly reduced (P<0.05) compared to the control group. Maize costs ₦300 kg^{-1} and fermented Cassava-PKC meal costs ₦250 kg^{-1}, making the use of fermented cassava-PKC meal as an alternative to maize in broiler diets financially beneficial, especially given that feed prices account for up to 80% of overall formulation costs according to Olugbemi et al. (2010). This study's findings suggest that the use of fermented Cassava-PKC meal could help reduce the cost of chicken feed, making poultry more affordable for consumers in Nigeria. However, the high cost of feed has already driven many small farmers out of the poultry industry, and major farmers may have no choice but to pass on the increased costs to customers.

Conclusion

The use of SSF to increase the nutritional value of cassava and PKC is a practical and promising approach. This experiment demonstrated that broiler chickens can effectively use fermented cassava-PKC as a substitute or addition to maize in their diet without any negative effects on their health or productivity. The fermented cassava-PKC is rich in energy-yielding metabolites similar to the control diet, and it does not appear to have any adverse effects on the liver or overall health of the broiler chicks. Additionally, this study found that incorporating fermented cassava-PKC into broiler finisher diets does not negatively impact the birds' blood biochemical profiles. Therefore, SSF has great potential in various biotechnological procedures and the production of improved bio-products.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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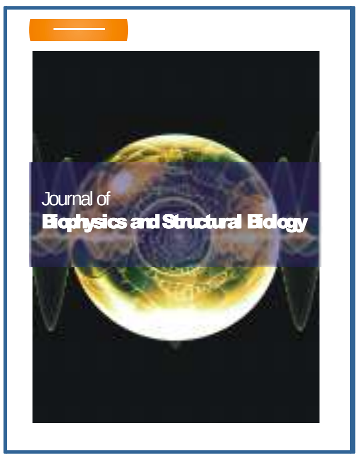

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