FEED VALUE OF PROCESSED AND ENZYME SUPPLEMENTED CASSAVA PEEL IN GROWING PIGS

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SUMMARY

Ten crossbred male pigs of 39 ± 3.9 kg body weight were used to evaluate the digestibility, energy value and nitrogen (N) retention of processed and of enzyme supplemented cassava root peel (CRP), as alternatives to increasingly expensive conventional feedstuffs. Employing an incomplete block design, pigs were individuallyhoused in metabolic crates for quantitative collection of faeces and urine. During two 7-day trial periods, two pigs were offeredeach of the following experimental diets: Basal diet (BD), BD + unprocessed cassava peel without (UCP) and with (UCP+E) enzyme addition, BD + fermented cassava peel (FCP) and BD + retted cassava peel (RCP). Samples of test ingredients, feeds and excrements were analysed for their chemical composition. Fermentation marginally improved the crude protein content of CRP. Retting and enzyme supplementation of CRP improved dry matter, organic matter and gross energy digestibility of the diets. Total N excreted per unit of N intake was higher in pigs fed the UCP diet, resulting in reduced N retention. Digestible and metabolizable energy values (DE, ME) of diets UCP+E, FCP and RCP were not significantly (P>0.05) improved, and energy values (DE, ME) of the four test ingredients ranged from 10.2 to 11.4 and from 9.4 to 11.3 MJ/kg DM, respectively. Results indicated that both retting and enzyme supplementation can improve the use of CRP by growing pigs, whereby retting is cheaper than the use of a multi-enzyme blend in the diet of growing pigs.

Keywords: Cassava root peel, fermentation, retting, digestibility, N-retention, energy value, pigs

INTRODUCTION

In many developing countries such as Nigeria, pig and poultry farmers heavily depend on maize, which accounts for 40-60% of animal feed (Adesehinwa *et al*., 2016;Huang *et al*., 2008). The identification of alternative cheap feedstuffs may help to reduce feed costs and hence the cost of animal products, which can contribute to higher human protein intake and higher food security (Coles *et al*., 2016). Yet, alternative feedstuffs may contain secondary plant compounds (Blache *et al*., 2008) and therefore require processing to avoid deleterious effects or reduced animal performance. Furthermore, their levels of inclusion into animal rations need to be determined (Akinola *et al*., 2016).

Viable alternative feedstuffs for animals are agro-industrial by-products that are cheap but without prior processing or supplementation their use in the feeding of non-ruminants may result in poor utilization (Akinola *et al*., 2016). Cassava root peel (CRP) constitutes 20.1% of the cassava tuber (Hahn & Chukwuma, 1986) and is a major by-product of the cassava tuber processing industry. In Nigeria, it is available in large amounts but it is characterised by a low concentration of protein and a high concentration of fiber. Several studies suggest that feeding CRP does not necessarily reduce animal performance (Akinola *et al*., 2013; Ojewola & Annah, 2006;Iyayi& Aderolu, 2004) when appropriate processing and inclusion levels are employed. Sun-dried CRP contains 91.8% dry matter, 8.4% ash, 14.0% starch, 6.0% crude protein, 1.5% ether extract, 37.4% crude fiber, 72.1% neutral detergent fiber, 61.7% acid detergent fiber and 34.2% acid detergent lignin (Blank *et al*., 2012); its hydrogen cyanide (HCN) content is higher (264–322 ppm) than that of the cassava pulp (Iyayi and Tewe, 1991). Locally, CRP is used to feed pigs, sheep and goats (Tewe and Egbubunike, 1992; Iyayi and Tewe, 1992). Although CRP is generally considered as a waste material, it might replace maize to a certain degree in pig diets if appropriate processing technologies are employed.

Offering fermented feed to pigs positively affects pancreatic secretion, villus architecture and absorption of dietary nutrients, and improves animal performance (Missotten *et al*., 2015; Missotten *et al*., 2010;Scholten *et al*., 1999). Fermentation of CRP for seven days resulted in a reduced fiber and increased crude protein contents(Oboh, 2006). Retting of fibrous products in water is frequently used to break down plant tissues. It has been reported to reduce the cyanide content of CRP and to improve feed intake and utilization in weaner rabbits (Ayernor, 1985; Oluremi andNwosu, 2002; Shoremi *et al*., 1999), but it has not been tested until now in pig feeding.

Exogenous enzymes have proven to be beneficial when added to non-ruminant animal diets containing high levels of non-starch polysaccharides (de Vries *et al*., 2012; Mateos *et al*., 2012; Munir andMaqsood, 2013). However, the use of a blend of more than one enzyme did not improve feed utilization by non-ruminant animals (Akinola *et al*., 2016; O'Neill *et al*., 2014). Other studies showed that enzyme addition improves the utilization of fibrous diets by pigs (Kerr andShurson, 2013; Café *et al*., 2002, Adesehinwa *et al*., 2008).

From all indications, the response of growing pigs to fermented, retted or enzyme-supplemented CRP has not yet been explored in a comparative study, although potentially these technologies improve its utilization. The present study therefore investigated the nutritive value of non-processed and processed as well as enzyme-supplemented cassava root peel meal in the diet of growing pigs.

ANIMALS, MATERIALS AND METHODS

Site:

The study was conducted at the piggery unit of the teaching and research farm of the University of Agriculture, Abeokuta (7°9'39"N, 3°20'54"E, 76 m a.s.l), located in the derived savannah vegetation zone of south western Nigeria. The region's climate is tropical humid, with annual precipitation averaging 1037 mm and rainfall occurring from March to October. Daily temperatures average 29.6°C in January (coolest month) and 30.4°C in April (hottest month).

Processing of test feeds:

Fresh CRP was collected from the local *gari* (cassava meal) processing factory and divided into three portions; fermented cassava root peel (FCP) was prepared by weighing 30-40 kg fresh cassava root peel into individual plastic sacks and allowing it to undergo natural anaerobic fermentation with the entrance sealed for a period of five days. It was then sun-dried for 2 to 3 days. The retted cassava root peel (RCP) was produced by soaking fresh cassava root peel in water for five days, with renewal of water every 24 hours, followed by sun-drying for 3 days. The third portion of CRP was only sun-dried and considered as untreated cassava root peel (UCP).

Animals and housing:

Ten crossbred (Large White x Landrace) male pigs with an initial body weight (BW) of 39 ± 3.9 kg were used in an incomplete block design. The animals were treated against intestinal parasites with Ivomectin®. The pigs were then individually housed in confinement-type metabolic crates that allowed for separate collection of urine and faeces. The crates were placed on a cemented floor in a roofed shed with 107 cm high side walls. Pigs were allowed 14 days of adaptation to the environment, the metabolic crate and the supply of feed and water. Mean shed temperature was 32°C with 80% relative humidity during November and December.

Diets and feeding:

The FCP, RCP and UCP were added to the basal diet (BD). The latter consisted of 79% maize meal, 18% soya bean meal and 3% minerals and vitamin premix (Table 1). Of the respective test feeds, 300 g were added to each 1000 g of BD (on dry matter basis, DM), thoroughly mixed and fed in wet mash form (water : feed = 2:1) in two equal meals at 08:00 and 17:00 h. Water was supplied for *ad libitum* intake. For enzyme supplementation, the enzyme Rovabio(R) (Endo-1, 4, β-xylanase: 22,000 Visco. Units/g, β-Endo-1, 3(4) β-glucanase: 2,000 AGL units/g) was added at a concentration of 100 mg per kg feed DM when compounding the BD, while the test feeds were added at the moment of feeding. Pigs fed BDalone were offered 1500 g DM per day while other pigs were offered 1000 g DM of BD plus 300 g DM of FCP, RCP and UCP, respectively. Feed leftovers were air-dried and measured to determine feed intake.

Table 1.Composition (g kg^{-1} DM) of the basal and experimental diets

	Experimental diets				
Component	**BD**	**UCP**	**UCP+E†**	**FCP**	**RCP**
Maize	790	790	790	790	790
Soybean	180	180	180	180	180
Premix*	30	30	30	30	30
UCP	-	300	300	-	-
FCP	-	-	-	300	-
RCP	-	-	-	-	300
Total	1000	1300	1300	1300	1300

† Untreated cassava root peel meal plus enzyme.

BD: Control diet; UCP: untreated cassava root peel + BD; FCP: fermented cassava root peel +BD; RCP: retted cassava root peel + BD; UCP+E: untreated cassava root peel plus Enzyme + BD

*Mineral-vitamin premix supplied per kg as fed of complete diet: 100 mg Fe as $FeSO_4$; 100 mg Zn as $ZnSO_4$; 20 mg Mn as MnO; 10 mg Cu as $CuSO_4$; 0.30 mg I as CaI; 0.30 mg Se as Na_2SeO_3; 5.506 IU vitamin A; 551 IU vitamin D3; 33 IU vitamin E; 3.6 mg vitamin K; 5.5 mg riboflavin; 25 mg D-pantothenic acid; 33 mg niacin; 27µg vitamin B12; 1.7 mg folic acid; 220 µg biotin; 120 mg choline.

Experimental procedure:

For the first experimental period, two of the ten pigs were assigned to each of the five experimental diets. In the following experimental period pigs were assigned to the diets such that no pig received the same experimental diet twice and no sequence of change-over from one diet to another was repeated for any pig throughout the two periods (incomplete block crossing over design). Thus, four observations per treatment were obtained.

Of each pig, faeces and urine were collected quantitatively twice daily and stored as pool samples in a freezer. To avoid ammonia losses, urine was collected into bottles with H_2SO_4 (20%, v/v) to keep pH below 3. After each collection period, faeces and urine were thawed and separately homogenized and stored at -4^{O}C until analysis.

Sample analysis:

After oven-drying at 60°C for 24 hours, samples were ground to 2 mm particle size and analyzed for their proximate constituents. Following AOAC (2000) protocols, DM content of samples was determined by oven drying (930.15), the crude protein (CP) concentration by the Kjeldahl method (984.13) and the ether extract by Soxhlet extraction (920.39). Ash content was determined by incineration at 550^{o}C (942.05). The crude fiber (CF), neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations were determined by a modification of the method of Van Soest *et al*. (1991) using a semi-automated ANKOM$^{200/220}$ Fiber Analyzer (ANKOM Technology, Macedon, NY, USA). NDF and ADF values are expressed without residual ash. The gross energy (GE) content of feeds and faeces was determined using a bomb calorimeter (CAL^{2K} Calorific Value Analyser).

Records of nutrient and gross energy consumed in the various diets were related to the corresponding nutrient and gross energy voided in faeces and urine; and the nutrient digestibility, digestible energy and metabolizable energy of diets were calculated by difference. Digestibility of the test ingredients and their energy values were calculated from the determined energy values of the test diets containing the test ingredients and the basal diet; along with the proportion of the test ingredients in the test diets, using the formulae proposed by Adeola (2001).

Energy in urine was estimated from urine N content as described by Susenbeth (1996). Based on GE and nutrient concentration of BD and the test feeds as well as the respective quantitative intake, digestible energy (DE) and metabolizable energy (ME) contents were calculated (Eq. 1 and Eq. 2). For the calculation of ME corrected to zero nitrogen retention (ME_N), the value of 31.2 MJ ME/kg N retained (ARC, 1981) was used as the correction factor (Eq. 3).

$$DE = \frac{[(F_d \times GE_{fd}) - (F_c \times GE_{fc}]}{F_d} \quad \text{Eq. 1}$$

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$$ME = \frac{[(F_d \times GE_{fd}) - (F_c \times GE_{fc}) - (U_r \times N_{ur} \times K_n)]}{F_d} \quad \text{Eq. 2}$$

$$ME_N = \frac{ME - [(F_d \times N_{fd}) - (F_c \times N_{fc}) - (U_r \times N_{ur})] \times K_p}{F_d} \quad \text{Eq. 3}$$

where *DE* is digestible energy (MJ/kg DM), *ME* is metabolizable energy (MJ/kg DM), ME_N metabolizable energy corrected to nitrogen retention, F_d is feed intake (kg DM), GE_{fd} is gross energy content of feed (MJ/kg DM), F_c is faecal output (kg DM), N_{fd} is nitrogen content in feed (g/kg DM), N_{fc} is nitrogen content in faeces (g/kg DM), N_{ur} is nitrogen content in urine (g/kg), GE_{fc} is gross energy content of faeces (MJ/kg DM), U_r is urine output (kg), K_n is gross energy content of urine and equals 40 MJ/kg N in urine (Susenbeth, 1996), K_p is the correction factor and equals 31.2 MJ ME/kg N retained (ARC, 1981).

Statistical Analysis:

Statistical analysis on the normally distributed data was carried out using the General Linear Models procedure of Minitab 17 statistical package (Minitab, 2016). The model (Eq. 4) used is shown below:

$$Y_{ijkl} = \mu + D_i + P_j + A_k + e_{ijkl} \quad \text{Eq. 4}$$

where Y_{ijkl} is the observed response, μ the overall mean, D_i the effect of diet *i*, P_j the effect of period j, A_k the effect of animal *k* and e_{ijkl} is the residual error. Diet was considered as fixed effect and period and animal as random effects. The Tukey-Kramer post hoc test in Minitab 17 for multiple comparisons was used for separating significantly different treatment means; significance was declared at P<0.05.

RESULTS

Effects of processing on proximate composition of CRP:

During the first two days of CRP fermentation the pH decreased from 6.2 to 3.1 and to 2.8 on day 5. The temperature of the fermenting product increased from 33°C to 54°C on day 3 and later stabilized at 53.5°C on days 4 and 5 of fermentation (Fig. 1).

The proximate composition of BD and the three by-products is shown in Table 2. The concentration of ADF was higher in RCP and FCP than in UCP, while CF was lower in processed (FCP and RCP) than in unprocessed (UCP) cassava root peel. The content of CP was higher in FCP than in UCP and RCP, while the GE content of FCP and RCP was lower than of UCP.

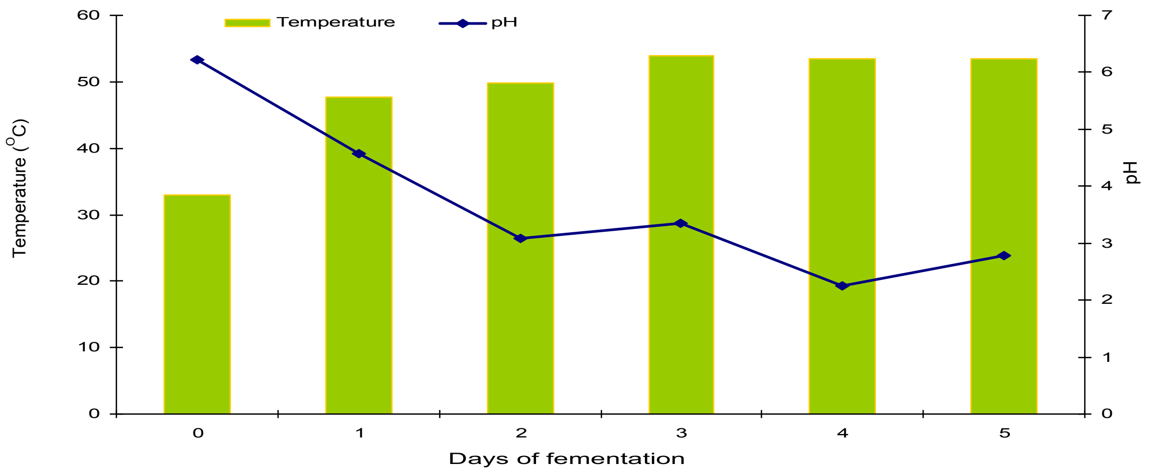

Fig. 1. Changes in temperature and pH during fermentation of cassava root peel meal in air tight plastic bags.

Table 2. Proximate **composition and gross energy content of the basal diet and test ingredients(values are means of two replicates and are given in g kg^{-1} DM unless mentioned otherwise)**

Component	BD	UCP	FCP	RCP
Dry matter	925	915	910	910
Neutral detergent fiber	246	425	472	405
Acid detergent fiber	30	191	263	266
Hemicellulose	215	234	209.	138
Crude fiber	30	164	150	129
Crude Ash	48	169	142	115
Crude protein	165	47	76	43
Gross energy (MJ/kg)	16.0	17.5	16.7	16.8

BD: basal diet; UCP: untreated cassava root peel; FCP: fermented cassava root peel; RCP: retted cassava root peel.

Feed intake, nutrient digestibility and nitrogen balance:

Table 3 shows the feed intake, faecal and urine output of pigs fed the various test diets. Faecal DM output from pigs fed FCP, RCP and UCP+E containing diets was not significantly (P>0.05) different from those on the UCP containing diet. Processing or enzyme supplementation of CRP did not affect intake by pigs. Faecal output of pigs on FCP, RCP, UCP and UCP+E containing diets was also not different (P>0.05) from BD. Urine output of pigs was not affected (P>0.05) by processing (FCP and RCP) and enzyme supplementation (UCP+E).

Digestibility of the dietary components of the experimental diets is shown in Table 4. The DM, OM and GE digestibility coefficients were significantly lower (P<0.05) in UCP and FCP containing diets compared to BD. Processing and enzyme supplementation did not significantly (P>0.05) improve the DM digestibility of CRP. Likewise, the digestibilities of CP, CF, NDF and ADF (Table 5) were not significantly (P>0.05) improved by processing (FCP, RCP) and enzyme supplementation (UCP+E).

Table 3. Feed intake and faeces and urine excretion of pigs fed the basal and experimental diets (Values are means of 4 animals per diet and are expressed per animal in g DM d^{-1} unless mentioned otherwise)

Variable	BD	FCP	RCP	UCP	UCP+E	SEM	P-value
Feed intake	1308	921	900	897	899	-	-
		275	269	2678	268	-	-
Faecal output	148	209	166	207	185	10.6	0.068
Urine excretion (g d^{-1})	12706	15291	14288	10375	9576	989	0.358

DM: dry matter; ; BD: basal diet;FCP: fermented cassava root peel + BD; UCP: untreated cassava root peel + BD; RCP: retted cassava root peel + BD; UCP+E: untreated cassava root peel plus enzyme + BD.

Table 4. Digestibility Coefficient of the various proximate components in the basal and experimental diets.

Variable	BD	FCP	RCP	UCP	UCP+E	SEM	P-value
DMD	0.88^{a}	0.83^{b}	0.86^{ab}	0.82^{b}	0.84^{ab}	0.009	0.030
NDFDom†	0.79	0.70	0.73	0.68	0.70	0.016	0.105
ADFDom†	0.29	0.37	0.37	0.25	0.28	0.039	0.754
CFD	0.55	0.47	0.49	0.52	0.62	0.029	0.376
HCDom†	0.86	0.83	0.88	0.82	0.83	0.012	0.481
OMD	0.90^{a}	0.84^{b}	0.87^{ab}	0.83^{b}	0.86^{ab}	0.009	0.019
CPD	0.89	0.78	0.82	0.77	0.80	0.015	0.108
GED	0.89^{a}	0.84^{b}	0.85^{ab}	0.83^{b}	0.85^{ab}	0.008	0.037

Mean values in the same row bearing different superscripts are significantly different (Comparison wise error rate, P < 0.05)
BD: basal diet;FCP: fermented cassava root peel + BD; RCP: retted cassava root peel + BD; UCP: untreated cassava root peel + BD; UCP+E: untreated cassava root peel plus enzyme + BD.
DMD: dry matter digestibility; OMD: organic matter digestibility; CPD: crude protein digestibility; NDFD: neutral detergent fiber digestibility; ADFD: acid detergent fiber digestibility; HCD: hemicellulose digestibility; GED: gross energy digestibility.
†om, exclusive residual ash

Table 5. Coefficient of digestibility of unprocessed, processed and enzyme supplemented cassava root peel meal(as single ingredients). Values are means of 4 pigs collected during 2 sampling periods.

Variable	FCP	RCP	UCP	UCP+E	SEM	P-value
DMD	0.62	0.76	0.60	0.69	0.037	0.365
NDFDom†	0.50	0.54	0.45	0.48	0.038	0.905
ADFDom†	0.32	0.34	0.11	0.19	0.055	0.340
CFD	0.40	0.39	0.44	0.60	0.059	0.452
HCDom†	0.14	0.11	0.16	0.16	0.012	0.588
OMD	0.62	0.78	0.60	0.71	0.037	0.275
CPD	-0.09	-0.18	-0.82	-0.47	0.018	0.550
GED	0.60	0.67	0.59	0.66	0.028	0.714

Mean values in the same row bearing different superscripts are significantly different (Comparison wise error rate, P < 0.05)
FCP: fermented cassava root peel, RCP: retted cassava root peel, UCP: untreated cassava root peel, UCP+E: untreated cassava root peel plus enzyme.
DMD: dry matter digestibility; OMD: organic matter digestibility; CPD: crude protein digestibility; NDFD: neutral detergent fiber digestibility; ADFD: acid detergent fiber digestibility; HCD: hemicellulose digestibility; GED: gross energy digestibility.
†om, exclusive residual ash

Table 6 shows the nitrogen balance of pigs fed diets containing processed and enzyme supplemented CRP. Faecal N excretion of pigs was nonsignificantly (P=0.108) increased by processing and enzyme supplementation, and urine N was nonsignificantly (P=0.105) reduced by these treatments. Total N excretion as related to N intake was increased (P=0.045) in the UCP containing diet compared to pigs fed BD. N retained as related to N intake was significantly lower (P=0.045) in pigs fed the UCP containing diet compared to those on BD.

Energy values:

Table 7 shows the energy value of the basal diet and of diets containing the processed or enzyme supplemented CRP. Digestible energy (DE) was nonsignificantly (P=0.103) improved in diets containing FCP, RCP and UCP+E as compared to the UCP containing diet; similar pictures emerged for ME and ME_N. In consequence, the ME-to-DE ratio was alsoamong all test diets. The GE-to-ME ratio was lower (P=0.024) in the UCP containing diet compared with BD, while no differences (P>0.05) were found between BD and FCP, RCP as well as UCP+E. Processing and enzyme supplementation of CRP only marginally increased its DE and ME concentration (Table 8).

Table 6. Nitrogen (N) balance of pigs fed the basal and experimental diets(Values are means of 4 pigs collected during 2 sampling periods)

N balance (g N pig^{-1} d^{-1})	BD	FCP	RCP	UCP	UCP+E	SEM	P-value
N Feed	34.8^{a}	27.6^{b}	25.8^{b}	25.6^{b}	25.6^{b}	0.93	0.000
N Faeces	3.8	6.0	4.7	5.7	5.2	0.36	0.269
N Urine	10.2	7.7	6.4	12.9	8.6	0.83	0.158
Total N Excreted	14.3	13.5	11.2	18.7	13.8	0.87	0.148
N Retained	19.9^{a}	14.4^{ab}	14.6^{ab}	6.8^{b}	11.8^{b}	1.23	0.006
N balance (g g^{-1} N intake)							
Faecal N	0.11	0.22	0.18	0.23	0.20	0.015	0.108
Urine N	0.30	0.27	0.25	0.51	0.34	0.032	0.105
Total N Excreted	0.42^{b}	0.48^{ab}	0.44^{ab}	0.73^{a}	0.54^{ab}	0.036	0.045
N Urine/N Faeces	2.97	1.30	1.59	2.36	1.95	0.275	0.338
N Retained	0.58^{a}	0.52^{ab}	0.56^{ab}	0.27^{b}	0.46^{ab}	0.036	0.045

^{a,b}Least square mean values in rows bearing different superscripts are significantly different at the indicated probability level. Where no superscripts are given, treatment means are not significantly different.
BD: basal diet;FCP: fermented cassava root peel + BD; RCP: retted cassava root peel + BD; UCP: untreated cassava root peel + BD; UCP+E: untreated cassava root peel plus enzyme + BD.

Table 7. Energy values (MJ/kg DM) of the basal and experimental diets (Values are means of 4 pigs collected during 2 sampling periods)

Variable	BD	FCP	RCP	UCP	UCP+E	SEM	P-value
DE	13.2	12.5	12.7	12.5	12.8	0.117	0.103
ME	12.9	12.3	12.5	12.1	12.5	0.107	0.086
ME_N	12.4	11.9	12.1	11.9	12.2	0.104	0.409
ME/DE	0.98	0.98	0.98	0.97	0.98	0.002	0.104
DE/GE	0.89	0.84	0.85	0.83	0.85	0.008	0.059
ME/GE	0.87^{a}	0.83^{ab}	0.84^{ab}	0.80^{b}	0.83^{ab}	0.008	0.024
ME_N/GE	0.84	0.80	0.81	0.79	0.81	0.008	0.199

^{a,b}Least square mean values in rows bearing different superscripts are significantly different at the indicated probability level. Where no superscripts are given, treatment means are not significantly different.
BD: basal diet;FCP: fermented cassava root peel; RCP: retted cassava root peel; UCP: untreated cassava root peel; UCP+E: untreated cassava root peel plus enzyme.
DE: digestible energy; ME: metabolizable energy; ME_N: metabolizable energy corrected for nitrogen retention

Table 8. Mean digestible (DE) and metabolizable (ME) energy concentration[1] (MJ/kg DM) of unprocessed, processed and enzyme supplemented cassava root peel meal. Values are means collected from 4 pigs during 2 sampling periods

Variable	FCP	RCP	UCP	UCP+E	SEM	P-value
DE	10.3	11.3	10.2	11.4	0.44	0.646
ME	10.2	11.1	9.4	11.3	0.44	0.456

DE: digestible energy; ME: metabolizable energy.
FCP: fermented cassava root peel; RCP: retted cassava root peel; UCP: untreated cassava root peel; UCP+E: untreated cassava root peel plus enzyme.
[1] Calculated from the determined energy values of the diets containing the test ingredients and the basal diet along with the proportions of the test ingredients in the test diets.

DISCUSSION

In this study the process of fermentation and retting was carried for only five days. This was done with the knowledge of the low energy level of cassava peel, as compared with maize. And longer fermentation days might not serve the, energy supply, purpose for which it was intended, as much of the energy would be converted to other products, thereby not yielding appreciable energy. Although Oboh (2006), fermented cassava peel for 7 days, but the author did not test the result on life animals and also did not report the gross energy level before and after fermentation.

Fermentation and retting reduced fiber concentration of CRP. Oboh (2006) also reported a reduced crude fiber concentration in CRP after solid state fermentation. The reduction in NDF, crude fiber, ash and in the energy value of retted CRP may at least partly be due to the renewal of water every 24 hours for the whole retting period. Water soluble organic matter leaches into the water during the retting process, leading to a nutrient-reduced product. In contrast to retting, fermentation increased the CP content of CRP, as also reported by Oboh (2006). However, the natural fermentation process employed in this study yielded a lower CP concentration in FCP than that reported by Oboh (2006). Yang *et al*. (2006) found that CP was increased while NDF and ADF values were decreased after one to ten days of microbial fermentation of a food waste mixture, whereas the present fermentation and retting processes reduced the energy concentration of FCP and RCP as compared to UCP.

There were significant reductions in the digestibilities of DM, OM and GE for UCP and FCP diets as compared to BD, RCP and UCP+E diets. Thus, fermenting the cassava root peel meal did not improve its feed value, even though other studies have reported a better digestibility of fermented than unfermented feed (Ao *et al*., 2010; Dung *et al*., 2005). The micro-organisms involved in the natural fermentation were probably not effective in degrading the fiber contained in CRP to release bound nutrients (Mostafa, 1999) and increase the availability of microbial protein. Furthermore, the digestibilities of RCP and UCP+E diets were similar to that of BD, whereby pigs fed RCP appeared to digest the diet slightly better than those fed FCP and UCP+E. Although the use of exogenous enzymes has been shown to improve the use of fiber-containing diets by pigs (Jang *et al*., 2017; Nortey *et al*., 2015; Nortey *et al*., 2007), xylanase supplementation to UCP did not significantly improve its digestibility in the present study. This missing response might be attributed to the fact that non-starch-polysaccharides (NSPs) in CRP are not addressed by the specific activity of xylanase, as hypothesized by Widyaratne *et al*. (2009) for wheat distiller's dried grains.

Few information is available about the effects of CRP retting *versus* fermentation in pig feeding. In rabbits, retting, as compared to ensiling and sun-drying lowered HCN content of CRP and improved the animals' performance (Oluremi andNwosu, 2002; Olafadehan, 2011).

The negative values for CP digestibility indicate a higher faecal N excretion than N intake. This can be attributed to the enhanced fiber fermentation in the caecum (Wilfart *et al*., 2007), which results in the multiplication of hindgut bacteria and their excretion via faeces (Bindelle *et al*., 2009). The increased fractional excretion of faecal N in pigs fed CRP is consistent with earlier studies (Tetens *et al*., 1996; Agunbiade *et al*., 2004; Blank *et al*., 2012).

Despite lower N intake of pigs on cassava root peel diets as compared to pigs on BD, their absolute excretion of faecal N was similar. Processing and enzyme supplementation, therefore, did not significantly lower absolute faecal N excretion. In contrast to earlier reports (Hansen *et al*., 2007; Shriver *et al*., 2003), hindgut fermentation of fiber in pigs fed processed and enzyme supplemented CRP did not shift N excretion from urine to faeces in the present study. This may indicate that the fiber in CRP is not easily fermentable in the large intestine of pigs, and that processing and xylanase supplementation did not improve this situation.

Nitrogen retention was marginally improved with processing and enzyme use, compared with pigs fed the UCP diet. This contrasts with the findings of Stanogias andPearce (1985) who reported a trend towards higher N retention with increasing inclusion of purified NDF in the diet of growing pigs. Since NSPs in UCP were contained in their natural form, a negative effect on protein absorption and amino acid metabolism may be expected, as reduced energy availability has been shown to lower N retention in lambs (Singh *et al.,* 2013). The high proportions of N retention related to N intake recorded in pigs fed BD, FCP and RCP are similar to values reported by (Otto *et al.,* 2003) for pigs on N-reduced diets.

The observed marginal reduction in DE and ME concentrations of FCP, RCP, UCP and UCP+E diets is attributed to the increased fiber intake by pigs on these diets. It is well known that fibrous diets are energy-poor as a result of their low digestibility (Agunbiade *et al*., 2004; Fanimo *et al*., 2010), but even high hindgut degradation of dietary fiber by pigs does not provide significant amounts of energy for growing pigs (Noblet and Le Goff, 2001; Jørgensen *et al*., 2007). This is due to negative interactions between dietary fiber and other dietary components and to the fact that fiber degradation is associated with the excretion of endogenous protein and fat (Shi & Noblet, 1993; Noblet & Le Goff, 2001). On the other hand, dietary fiber has been found to provide considerable amounts of energy through hindgut fermentation as the animal matures, especially in adult sows (Noblet & Le Goff, 2001).

The slightly increased DE of RCP and UCP+E compared to UCP indicated a beneficial effect of retting and enzyme supplementation. As far as the ME-to-DE ratio is concerned, the fraction of metabolized DE was the same for all diets, indicating that the supplied levels of dietary fiber increased energy losses. However, the ratio of ME-to-DE obtained in this study is higher than the values reported by Noblet & Henry, (1993). The latter authors accounted for energy lost in methane originating from hindgut fermentation (0.4% for growing pigs), which was not taken into account in the present study. The fraction of digested GE was also not affected by the inclusion of UCP or processed and enzyme supplemented CRP. However, the fraction of GE available as ME was lower for pigs fed UCP than for those on the other diets.

CONCLUSIONS

Cassava root peel meal is characterized by high concentrations of anti-nutritive fractions of non-starch-polysaccharides which limit its utilization in pig feeding due to adverse effects on digestibility, nitrogen retention and energy availability.

Although enzyme supplementation was not superior to retting for utilization of cassava root peel meal by growing pigs, it offers a certain level of convenience as it greatly reduceslabor input into processing as compared to fermenting and retting processes. However, retting appeared to yield the best responses in growing pigs among all tested CRP treatments. On resource-poor farms, retting will therefore be a better option than enzyme supplementation to process cassava root peel for use in the diet of growing pigs.

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القيمة العلفية لقشر الكاسافا المعاملة والمضاف إليها الإنزيمات فى الخنازير النامية

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تم إستخدام عشرة خنازير ذكور هجينة وزن أجسامها ٣.٩ ± ٣٩ كجم لتقييم القابلية للهضم ، قيمة الطاقة وإحتجاز النيتروجين(N) لقشور جذر الكاسافا cassava المعالج (CRP) والقشور المزودة بالإنزيم كبدائل لمواد العلف التقليدية ذات التكلفة المتزايدة. بإستخدام التصميم الكتلى غير المكتمل تم إيواء الخنازير بشكل فردى فى صناديق التمثيل الغذائى لجمع كميات من الروث والبول. خلال فترتين تجريبيتين لمدة سبعة أيام تم تقديم العلائق التجريبية التالية لإثنين من الخنازير. العليقة الأساسية (BD) ، العليقة الأساسية + قشور الكاسافا غير المعالج بدون إضافة إنزيم (UCP) ومع إضافة إنزيم (UCP+E) ، العليقة الأساسية + قشور الكاسافا المخمرة (FCP) ، العليقة الاساسية + قشور الكاسافا المتحللة بالتعطين (RCP).تم تحليل عينات للمكونات المختبرة لمواد العلف ، الروث لمعرفة تركيبها الكيميائى. أدى التخمير بشكل هامشى إلى تحسين محتوى البروتين الخام للعليقة (CRP). أدى التعطين وإضافة الإنزيم للعليقة (CRP) إلى تحسين المادة الجافة ، المادة العضوية والطاقة الكلية لهضم العلائق. كان النيتروجين الكلى الإخراجى لكل وحدة نيتروجين مأخوذة أعلى فى الخنازير التى غذيت على عليقة (UCP) ،مما أدى إلى إنخفاض إحتجاز النيتروجين. لم تتحسن معنوياً (على مستوى ٥%) قيم الطاقة الهضمية (DE) والطاقة التمثيلية (ME) للعلائق (UCP+E) ، (FCP) ، (RCP) وتراوحت قيم (ME)، (DE) للمكونات الأربعة المختبرة من ١٠,٢ إلى ١١,٤ ومن ٩,٤ إلى ١١,٣ ميجا جول/كجم مادة جافة على الترتيب. أشارت النتائج إلى أن كلا من التعطين (Retting) وإضافة الإنزيم يمكن أن تحسن إستخدام (CRP) للخنازير النامية حيث أن التعطين أرخص فى إستعمال خليط متعدد من الإنزيمات فى علائق الخنازير النامية.