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Dietary replacement of maize with processed cassava peel–leaf blends: impact on the growth performance and blood parameters of growing pigs

Gabriel Adedotun Williams[1#], Olufemi Sunday Akinola[2], Tolulope Modupe Adeleye[3], Oluwakemi Titilayo Irekhore[4], Abimbola Oladele Oso[5,6], Joshua Olumide Ogunrombi[5] and Oluwaseyi Kudirat Williams[5]

[1]Department of Animal Science, School of Agriculture, Lagos State University Epe Campus, Lagos, Nigeria
[2]Department of Animal Production and Health, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta PMB 2240, Nigeria
[3]Department of Microbiology, College of Biological Sciences, Federal University of Agriculture, Abeokuta PMB 2240, Nigeria
[4]Agricultural Media Resources and Extension Centre, Federal University of Agriculture, Abeokuta PMB 2240, Nigeria
[5]Department of Animal Nutrition, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta PMB 2240, Nigeria
[6]World Bank Centre of Excellence in Agricultural Development and Sustainable Environment, Federal University of Agriculture, Abeokuta PMB 2240, Nigeria

SUMMARY

This study investigated the effect of dietary inclusion of cassava peel–leaf blend (CPLB) processed in different ways on the performance and blood parameters of growing pigs. CPLB (cassava peel: cassava leaf; 5:1) was included in the diet of pigs in an 8-week feeding trial. The processed CPLB (unfermented (UCPLB), water-fermented (WCPLB) and microbial fermented (MCPLB)) replaced maize at 50%. Twenty-four male crossbred (Large White x Landrace) pigs with a weight range of 21±1 kg) were assigned to four weight-matched dietary treatments with six pigs in each. A standard maize and soya-based diet (control) was formulated, as well as diets with unfermented CPLB (diet UF), water-fermented CPLB (WF) and microbial fermented CPLB

Corresponding author e-mail: gabriel.williams@lasu.edu.ng
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(MF), using *Aspergillus tamarii* as the inoculum. The growth response was measured weekly, and haematological and biochemical analyses were carried out after 8 weeks. The diets had no significant (P > 0.05) effect on growth performance or haematological parameters at the end of 8 weeks. Serum creatinine and thiocyanate were significantly (P < 0.05) affected by dietary inclusion of processed CPLB at 8 weeks. Pigs fed diet UF had reduced (P < 0.05) serum creatinine (0.58 mg/dl). Serum thiocyanate was reduced (P < 0.05) in pigs fed diet WF (1.16 µg/ml) and diet MF (1.10 µg/ml). In conclusion, a CPLB-based diet, irrespective of the processing method, did not significantly affect growth performance or haematological parameters and had no negative effect on biochemical parameters.

KEY WORDS: Cassava peel, Cassava leaf, Fermentation, Pigs, Growth performance, Blood parameters

INTRODUCTION

Pig production can mitigate the animal protein shortage in Africa due to the animals' fast growth, short generation interval, high prolificacy, efficient nutrient conversion into high quality meat, and ability to convert agro-waste into nutritious meat (Adesehinwa et al., 1998). Pigs are monogastric animals, which are the largest consumer of commercial livestock feeds in Africa (FAO 2005). Commercial pig production employs concentrate feeds (maize and soybean-based), whose cost is increasing due to poor local production that fails to meet the demand for consumption by people and animals and other uses (Afolayan 2010). Therefore there is a need to find ways to utilize available agro-industrial waste in the formulation of pig diets, in order to reduce the cost of meat production.

Such available agro-industrial by-products and crop residues that could be explored for use in the diet of pigs include cassava peels and leaves. Cassava peels constitute about 10–13% of tuber weight (Oyebimpe et al., 2006), with protein content of approximately 46 to 55 g/kg (Morgan and Choct 2016) and 9.40% crude fibre (Oladimeji et al., 2002). Cassava peel contains crude protein (5.98%), ether extract (0.65%), ash (7.0%), nitrogen-free extract (65.87%) and metabolizable energy of 2044.80 kcal/kg (Salami 2000). Cassava leaf is high in protein (16.6% to 39.9%) and a good source of vitamin B, vitamin C and carotenes (Dada and Oworu, 2010), with fibre content of 9.68–14.6% (Phuc et al., 1996).

The use of cassava peels in monogastric nutrition is limited by the presence of high fibre fractions (Ngudi et al., 2003; Cardoso et al., 2005). Cassava leaf has high crude protein content, but with a poor amino acid profile due to its low content of sulphur-containing amino acids, methionine and cysteine (Fasuyi and Aletor, 2005). Another important limitation for the utilization of cassava by-products as feed for monogastric animals is the presence of anti-nutritional factors (hydrocyanide and tannins) (Man and Wiktorsson, 2001).

Thus, to adequately access the rich nutritive potential of these cassava products in pig nutrition, various processing strategies and methods must be used to increase soluble carbohydrates by breaking down the constituent fibre (Motarjemi, 2000). Fermentation has been reported to be responsible for product stability, flavour development and cyanide elimination (Motarjemi, 2000). Sun-drying has also

been reported to eliminate almost 90% of nutritionally active deleterious factors (Cardoso et al., 2005 and Nguyen et al., 2012). Evaluation of blood parameters provides information on the quality of the feed ingredients which make up the diet (Czech et al., 2020). In addition, haematological characteristics can provide useful information for diagnostic and management purposes, as the blood serves as an important indicator of animals' physiological, pathological and nutritional status (Oleforuh-Okoleh et al., 2015). We hypothesized that replacement of maize with processed cassava peel–leaf blends in the diet of growing pigs will support growth as maize does without deleterious effects on blood parameters. Hence, the current study seeks to investigate the effect of processed cassava peel–leaf blends on the growth performance and haematological and biochemical parameters of growing pigs.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the piggery unit of the Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta, Alabata, Ogun State, Nigeria, in accordance with approved guidelines for Animal Research by the Nigeria Institute of Animal Science in Nigeria (NIAS-NREP-2017). The site is situated in the derived savanna zone of Southwestern Nigeria at 7°9' 39N and 3°20' 54E, 76 m above sea level. The mean annual rainfall is 1040 mm and occurs from March to October, and the temperature average is 34°C throughout the year.

Processing of test ingredients

Cassava peel meal (CPM) and cassava leaf meal (CLM)

Dried cassava peels were obtained from the cassava processing plant in Igbo-ora, Oyo state, Nigeria. The dried peels were subsequently hammer milled (2 mm sieve) to yield cassava peel meal (CPM) and stored at room temperature in plastic bags. Fresh cassava leaves without petioles were picked manually from an established cassava farm (Odeda, Ogun State, Nigeria). The leaves were spread evenly on the concrete floor and sun-dried for 2–3 days until they became crispy, while still retaining their greenish colour. The dried crispy leaves were milled (2 mm sieve) to yield cassava leaf meal (CLM), which was stored in plastic bags at room temperature.

Unfermented cassava peel–leaf blend (UCPLB)

The Pearson Square method according to Wagner and Stanton (2012), as described by Adeyemi et al. (2014), was used to prepare a blend of cassava peel meal (CPM) and cassava leaf meal (CLM). The target protein level for the unfermented cassava peel–leaf blend (UCPLB) was set at 8.83%, with crude protein contribution of 81.26% and 18.74% from CPM and CLM, respectively. The components were mixed in a 5:1 ratio (5 parts CPM to 1 part CLM) due to the higher availability of the peel than the leaves. The crude protein (CP) content of CPM (4.46%) and CLM (27.78%) in Table 1 were determined by a standard method (AOAC, 2005) and used to calculate the crude protein content of the blend before chemical composition analysis. The individual CP was multiplied by the individual ratio (4.46% × 5) and (22.78% × 1) to yield 22.30% and 27.78% for CPM and CLM, respectively, and the two were added together (22.30% + 27.78% = 49.97%) and divided by the sum of the ratio components (5+1 = 6). The CP content of the CPM and CLM blend is 49.97%/6 = 8.34%.

Water-fermented cassava peel–leaf blend (WCPLB)

The blend was prepared by mixing dried CPLB (5:1) with water (1:1, kilogram: litre) in plastic drums. The blend was mixed thoroughly to ensure that all portions of the blend came in contact with water. Then the wet blend was placed in black polythene bags and tied securely to create an anaerobic environment within the bags. The bags were left for 7 days to ensure proper fermentation of the contents. Then the bags were opened and the ingredients were sundried (50–58°C) for 3 days and stored before diet formulation.

Microbial (*Aspergillus tamarii*) fermented cassava peel–leaf blend (MCPLB)

Pure strains of *Aspergillus tamarii* obtained from the Culture Collection Unit of the Department of Microbiology, Federal University of Agriculture, Abeokuta, were used as inocula. *Aspergillus tamarii* spores used for fermentation of CPLB were prepared using standard protocols described by Murray et al. (2003). A spore suspension (inoculum) of *Aspergillus tamarii* was prepared by inoculating spores from Petri dishes into CPLB at 10.5×10^8 spores/g of CPLB. The wet blend was mixed thoroughly and placed in black polythene bags, which were tied securely to create an anaerobic environment within the bags. The bags were stored and left for 7 days to ensure proper fermentation of the contents. Then the bags were opened and the ingredients were sundried (50–58°C) for 3 days and stored before diet formulation.

Chemical composition of test ingredients

Ground samples (3 g) were taken for analysis of the proximate composition of CPM, CLM, UCPLB**,** WCPLB, MCPLB and the diets (control, UF, WF and MF). The proximate composition was determined using a standard method (AOAC (2005) according to Nochera and Ragone (2016), and fibre fractions according to a standard method by McCleary (2007). All analyses were on a dry matter basis. Neutral detergent fibre (NDF) was assayed without heat-stable amylase and expressed inclusive of residual ash; acid detergent fibre (ADF) was expressed inclusive of residual ash; lignin was determined by solubilization of cellulose with sulphuric acid; and crude protein was calculated as total nitrogen × 6.25. Gross energy was estimated using an adiabatic bomb calorimeter (Model 1261; Parr Instrument Co., Moline, IL, USA), while digestible and metabolizable energy were calculated according to the National Research Council (NRC) (2012). The total hydrocyanide levels of the CPM, CLM, UCPLB, WCPLB and MCPLB samples were analysed using the AOAC (1990) alkaline titration method according to Vetter (2000). Grounded samples of 5 g were soaked in a mixture of distilled water (50 ml) and orthophosphoric acid. The samples were each thoroughly mixed and stored at room temperature for 48 h to release residual cyanoglycosides. The resulting sample (mixture) was then transferred to a distillation flask, and a drop of paraffin (antifoaming agent) was added. The flask was then fitted to a distillation apparatus and distilled. About 50 ml of the distillate was collected in a receiving flask containing 4 ml of distilled water and 0.1 g of sodium hydroxide pellets. The distillate was transferred to a 50 ml volumetric flask and made up to mark with distilled water, and then 1.6 ml of 5% potassium iodide was added and titrated against 0.02M silver nitrate ($AgNO_3$). The amount of cyanide in the samples was determined from the following relation: 1 ml of 0.02M $AgNO_3$ = 1.08 mg HCN.

Experimental animals, experimental design and dietary treatments

Twenty-four crossbred (Large White x Landrace) male pigs (8 wks. old) with a weight range of 21±1 kg, purchased from a reputable pig farm at Iperu Remo, Ogun State, were randomly assigned to four weight-matched dietary treatments with 6 pigs in each. Pigs were housed individually in 24 pens (0.5 m × 0.25 × 0.3 m). Six pens were assigned to each treatment (one pig per pen). A standard soybean–maize-based diet (control; Diet 1) was formulated as described by Nyachoti et al. (2005) according to NRC (2012) requirements for growing pigs. Three additional experimental diets were formulated with the inclusion of the processed cassava peel–leaf blends, i.e. with UCPLB (Diet UF), WCPLB (Diet WF) and MCPLB (Diet MF), as a replacement for 50% of the maize (weight for weight) in the control diet (Table 1). Pigs in each treatment group were fed their respective experimental diets in their individual pens. Feed was provided to the animals during the 8-week trial based on the NRC (2012) recommended intake for each body weight range. Experimental diets were supplied twice daily (8:00 and 18:00), and clean water was supplied *ad libitum.* Data on pen temperature and relative humidity were monitored using a thermo-hygrometer at 08:00, 14:00 and 19:00 daily. The average temperature was 30.2 ± 1.39°, and the relative humidity was 67.5 ± 2.7.

Table 1.
Gross composition of experimental diet

	Control	UF	WF	MF
Ingredients				
Maize	50.00	25.00	25.00	25.00
UCPLB	0.00	25.00	0.00	0.00
WCPLB	0.00	0.00	25.00	0.00
MCPLB	0.00	0.00	0.00	25.00
Soybean meal	14.50	14.00	14.00	14.00
Groundnut cake	8.00	8.00	8.00	8.00
Palm kernel cake	4.00	4.00	4.00	4.00
Wheat offal	7.00	7.00	7.00	7.00
Corn bran	10.00	10.00	10.00	10.00
Soybean oil	1.50	2.00	2.00	2.00
Limestone	1.00	1.00	1.00	1.00
Bone meal	3.00	3.00	3.00	3.00
Lysine	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25
Vitamin-mineral premix*	0.30	0.30	0.30	0.30
Salt (NaCl)	0.20	0.20	0.20	0.20
Total	**100.00**	**100.00**	**100.00**	**100.00**
Analysed nutrients				
Gross energy (Kcal/Kg)	3824.14	3669.81	3618.44	3627.17
Protein (%)	19.16	19.68	19.29	19.66
Ether extract (%)	3.88	2.97	3.83	4.24
Ash (%)	7.20	9.03	8.40	9.23
NDF (%)	2.02	2.74	2.68	2.61
ADF (%)	7.40	14.21	10.52	9.95
Total cyanide (mg kg^{-1} DM)	0.00	5.56	4.28	3.02
Calculated nutrients				
Digestible energy (Kcal/kg)**	3256.10	3130.49	3068.60	3026.40
Metabolizable energy (Kcal/kg)***	2588.00	2516.25	2508.25	2505.50
Calcium (%)	1.22	1.02	1.04	1.05
Avail. phosphorus (%)	0.53	0.49	0.46	0.44
Methionine (%)	0.55	0.37	0.38	0.41
Methionine + Cysteine (%)	0.74	0.64	0.57	0.68
Lysine (%)	1.08	1.02	1.06	1.04

*Vitamin/mineral premix: vit. A 5,500,000 IU, vit. D_3 1,500,000 IU, vit. E 10,000 mg, vit. K_3 1,500 mg, vit. B_1 1,600 mg, vit. B_2 24,000 mg, niacin 20,000 mg, pantothenic acid 5,000 mg, vit. B_6 1,500 mg, vit. B_{12} 10 mg, folic acid 500

mg, biotin H_2 750 mg, choline chloride 175,500 mg, cobalt 200 mg, copper 300 mg, iodine 1,000 mg, iron 20,000mg, manganese 40,000 mg, selenium 200 mg, zinc 30,000 mg, antioxidant 1,250 mg.

UF = diet with UCPLB, WF = diet with WCPLB, MF = diet with MCPLB, UCPLB = unfermented cassava peel–leaf blend, WCPLB = water-fermented cassava peel–leaf blend, MCPLB = microbial fermented cassava peel–leaf blend

**Estimated using the Nutrient Requirements of Swine, NRC (2012) formula: DE (kcal/kg) = 4,168 − (91×% ash) + (19×% CP) + (39×% EE) – (36×% NDF)

***Estimated using the Nutrient Requirements of Swine, NRC (2012) formula: ME (kcal/kg) = DE – (6.8 × %CP)

Growth performance

The initial body weight of individual pigs was measured, and subsequently their individual weight was measured weekly. Weekly weight gain was calculated as the difference between the final weight at the end of the week and the initial weight at the beginning of the week. Daily feed intake was measured as the difference between the feed offered and leftovers, and feed conversion ratio (FCR) was calculated as feed consumed / weight gain.

Blood collection

Blood samples were collected from 5 pigs per treatment after 8 weeks. The pigs were without feed from 00.00 to 7.00. The pigs were restrained in the restraining cubicle before blood collection. Blood was drawn from the jugular vein using disposable syringes with 20 × 100 mm metallic needles. Two 2.5 ml samples of blood were collected from each pig; one into vials containing ethylene diamine tetra-acetate (EDTA) for determination of haematological indices, and the other set into plain bottles (without EDTA) for analysis of biochemical parameters. Blood samples for biochemical analysis were centrifuged (1200 rpm for 15 min) for serum separation. Aliquots of serum were frozen at −20°C until further analysis.

Haematological parameters

Haemoglobin concentration (Hb) was estimated using the cyanmethaemoglobin method (Cannan, 1958). Packed cell volume (PCV), red blood cell count (RBC), and white blood cell count (WBC) were determined with a Wintrobe haematocrit tube using the method of Schalm et al. (1975). Differential leucocyte counts (lymphocytes, eosinophils, and monocytes) were determined on blood smears stained with May–Grunwald–Giemsa stain. Mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC) and mean corpuscular volume (MCV) were calculated according to Bush (1991).

Biochemical parameters

Total serum protein, albumin and globulin were determined using the bromocresol purple method (Varley et al., 1980), and serum creatinine according to Bonsness and Taussky (1945). Serum enzymes, i.e. alanine aminotransferase (ALT), alkaline phosphatase (ALP) and aspartate aminotransferase (AST), were analysed using commercial kits (Qualigens India. Pvt. Ltd., Catalogue number 72201-04). Serum cholesterol was estimated by enzymatic colorimetric methods (according to the manufacturer's manual) using the Randox® diagnostic cholesterol kit.

Statistical analysis

All data were subjected to one-way analysis of variance using Statistical Analysis System (SAS) software, and means were separated using Tukey's test in SAS as described by Ramatsoma et al. (2015). Differences were considered significant at $P < 0.05$.

Statistical model

$Y_{ij} = \mu + T_i + + \varepsilon_{ij}$

where

Y_{ij} = observed value of the dependent variable (output),

μ = population mean (overall mean),

T_i = effect of dietary inclusion of CPLB (i = maize, UCPLB, WCPLB, MCPLB),

ε_{ij} = sampling error.

RESULTS

Chemical composition of test ingredients

Table 2 shows the nutrient composition, fibre fraction, gross energy and cyanide content of the test ingredients. Crude protein (CP) ranged from 4.46–27.78%; it was lowest in CPM (4.46%) and highest in CLM (27.78%), while that of MCPLB (11.68%) was higher than that of UCPLB (8.97%) and WCPLB (8.11%). Ether extract content ranged from 0.61–4.93%; it was lowest in MCPLB and highest in CLM. The crude fibre content of WCPLB (12.24%) and MCPLB (12.87%) was lower than that of UCPLB (18.00%), CPM (14.23%) and CLM (17.70%). The total cyanide content of CPM (14.23 mg/kg DM) was higher than that of CLM (3.82 mg/kg), UCPLB (4.37 mg/kg), WCPLB (2.32 mg/kg) and MCPLB (2.28 mg/kg). The content of nitrogen-free extract (NFE) was highest in CPM (84.25%) and lowest in CLM (44.57%), while UCPLB, WCPLB and MCPLB had 57.39%, 56.03% and 60.79% NFE, respectively. The ADF, ADL and NDF of WCPLB (23.55%, 20.23% and 35.62%) and MCPLB (26.96%, 20.23% and 26.19%) were lower than in UCPLB (37.48%, 21.59% and 37.84%). The gross energy and digestible energy content of UCPLB (3011.01 and 3184.64 Kcal/kg) and WCPLB (3918.95 and 3135.16 Kcal/kg) were higher than in MCPLB (3825.34 and 3060.27 Kcal/kg). The gross energy and digestible energy content of CPM (3575.70 Kcal/kg and 2860.56 Kcal/kg) were higher than in CLM (3011.01 Kcal/kg and 2408.81 Kcal/kg).

Table 2.
Chemical composition of test ingredients

Nutrient composition	CPM	CLM	UCPLB	WCPLB	MCPLB
Crude protein (%)	4.46	27.78	8.97	8.11	11.68
Ether extract (%)	1.81	4.93	0.76	1.66	0.61
Crude fibre (%)	14.23	17.70	18.00	12.24	12.87
Ash (%)	5.51	8.08	7.73	9.06	7.56
Nitrogen-free extract	84.25	44.57	57.39	56.03	60.79
Total cyanide (mg kg^{-1} DM)	14.03	3.82	4.37	2.32	2.28
ADF (%)	25.04	26.14	37.48	23.55	26.96
ADL (%)	13.67	14.10	21.59	20.23	20.23
NDF (%)	24.26	21.32	37.84	35.62	26.19
Gross energy (Kcal/g)	3575.70	3011.01	3980.80	3918.95	3825.34
Digestible energy (Kcal/g)[a]	2860.56	2408.81	3184.64	3135.16	3060.27

CPM = cassava peel meal, CLM = cassava leaf meal, UCPLB = unfermented cassava peel–leaf blend, WCPLB = water-fermented cassava peel–leaf blend, MCPLB = Microbial fermented cassava peel–leaf blend, ADF = acid detergent fibre, ADL = acid detergent lignin, NDF = neutral detergent fibre, a: estimated using the Nutrient Requirements of Swine, NRC (2012) formula: DE (kcal/kg) = 4,168 − (91×% Ash) + (19×% CP) + (39×% EE) – (36×% NDF)

Growth performance

The growth performance of growing pigs is shown in Table 3. The results show no significant ($P > 0.05$) effect of processed CPLB inclusion on any performance indices measured at the end of 8 weeks.

Table 3.
Growth performance of growing pigs fed diets containing cassava peel–leaf blend processed in different ways

Parameters	Control	UF	WF	MF	SEM	P-value
Initial weight (kg)	20.17	20.83	20.58	22.00	1.07	0.948
Final weight (kg)	65.83	66.83	64.00	67.17	1.89	0.944
Weight gain (kg)	45.66	46.08	43.42	45.17	0.92	0.356
Weight gain/week (kg)	5.71	5.76	5.43	5.65	2.39	0.619
Total feed intake (kg)	91.55	92.50	93.98	89.76	2.40	0.875
FCR	2.01	2.01	2.16	1.99	0.13	0.363

UF = diet with UCPLB, WF = diet with WCPLB, MF = diet with MCPLB, UCPLB = unfermented cassava peel–leaf blend, WCPLB = water-fermented cassava peel–leaf blend, MCPLB = microbial fermented cassava peel–leaf blend, SEM = pooled standard error of means.

Haematology

The haematological parameters of growing pigs are shown in Table 4. Dietary inclusion of processed CPLB had no significant ($P > 0.05$) effect on any of the haematological indices at the end of 8 weeks.

Table 4.
Haematological parameters of growing pigs fed diets containing cassava peel–leaf blend processed in different ways

Parameters	Control	UF	WF	MF	SEM	P-value	Normal* range
PCV (%)	40.00	38.00	42.33	40.00	0.79	0.318	36-43
Haemoglobin (g/dL)	13.47	12.87	14.13	13.47	0.25	0.408	9-16
RBC ($x10^{12}$/L)	6.70	6.43	7.20	6.77	0.15	0.380	5-7
WBC ($x10^{9}$/L)	17.33	17.50	14.23	17.00	0.59	0.164	11-22
Lymphocytes (%)	64.00	70.00	69.00	68.00	2.14	0.821	35-75
Eosinophils (%)	0.00	0.00	0.00	0.33	0.08	0.441	0-15
Monocytes (%)	0.33	0.67	0.00	1.00	0.29	0.708	0-10
MCV (fL)	59.70	59.10	58.87	59.20	0.43	0.939	52-62
MCH (pg)	20.07	20.00	19.67	19.97	0.15	0.832	17-24
MCHC (g/dL)	33.67	33.87	33.37	33.70	0.12	0.582	29-34

PCV = packed cell volume, RBC = red blood cells, WBC = white blood cells, MCV = mean corpuscular volume, MCH = mean corpuscular haemoglobin, MCHC = mean corpuscular haemoglobin concentration, UF = diet with UCPLB, WF = diet with WCPLB, MF = diet with MCPLB, UCPLB = unfermented cassava peel–leaf blend, WCPLB = water-fermented cassava peel–leaf blend, MCPLB = microbial fermented cassava peel–leaf blend, SEM = pooled standard error of means.
*Normal range: Merck's Manual (1998)

Biochemical parameters

Biochemical parameters of growing pigs are shown in Table 5. At the end of 8 weeks, a significant ($P < 0.05$) effect of processed CPLB inclusion was observed for serum creatinine and thiocyanate, while other parameters were not significantly ($P > 0.05$) influenced. Serum creatinine content in pigs fed diet UF was reduced ($P < 0.05$) compared to those fed diet MF but similar to those fed the control diet and diet WF. Serum thiocyanate was highest in pigs fed diet UF ($P < 0.05$) and lower in pigs fed diets WF and MF ($P < 0.05$), while no thiocyanate was observed for pigs fed the control diet.

Table 5. Biochemical parameters of growing pigs fed diets containing cassava peel–leaf blend processed in different ways

Parameters	Control	UF	WF	MF	SEM	P-value	Normal range
Total protein (g/L)	74.20	75.40	76.70	78.70	3.32	0.973	66.00-89.00¶
Albumin (g/L)	38.60	48.80	41.90	44.80	2.44	0.904	36.00-50.00¶
Globulin (g/L)	35.60	26.60	34.90	34.10	0.31	0.775	28.00-41.00Б
Cholesterol (mmol/L)	4.20	4.70	4.30	4.60	1.08	0.148	4.50-7.40*
Creatinine (mmol/L)	0.65^{ab}	0.58^{b}	0.61^{ab}	0.75^{a}	0.03	0.032	1.00-2.30¶
Thiocyanate (µmol/L)	0.00^{c}	4.61^{a}	3.77^{b}	3.57^{b}	0.19	0.039	8.12 (lethal level)ǂ
ALP (iU/L)	51.33	40.00	49.33	39.67	3.08	0.450	27.00-160.00¶
AST (iU/L)	38.00	38.00	44.00	36.33	2.83	0.835	16.00-64.00¶
ALT (iU/L)	38.67	33.00	40.00	39.00	1.88	0.614	10.90-95.10¶

ab Means in the same row with different superscripts are significantly different ($P < 0.05$).

ALT = alanine aminotransferase, AST = aspartate aminotransferase, ALP = alkaline phosphatase,

UF = diet with UCPLB, WF = diet with WCPLB, MF = diet with MCPLB, UCPLB = unfermented cassava peel–leaf blend, WCPLB = water-fermented cassava peel–leaf blend, MCPLB = microbial fermented cassava peel–leaf blend, SEM = pooled standard error of means.

¶Brockus et al. (2005), Б(Klem et al. (2010), *Merck's Manual (1998), ǂKampe et al. (2000)

DISCUSSION

The performance of growing pigs revealed no difference in the response to processed CPLB inclusion for any of the indices measured at the end of 8 weeks. This is in concordance with the report of Irekhore et al. (2015), who observed no significant effect of dietary inclusion of cassava peel as a replacement for maize on the performance indices of growing pigs. Ly et al. (2010) also reported no significant effect of dried and ensiled cassava leaf in the diet of crossbred pigs on final body weight, average daily gain or FCR. In contrast, Hong et al (2016) observed significantly reduced feed intake when fermented cassava tuber waste was included in the diet of crossbred pigs. Fatufe et al. (2007) also reported depressed feed

intake when cassava root peel was used in the diets of pigs. These discrepancies may be linked to differences in the processing of the cassava by-product or in the age or size of the animals. Adeyemi et al. (2014) found no difference in the performance of rabbits fed 50% fermented cassava peel and leaf meal as a replacement for maize, which corroborates the results of the present study. Overall, the similar weight gain of pigs fed diets containing processed CPLB compared with the control diet indicates that the diets with processed CPLB were able to support growth as well as the maize diet.

Haematological parameters were not significantly influenced by the replacement of maize with processed CPLB in the diets of growing pigs throughout the feeding trial. This is similar to the findings of Ngiki et al. (2014), who observed no significant difference in haematological parameters of broiler chickens fed diets with varying levels of cassava root meal. The haematological parameters obtained for the pigs fell within the normal range reported for pigs (Merck Manual 1998). This is in agreement with Unigwe et al. (2016), who also reported no significant effect of fermented cassava peel with or without enzyme supplementation on packed cell volume (PCV), haemoglobin (Hb) white blood cell count (WBC), platelet count, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) or mean corpuscular haemoglobin concentration (MCHC) in growing pigs. The results of this study indicate that the diets had no adverse effect on haematological parameters during the experimental period (Togun et al., 2007).

Biochemical parameters, except creatinine, were not significantly affected at the end of 8 weeks. Increased serum creatinine was obtained for growing pigs fed diet MF. Similarly, Midau et al. (2011) reported increased serum creatinine in broiler chickens fed graded levels of enzyme (Maxigrain®)-supplemented cassava peel meal (CPM)-based diets. However, the serum creatinine values across treatments were below the normal range, indicating the absence of muscle wastage which could have been caused by inadequate protein. High serum creatinine indicates that the animal is surviving at the expense of body tissue, and serum creatinine values are used as an indirect measure of protein utilization (Rafiu et al., 2013). Reduced thiocyanate content was observed in pigs fed diets WF and MF compared to those fed diet UF. The reduction in thiocyanate in those groups is due to the reduction in the cyanide content in CPLB as a result of fermentation. Nwafor and Ejukonemu (2004) reported that biodegradation of waste materials through fermentation improves nutritional quality by reducing anti-nutrient content. The values obtained across the treatments with processed CPLB were below the lethal level, which suggests that there was no kidney damage due to HCN or other anti-nutrients in the diets, as they were reduced to tolerable levels by sun drying and fermentation, corroborating the report of Ajagbonna et al. (1999). The serum activity of AST and ALT in this study did not differ across treatments. This is consistent with the report of Orororo et al. (2014), who observed similar AST and ALT activity in pigs fed a cassava peel-based diet and those fed a maize-based diet. It is also in agreement with results reported by Adesehinwa et al. (2008) for growing pigs fed cassava peel-based diets supplemented with Avizyme® 1300. High serum concentrations of these enzymes are indicative of hepatocellular injury or damage (Orororo et al., 2014). Thus, the outcome of the current study implies a healthy liver condition.

CONCLUSION

The inclusion of cassava peel–leaf blends as a replacement for maize in the diet of pigs, irrespective of the processing method, did not adversely affect the performance, haematological or biochemical parameters of pigs. Therefore processed cassava peel–leaf blends can replace maize in the diet of pigs in the amount of up to 50%.

REFERENCES

1. Adesehinwa, A.O.K., Dafwang, I.I., Ogunmodede, B.K. and Tegbe, T.S.B. (1998). A review of utilization of some agro-industrial by-products in pig rations. Nigerian Journal of Agricultural Extension. 11(1&2): 50-64.
2. Adesehinwa, A.O.K., Dairo, F.A.S. and Olagbegi, B.S. (2008). Response of growing pigs to cassava peel based diets supplemented with Avizyme® 1300: growth, serum and hematological indices. Bulgarian Journal of Agricultural Science. 14 (5): 491-499.
3. Adeyemi, O.A., Adesanya, P.A., Eniolorunda, O.O., Sogunle, O. M., Egbeyale, L.T. and Njoku, C.P. (2014). Performance of growing rabbits fed diets containing fermented and unfermented cassava leaf: peel meal mix as replacement for maize. Malaysian Journal of Animal Science. 17(1): 61-72.
4. Afolayan, S.B. (2010). Evaluation of sweet potato meal as a source of energy in the diets of chickens. Ph.D. Thesis, Department of Animal Science, Ahmadu Bello University, Zaria, Nigeria.
5. Ajagbonna, O.P., Onifade, K.I. and Suleman, U. (1999). Haematological and Biochemical Changes in Rats Given Extracts of Calotropis procera. Sokoto Journal of Veterinary Science. 1: 36-42.
6. Association of Official Analytical Chemists (AOAC). (1990). Official Method of Analysis. (15th Ed.). Washington D.C.
7. Association of Official Analytical Chemists (AOAC), (2005). Determination of moisture, ash, protein and fat. 18th edn. Washington, USA
8. Bonsness R.W., Taussky H.H. (1945). On the colorimetric determination of creatinine by the Jaffe reaction. Journal of Biological Chemistry. 158: 581-591.
9. Brockus C.W., Mahaffey E.A., Bush, S.E. and KruppDespain A.W. (2005). Hematologic and serum biochemicalreference intervals for Vietnamese potbellied pigs (Sus scrofa). Comparative Clinical Pathology. 13 (4): 162–165. http://dx.doi.org/10.1007/s00580-005-0539-5
10. Bush B.M. (1991). Interpretation of Laboratory Results for Small Animal Clinicians. Blackwell Scientific Publications. London, UK, pp: 32–67.
11. Cannan R.K. (1958). Book of Clinical Practical Chemistry. Vol. I, fifth ed. CBS Publisher and Distributors, New Delhi, India. pp. 479-480.
12. Cardoso A.P., Estevao M., Mario E., Fernando. M., Julie C., Haque M.R. and Bradbury J.H. (2005). Processing of cassava roots to remove cyanogens. Journal of Food Composition and Analysis. 18: 451-460. DOI: 10.1016/j.jfca.2004.04.002
13. Czech A., Grela E.R., Kiesz M. and Klys S. (2020). Biochemical and hematological blood parameters of sows and piglets fed a diet with a dried fermented rape seed meal. Annals of Animal science. 20 (2): 535-550

14. Dada, O.A., Oworu, O.O. (2010). Mineral and nutrient leaf composition of two cassava (Manihot esculenta Crantz) cultivars defoliated at varying phenological phases. Notulae Scientia Biologicae. 2: 44.
15. FAO. 2005. The role of biotechnology for the characterisation and conservation of crop, forestry, animal and fishery genetic resources. Proceedings of a workshop (FAO, EAAP, ASPA, ECONOGENE), Turin, Italy, 5-7 March 2005.
16. Fasuyi, A.O., Aletor, V.A. (2005). Varietal composition and functional properties of cassava (Manihot esculenta, Cranzt) leaf meal and leaf protein concentrates. Pakistan Journal of Nutrition. 4: 43-49. DOI: 10.3923/pjn.2005.43.49.
17. Fatufe A.A., Akanbi I.O., Saba G.A., Olowofeso O. and Tewe O.O. (2007). Growth performance and nutrient digestibility of growing pigs fed a mixture of palm kernel meal and cassava root peel. Livestock Research for Rural Development. 19 (12).
18. Hong T.T.T., Van An Le Be P.T., Lindberg J.E. (2016). Effect of fermented rice bran and cassava waste on growth performance and meat quality of crossbred pigs. World Journal of Agricultural Research. 4(5): 132-138. DOI: 10.12691/wjar-4-5-1.
19. Irekhore O.T., Adeyemi O.M., Idowu O.M.O., Akinola O.S. and Bello K.O. (2015). Growth performance, hematological indices and cost benefits of growing pigs fed cassava peel meal diets supplemented with Allzyme® SSF. International Journal of Applied Agricultural and Apicultural Research. 11 (1& 2): 51-59.
20. Kampe S., Iffland R., Korenkov M. and Diefenbach Ch. (2000). Survival from a lethal blood concentration of cyanide with associated alcohol intoxication. Anaesthesia. 55: 1189-1191
21. Klem T.B., Bleken, E., Morberg, H., Thoresen, S.I. and Framstad, T. (2010). Hematologic and biochemical reference intervals for Norwegian crossbreed grower pigs. Veterinary Clinical Pathology. 39(2):221-226. doi: 10.1111/j.1939-165X.2009.00199.x.
22. Ly, N.T.H., Ngoan, Le D., Verstegen, M.W.A. and Hendriks, W.H. (2010). Ensiled and dry cassava leaves, and sweet potato vines as a protein source in diets for growing Vietnamese large white×mong cai pigs. Asian Australasian Journal of Animal Science. 23(9): 1205 – 1212. https://doi.org/10.5713/ajas.2010.90591.
23. Man, N.V. and Wiktorsson, H. (2001). Cassava tops ensiled with or without molasses as additive effects on quality, feed intake and digestibility by heifers. Asian Australian Journal of Animal Science. 14: 624-630.
24. McCleary, B.V. (2007). An integrated procedure for the measurement of total dietary fibre (including resistant starch), non-digestible oligosaccharides and available carbohydrates. Analytical and Bioanalytical Chemistry. 389:291–308. https://doi.org/10.1007/s00216-007-1389-6.
25. Merck Manual, (1998). The Merck Veterinary Manual. Susan E. Aiello and Asa Mays (eds), Pub. Merck and Co., Inc, Whitehouse station, N.J., U.S.A.
26. Midau, A., Augustine, C., Yakubu, B., Yahaya, S.M., Kibon, A. and Udoyong, A.O. (2011). Performance of broiler chicken fed enzyme supplemented cassava peel meal based diets. International Journal of Sustainable Agriculture. 3 (1): 01-04.

27. Morgan, N.K. and Choct, M. (2016). Review Article. Cassava: Nutrient composition and nutritive value in poultry diets. Animal Nutrition. 2: 253-261. doi.org/10.1016/j.aninu.2016.08.010.
28. Motarjemi, Y. (2000). Impact of small scale fermentation technology on food safety in developing countries. International Journal of Food Microbiology. 75(3): 213-229. DOI: 10.1016/s0168-1605(01)00709-7.
29. Murray, P.R., Baron, J.H., Pfaller, M.A., Jorgensen, J.H. and Yolken, RH. (2003). Manual of Clinical Microbiology, (Ed.), 8th Edn., American Society for Microbiology, Washington, D.C. https://doi.org/10.1086/383067.
30. Ngiki, Y.U., Igwebuike, J.U. and Moruppa, S.M. (2014). Implications of replacing varying dietary levels of maize with cassava root-leaf meal mixture on hematology and carcass characteristics of broiler chickens. Integrated Science and Technology. 3(6): 363-373.
31. Ngudi, D.D., Kuo, Y.H. and Lambein, F. (2003). Cassava cyanogens and free amino acids in raw and cooked leaves. Food and Chemical Toxicology. 41: 1193-1197. http://dx.doi.org/10.1016/S0278-6915(03)00111-X.
32. Nguyen, T.H.L., Verstegen, M.W.A. and Hendriks, W.H. (2012). Ileal and total tract apparent crude protein and amino acid digestibility of ensiled and dried cassava leaves and sweet potato vines in growing pigs. Animal Feed Science and Technology. 172:171-179 DOI: 10.1016/j.anifeedsci.2011.11.009.
33. Nochera, C.L. and Ragone, D. (2016). Preparation of a Breadfruit Flour Bar. Foods. 5(2):37 https://doi.org/10.3390/foods5020037.
34. NRC. National Research Council (2012). Nutrient requirements of swine. 11th revised Edition, National Academy Press, Washington, DC.
35. Nwafor, O.E. and Ejukonemu, F.E. (2004). Bioconversion of cassava wastes for protein enrichment using amylolytic fungi. A preliminary report. Global Journal of Pure and Applied Sciences. 10: 505-507.
36. Nyachoti, C.M., House, J.D., Slominski, B.A. and Seddon, I.R. (2005). Energy and nutrient digestibilities in wheat dried distillers' grain with solubles fed to growing pigs. Journal of the Science of Food and Agriculture. 85: 2581–2586. https://doi.org/10.1002/jsfa.2305.
37. Oladimeji, S.O., Adeyemi, A.A., Mosuro, A.O., Adebayo, B.F., Etop, S.C., Adebiyi, F.G. and Ogunwole, O.A. (2022). Nutritional composition of cassava (Manihot esculenta Crantz) peel products. Livestock Research for Rural Development. 34 (10). Article #90 Retrieved December 22, 2022, from http://www.lrrd.org/lrrd34/10/3490olad.html.
38. Oleforuh-Okoleh, V.U., Ndofor-Foleng, H.M., Olorunleke, S.O. and Uguru, J.O. (2015). Evaluation of growth performance, hematological and serum biochemical response of broiler chickens to aqueous extract of ginger and garlic. Journal of Agricultural Science. 7:167-173. https://doi.org/10.5539/jas.v7n4p167.
39. Orororo, O.C., Tonukari, N.J., Avwioroko, O.J. and Ezedom, T. (2014). Effect of Supplementation of Animal Feed with Dried Cassava (Manihot esculenta) Peels, and Stems of Vernonia amygdalina

and Pennisetum purpereum on Some Biochemical Parameters in Pigs. Nigerian Society of Experimental Biology. 14(4): 177-183.

40. Oyebimpe, K., Fanimo, A.O., Oduguwa, O.O. and Biobaku, W.O. (2006). Response of broiler chickens to cassava peel and maize offal in cashew nut based-diets. Archivos Zootechnica. 55(211): 301-304.
41. Phuc, B.H.N., Ogle, R.B., Lindberg, J.E. and Preston, T. R. (1996). The nutritive value of sun-dried and ensiled cassava leaves for growing pigs. Livestock Research for Rural Development. 8(3) Article #30. Retrieved December 22, 2022, from http://www.lrrd.org/lrrd8/3/phuc83.htm.
42. Rafiu, T.A, Aderinola, O.A., Akinwumi, A.O., Alabi, T.A. and Shittu, M.D. (2013). Performance and blood chemistry of broiler chickens fed Moringa oleifera leaf meal. Proceedings of the 18th Annual Conference of Animal Science Association of Nigeria. 294.
43. Ramatsoma, N.I., Banga, C.B., Lehloenya, K.C. and Gibson, R. (2015). Estimation of Genetic Parameters for Live Weight in South African Holstein Cattle. Open Journal Animal Science. 5: 242-248. http://dx.doi.org/10.4236/ojas.2015.53028.
44. Salami, R.I. (2000). Preliminary studies on the use of parboiled cassava peel meal as a substitute for maize in layers' diets. Tropical Agriculture. 77: 199-204. https://scialert.net/abstract/?doi=ijps.2003.112.116.
45. Schalm, O.W., Jain, N.C. and Qureshi, M.Q. (1975). Veterinary Hematology, third ed. Lea and Fibinger, Philadelphia.
46. Togun, V.A., Oseni, B.S.A., Ogundipe, J.A., Arewa, T.R., Hameed, A.A., Ajonijebu, D.C., Oyeniran A, Nwosisi, I. and Mustapha, F. (2007). Effects of chronic lead administration on the hematological parameters of rabbit-a preliminary study. Proceedings of the 41st conference of the Agricultural Society of Nigeria. 341.
47. Unigwe, C.R., Marire, B.N., Omeke, B.C.O., Abonyi, F.O., Oladipo, T.A. and Adebayo, D.M. (2016). Effects of maize-replaced fermented cassava peels and enzyme- supplemented diet on hematology and serum biochemistry of cross-bred female pigs. International Journal of Advance Research in Biological Science. 3(6): 198-208. ISSN: 2348-8069.
48. Varley, H., Gowenlock, A.H. and Bell, M. (1980). The Plasma Proteins. In Practical Clinical Biochemistry, Vol. I 5th edition. William Heinemann Medical Books Ltd, London. pp 535-595.
49. Vetter, J. (2000). Plant Cyanogenic Glycosides. Toxicon. 38: 11-36. http://dx.doi.org/10.1016/S0041-0101(99)00128-2.
50. Wagner, J. and Stanton, T.L. (2012). Formulating rations with the Pearson Square. A publication of Colorado State University Extension Services https://extension.colostate.edu/docs/pubs/livestk/01618.pdf.