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Cassava root peel as a replacement for maize in diets for growing pigs: effects on energy and nutrient digestibility, performance and carcass characteristics

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Abstract

Two experiments were conducted to evaluate cassava root peel (CRP) as diet component for fattening pigs. In the first experiment, ten male pigs were used to investigate the nutrient digestibility and the nutritive value of CRP as replacement for maize in the diet at 0 %, 30 %, 40 %, 50 % and 60 %, while supplementing free amino acids (fAA). During two experimental periods, faeces were quantitatively collected and analysed for chemical composition. In the second experiment, 40 pigs received the same diets as in Experiment 1, and daily feed intake and weekly weight changes were recorded. Four pigs per diet were slaughtered at 70 kg body weight to evaluate carcass traits. Digestibility of dry and organic matter, crude protein, acid detergent fibre and gross energy were depressed ($p < 0.05$) at 60 % CRP; digestible energy content (MJ kg^{-1} DM) was 15.4 at 0 % CRP and 12.7 at 60 % CRP. In the second experiment, CRP inclusion had only a small impact on feed intake, weight gain and feed conversion ratio ($p > 0.05$) as well as on the length of the small intestine and the *Longissimus dorsi* muscle area. The missing correlation of daily weight gain and feed-to-gain ratio up to a CRP inclusion of 40 % indicates that negative effects of CRP on pig growth can be avoided by respecting upper feeding limits. Hence, a combined use of CRP and fAA can reduce feeding costs for small-scale pig farmers in countries where this crop-by product is available in large amounts.

Keywords: energy value, free amino acids, *Manihot esculenta*, Nigeria, weight gain

1 Introduction

Cassava root peel (CRP), a residue of cassava (*Manihot esculenta* Crantz) root processing, is a valuable feedstuff in pig nutrition in the tropics that helps small and medium scale pig farmers to reduce their feeding costs. Various studies reported its possible utilization for a replacement of maize up to a level of 57 % and its better use by pigs when processed by fermentation or sun drying (Adesehinwa *et al.*, 2008; Balogun & Bawa, 1997; Iyayi & Tewe, 1988). However, major hindrances to a high level of CRP inclusion in pig diets are its low crude protein content, poor amino acid profile, comparatively high fibre concentration, high concentration of free cyanide, and low energy value (Balogun & Bawa,

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1997; Salami & Odunsi, 2003). While the cyanide problem can be overcome effectively by simple and cheap sun drying (Salami, 2000; Chauynarong *et al.*, 2009) the main drawback is its high fibre content and low digestibility. Dietary fibre has been reported to reduce digestibility of nutrients (Ndindana *et al.*, 2002) and increase endogenous nitrogen and amino acid (AA) losses in pigs (Leterme & Théwis, 2004). However, Blank *et al.* (2012) reported that fibre from cassava leaf meal (653 g neutral detergent fibre (NDF) and 472 g acid detergent fibre (ADF) per kg ash free dry matter) and CRP (721 g NDF and 617 g ADF per kg ash free dry matter) had less effect on endogenous threonine losses in pigs than fibre originating from wheat bran (856 g NDF and 241 g ADF per kg ash free dry matter). Moreover, lowered dietary crude protein concentration, when balanced by a supply of free amino acids (fAA), has been reported to be accompanied by less losses of energy via urine and heat production, and an increased energy retention in pigs (Le Bellego *et al.*, 2001).

The present study evaluated the nutritive value of CRP and its potential as a feedstuff for growing pigs in AA-balanced diets, along with the effects of such diets on the animals' growth performance and carcass traits. Thereby the range of CRP inclusion in pig diets reported in literature (Balogun & Bawa, 1997; Iyayi & Tewe, 1988) served orientation of our own formulation of experimental rations.

2 Materials and methods

The study consisted of a digestibility trial (Exp. 1) and a growth trial (Exp. 2) conducted at the piggery unit of the Teaching and Research Farm, University of Agriculture, Abeokuta, Nigeria, (7°9'39"N, 3°20'54"E, 76 m a.s.l). The farm is located in the derived savannah vegetation zone of south western Nigeria. The region's climate is humid, with 1181 mm a^{-1} (±254.2) of rain falling during April to September (Obot *et al.*, 2011). Daily temperatures average 29.6°C in January (coolest month) and 30.4°C in April (hottest month).

2.1 Digestibility trial

In Exp. 1, ten Large White × local crossbred male pigs with an average initial body weight (BW) of 33 kg (±11.7) were individually housed in metabolic crates equipped with a feeding trough and water bucket. These crates allowed for the quantitative collection of faeces and urine. Five different diets were tested, with CRP replacing maize at 0 %, 30 %, 40 %, 50 % and 60 % on dry matter (DM) basis. Free amino acids (fAA), namely L-lysine, DL-methionine, L-threonine, L-tryptophan, and L-valine were added to all CRP-containing diets to reach concentrations at least as high as the control diet (Table 1).

In two subsequent experimental periods, two pigs were assigned to each of the five diets. A seven day adaptation to the environment, the metabolic crate and the feed was followed by seven days of determination of feed intake and thorough collection of faeces. The offer of feed DM corresponded to three times maintenance energy requirements calculated according to de Lange (1995); feed was offered in wet mash form (feed : water = 1 : 2) in two equal meals per day (8:00 a.m. and 4:00 p.m.). Drinking water was available *ad libitum*. Faeces were collected daily and stored in a freezer (–20°C); at the end of the sampling period, faeces from each animal were pooled and thoroughly homogenized. At the end of the first period, there was a changeover of diets in a way that two animals did not receive the same diet twice. After another seven days adaptation period the second seven day collection period started, following the protocol of the first period.

2.2 Growth trial

Forty Large White × Duroc crossbred pigs (30 ± 4.4 kg BW) were used (20 males and 20 females). The pigs were housed in individual pens (2.67 m × 0.93 m) equipped with a feeding and watering trough. Four males and four females were assigned to each dietary treatment group. The same diets as in Exp. 1 were used, and were offered at 3.5 times maintenance energy requirements. Feed was provided in wet mash form (water : feed = 1 : 1) at 8:00 a.m. and 4:00 p.m. The trial lasted 90 days during which daily feed intake and weekly body weight changes were recorded. The first two males and two female pigs that attained 70 kg BW on each diet were slaughtered; the empty weight of the stomach, small intestine, caecum and total hindgut was recorded and the length of the small intestine determined. The hot carcass was split into two equal halves and the back fat thickness at the first and the last rib was determined with the aid of a Vernier caliper. The two halves were hung for 16 hours in a cold room (4°C), after which the cold carcass weight was measured. The surface area of the *Longissimus dorsi* muscle was determined by tracing out the muscle shape on a tracing paper and determining the area with a planometer.

Table 1: *Ingredients of the diets used in experiments 1 and 2, supplemented free amino acids (fAA), proximate composition and gross energy concentration of cassava root peel meal (CRP) and of the five experimental diets containing different proportions of CRP.*

Ingredients (g kg^{-1} DM)	*CRP*	*0 %*	*30 %*	*40 %*	*50 %*	*60 %*
Maize		750	525	450	375	300
Soybean meal		220	220	220	220	220
Cassava root peel		0	225	300	375	450
Bone meal		15	13	12	11	9
Mineral premix *		10	10	10	10	10
NaCl		5	5	5	5	5
Supplemented fAA (g kg^{-1} CP)						
DL-methionine		0.00	3.44	4.91	6.41	11.05
L-threonine		0.00	3.94	5.85	7.60	9.57
L-tryptophan		0.00	0.00	1.35	1.74	2.10
L-valine		0.00	0.00	0.00	2.99	5.06
L-lysine		0.00	3.61	5.09	6.47	8.09
Proximate composition (g kg^{-1} DM)						
DM (g kg^{-1} FM)	881	917	918	921	920	921
Crude ash	77	59	56	62	79	80
CP	55	191	180	171	167	162
NDFom	321	203	244	260	274	295
ADFom	291	74	125	133	142	159
Gross energy (MJ kg^{-1} DM)	17.3	18.2	17.9	17.7	17.5	17.1
HCN (mg kg^{-1} DM)	23	0	5	7	9	10

DM dry matter; FM fresh matter; CP crude protein; NDFom ash-free neutral detergent fibre; ADFom ash-free acid detergent fibre, OM organic matter.
* Mineral-vitamin premix supplied per kilogram of complete diet: 100 mg of Fe as $FeSO_4$; 100 mg of Zn as $ZnSO_4$; 20 mg of Mn as MnO; 10 mg of Cu as $CuSO_4$; 0.30 mg of I as CaI; 0.30 mg of Se as Na_2SeO_3; 5,506 IU of vitamin A; 551 IU of vitamin D3; 33 IU of vitamin E; 3.6 mg of vitamin K; 5.5 mg of riboflavin; 25 mg D-pantothenic acid; 33 mg of niacin; 27μg of vitamin B12; 1.7 mg of folic acid; 220μg of biotin, and 120 mg of choline.

2.3 *Analytical procedures*

From both experiments, CRP, complete diets and faecal samples (Exp. 1 only) were analysed for neutral detergent fibre (NDF) and acid detergent fibre (ADF; both expressed exclusive of residual ash) in a semi-automated ANKOM$^{200/220}$ Fibre Analyser (ANKOM Technology, Macedon, NY, USA), and gross energy (GE) was determined using an adiabatic bomb calorimeter. DM and crude ash (CA) content of diets and faeces were determined according to AOAC (1990), the nitrogen concentration in diets and faeces was determined using an N-analyser (FP-328 LECO, USA). AA analyses were performed according to the EC Directives (European Commission, 1998, 2000). The concentration of hydrocyanic acid (HCN) in CRP and the test diets was determined according to Bradbury *et al.* (1999).

2.4 *Statistical analysis*

Data were subjected to analysis of variance using the GLM procedure of SAS 9.2 (2007). In Exp. 1, the following model was used:

$$Y_{ijk} = \mu + D_i + P_j + A_k + e_{ijk}$$

where Y_{ijk} 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_{ijk} the residual error. D_i and P_j were fixed effects, while A_k and e_{ijk} were random components. Since two out of four pigs on the 50 % CRP inclusion level had feed refusals greater than 10 % of offer, their data was not considered in the statistical analysis. Simple linear regression was used to determine the relationship between CRP inclusion level (percent of DM) and the digestibility of diet constituents (percentages).

Data of Exp. 2 were analysed using the model:

$$Y_{ij} = \mu + D_i + S_j + e_{ij}$$

where Y_{ij} is the observed response, μ the overall mean, D_i the effect of diet i (fixed effect), S_j the effect of sex j and e_{ij} the residual error (both random components). The Tukey-Kramer *post hoc* test for multiple comparisons was used for separating treatment means. Linear regression models were used to determine the relationship between CRP inclusion level (kg kg^{-1} DM) and performance as well as carcass variables.

The examination of ANOVA residuals of both experimental data sets indicated deviations from the normal distribution. As these could not be effectively removed by data transformation, F- and p-values obtained for differences in treatment means are only approximates.

3 Results

3.1 Composition of the diets

The CA content of the diets increased whereas the CP concentration decreased by 29 g kg^{-1} DM from 0 % CRP to 60 % CRP (Table 1), yet, essential AA were supplied in adequate amounts in all five diets (Table 2). The concentrations of ADF and NDF (g kg^{-1} OM) increased from 0 % CRP (74 g ADF, 203 g NDF) to 60 % CRP (159 g ADF, 295 g NDF). The GE content (MJ kg^{-1} DM) decreased from 18.2 at 0 % CRP to 17.1 at 60 % CRP, while the HCN content of the diets increased with increasing inclusion level of CRP from 0 mg kg^{-1} in the 0 % CRP diet to 10.3 mg kg^{-1} in the 60 % CRP diet.

Table 2: *Analytically determined amino acid concentrations (g kg^{-1} CP) of cassava root peel meal (CRP) and of the five experimental diets containing different proportions of CRP.*

Amino acid	*CRP*	*0 %*	*30 %*	*40 %*	*50 %*	*60 %*
Lysine	27	33	42	44	52	49
Asparagine	54	72	82	83	92	92
Threonine	24	31	37	38	43	44
Serin	31	43	47	46	49	49
Glutamine	87	134	139	143	150	143
Glycine	31	36	39	38	40	40
Alanine	36	49	50	48	49	49
Cystine	9	13	13	13	13	12
Valine	29	43	49	43	53	56
Methionine	5	13	16	18	19	20
Isoleucine	24	31	36	36	39	38
Leucine	43	84	86	82	85	83
Tyrosine	*	28	29	28	29	28
Phenylalanine	25	41	44	43	47	46
Histidine	11	22	24	23	25	25
Arginine	29	47	55	55	61	59
Proline	33	72	71	69	70	71
Tryptophan	n.d.	8.0	9.0	10	13	12

CP crude protein;
* below detection limit, n.d. not determined;
For diet composition see Table 1.

3.2 Digestibility trial

Dry matter digestibility (DMD) of the 0 % CRP diet was similar ($p > 0.05$) to that of the 40 % CRP diet but significantly higher than the value obtained for the 60 % CRP diet ($p < 0.05$) (Table 3). Digestibility of organic matter (OMD), crude protein (CPD), ADF (ADFD), and GE (GED) showed similar patterns as DMD. Although the digestibility of NDF (NDFD) did not differ among diets ($p > 0.05$), regression analyses showed a reduction of NDFD with increasing CRP inclusion ($p < 0.05$). Similarly, the digestibility of all other diet constituents decreased with increasing inclusion of CRP as derived from linear regression analysis between CRP level and the digestibility of the respective constituent. The digestibilities of the 50 % CRP diet (that is the experimental group which could not be tested successfully) were calculated from the regression equations. The digestibilities of the constituents of CRP alone and its corresponding nutritive value were derived by assuming the following digestibility values of maize: DM 86.5 %, organic matter (OM) 89.9 %, CP 78.0 %, GE 87.8 % (Kyriazakis & Whittemore, 2006; Pascual-Reas, 1997), NDF 59.3 % and ADF 58.5 % (Urriola *et al.*, 2010), and the respective nutritive value of maize (digestible CP 70.2 g kg^{-1} DM and digestible energy (DE) 14.5 MJ kg^{-1} DM; Kyriazakis & Whittemore, 2006). The digestibility values for CRP were 69.8 % for gross energy, 68.7 % for DM, 73.9 % for OM, 61.7 % for CP, 39.1 % for NDF, and 10.0 % for ADF (Table 3), resulting in a concentration of 34 g kg^{-1} DM of digestible CP and 12.1 MJ DE kg^{-1} DM.

3.3 Growth trial and carcass measurements

Due to difficulties in purchasing a homogenous group of crossbred pigs for this experiment, the animals' starting weights ranged from 23 to 40 kg. In consequence, the number of days needed to attain a BW of 70 kg ranged from 44 to 90, with an average of 76 (± 17). However, pigs were allotted to treatment groups in such a way that initial group mean BW ranged from 30.1 kg (40 %, 50 % and 60 % CRP) to a maximum of 30.6 kg (0 % CRP). Daily feed intake, BW gain, final BW and feed-to-gain ratio (FGR) were not different between treatments ($p > 0.05$; Table 4). There was however a weak though significant correlation between CRP inclusion level (kg CRP kg^{-1} DM) and FGR (FGR = 3.36 + 1.46 * CRP; n=38, r^2=0.16, p=0.02) as well as between CRP inclusion level and average BW gain (kg d^{-1}; BW-gain = 0.64 – 0.25 * CRP; n=38, r^2=0.11; p = 0.04). CRP inclusion level did not affect ($p > 0.05$) carcass back fat thickness and *Longissimus dorsi* muscle surface area as well as mass of empty intestine (Table 5). However, the *Longissimus dorsi* area (Ld-A, cm^2) was slightly and negatively correlated to CRP inclusion level (Ld-A = 31.85 – 9.82 * CRP; n=20, r^2=0.25, p=0.02), while for all other carcass traits no correlation with CRP inclusion level was observed.

Table 3: *a) Digestibility (%) of the components of five experimental diets containing different proportions of cassava root peel meal (CRP) and their digestible energy content (MJ kg^{-1} DM); treatment means and standard error of the means (SEM).*
b) Parameters of the simple linear regression equations between CRP (% in DM, x) and the digestibility (%) of proximate constituents and energy values (y).

Variable	a) Experimental data								b) Parameters of the regression equations†					
	CRP	0 %	30 %	40 %	50 %	60 %	SEM	p =	a	b	r	$S_{x.y}$	n	p_r
DMD	68.7	85.7 ^{a}	82.4 ^{ab}	80.9 ^{ab}	77.8 *	74.6 ^{b}	1.46	0.020	85.9	–0.178	0.69	–1332.66	16	0.004
OMD	73.9	87.2 ^{a}	84.9 ^{ab}	83.3 ^{ab}	80.2 *	76.9 ^{b}	1.37	0.017	88.4	-0.160	0.67	–1229.34	16	0.005
CPD	61.7	83.3 ^{a}	80.2 ^{ab}	78.7 ^{ab}	76.0 *	73.1 ^{b}	1.51	0.049	84.1	–0.163	0.60	–1223.52	16	0.013
NDFD	39.1	72.4	70.3	66.9	63.2 *	58.7	2.21	0.055	74.2	–0.220	0.56	–1650.64	16	0.025
ADFD	10.0	65.6 ^{ab}	57.9 ^{ab}	49.6 ^{ab}	42.9 *	34.2 ^{b}	4.14	0.011	68.6	–0.515	0.69	–3860.65	16	0.003
GED	69.8	85.0 ^{a}	81.8 ^{ab}	79.6 ^{ab}	76.9 *	73.9 ^{b}	1.52	0.026	85.9	–0.180	0.66	–1348.39	16	0.005
DE	12.1	15.4 ^{a}	14.7 ^{a}	14.1 ^{ab}	13.8 *	12.7 ^{b}	0.32	0.002						

^{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.
DMD dry matter digestibility; OMD organic matter digestibility; CPD crude protein digestibility; NDFD digestibility of ash free neutral detergent fibre; ADFD digestibility of ash free acid detergent fibre; GED Gross energy digestibility; DE digestible energy (MJ kg^{-1} DM)
* Calculated using the regression equations.
† *a* intercept; *b* regression coefficient; *r* correlation coefficient, $S_{x.y}$ = standard deviation; *n* = number of observations; p_r = p-value for the individual hypothesis tests of the correlations; i.e. of the overall equation.
For diet composition see Table 1.

Table 4: *Body weight gain and feed intake of pigs (n=8 per diet*) fed five diets containing different proportions (0–60 %) of cassava root peel meal. Treatment means and standard error of the means (SEM).*

Variable	*0 %*	*30 %*	*40 %*	*50 %*	*60 %*	*SEM*	*p =*
Initial weight (kg)	30.5	30.2	30.1	30.1	30.1	0.71	1.000
Final weight (kg)	72.3	70.1	72.4	65.9	67.8	0.86	0.055
Average feed intake (kg DM d^{-1})	2.03	2.09	2.24	1.87	2.04	0.04	0.116
Average body weight gain (kg d^{-1})	0.600	0.577	0.604	0.483	0.485	0.023	0.233
Days to final weight	72.9	72.5	73.4	77.9	81.1	2.73	0.839
Feed-to-gain ratio	3.4	3.8	3.8	4.0	4.4	0.12	0.098

* n=7 for diet 0 %.
DM dry matter; Feed-to-gain ratio: kg feed DM per kg body weight gain.
For diet composition see Table 1.

Table 5: *Carcass traits of pigs (n=4 per diet) fed five diets containing different proportions (0–60 %) of cassava root peel meal. Treatment means and standard error of the means (SEM).*

Variable	*0 %*	*30 %*	*40 %*	*50 %*	*60 %*	*SEM*	*p =*
Body weight (BW, kg)	72.3	70.3	69.9	70.3	71.8	0.48	0.43
Hot carcass (g kg^{-1} BW)	667	669	655	660	671	6.5	0.97
Cold carcass (g kg^{-1} BW)	640	643	628	618	620	0.9	0.91
Stomach weight* (g kg^{-1} BW)	8.9	9.7	10.6	9.3	9.2	0.02	0.12
Small intestine weight* (g kg^{-1} BW)	16.3	15.7	17.3	15.3	14.8	0.05	0.65
Caecum weight* (g kg^{-1} BW)	2.2	1.8	2.0	2.0	2.3	0.01	0.67
Hindgut weight* (g kg^{-1} BW)	26.8	30.6	35.8	24.5	21.4	0.29	0.55
Small intestine length (cm)	1573	1806	1693	1542	1436	45.7	0.09
Fat thickness at first rib (cm)	3.9	3.5	3.3	3.8	3.2	0.21	0.77
Fat thickness a last rib (cm)	1.8	1.3	1.5	1.7	1.3	0.08	0.23
Longissimus dorsi area (cm^2)	33.5	30.4	27.6	28.2	27.9	0.83	0.07

* Empty weight immediately after slaughter.
For diet composition see Table 1.

4 Discussion

The digestibility of DM, OM, CP, NDF, ADF and GE of the diets decreased with increasing replacement of maize by CRP. This can primarily be related to the increasing fraction of CRP fibre in the diets, which is fermented in the hindgut to a small extent only, and may negatively affect total tract and ileal digestibility of other nutrients (Mroz *et al.*, 2000; Wilfart *et al.*, 2007). Shi & Noblet (1993) showed a decrease in ileal digestible CP as dietary ADF increased when using diets containing different concentrations of wheat straw, sugar beet pulp, wheat middlings and wheat bran, where ADF concentration ranged from 45 to 110 g per kg DM. In contrast, Shriver *et al.* (2003) reported non-significant effects of beet pulp and soybean hull fibre on CP digestibility in AA supplemented diets. The divergent results of the various studies might be due to the amount and the origin or nature of fibre (Andersson & Lindberg, 1997; Blank *et al.*, 2012). Since in the present study CP concentration of the diets decreased with increasing CRP inclusion level, the decrease in apparent CPD cannot conclusively be attributed to properties of CRP only and, therefore, not be further interpreted.

The decrease in DE concentration with increased inclusion of CRP was caused by the increasing fibre concentration and the low digestibility of CRP fibre (NDF 39.1 %, ADF 10.5 %), resulting in an obviously lower value of 12.1 MJ kg^{-1} DM than that of maize. Yet, increased inclusion of CRP did not affect feed intake of pigs but increased slightly feed-to-gain ratio. This diverges from findings of Balogun & Bawa (1997) who reported an increased feed intake at higher levels of CRP, while Fatufe *et al.* (2007) reported depressed feed intake when CRP was used in the diets. The missing correlation of daily weight gain and feed-to-gain ratio with CRP inclusion level up to 40 %, and the lower daily weight gain at 50 % and 60 % inclusion indicates that negative effects of CRP on the growth of pigs can be avoided by being aware of an upper limit. This notion is further supported by the data of Knowles *et al.* (1998, fibre sources: rice hulls and wheat middlings) and Shriver *et al.* (2003), who also did not determine an effect of their fibre sources on carcass traits and growth performance in AA-supplemented pigs. However, it should be noted that an increasing fill of the hindgut caused by higher fibre levels in the diets could have masked negative effects of reduced nutrient digestibility on body weight changes and feed-to-gain ratio.

5 Conclusions

In many tropical regions maize is a major component of human diets and therefore expensive and often in short supply as livestock feed. Here, cassava root peel, of which huge amounts are wasted daily in major producing countries such as Nigeria, can be effectively used for the partial replacement of maize in pig diets. Despite its lower nutritive value than maize, CRP can be considered as a valuable source of energy and can be used to replace up to 40 % of maize in the diet of grower pigs, if deficient amino acids are supplemented.

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