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Solid-state fermentation improves the nutritive value of grated cassava roots and palm kernel cake mix for growing pigs

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Abstract

The increasing need to transform the abundant agro-industrial by-products into livestock feed materials is limited by the high contents of non-starch polysaccharides such as cellulose and mannan. In this study, the potential of solid-state fermentation to enhance the nutritive value of a mixture of grated cassava roots and palm kernel cake for pigs was evaluated. Solid state fermented mixture of grated cassava roots and palm kernel cake was used to replace maize in diets of growing pigs and compared to a negative control in which maize was replaced with a blend of cassava meal and palm kernel cake in a ratio of 1:1. Data was collected on weight gain, feed intake, feed conversion ratio; carcass and meat quality attributes. The live weights of boars and gilts fed diets containing the fermented mixture of grated cassava roots and palm kernel cake (38.07 and 37.86 Kg) were similar to ($p>0.05$) those fed maize based diets (37.94 and 36.93 Kg) but superior ($p<0.05$) to those fed diets containing CSM-PKC (33.22 and 31.92 Kg). Similar trends were also found for the weight gain and feed conversion ratio. The cost of feed per kg weight gain was lowest among boars fed FCP based diets (N378.53) which resulted to higher profit margin and highest among gilts fed diets containing maize and CSM-PKC. It is therefore concluded that solid state fermentation is an effective tool for enhancing the nutritive value of mixture of grated cassava roots and palm kernel cake for swine feeding.

Keywords: Solid-state fermentation, cassava, palm kernel cake, agro industrial by-product, returns on investment, pigs

La fermentation en phase solide améliore la valeur nutritive des racines de manioc râpées et du tourteau de palmiste pour les porcs en croissance

Résumé

Le besoin croissant de transformer les abondants sous-produits agro-industriels en matières premières pour l'alimentation du bétail est limité par les teneurs élevées en polysaccharides non amylacés tels que la cellulose et le mannane. Dans cette étude, le potentiel de la fermentation en phase solide pour améliorer la valeur nutritive d'un mélange de racines de manioc râpées et de tourteau de palmiste pour les porcs a été évalué. Un mélange fermenté en phase solide de racines de manioc râpé et de tourteau de palmiste a été utilisé pour remplacer le maïs dans l'alimentation des porcs en croissance et comparé à un témoin négatif dans lequel le maïs a été remplacé par un mélange de tourteau de manioc et de tourteau de palmiste dans un rapport de 1:1 . Des données ont été recueillies sur le gain de poids, la prise alimentaire, le taux de conversion alimentaire ; attributs de qualité de la carcasse et de la viande. Les poids vifs des verrats et des cochettes nourris avec des régimes contenant le mélange fermenté de racines de manioc râpées et de tourteau de palmiste (38,07 et 37,86 Kg) *étaient similaires (p>0,05) à ceux nourris avec des régimes à base de maïs (37,94 et 36,93 Kg) mais supérieurs (p <0,05) à ceux nourris avec des régimes contenant du CSM-PKC (33,22 et 31,92 kg). Des tendances similaires ont également été observées pour le gain de poids et le taux de conversion alimentaire. Le coût des aliments par kg de gain de poids était le plus bas chez les verrats nourris avec des régimes à base de FCP (N378.53), ce qui a entraîné une marge bénéficiaire plus élevée et le plus élevé chez les cochettes nourries avec des régimes contenant du maise et CSM-PKC. Il est donc conclu que la fermentation en phase solide est un outil efficace pour améliorer la valeur nutritive du mélange de racines de manioc râpées et de tourteau de palmiste pour l'alimentation des porcs.*

Mots clés : Fermentation en phase solide, manioc, tourteau de palmiste, sous-produit agro-industriel, retour sur investissement, porcs

Introduction

Agro-industrial by-products (AIBPs) such as palm kernel cake (PKC), wheat offal, and cassava processing wastesare increasingly being used as the major feedstuffs for pig productionin many sub-Saharan Africa(Okeudo *et al*., 2005; Okoli *et al*., 2012). This has been seen as a welcome development particularly from the environmental point of view because, it creates value for these seemingly waste products by converting them to high quality animal food products and nutrient-dense farmyard manure (Bakshi, 2016). According to Wadhwa *et al* (2015), their use as animal feed will not only bring them back into the human food chain, but will help to mitigate environmental problems that arise due to decomposition of such wastes in the environment. From the farmers' perspective however, the principal aim is to reduce the cost of feed (Esonu *et al*., 2005; Uchegbu *et al*., 2011, Udedibie *et al*., 2012). The demand for and cost of feed ingredients have been on the increase in the region, largely due to increase inhuman population and urbanization and the concomitant increased demand for animal food products, namely meat, milk and eggs (Delgado, 2001). In these sub-Saharan African countries, maize is a staple food and its demand for brewing, biofuel production is on the increase, and hence, the utilization AIBPs will ameliorate the growing food-feed-fuel competition (Makkar, 2016). However, the sustainable use of these unconventional feed materialsby farmers will largely depend on their ability to guarantee productivity of livestock at justifiably reduced cost. Though farmers are often attracted to use the non-conventional feed resources (NCFRs) due to their comparatively lower prices, their inclusions in monogastric diets such as pig rations have most often than not resulted in reduced performance and negatively affected the quality of animal food products (Aladi, 2016). High contents of non-starch polysaccharides (NSPs) such as cellulose, lignin, mannanetc, is largely blamed for the relatively poorer performances (Esonu *et al*., 2005; Okeudo *et al*., 2006;Udedibie *et al*., 2012). His is because monogastric such as pig have limited ability to digest and utilize these NSPs due to their limited ability to produce enzymes needed to break down these complex polysaccharides into more readily digestible sugars. Solid state fermentation (SSF) – the growth of microorganism in solid media in the absence of free-flowing water (Pandey, 2003; Godoy *et al*., 2018) has been reported to have the potential to breakdown these complex polysaccharides and hence make them more digestible for farm animals (Brooks *et al*., 2008; Niba *et al*., 2009a; 2009b;Aladi*et al* 2013; Costa *et al*., 2018). According to Wadhwa *et al.* (2015), solid-state fermentation can be used to enrich the NCFRs with proteins and other nutrients, make them better feed materials and also conserve them. Aladi *et al* (2013) reported that SSF improved the crude protein content of a 3:1 mixture of grated cassava roots and palm kernel cake from 10 to 13 percent and Chukwukaelo *et al*. (2018) found that the product could replace maize in broiler chicken diets without any deleterious effect on performance and product quality. A possible probiotic effect of the fermented feed material was reported by Aladi *et al*. (2017). Pigs and poultry are similar in their digestive anatomy and physiology. However, it is not known whether the utilization of SSF enhanced feed materials will yield similar benefits or outcomes observed in poultry when fed to pigs. Any such potential benefits may increase the use of NCFRs, improve productivity from a more nutritious feed and at the same time cut cost of feed in the swine industry. In this study therefore, the efficacy of solid-state fermentation to improve the nutritive value of mixture of grated cassava roots and PKC in the diet of growing-finishing pigs was evaluated.

Materials and methods

Experimental materials and diets

The fermented mixture of grated cassava and palm kernel cake (FCP) was produced following the procedures described by Aladi*et al*. (2013). Freshly harvested cassava tubers were peeled, washed and grated. The grated cassava tubers were then mixed with palm kernel cake (PKC) in a ratio 3:1. The mixture was fed into high density polyethene bags, compressed to exclude as much air as possible and sealed. These were allowed to ferment for seven days and then used to formulate experimental diets. Three experimental diets were formulated. Diet 1 (Control) contained maize as the principal energy source. In Diet 2, maize was replaced with a solid-state fermented mixture of grated cassava tuber and palm kernel cake (FCP) while in Diet 3, maize was replaced by cassava meal and PKC in a ratio of 1:1. Fresh cassava roots contain about 33 – 35 % dry matter, hence a three parts of fresh cassava tuber is equivalent to one part of dry cassava meal. Two diets were formulated: growers' and finishers' diets. The growers' and finishers' pig diets were fed from 12 to 20 weeks and 21 to 24 weeks of age, respectively. The ingredients and nutrient composition of the experimental diets are shown in Tables 1 and 2.

Experimental animals and design

36 twelve weeks' old crossbred (Large White x Nigerian Indigenous) weaner pigs (18 boars and 18 gilts) were used for the experiment in a factorial arrangement with treatment diets and sex as factors. The pigs were dewormed with Piperazine and then randomly allocated to three treatment groups with six replicates each. Each replicate had either two gilts or two young boars: giving a total of six gilts and six young boars per treatment.

Performance and economics of feed utilization

The pigs were individually weighed at the beginning of the experiment and on weekly basis thereafter. Daily feed allowance was based on 4 % of body weight and any unconsumed feed was removed between 6.30 – 7.00 pm daily. Data were collated on replicate basis for live weight, weight gain, feed intake and feed conversion ratio. The cost of feed was determined by multiplying the quantity of each ingredient in the feed composition table with the prevailing market price per kilogram. The ingredient costs were summed up and divided by 100 to get the cost per kg of the diet. The later was then multiplied by quantity of feed consumed by the pigs to get the cost of feed per treatment diet. The gross income (Ending Investment) was estimated by multiplying the mean live weight of pigs in each treatment by the average price per Kg live weight.

Table 1: Ingredients and calculated chemical composition of swine growers' diets

Ingredients	**Diets containing**		
	Maize	**FCP**	**CSM-PKC**
Maize	50.00	-	-
FCP[b]	-	50.00[c]	-
Cassava meal	-	-	25.00
Palm kernel cake	-	-	25.00
Soybean meal	10.00	10.00	10.00
Wheat offal	32.00	32.00	32.00
Fish meal	4.00	4.00	4.00
Bone meal	3.00	3.00	3.00
Vitamin/mineral premix*	0.25	0.25	0.25
Salt	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Lysine	0.25	0.25	0.25
Total	100.00	100.00	100.00
Calculated chemical composition			
Crude protein. (%)	16.40	19.25	16.90
Metabolizable energy (Kcal/kg)	2475.00	2224.00	2318.00
Crude fibre (%)	5.25	9.71	14.78
Calcium (%)	1,28	1.31	1.39
Phosphorus (%)	1.17	1.40	1.39
Lysine	0.72	1.02	1.02
Methionine	0.22	0.45	0.45
Total ash	3.98	5.73	5.73

FCP - Fermented mixture of grated cassava tubers and palm kernel cake
CSM-PKC – 1:1 mixture of cassava meal and palm kernel cake
*Grower premix formulated to supply per kg diet: Vit.A 10,000,000 IU; Vit. D3 2,000,000 IU; Vit. E 8,000 IU; Vit. K 2,000 mg; Vit. B1 2,000 mg; Vit. B2 5,500 mg; Vit. B6 1,200 mg; Vit. B12 12 mg; biotin 30 mg; folicacid 600 mg; niacin 10,000 mg; pantothenicacid 7,000 mg; cholinechloride 500,000 mg; Vit. C 10,000 mg; Iron 60,000 mg; Mn 80,000 mg; Cu 8,00 mg; Zn 50,000 mg; iodine 2,000 mg; cobalt 450 mg; Selenium 100 mg; mg 100,000 mg and antioxidant 6,000 mg.[b]nutrient composition based on data reported by Aladi (2016)
[c] air dry basis

The average price per kg liveweight was estimated using prevailing market price.Since cost of feed is usually 60% of the cost of production, the later was estimated as cost of feed consumed multiplied by 1.67. Margin (Gain or Loss) was estimated as the difference between the Ending Investment (income) and the opening Investment (cost of production). The Returns on Investment (ROI) was calculated using the formulae

$$\text{ROI} = \frac{\textit{margin}}{\textit{Opening Investment}} \times 100\%$$

$$\text{Simple Annual ROI} = [(1 + \text{ROI})^{1/n} - 1) \times 100\%$$

Where n is,the period of investment (4 months for growing-finishing pigs)

The compound annual ROI, the rate of return that represents the cumulative effect that a series of gains or losses has on an Original Investment over a period of time was calculated using the software, Financial Calculator version-v3.1.3 (Bishinews fncalculator.com)

Carcass and internal organ characteristics

At the end of the feeding trial, all the boars were fasted for 24 hours, individually weighed and humanely slaughtered following approved protocol. Thereafter, the carcasses were dressed, weighed and the carcass length measured. The carcasses

Table 2: Ingredients and calculated chemical composition of swine finishers' diets

Ingredients	Diets containing		
	Maize	FCP	CSM-PKC
Maize	50.00	-	-
FCP[b]	-	50.00[c]	-
Cassava meal	-	-	25.00
Palm kernel cake	-	-	25.00
Soybean meal	4.00	4.00	4.00
Wheat offal	38.00	38.00	38.00
Fish meal	4.00	4.00	4.00
Bone meal	3.00	3.00	3.00
Vitamin/mineral premix*	0.25	0.25	0.25
Salt	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Lysine	0.25	0.25	0.25
Total	100.00	100.00	100.00
Calculated chemical composition (%)			
Crude protein	14.90	15.35	15.35
Metabolizable energy (kcal/kg)	2405	1954	2248
Crude fibre	5.46	9.92	14.99
Calcium	1.27	1.39	1.39
Phosphorus	1.21	1.43	1.44
Lysine	0.60	0.90	0.90
Methionine	0.20	0.43	0.43
Total ash	4.00	5.75	5.75

FCP- Fermented mixture of grated cassava tubers and palm kernel cake.
CSM-PKC – 1:1 mixture of cassava meal and palm kernel cake.
*Premix formulated to supply per kg diet: Vit. A 10,000,000 IU; Vit. D3 2,000,000 IU; Vit. E 8,000 IU; Vit. K 2,000 mg; Vit. B1 2,000 mg; Vit. B2 5,500 mg; Vit. B6 1,200 mg; Vit. B12 12 mg; biotin 30 mg; folicacid 600 mg; niacin 10,000 mg; pantothenicacid 7,000 mg; cholinechloride 500,000 mg; Vit. C 10,000 mg; Iron 60,000 mg; Mn 80,000 mg; Cu 8,00 mg; Zn 50,000 mg; iodine 2,000 mg; cobalt 450 mg; Selenium 100 mg; mg 100,000 mg and antioxidant 6,000 mg.[b]nutrient composition based on data reported by Aladi (2016)
[c] air dry basis

were cut into primal cuts following the guidelines described by FAO (1991) and North American Meat Processors Association (2007) and expressed as percentages of live weights. The rib-eye area was determined by tracing on an acetate paper while dressing percentage and percentage lean were calculated as described by Burson (2001). The offals (head, trotters, tail and internal organs) were also carefully separated and weighed and also expressed as percentages of the live weight of the animals.

Meat quality and sensory evaluation

Section of the *Longissimusdorsi* (LD) muscle between the 10th and 11th ribs from both sides of each carcass were used to determine the water holding capacity and drip loss following the procedures described by Kauffman *et al*. (1992) and Honikel (1998). The sections from the left side of carcass were individually weighed and kept in airtight polythene bags. These samples were properly labelled and left in a refrigerator at 10 ^{0}C for 24 hours. The following day, the samples were carefully removed from the polyethene bags, dried with filter paper and reweighed. The difference in weight were expressed as a percentage of the initial weight and recorded as the drip loss for each sample. A portion weighing approximately 3.5 ± 0.05 g was carefully cut from the right side of the LD muscle and wrapped in filter papers (Whatmann 11cm) and reweighed. The samples were then subjected to mechanical pressure for 3 minutes using a screw jack. The meat residues were then recovered and reweighed. The difference in weight of meat sample was recorded as the weight of expelled fluid. This was expressed as a percentage of the weight of initial sample and recorded as the water holding capacity of the meat. Cooking loss was determined using sections of the LD muscle cut between 11thrib to the last lumbar vertebra. Each cut was weighed and wrapped in polythene bag, labelled, and heated under steam for 20 minutes. After cooling to room temperature, they were dried with filter paper and reweighed. The decrease in weight was expressed as a percentage of the initial weight and recorded as percentage cooking l**oss.**After 48 hours of refrigerated storage, the *Semitendinosus* muscle of each carcass was carefully removed and chopped into pieces weighing approximately 50 g each. The samples were soaked for 30 seconds in a saline solution (30 g/L) and then cooked under steam for 15 min. A panel of trained assessors were used to evaluate the cooked pork samples for tenderness, juiciness, flavour intensity, connective tissue amounts and hedonic rating using 8-point category rating scale as described by AMSA (2015).

Statistical analysis

Performance and economics of feed utilization data were subjected to one-way analysis of variance (ANOVA) in a completely randomized design (CRD).Significantly different means were separated using Least Significant Difference method as described by Littleand Hills (1974).

Results and discussion

Performance parameters

The performances of grower pigs fed the experimental diets are shown in Table 3.The experimental diets significantly affected ($p < 0.05$) the performance of the growing-finishing pigs but sex did not. The live weights of pigs fed diets containing FCP were similar to those fed the control diet ($p > 0.05$) and both were superior to those fed the CSM-PKC based diet. The superior live weight of boars and gilts fed FCP based diets (36.07 and 37.86 kg) over those fed diets containing CSM-PKC mix (33.22 and 31.92), indicate that solid state fermentation improved the nutritive value of FCP. Similar findings have been reported by Dairo *et al.* (2008) and Oboh (2006) on solid state fermented palm kernel cake and cassava peels, respectively.

Table 3: Performance of grower-finisher pigs fed FCP and CSM-PKC mix as replacement for maize

PARAMETER	Sex	Diets containing Maize	FCP	CSM-PKC	SEM
Initial live weight (kg)	Boar	15.96	15.70	16.27	0.701
	Gilt	16.50	16.90	15.97	
Final live weight (kg)	Boar	37.94^{a}	38.07^{a}	33.22^{c}	0.639
	Gilt	36.93^{a}	37.86^{a}	31.92^{c}	
Average daily weight gain (kg/pig/day)	Boar	0.25^{a}	0.25^{a}	0.21^{b}	0.041
	Gilt	0.23^{a}	0.25^{a}	0.19^{b}	
Feed intake (kg/pig/day)	Boar	0.86^{ab}	0.87^{ab}	0.87^{ab}	0.039
	Gilt	0.84^{ab}	0.92^{a}	0.83^{b}	
Feed conversion ratio	Boar	3.44^{b}	3.50^{b}	4.05^{a}	0.505
	Gilt	3.60^{b}	3.72^{b}	4.30^{a}	

^{a,b,c} Means within the same row with different superscript are significantly different($p<0.05$).
FCP- Fermented mixture of grated cassava tubers and palm kernel cake.
CSM-PKC – 1:1 mixture of cassava meal and palm kernel cake.

The feed intakes of pigs on the treatment diets were similar except for the females on CSM-PKC based diets, which consumed significantly ($p < 0.05$) smaller quantity of feed. Since daily feed allowance was based on 4 % of body weight, the slightly reduced feed intake among gilts on diets containing the CSM-PKC mix may have been due to their relatively smaller live weights. Diets containing FCP were bulkier and pigs on FCP-based diets consumed their feed gradually and rarely finished their daily feed allowance. This suggests that solid state fermentation affected the physicochemical characteristics of FCP which led to improved utilization of feed. Maize based (control) diets had higher bulk density, lower volumes and may have been more palatable, stimulating animals to consume more. It is possible that if the animals were fed *ad libitum* or allowed higher quantities of feed, pigs fed rations based on maize and CSM-PKC mix could have consumed more feed. However, if the extra feed is not optimally utilized, that will obviously increase cost of production and increase nutrient loss in faeces which in turn will have obvious negative consequences for the environment (NRC, 1998; Makkar, 2016). The feed conversion ratio of pigs on diets based on CSM-PKC mix was inferior ($p < 0.05$) to those of pig fed either the control or FCP-based diets. The FCR of pigs on FCP(3.50 and 3.72) were similar to those fed control diets (3.44 and 3.60). This agrees with the reports by Ao *et al.*(2011) and Aro and Akinjokun (2012). The lower calculated metabolizable energy and higher crude fibre contents did not negatively affect the performance of pigs on diet containing FCP. The weekly live weights, weight gains, feed intakes and feed conversion ratios are shown as in Figures 1, 2, 3 and 4,respectively. These figures show that, while the live weight, weight gain and feed intake of all the experimental animals varied with age (period of treatment), feed conversion ratios were not affected by age. Average daily weight gain increases progressively in all treatment groups until the 20th week of the experiment. This period coincided with the grower phase of the pigs. The values however dropped in all treatment groups at the 24th week and the rate of drop was similar in all treatment groups. This suggests that most of the experimental pigs may have achieved optimal muscle size by 20 weeks of age (6 - 8th week of the experiment) and if so, further increment in body size must have been due to fat deposition rather than increase in protoplasmic cell mass. Fat accretion requires more energy and hence the lower feed conversion ratio. According to Reeds *et al*. (1992), as an animal approaches maturity protein deposition approaches zero while lipid accretion tends to dominate carbon storage. This decrease in the ratio of lean-to-fat deposition will obviously reduce the efficiency of feed utilization (Silence, 2004; Sun *et al*., 2017).

Economics of feed utilization and production

The results on the economics of feed utilization are shown in Table 5. The replacement of maize with FCP or CSM-PKC mix reduced the unit cost of feed produced. Since the pigs were allowed a quantity of feed equivalent to their body weight, the cost of feed consumed was directly proportional to the unit price of the respective rations. The feed cost for boars on maize-based diet was 9076.96, followed by those on FCP-based diet (7903.60) and 7629.55 for those on CSM-PKC based diet. Similar trend was found for the gilts. The cost per Kg weight gained was lower in pigs fed diets containing FCP, indicating that it is economically more feasible to raise the pigs on such diets. The superior economic indices (margins and returns on investment) among pigs fed FCP based diets, reflects the economic value added by the solid-state fermentation to the mixture of grated

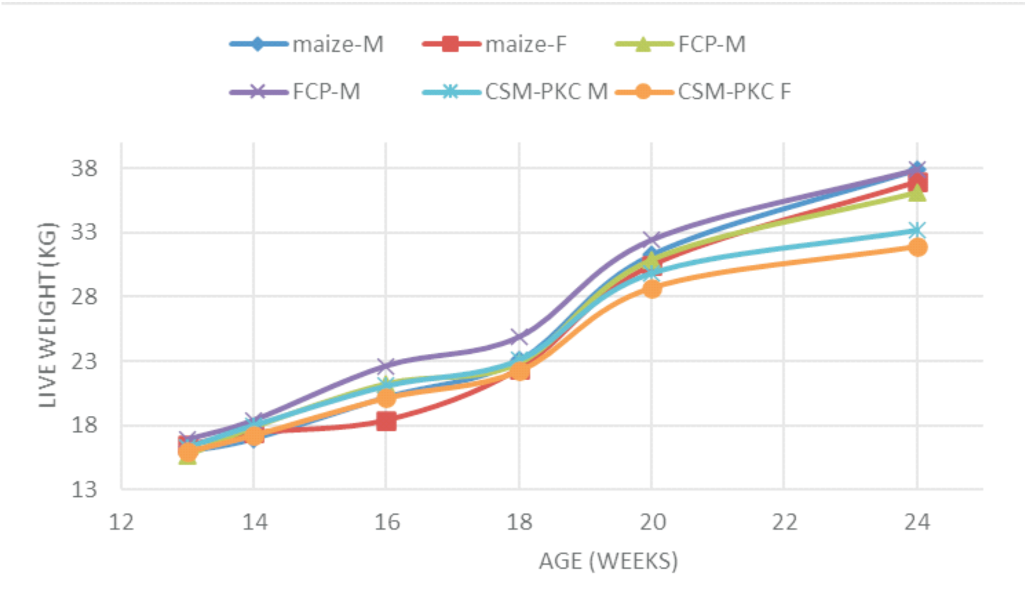

Figure 1: Graph of live weight of grower pigs fed experimental diets against age

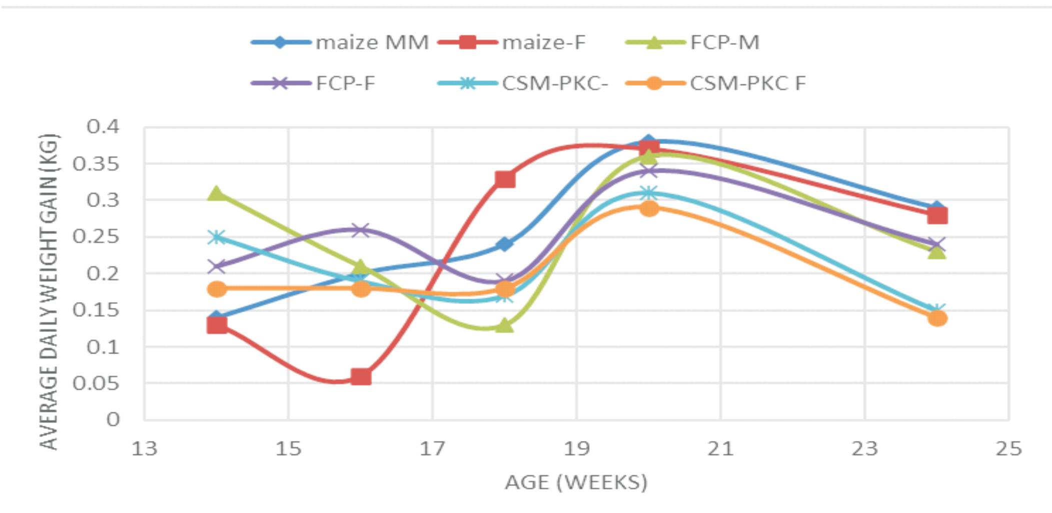

Figure 2: Graph of average daily weight gain of grower pigs fed experimental diets against age

cassava and PKC. The margin and return on investment for pigs fed diets containing FCP were N5862.33 naira and 44.51% while those fed maize based ration had N 3841.74 and 25.39 %, respectively.

Carcass and internal organ characteristics

Significant differences were not found for carcass and internal organs characteristics of the pigs fed experimental diets except for the proportion on tail (Table 6), suggesting that the nutrients were well assimilated in all treatment diets. The reason for the significantly higher proportion of tail among animal on control diet is not clear but may have resulted from precision errors during cutting rather than treatment effect. Though not significant, proportion of

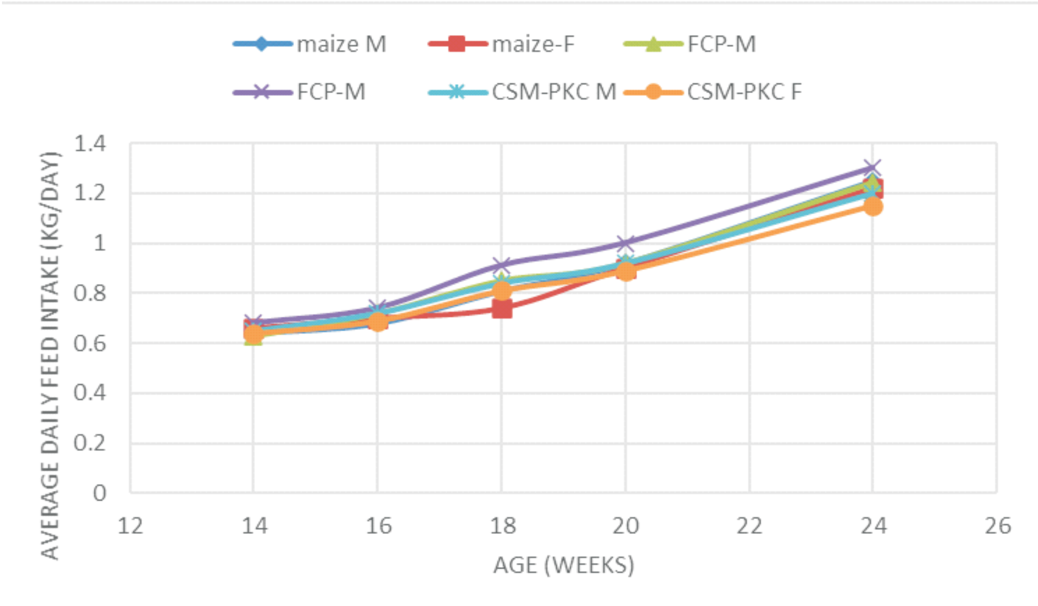

Figure 3: Graph of average daily feed intake of grower pigs fed experimental rations against age

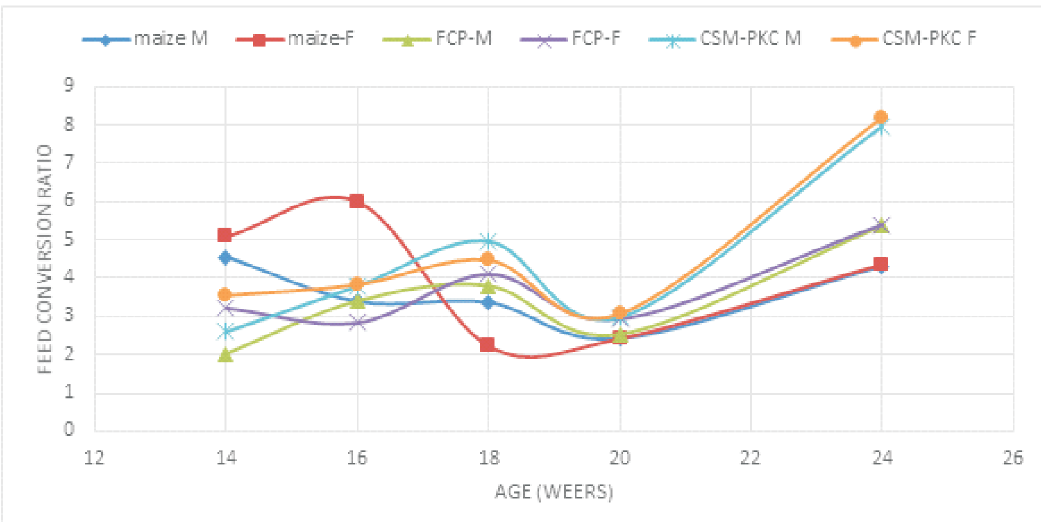

Figure 4: Graph of feed conversion ratio of grower pigs fed experimental ration against age

gastrointestinal tract increased numerically from treatment A to C.

Meat quality characteristics

The meat quality and panel sensory scores for meat from pigs fed experimental rations are shown in Table 7. The pig fed diets based on FCPmix had significantly lower water holding capacity, drip loss and tenderness score when compared with other treatments. The water holding capacity of pigs fed maize based rations (49.93 %) was significantly higher ($p < 0.05$) than in those fed FCP (46.82 %) which in turn was higher than those fed CSM-PKC mix (43.55 %). Cooking loss also followed the same trend. The panellists scored pork from boars fed CSM-PKC based diets to be significantly ($p < 0.05$) less tendered than those fed FCPand

Table 5: Economics of feed utilization

	Boar			Gilt		
PARAMETER	Maize	FCP	CSM-PKC	Maize	FCP	CSM-PKC
Cost estimates						
Feed cost per (₦/kg)	125.65	108.15	104.4	125.65	108.15	104.4
Feedconsumed (kg)	72.24	73.08	73.08	70.56	77.28	69.72
Cost of feed consumed (₦)	9076.95	7903.60	7629.55	8865.86	8357.83	7278.77
Cost of production (₦)	15128.26	13172.67	12715.92	14776.44	13929.72	12131.28
Feed cost (₦ per kg weight gained (₦)	432.24	378.53	422.82	452.34	402.32	448.92
Income (farmgate price for grower pigs)	18970	19035	16610	18465	18930	15960
Gross margin	3841.74	5862.33	3894.08	3688.56	5000.28	3828.72
Returns on investment (ROI)						
Simple ROI (%)	25.39	44.51	30.62	24.96	35.9	31.56
Simple Annual ROI (%)	76.18	133.53	91.87	74.89	107.69	94.68
Compound Annual ROI (%)	97.17	201.79	122.88	95.14	150.97	127.71

FCP- Fermented mixture of grated cassava tubers and palm kernel cake.
CSM-PKC – 1:1 mixture of cassava meal and palm kernel cake.

Table 6: Carcass and organ weights of pigs fed FEMCARPP or CSM -PKC mix as replacements for maize

PARAMETERS	Treatments			SEM
	Maize	FEMCARPP	CSM-PKC	
Live weight Kg	41.40	35.53	32.73	5.892
Carcass weight (kg)	27.69	23.43	21.32	4.133
Dressing percentage (% live weight)	66.91	65.80	64.91	1.044
lean cuts (% of Live weight)	47.91	46.82	46.20	0.789
Lean cuts (% carcass weight)	71.50	71.16	71.18	0.981
% Ham	19.74	18.25	19.50	0.505
% Shoulder	16.44	15.83	15.13	0.500
% Loin	11.73	12.75	11.56	0.989
Fat cuts				
% Spareribs	7.69	8.89	8.98	0.674
% Jowl meat	5.53	5.77	5.40	0.355
% Belly	4.54	4.09	3.58	0.534
Offals				
% Head	8.89	9.53	9.89	0.648
% Trotters	2.59	2.58	2.63	0.148
% Tail	0.45^{a}	0.39^{b}	0.38^{b}	0.016
% Liver	1.87	1.72	1.74	0.127
% Lung	0.79	0.93	0.85	0.097
% Heart	0.43	0.47	0.49	0.047
% Testes	0.72	0.45	0.49	0.303
% Kidney	0.31	0.21	0.19	0.118
% GIT*	18.21	19.24	20.28	3.266

*Calculated value; ^{a,b} – mean values with different superscript are significantly different ($p<0.05$)
FCP- Fermented mixture of grated cassava tubers and palm kernel cake.
CSM-PKC – 1:1 mixture of cassava meal and palm kernel cake.

maize based diets. Water holding capacity and drip loss are known to negatively affect tenderness in meat. According to Aaslyng (2002), poor WHC results in high drip loss from meat and this loss ultimately affect tenderness of cooked meat. It is therefore likely that the reduced tenderness of pork from pig fed CSM-PKC based diets must have resulted from their lower water holding capacities. However, other factors such as susceptibility to stress, breed, post-mortem handing, marbling score, etc are known to affect tenderness of meat. It is possible as well that the relatively lower live weight gains, and possible poorer marbling of pig fed diets based on CSM-PKC may have contributed to the reduced tenderness of their meats.

Table 7: Meat quality characteristics of grower -finisher pigs fed FCP or mixture of Cassava meal and Palm Kernel cake as replacements for maize

Parameters	Maize	FCP	CSM-PKC	SEM
Drip loss (%)	6.43	6.10	7.84	1.147
Water holding capacity (%)	49.93[a]	46.82[b]	43.55[c]	1.300
Cooking loss (%)	41.00[a]	38.73[b]	34.47[c]	1.559
Organoleptic assessment				
Juiciness	6.33	6.16	5.25	0.475
Tenderness	6.50[a]	6.64[a]	5.00[b]	0.387
Connective tissue amount	6.33	6.33	5.42	0.533
Flavour intensity	5.92	6.00	5.67	0.387
Hedonic rating	5.92	6.90	6.33	0.717

[a,b,c] – mean values with different superscript are significantly different ($p<0.05$)
FCP- Fermented mixture of grated cassava tubers and palm kernel cake.
CSM-PKC – 1:1 mixture of cassava meal and palm kernel cake.

Conclusion and recommendations

The study showed that the changes in the physicochemical characteristics of mixture of grated cassava tubers and palm kernel cake, brought about by solid state fermentation resulted improved the efficiency of feed utilization for growing pigs. The pigs fed diets containing the fermented feed material consumed less feed, had similar feed conversion ratio, lower cost per Kg weight gained relative to those fed diets containing maize and a mixture of cassava meal and palm kernel cake. The fermented feed material did not negatively affect the carcass and meat quality parameters evaluated.

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Declarations

Conflicts of interest/Competing interests: All authors certify that as at the time of this research, they had no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethics approval: The ethics governing the use and conduct of experiments on animals were strictly observed, and the experimental protocol was approved by the Research and Ethics Committee of the Department of Animal Science and Technology, Federal University of Technology, Owerri.

Consent to participate: Permission and informed consent of all persons involved in the sensory evaluation of samples was sought and freely given,

Availability of data and material (data transparency): The datasets generated during and/or analysed during the current study are not publicly available due data restrictions policy of the host institution, Federal University of Technology, Owerri. They can be made available from the corresponding author on reasonable request.

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