High-quality-cassava peel meal: Impact on growth performance, blood characteristics, and economic indices of grower pigs

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ABSTRACT

Background and Objective: Cassava peel, a byproduct of cassava tuber processing, is considered a waste. Processing using multi-level techniques enhances shelf-life and quality as a feed resource. The study examined the effects of high-quality-cassava peel meal (HQCPM) on growth, blood characteristics, and economic indices of growing pigs.

Methodology: Landrace-Large White crossbred male growing pigs ($n = 30$, $\bar{X} = 23.85 \pm 0.25$ kg) were randomly assigned to five dietary treatments, with six pigs in each group and each pig being a replicate. The control diet (1) had maize as the major calorie source, while it was replaced with HQCPM at 25%, 50%, 75%, and 100% for diets 2, 3, 4, and 5, respectively, within seven weeks of the feeding trial.

Main Results: The drying methods caused variations in the proximate composition, metabolizable energy, and hydrogen cyanide. The growth response showed that significant differences ($P < 0.05$) were observed in total weight gain, average daily weight gain, total feed intake, and average daily feed intake, with those fed diet 3 having the highest value of 33.50 ± 1.80, 0.68 ± 0.04, 107.92 ± 9.21, and 2.21 ± 0.35 kg respectively. The HQCPM diets had no negative consequences on the blood parameters, as most values were within the acceptable range for growing pigs. Linear decrease ($P < 0.05$) existed in the feed cost per kg (₦86.68 ± 3.32 to ₦64.64 ± 2.43) and feed cost per kg weight gain (₦309.59 ± 13.85 to ₦217.65 ± 19.36) while an increased ($P < 0.05$) profit (₦424.63 ± 12.22 to ₦530.22 ± 101.13) and economy efficiency of gain (137.29 ± 5.71 to 246.85 ± 65.59) was recorded from diets 1 to 5, respectively ($1 = ₦360).

Conclusions: HQCPM can substitute maize in growing pigs‘ diets up to 100% without any insalubrious consequences for the pigs, as it favors reduced feed costs and increased economic returns.

Keywords: Processed-cassava-peel, cost-benefit, hematology, serum biochemistry, swine

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INTRODUCTION

Pig production plays an important role in the food chain and livelihood of rural and urban households, especially in areas where there are no sentiments against it. Pigs can consume a variety of feeds with high feed efficiency and a higher meat-to-bone ratio than other livestock. This makes pig production more beneficial to farmers with respect to economic benefits and returns (Ahaotu, 2017). Also, pig production remains one of the veritable sources of animal protein owing to the large litter size and high growth rate (Ogunniyi and Omoteso, 2011).

In addition to other factors like animal genetics and health, nutrition is key to successful livestock production, including pigs. Feeding swine accounts for more than 65% of the overall production cost, making it the largest expense in the industry, and thus influences the profitability of the investment (Ojediran *et al*., 2020a). Profitability and long-term livestock development depend more heavily on access to low-cost feed. To achieve the aim of reduced feed cost, it is pertinent to use low-cost feed ingredients (Ahaotu *et al*., 2018). Consequently, by-products from agro-industries with cheaper sources of nutrients have been an alternative for feed-cost reduction and sustainable livestock production, especially in developing countries.

Cassava peels are wastes generated from cassava root or tuber processing. Cassava processing has grown from subsistence units to commercial plants and has increased tremendously over time. The peels are cassava root processing by-products and account for about 10% of the unpeeled tuber weight without the woody portions (Okike *et al*., 2015). These peels are recognized as a potential feed resource but constitute a major environmental challenge within and around processing centers due to drying constraints, especially in the wet season (Ojediran *et al*., 2020b). The peels can be processed in diverse ways, such as sun dehydration and soaking to reduce the hydrogen cyanide (HCN) content, which could be as high as 923–2,815 mg/kg in the raw peel (Taabu *et al*., 2015). Conventionally, the peels are sundried for 2–3 days during the dry season. In wetter months, a longer time is needed for drying, while soaking a large quantity may be impracticable. As a result, the generated peel quality is low due to aflatoxins contamination, resulting in wastage and environmental concerns.

In 2015, the International Livestock Research Institute (ILRI) initiated a multi-processing technique for processing cassava peels, and the resulting product was named high-quality cassava peel (HQCP$^{®}$) (Okike *et al*., 2015). The procedure increased the shelf life and nutrients of the peels for livestock, unlike the conventionally processed cassava peel, which is inferior to high-quality-cassava peel meal (HQCPM) in quality and can easily be affected by mold and *Aspergillus flavus*. The cyanide content in HQCPM was reduced to tolerable levels of 2.4–7.6 mg/100g (<100 ppm; Amole *et al*., 2022). According to Adesehinwa *et al*. (2016), the energy content of HQCPM is comparable to that of maize. Adesehinwa *et al*. (2016) reported the availability of 2,985 kcal/kg metabolizable energy in HQCPM, while Ojediran *et al*. (2022b) recorded 2,896 kcal/kg metabolizable energy. This high energy level in HQCPM shows that it could serve as a replacement for maize in livestock diet formulation. However, the availability of nutrients for livestock use has to be assessed.

Blood parameters are a reliable diagnostic tool increasingly studied in the area of toxicology and environmental monitoring (Agbede *et al*., 1991; Ojediran *et al*., 2015), as the determination of blood component values provide reliable results and may also give inputs to research studies on nutrition, physiology, and pathology (Bounous and Stedman, 2000). A hematological profile usually furnishes vital information on the body's response to injury of all forms, including toxic injury (Ihedioha *et al*., 2004). Hematological parameters can be influenced by anti-nutritional constituents present in the feed, while serum parameters, on the other hand, provide information on the integrity of the internal organs (Abioye *et al*., 2017). Therefore, this study focused on assessing the growth performance, blood characteristics (hematological parameters and serum biochemistry), and economic indices of growing pigs fed dried HQCPM.

MATERIALS AND METHODS

Experimental Site and Duration of the Experiment

All procedures were certified by the University's Animal Use Committee under reference ANB/UP/130124. This study made use of the swine facilities of Ladoke Akintola University of Technology Teaching and Research Farm in Ogbomoso, Oyo State, Nigeria. The city of Ogbomoso is geographically situated in Nigeria's derived savannah zone between the coordinates 8° 15'N and 8° 08'N of the equator and 4° 25'E and 4° 16'E of the Greenwich meridian. The average annual temperature of Ogbomoso is about 26.20°C, and the average annual rainfall is about 1,200 mm, with the relative humidity ranging from 75–95% (Ojedapo *et al*., 2009). The experiment lasted for seven weeks, from August 31 to October 19, 2021. The pen temperature and humidity were 24.6°C and 83.5% at the time of the experiment.

Preparation of Test Ingredients

The cassava peels utilized in this study were sourced from a local cassava processing plant in Ogbomoso, Oyo state. The assembled peels were subjected to the International Livestock Research Institute's multi-processing technique, involving sorting, washing, grating, pressing, sieving, and drying to engender high-quality cassava peel meal (ILRI, 2015). The drying was done in two ways. The first portion was sundried for three days, thinly spread on polythene nylon at an average of 30°C at eight sunshine hours, while the other portion was fried on a 1.5 × 1.0 m frying metal plate at 80–85°C with 5–7 kg output per frying depending on the volume design and capacity of the metal plate. However, the sundried portion was used in the feed composition because of the ease of adoption by farmers.

Management of the Pigs

Thirty male growing pigs (Landrace-Large White crossbred, weighing an average of 23.85 ± 0.25 kg) with good body conformation were purchased from a reliable farm and housed in the piggery. The piggery was an open-sided house with a concrete floor with 1.5 m by 2.5 m per pen. Each pen housed two pigs. They were randomly allotted to five dietary treatment groups of six pigs in each treatment, and each pig was a replicate. Before the start of the actual experiment, which involves taking readings, the pigs were acclimatized for one week. At the beginning of the experiment, the pigs were weighed, and subsequent weights were taken and recorded at weekly intervals. The pigs had free access to carefully measured feed and water throughout the seven-week duration of the experiment.

Experimental Diets

Table 1 shows the five diets formulated for the experiment. Diet 1 was a maize-palm kernel cake meal-based diet, serving as the control diet. HQCPM was included in diets 2, 3, 4, and 5, replacing maize at 25%, 50%, 75%, and 100% respectively. The crude protein for the formulated diets ranged from 16.78–17.15%, while the metabolizable energy ranged from 2,701.07–2,838.80 kcal/kg.

Data Collection

Growth performance

The pigs' initial body weights were determined before being randomly distributed into treatments. Their body weights were measured weekly to determine weight gain. The feed offered, and the leftover was weighed daily, and their variance was routinely used to calculate the feed intake. The summation of the feed intake per pen was divided into two feed intakes for each pig. The total feed intake per pig (TFI) was divided by the number of days to arrive as the average daily feed intake per pig (ADFI). Afterward, the growth performance indices, including the average daily gain (ADWG) and feed conversion ratio (FCR), were determined using the estimated values for feed intake and body weight gain (Ojediran *et al*., 2021b). The FCR was computed from the ratio of feed intake to weight gain (Ojediran *et al*., 2020a).

Blood characteristics

On terminating the experiment, 10 mL of blood samples were withdrawn from the jugular vein of three pigs in each treatment (one pig was randomly selected from each pen) using a sterilized needle and syringe (Adesehinwa *et al*., 2016). Five milliliters (5 mL) of each blood sample were collected into individual ethylene diamine tetra acetic acid (EDTA) tubes and plain vacutainer bottles for the analysis of hematological parameters and serum metabolites, respectively. The blood profile analyses (hematological and serum biochemical parameters) were done as described by Ojediran *et al*. (2019). Hematological parameters were analyzed using an auto-analyzer.

Table 1 Gross composition of experimental diets

Composition	Diet 1 (0%)	Diet 2 (25%)	Diet 3 (50%)	Diet 4 (75%)	Diet 5 (100%)
Ingredient					
Maize (%)	40.00	30.00	20.00	10.00	0.00
HQCPM (%)	0.00	10.00	20.00	30.00	40.00
Soybean meal (%)	4.00	14.00	15.00	16.50	17.50
Full-fat soybean (%)	4.00	4.00	6.00	8.00	11.00
Groundnut cake (%)	8.00	8.00	8.00	8.00	8.00
Palm kernel cake (%)	24.00	24.00	22.00	20.00	19.00
Wheat offal (%)	7.00	7.00	7.00	7.00	5.00
Corn bran (%)	10.00	10.00	10.00	10.00	10.00
Bone meal (%)	2.00	2.00	2.00	2.00	2.00
Lysine (%)	0.25	0.25	0.25	0.25	0.25
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
Nutrient composition					
Crude protein (%)	17.15	16.78	16.78	16.79	17.02
ME (kcal/kg)	2,838.80	2,791.37	2,755.94	2,720.50	2,701.07
Ether extract (%)	4.49	4.23	4.47	4.38	4.46
Crude fiber (%)	6.00	6.24	6.35	6.46	6.58
Calcium (%)	0.61	0.63	0.65	0.67	0.69
Lysine (%)	0.81	0.83	0.99	1.10	1.23
Methionine (%)	0.54	0.55	0.58	0.61	0.65

Note: HQCPM = high-quality-cassava peel meal, ME = metabolizable energy, Diet 1 = 0% maize replacement (control), Diet 2 = 10% HQCPM inclusion (25% maize replaced with HQCPM), Diet 3 = 20% HQCPM inclusion (50% maize replaced with HQCPM), Diet 4 = 30% HQCPM inclusion (75% maize replaced with HQCPM), Diet 5 = 40% HQCPM inclusion (100% maize replaced with HQCPM).

Economic indices

All measures of economic benefits were determined in accordance with Ojediran *et al*. (2020a) methodology. Feed cost was obtained as the sum of the quantity of each ingredient after being multiplied by the unit cost of each ingredient divided by 100. The feed cost per kg weight gain was derived from feed cost minus feed conversion ratio. The final weight per pig divided by total weight gain subtracted from the selling price gave the income per kg weight gain. Profit per kg weight gain is derived from income minus feed cost per kg weight gain. The derived profit divided by feed cost per kg weight gain multiplied by 100 gave economic efficiency of growth.

Laboratory Analysis

The proximate composition and HCN of the experimental diets were determined using the AOAC (2005) method, while their respective metabolizable energy was calculated using Pauzenga's model (Pauzenga, 1985).

Statistical Analysis

All collated data were analyzed with a one-way analysis of variance (ANOVA) in SAS (2000). Using the same statistical package, Duncan's multiple range test was used to rank the differences among the means at 5% probability.

RESULTS AND DISCUSSION

Nutrient Composition of Differently-dried HQCPM

The nutrient composition of dried HQCPM used in this study is shown in Table 2. The sundried HQCPM contained 5.25% crude protein (CP), 4.61% crude fiber (CF), 6.21% ash, 0.44% ether extract (EE), 90.60% dry matter content, and 74.09% nitrogen-free extract (NFE). Additionally, the peel had a metabolizable energy and HCN of 2,873.22 kcal/kg and 34.74 mg/kg, respectively. The fried HQCPM contained 5.25% CP, 4.23% CF, 2.24% ash, 1.01% EE, 90.77% dry matter content, and 78.04% NFE. Additionally, the peel had a metabolizable energy and HCN of 3,047.29 kcal/kg and 43.23 mg/kg, respectively.

Adesehinwa *et al*. (2008) conveyed that cassava peel constitutes 5.69%, 20.49%, 5.04%, 0.75%, 68.08%, and 80.75% of CP, CF, ash, EE, NFE, and dry matter, respectively. Adesehinwa *et al*. (2016) further reported that HQCPM had improved nutritive value because it contained 6.63% CP, 8.47% CF, 3.28% ash, 2.47% EE, 70.00% NFE, and 90.94% dry matter. Additionally, it was opined by Ojediran *et al*. (2022b) that fermentation of HQCPM further enhanced the nutritive quality of HQCPM as fermented HQCPM had 7.85% CP, 4.46% EE, 7.10% CF, 6.80% ash, 64.09% NFE, 90.30% dry matter, and 2,896.31 kcal/kg metabolizable energy. The slight variations observed in the nutritional compositions of the HQCPM used in this study compared to those of the other aforementioned authors could be due to the cassava species, origin, and processing methods. However, the high metabolizable energy and moderately rich crude protein of HQCPM make it a suitable alternative replacer of maize. Subjecting cassava peel to different processing techniques is linked with a reduction in the HCN concentration. In the study to determine the influence of processing techniques on growing rabbits' performance, Olafadehan *et al*. (2012) reported that processed peels had reduced HCN content. Furthermore, sun-dried, retted, and ensiled cassava peel had 165.36, 299.21, and 98.10 mg/kg of HCN, respectively. This study revealed that the techniques involved in generating HQCPM resulted in a greater reduction in the HCN content than the other methods used in the study of Olafadehan *et al*. (2012). However, the differences observed in the cyanide content between the sundried and fried HQCPM could be attributed to the drying methods. Ndubuisi and Chidiebere (2018) reported that the cyanide in cassava is water soluble. Thus, soaking is more effective than drying, and frying as a method of drying reduces cyanide less effectively compared to sun drying. This is attributable to the bound cyanide. Sun drying may not be a one-time thing, while frying could.

Table 2 Chemical composition of dried high-quality-cassava peel meal (% dry matter)

Composition	Sundried	Fried
Crude protein (%)	5.25	5.25
Crude fiber (%)	4.61	4.23
Ash (%)	6.21	2.24
Ether extract (%)	0.44	1.01
Dry matter (%)	90.60	90.77
Nitrogen-free extract (%)	74.09	78.04
Metabolizable energy (kcal/kg)	2,873.22	3,047.29
Hydrogen cyanide (mg/kg)	34.74	43.23

Growth Performance of Grower Pig Fed Diets Containing Dried HQCPM

Table 3 illustrates the growth performance of grower pigs fed dried HQCPM. The result showed that the average initial weight, average final weight gain, and FCR were not substantially different ($P > 0.05$) by the inclusion of varied levels of HQCPM in the diets. However, variations ($P < 0.05$) exist in the TWG, ADWG, TFI, and ADFI. Diet 3, which contained 50% HQCPM as a replacement for maize, had the peak value among the significant growth indicators. The TWG ranged from 25.83 ± 2.65 to 33.50 ± 1.80 kg, with the highest and smallest values observed in diet 3 and diet 4, respectively. Pigs fed diet 2 had comparable TWG with diets 1, 3, and 5 but differed from pigs fed diet 4, whose value is similar to the values of pigs fed diet 5. The trend of variation occurring in the diets for ADWG is similar to that of TWG. The differences in diet composition had a significant effect ($P < 0.05$) on the TFI, with the highest value occurring in diet 3 (107.92 ± 9.21 kg), followed by diets 1 (102.50 ± 8.06 kg), 2 (102.41 ± 8.06 kg), 5 (92.38 ± 10.32 kg), and 4 (90.37 ± 6.72 kg) in relative order. However, despite the differences observed in feed intake and weight gain, no significant variation ($P > 0.05$) was observed in the FCR among the treatments.

In this study, the observations made on the average weight gain contradict the findings of Adeyemi and Akinfala (2019), who reported no variation in the average weight gain of grower pigs offered levels of cassava crop meal. However, the FCR reported in this study supports the findings of the same author. Also, the weight gain observed in this study differs from that of Irekhore *et al*. (2015), where it was reported that the body weight gain of grower pigs was neither influenced by cassava peel meal nor its supplementation with enzyme when replacing maize. However, the average feed intake observed in this study conformed with the findings of Unigwe *et al*. (2014), where it was reported that differences exist for the average feed intake of grower pigs fed sundried cassava peel meal as a replacement for maize. In the study examining the effects of replacing maize with HQCPM on weaned pigs, Adesehinwa *et al*. (2016) reported a decreasing weight gain as the inclusion of HQCPM increased across the group. However, in the assessment of the growth of weaned pigs fed fermented HQCPM in place of maize, Ojediran *et al*. (2022b) reported no differences in the animals‘ feed intake and weight gain, while feed was better utilized by the animals fed HQCPM diets. It was further elaborated that the fermentation of HQCPM and the quality and quantity of the other feedstuffs used in the study could have led to enhanced feed efficiency. Therefore, the results obtained in the study could be a function of the processing methods employed to improve the nutritive content of the cassava peels used. In this study, the diets were similarly utilized by the animals in the dietary groups despite the variations existing in the animal's feed intake and weight gain. Although the HQCPM diets had lower metabolizable energy than the control diet, the animals fed HQCPM, with the exclusion of those fed 50% HQCPM, had reduced feed intake. The palatability of the feed beyond 50% replacement of maize with HQCPM may have reduced, thus influencing feed intake. This could be due to higher dietary fiber content and residual cyanide in the diets. However, HQCPM-fed animals had a final weight and FCR comparable to those of the animals fed the control diet.

Hematological Parameters of Grower Pigs Fed Diets Containing Dried HQCPM

Table 4 shows the hematological parameters of grower pigs fed HQCPM as a replacement for maize. The red blood cell (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and platelet count (PLT) were not significantly affected by the diets ($P > 0.05$). On the contrary, the inclusion of HQCPM in the grower pigs' diet influenced the values of the white blood cell (WBC), hemoglobin (Hb), hematocrit (HCT), mean corpuscular hemoglobin concentration (MCHC), and lymphocytes (LYM) count in the pigs. Pigs fed diet 1 had the highest WBC value ($18.05 \pm 2.95 \times 10^3$/L), which is comparable to pigs fed diets 3 ($16.95 \pm 1.15 \times 10^3$/L) and 4 ($16.42 \pm 0.81 \times 10^3$/L), while the least WBC value was observed in pigs fed diet 2 ($12.95 \pm 1.55 \times 10^3$/L). Diet 3 had the most influence on the Hb (13.05 ± 1.85 g/dL), HCT (53.95 ± 8.05%), and LYM (74.65 ± 0.15%).

In veterinary medicine, the examination of blood biochemistry through hematological parameters and serum metabolites is often used to assess animals' health status. Many studies have shown that nutrition, including dietary protein, influences hematological markers (Orororo *et al*., 2014). This study's hematological findings are comparable to those of Adesehinwa *et al*. (2016), where the authors examined the effect of graded levels of HQCPM fine mash as a replacement for maize on the hematological parameters of growing pigs. In both studies, the inclusion of HQCPM influences WBC and LYM concentration in the blood of grower pigs by reducing the WBC count while the LYM was aggravated. The lower WBC values of animals fed HQCPM diets were indicative of impairment to the immunity status of the pigs (Ojediran *et al*., 2021b), attributable to the presence of residual HCN present in the cassava peel meal. However, it was within normal range. The observed increase in Hb, HCT, and MCHC among pigs fed HQCPM diets illustrates an improvement in the efficiency of RBC in transporting oxygen across the blood. Thus, erythropoiesis was not impaired. Perri *et al*. (2016) indicated that HCT above 30% suggests adequate blood iron status. Lymphocyte values were within the normal range for pigs and were indicative of antibody function (Dlamini *et al*., 2017). On the other hand, the decrease in the PLT values is also an indication of a reduction in the blood clotting ability of the pigs fed HQCPM. Generally, the effect of including HQCPM in growing pigs' diets is not detrimental to their health status as the hematological parameters measured did not deviate from the acceptable range for healthy growing pigs (Mitruka and Rawnsley, 1977; Merck Manual, 2022a).

Serum Metabolites of Grower Pig Fed Diets Containing Dried HQCPM

The serum metabolites of grower pig-fed dried HQCPM are presented in Table 5. Albumin, alanine aminotransferase (ALT), and aspartate aminotransferase (AST) were not influenced ($P > 0.05$) by the HQCPM diets. On the other hand, total protein, globulin, alkaline phosphatase (ALP), triglyceride, urea, cholesterol, creatinine, and glucose were significantly affected ($P < 0.05$) by the HQCPM diets. The total protein decreases linearly with increasing levels of HQCPM except for diet 4 (4.49 ± 0.16 g/dL), which had a similar value to diet 1 (5.04 ± 0.52 g/dL). Globulin, triglyceride, and cholesterol were reduced in the HQCPM diets. The highest value for ALP was recorded in animals fed diet 5 (47.68 ± 9.08 U/L) with similar values with those fed diets 3 (38.73 ± 7.40 U/L) and 4 (37.93 ± 10.26 U/L) while animals fed diet 2 had the least value.

Table 3 Growth performance of grower pigs fed dried high-quality-cassava peel meal (HQCPM)

Parameters	**Diet 1**	**Diet 2**	**Diet 3**	**Diet 4**	**Diet 5**	**P-value**
Initial weight (kg)	23.95 ± 0.05	23.70 ± 2.80	23.90 ± 0.10	24.20 ± 4.99	24.00 ± 6.81	0.999
Final weight (kg)	52.70 ± 2.00	54.80 ± 4.40	57.40 ± 1.90	50.03 ± 7.15	51.53 ± 7.76	0.500
TWG (kg)	28.75 ± 1.95^{bc}	31.10 ± 1.60^{ab}	33.50 ± 1.80^{a}	25.83 ± 2.65^{c}	27.53 ± 1.75^{bc}	0.048
ADWG (kg)	0.59 ± 0.04^{bc}	0.63 ± 0.03^{ab}	0.68 ± 0.04^{a}	0.53 ± 0.05^{c}	0.56 ± 0.04^{bc}	0.048
TFI (kg)	102.50 ± 8.06^{b}	102.41 ± 8.06^{c}	107.92 ± 9.21^{a}	90.37 ± 6.72^{e}	92.38 ± 10.32^{d}	0.021
ADFI (kg)	2.09 ± 0.32^{b}	2.09 ± 0.32^{b}	2.21 ± 0.35^{a}	1.84 ± 0.17^{d}	1.89 ± 0.16^{c}	0.021
FCR	3.58 ± 0.24	3.30 ± 0.17	3.23 ± 0.17	3.52 ± 0.36	3.36 ± 0.21	0.404

Note:^{a,b,c,d} Means within the same row with different superscripts differ ($P < 0.05$). Diet 1 = 0% maize replacement (control), Diet 2 = 10% HQCPM inclusion (25% maize replaced with HQCPM), Diet 3 = 20% HQCPM inclusion (50% maize replaced with HQCPM), Diet 4 = 30% HQCPM inclusion (75% maize replaced with HQCPM), Diet 5 = 40% HQCPM inclusion(100% maize replaced with HQCPM), TWG = total weight gain, ADWG = average daily weight gain, TFI = total feed intake, ADFI = average daily feed intake, FCR = feed conversion ratio.

Table 4 Hematological parameters of grower pigs fed diets containing dried high-quality-cassava peel meal (HQCPM)

Parameters	**Diet 1**	**Diet 2**	**Diet 3**	**Diet 4**	**Diet 5**	**P-value**	**Reverence value***
WBC (×10^3/L)	18.05 ± 2.95^{a}	12.95 ± 1.55^{c}	16.95 ± 1.15^{a}	16.42 ± 0.81^{ab}	13.80 ± 0.50^{bc}	0.016	10.00–22.00
RBC (×10^6/mm^3)	7.40 ± 0.46	9.06 ± 1.71	9.36 ± 1.23	7.69 ± 0.87	7.50 ± 0.71	0.140	5.00–9.00
Hb (g/dL)	9.95 ± 0.45^{c}	12.20 ± 1.30^{ab}	13.05 ± 1.85^{a}	11.10 ± 0.52^{abc}	10.77 ± 0.81^{bc}	0.047	9.00–16.00
HCT (%)	42.15 ± 2.85^{c}	50.20 ± 5.90^{ab}	53.95 ± 8.05^{a}	45.57 ± 3.56^{ab}	43.10 ± 2.62^{b}	0.043	32.00–50.00
MCV (μ^3)	56.95 ± 0.35	56.20 ± 4.10	57.55 ± 1.05	59.37 ± 2.66	57.80 ± 6.16	0.852	50.00–68.00
MCH (pg)	13.45 ± 0.25	13.65 ± 1.15	13.95 ± 0.15	14.50 ± 1.15	14.43 ± 1.53	0.646	13.00–21.00
MCHC (g/dL)	23.65 ± 0.55^{b}	24.35 ± 0.25^{ab}	24.20 ± 0.20^{ab}	24.40 ± 0.90^{ab}	24.97 ± 0.40^{a}	0.012	23.00–34.00
PLT (×10^3/mm^3)	2.66 ± 0.55	1.93 ± 0.84	1.72 ± 0.31	1.88 ± 1.22	2.09 ± 1.06	0.713	2.00–5.00
LYM (%)	63.30 ± 5.30^{c}	67.10 ± 0.40^{bc}	74.65 ± 0.15^{a}	71.93 ± 1.88^{ab}	70.17 ± 5.22^{ab}	0.019	39.00–63.00

Note:^{a,b,c} Means within the same row with different superscripts differ ($P < 0.05$). Diet 1 = 0% maize replacement (control), Diet 2 = 10% HQCPM inclusion (25% maize replaced with HQCPM), Diet 3 = 20% HQCPM inclusion (50% maize replaced with HQCPM), Diet 4 = 30% HQCPM inclusion (75% maize replaced with HQCPM), Diet 5 = 40% HQCPM inclusion(100% maize replaced with HQCPM), WBC = white blood cell, RBC = red blood cell, Hb = hemoglobin, HCT = hematocrit, MCV = mean cell volume, MCH = mean cell hemoglobin, MCHC = mean corpuscular hemoglobin concentration, PLT = platelet, LYM = lymphocytes. * Mitruka and Rawnsley (1977) and Merck Manual (2022a).

The urea values obtained vary from 8.38 ± 0.14 to 11.33 ± 1.58 mg/dL, with the highest value derived from pigs fed diet 5 while the lowest was from pigs fed diet 3. Pigs fed diet 2 (1.46 ± 0.25 mg/dL) had the maximum value for creatinine and differed from the pigs fed other diets, which shared some similarities. Cholesterol values were lower in pigs fed HQCPM diets. Glucose was highest in animals fed diet 3 (77.60 ± 8.07 mg/dL), while the pigs fed diets 1 (51.62 ± 5.74 mg/dL), 4 (51.61 ± 7.89 mg/dL), and 5 (51.02 ± 6.11 mg/dL) had similar values and differed from the value of animals fed diet 2 (33.88 ± 2.69 mg/dL).

Serum protein has been linked to the quality of feed, and serum albumin increases when protein intake exceeds the amount required for growth and maintenance (Ojediran *et al*., 2021a). Pigs fed a control diet and 75% HQCPM had elevated serum total protein, and the nonsignificant albumin levels showed that the feed was adequate in protein. The concentration of albumin for pigs fed HQCPM diets falls into the normal range for a healthy growing swine (Merck Manual, 2022b). Thus, it is evident that HQCPM dietary protein is adequate to support the animal‘s growth. The globulin levels were not elevated in pigs fed HQCPM diets, which suggests the absence of infections, liver damage, kidney dysfunction, or hemolytic anemia (Ojediran *et al*., 2022a). Observed values of ALT and AST, according to Unigwe *et al*. (2018), suggest that there was no liver, heart, kidney, and muscular wastage or impairment. Elevated ALP, as reported by Hyder *et al*. (2013), could be attributed to cholestatic situations because ALP is majorly made in the liver and osteoblasts in hepatic bile duct obstruction. The observed AST and ALP rule out liver damage because they fall within the normal range for the class of pigs (Ojediran *et al*., 2021b). However, prolonged use of 100% HQCPM as a replacement for maize may pose a threat to the liver of the pigs owing to the elevated level of ALP. The result on cholesterol and triglycerides in HQCPM diets does not indicate a cholestatic disease. Turyk *et al*. (2015) reported a lower triglyceride and cholesterol level when pigs were fed mixtures containing barley or triticales, as also observed in diets with HQCPM.

Urea is the major nitrogenous end product of amino acid catabolism that is not utilized in mammals (Adesehinwa *et al*., 2016). Hence, urea production is indicative of modifications to dietary protein intake and utilization patterns. In animals, the level of urea and creatinine is associated with muscular wastage (Adesehinwa *et al*., 2016). In this study, there is no specific trend in the urea and creatinine values of the animals, as the values overlap between the groups. However, Adesehinwa *et al*. (2016) suggested that higher values of urea and creatinine in some animals fed the HQCPM diets might be due to inefficient utilization of the dietary protein. Yet, this was not reflected in the overall performance of the pigs. The high fibrousness of feed ingredients like cassava peel influences diet retention time in the digestive tract and nutrient utilization (Ojediran *et al*., 2021b). Davis and Briggs (1947) reported that diets high in fiber are linked with reduced blood glucose. The higher fiber content of HQCPM diets might have resulted in the lower glucose values obtained in this study, excluding diet 3.

Economic Indices of Grower Pigs Fed Diets Containing Dried HQCPM

As shown in Table 6, the diets impacted ($P < 0.05$) the economic indices of the grower pigs. Although the income per kg weight gain (WG) was parred ($P > 0.05$) in all the pigs fed the different diets, the feed cost per kg, feed cost per kg WG, profit per kg WG, and economic efficiency of gain were significantly different ($P < 0.05$). Feed cost per kg decreased linearly across the treatments, but pigs fed diets 4 (₦68.12 ± 2.09) and 5 (₦64.64 ± 2.43) had comparable values. The values of feed cost per kg WG ranged from ₦217.65 ± 19.36 to ₦309.59 ± 13.85, with the highest and lowest values occurring in diets 1 and 5, respectively.

Table 5 Serum metabolites of grower pigs fed dried high-quality-cassava peel meal (HQCPM)

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	P-value	Reverence value*
Total protein (g/dL)	5.04 ± 0.52^{a}	3.74 ± 0.04^{b}	3.71 ± 0.08^{b}	4.49 ± 0.16^{a}	3.67 ± 0.40^{b}	0.001	3.00–7.00
Albumin (g/dL)	2.52 ± 0.20	2.34 ± 0.20	2.16 ± 0.20	2.49 ± 0.25	2.52 ± 0.28	0.303	1.00–4.00
Globulin (g/dL)	2.52 ± 0.33^{a}	1.40 ± 0.16^{c}	1.55 ± 0.13^{c}	2.00 ± 0.28^{b}	1.15 ± 0.14^{c}	0.001	1.00–6.00
ALT (U/L)	27.93 ± 5.10	34.25 ± 6.89	33.78 ± 3.40	35.16 ± 3.38	33.65 ± 3.16	0.383	26.00–58.00
AST (U/L)	76.32 ± 8.94	83.42 ± 9.21	78.95 ± 4.73	87.19 ± 3.99	76.31 ± 20.08	0.696	32.00–84.00
ALP (U/L)	36.96 ± 1.31^{b}	27.39 ± 0.74^{b}	38.73 ± 7.40^{ab}	37.93 ± 10.26^{ab}	47.68 ± 9.08^{a}	0.036	11.00–40.00
Triglyceride (mg/dL)	101.30 ± 7.87^{a}	75.58 ± 13.65^{b}	54.06 ± 4.72^{bc}	39.19 ± 15.79^{c}	50.39 ± 17.65^{c}	0.001	50.00–102.00
Urea (mg/dL)	9.32 ± 0.81^{ab}	10.31 ± 1.08^{a}	8.38 ± 0.14^{b}	9.62 ± 0.29^{ab}	11.33 ± 1.58^{a}	0.044	9.00–30.00
Cholesterol (mg/dL)	140.38 ± 13.59^{a}	125.66 ± 61.51^{ab}	72.83 ± 26.79^{b}	71.45 ± 8.31^{b}	125.28 ± 21.75^{ab}	0.047	70.00–140.00
Creatinine (mg/dL)	1.03 ± 0.06^{bc}	1.46 ± 0.25^{a}	1.27 ± 0.12^{ab}	0.77 ± 0.15^{c}	1.01 ± 0.18^{bc}	0.004	0.50–2.70
Glucose (mg/dL)	51.62 ± 5.74^{b}	33.88 ± 2.69^{c}	77.60 ± 8.07^{a}	51.61 ± 7.89^{b}	51.02 ± 6.11^{b}	0.001	34.00–150.00

Note: ^{a,b,c} Means within the same row with different superscripts differ ($P < 0.05$). Diet 1 = 0% maize replacement (control), Diet 2 = 10% HQCPM inclusion (25% maize replaced with HQCPM), Diet 3 = 20% HQCPM inclusion (50% maize replaced with HQCPM), Diet 4 = 30% HQCPM inclusion (75% maize replaced with HQCPM), Diet 5 = 40% HQCPM inclusion(100% maize replaced with HQCPM), ALT = alanine aminotransferase, AST = asparate aminotransferase, ALP = alkaline phosphatase. * Mitruka and Rawnsley (1977) and Merck Manual (2022b).

Table 6 Economic indices of grower pigs fed diets containing dried high-quality-cassava peel meal (HQCPM)

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	P-value
Feed cost per kg (₦)	86.68 ± 3.32^{a}	77.76 ± 1.93^{b}	72.96 ± 1.98^{c}	68.12 ± 2.09^{d}	64.64 ± 2.43^{d}	0.000
Feed cost per kg WG (₦)	309.59 ± 13.85^{a}	256.35 ± 9.86^{b}	235.57 ± 17.65^{bc}	239.75 ± 22.59^{bc}	217.65 ± 19.36^{c}	0.001
Income per kg WG (₦)	734.21 ± 22.02	704.12 ± 20.39	685.88 ± 14.18	773.69 ± 54.32	747.87 ± 90.09	0.275
Profit per kg WG (₦)	424.63 ± 12.22^{b}	447.76 ± 29.56^{ab}	450.32 ± 5.73^{ab}	533.75 ± 57.49^{a}	530.22 ± 101.13^{a}	0.010
Economic efficiency of gain	137.29 ± 5.71^{c}	175.12 ± 17.72^{bc}	191.94 ± 15.59^{abc}	224.51 ± 37.69^{a}	246.85 ± 65.59^{a}	0.027

Note: ^{a,b,c,d} Means within the same row with different superscripts differ ($P < 0.05$). Diet 1 = 0% maize replacement (control), Diet 2 = 10% HQCPM inclusion (25% maize replaced with HQCPM), Diet 3 = 20% HQCPM inclusion (50% maize replaced with HQCPM), Diet 4 = 30% HQCPM inclusion (75% maize replaced with HQCPM), Diet 5 = 40% HQCPM inclusion(100% maize replaced with HQCPM), WG = weight gain. $1 = ₦360.

Diet 2 had a higher feed cost per kg WG value than diet 5 but had similar values to diets 3 and 4. All diets with HQCPM had comparable values for profit per kg WG, with diet 5 (₦530.22 ± 101.13) having the highest numerical value. However, pigs fed diet 1 with no HQCPM included had similar values with diets 2 (₦447.76 ± 29.56) and 3 (₦450.32 ± 5.73). The economic efficiency of gain was highest in pigs fed diet 5 (246.85 ± 65.59), even though its value is similar to pigs fed diets 3 (191.94 ± 15.59) and 4 (224.51 ± 37.69). Similarity occurred in the economic efficiency of gain in pigs fed diets 1 (137.29 ± 5.71), 2 (175.12 ± 17.72), and 3 with diet 1 having the lowest value.

The profitability of any livestock industry, including swine, is dependent on several factors, but nutrition plays a huge role due to the high feed cost (Choi *et al*., 2015; Ojediran et al., 2020a). Replacement of maize with HQCPM influences feed cost with reduced feed cost per kg and feed cost per kg WG due to the high cost of corn. The control diet had the highest feed cost per kg and feed cost per kg WG with ₦86.68 and ₦309.59, respectively, while the lowest feed cost per kg and feed cost per kg WG were recorded in diet 5 with ₦64.64 and ₦217.65, respectively. Furthermore, the profit margin and economic efficiency of gain were further widened with increasing HQCPM in the diets. The best economic efficiency of gain was achieved at 75% and 100% HQCPM replacement for maize. This depicts that replacing maize with HQCPM offers economic benefits to pig producers. Irekhore *et al*. (2015) reported that the inclusion of cassava peels in growing pigs‘ diets reduces feed cost, and Adesehinwa *et al*. (2011) reported that enzyme supplementation of cassava peel-based diets reduces feed cost per kg WG. In this study, feed costs decreased linearly with the increasing inclusion of HQCPM. Several studies have reported similar outcomes of reduction in feed cost with HQCPM diets in weanling and growing pigs (Adesehinwa *et al*., 2016; 2019; Sonta *et al*., 2016; Ojediran *et al*., 2022b). Ojediran *et al*. (2022b) observed higher economic efficiency of gain with HQCPM at 75% and 100% replacement for maize.

CONCLUSIONS

Substituting maize with 50% dried HQCPM increased weight gain and feed intake of growing pigs. However, 100% dried HQCPM did not influence the FCR. Feeding 100% dried HQCPM as a substitute for maize did not compromise the hematological and serum biochemical indices of growing pigs. The use of 100% dried HQCPM favors reduced feed costs and increased economic returns. Therefore, maize can be substituted with 100% dried HQCPM in the diet of growing pigs.

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