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Gelatinization of fermented cassava tuber meal and its nutritive value for laying hens

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The effect of fermentation of cassava tuber followed by its gelatinization was evaluated as a method of processing cassava for use as source of energy in layers diets. Peeled and unpeeled cassava tubers were separately fermented in water for 4 days, dried in the sun and then milled to produce fermented peeled and unpeeled cassava tuber meals, respectively. The dusty meals were then gelatinized by mixing with water in pots seated over fire at the rate of 1kg of cassava tuber meal to one litre of water and stirred until they gelatinized into semi-solid paste, the form that cassava is prepared and eaten locally. The gelatinized pastes were then taken bit by bit and flattened on polythene sheets and dried in the sun. The resultant fermented and gelatinized peeled and unpeeled cassava tuber cakes were then milled to produce fermented and gelatinized unpeeled cassava tuber meal (UFGC), a brownish-looking non-dusty product and fermented and gelatinized peeled cassava tuber meal (PFGC), an ash-looking non-dusty product. Three diets were made such that diet 1 (control) contained maize as the main source of energy, while in diets 2 and 3 the maize was completely replaced with PFGC and UFGC, respectively. Each diet was fed to a group of 40 laying hens for 12 weeks using completely randomized design. There were no significant differences in body weight changes and hen-day egg production ($P > 0.05$) among the groups. The group on UFGC diet consumed significantly ($P < 0.05$) less feed, laid heavier eggs and had superior feed conversion ratio. Egg quality was not affected by the treatments ($P > 0.05$), although the group on PFGC diet recorded significantly ($P < 0.05$) thicker egg shell. Dressed weight, weights of the livers and hearts were not affected by the treatments ($P < 0.05$) but the group on PFGC developed significantly ($P < 0.05$) more abdominal fat and less gizzard weights. Almost all the haematological and serum biochemical indices were not affected by the treatments. Total billirubin and albumin were, however, reduced by the cassava diets.

Keywords: Fermentation, gelatinization, cassava, dietary energy, laying hens.

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Introduction

Cereal grains form the bulk of commercial poultry feeds, with maize having the highest inclusion rate of 40– 50% as compared to other cereal grains (Udedibie, 2003). The demand for maize has, however, exceeded its supply in Nigeria because it is also used as staple food for a large proportion of Nigerians, as well as industrial raw material (Udedibie and Asoluka, 2008). This invariably has contributed to high cost of poultry feeds in the country with concomitant increase in cost of poultry products. There is the need, therefore, for the use of other readily available alternatives if poultry industry in the country has to survive.

One of the energy sources that has great potential as alternative to maize is cassava. Nigeria is regarded as the greatest producer of cassava in the world today, with production estimate of about 33 million metric tonnes per annum (FAO, 2005). The potential of cassava as an energy feed is enormous despite its limitations. It is low in crude protein as compared to maize but this can be remedied by balancing with high protein feeds (Udedibie *et al*., 2008). It has short shelf- life and is high in cyanogenic glucosides, linamarin and lotaustralin, which on hydrolysis yield hydrogen cyanide (HCN), which is highly toxic (Udedibie *et al.*, 2004; Sayre, 2007). It is dusty and therefore affects feed intake of young birds (Odukwe, 1994; Udedibie *et al.*, 2004).

Various methods have been used in processing cassava tuber so as to render it utilizable in poultry feeds. These include cooking, sun-drying, use of additives and fermentation (Obioha *et al.*, 1984; Manhungu *et al.*¸1987; Odukwe, 1994; Udedibie *et al.*, 2004). Udedibie *et al.* (2004) have demonstrated that fermentation before drying is a better processing method than direct sun-drying.

A recent work by Bradbury (2004) has shown that cyanide content of sun-dried cassava flour could be greatly reduced if it is wetted and thinly spread for 5 hours before cooking for human consumption. Enyenihi *et al.* (2009) demonstrated that HCN content of cassava flour so processed was reduced to about 1/5 of the original level and the cassava flour so processed had no deleterious effects on performance of laying hens. The product was, however, dusty and so rendered the diets dusty too.

Traditionally, fermentation has remained the best way to eliminate HCN from cassava (Udedibie *et al.*, 2004). However, fermented cassava flour still has the limitation of dustiness and short shelf-life. Chukwuemeka (2009) and Emeh (2009) have demonstrated that when fresh cassava tubers are boiled for an hour, they gelatinize and yield non-dusty cassava tuber meal when dried and milled. However, when used in place of maize in balanced broiler diets, it depressed growth performance of broilers. Analysis of the meal for HCN using

picrate paper method of Bradbury *et al.* (1999) showed that the product still contained up to 50 ppm HCN, which is still considered high in poultry diets. It may therefore follow that gelatinization of fermented cassava tuber, which is already HCN-free could be the solution to limitations of cassava tuber as feedstuff in poultry diets.

The study herein reported was therefore designed to determine the efficacy of fermentation followed by gelatinization as a method of processing cassava tubers for use as alternative to maize in the diets of laying hens.

Materials and methods

Experimental site

The experiment was carried out in the Poultry Unit of the Teaching and Research Farm and the Animal Science Laboratory of the Federal University of Technology, Owerri, Imo State – Nigeria. Owerri is in the south-eastern agro-ecological zone of Nigeria with mean annual rainfall, temperature and relative humidity of 2500 mm, 26.5 - 27^{o}C and 70 - 80%, respectively. The duration of the dry season (number of months with less than 65 mm of rainfall) is 3 months and the annual evapo-transpiration is 1450 mm. The soil is sandy loam with average pH of 5.5 (Atlas of Imo State, 1984).

Source and Processing of the Cassava Tubers

Fresh cassava tubers of bitter variety were procured from a local market and divided into 2 batches. One batch was peeled while the other was left unpeeled. Samples of both batches were analyzed for HCN content, using the picrate paper method of Bradbury *et al.* (1999).

The peeled and unpeeled tubers were cut into pieces of about similar sizes and separately fermented for 4 days in plastic vats under atmospheric temperature. The fermented tubers were then put in sacs, pressed to reduce water content and then spread in the sun to dry. Thereafter, they were milled using a hammer mill with 2 mm sieve after removing the strings to produce fermented peeled and unpeeled cassava tuber meals, respectively. The two dusty cassava products were then subjected to gelatinization process. This involved mixing the meal in water in a pot seated on fire at the rate of 1kg of the meal to 1 litre of water and the mixture stirred until it sufficiently gelatinized into *fufu*, the form cassava is prepared and eaten locally.

The products were then taken bit by bit and flattened on polyethylene sheets and left to dry into cakes under the sun. The cakes were considered adequately dried when they became crispy to the touch and snapped at bending.

They were then milled in a hammer mill with 2 mm sieve to produce peeled fermented and gelatinized cassava tuber meal (PFGC) and unpeeled fermented and gelatinized cassava tuber meal (UFGC), respectively. Their samples were subjected to both proximate and HCN analysis, according to AOAC (1995) and Bradbury *et al.* (1999), respectively.

Experimental diets

Three experimental diets were made such that diet 1 (control) contained yellow maize as the main source of energy and no cassava tuber meal. In diets 2 and 3, the maize in the control diet was completely replaced with peeled and unpeeled fermented and gelatinized cassava tuber meals, respectively. Other ingredients were adjusted in such a way that the diets were similar in crude protein and energy and met nutrient requirements of laying hens. Ingredients and calculated nutrient composition of the diets are presented in Table 1.

Experimental birds and design

A total of 120 laying hens at 10 months of laying life were divided into 3 groups of 40 birds each and each group randomly assigned to one of the experimental diets in completely randomized design. Each group was further replicated 4 times and each replicate of 10 birds housed in a pen measuring 1.5 x 2 m. Wood shavings were used as litter material. The birds were weighed at the beginning and end of the trial to determine their body weight changes. Feed and water were provided *ad libitum*. The trial lasted for 12 weeks.

Table 1. Ingredient and nutrient composition of the experimental layers diets

Ingredients (%)	**Experimental diets**		
	Control	PFGC diet*	UFGC diet**
Yellow maize	50.00	0.00	0.00
Cassava tuber meal	0.00	50.00	50.00
Soy bean meal	16.00	18.00	18.00
Fish meal	3.00	3.00	3.00
Blood meal	2.00	4.00	4.00
Palm kernel cake	11.50	10.00	10.00
Wheat offal	5.00	5.00	5.00
Bone meal	4.50	4.50	4.50
Common salt	0.25	0.25	0.25
TM/Vit. Premix ***	0.25	0.25	0.25
L-Lysine	0.25	0.25	0.25
L-Methionine	0.25	0.25	0.25
Total	100	100	100
Calculated chemical composition (% DM)			
Crude protein	17.57	17.24	17.44
Ether extract	3.53	2.97	2.97
Crude fibre	4.63	5.46	5.96
Ash	6.19	6.37	6.37
NFE	68.08	67.96	67.26
Calcium	3.71	4.00	4.00
Phosphorus	1.35	2.56	2.56
ME (Mcal/kg)	2.76	2.82	2.80

*PFGC = peeled, fermented and gelatinized cassava tuber meal.

**UFGC = unpeeled, fermented and gelatinized cassava tuber meal.

*** To provide the following per kg of feed: vitamin A, 10,000 iu; vitamin D_3, 2,000 iu; vitamin E, 12 mg; vitamin K, 2 mg; vitamin B_1, 1.5 mg; vitamin B_2, 4 mg; vitamin B_6, 1.5 mg; vitamin $B_{12,}$ 12 mg, Niacin, 15 mg; pantothenic acid, 5 mg; folic acid, 5 mg; Biotin, 2 mg; Choline chloride, 100 mg; Manganese, 75 mg; zinc, 5 mg; iron, 2 mg; copper, 5 mg; iodine, 1.0 mg; selenium, 2.0 mg; cobalt, 5 mg; Antioxidant, 125 mg.

Data collection and analysis

The collected data included initial body weight, final body weight, feed intake, feed conversion ratio, egg production, egg weights, egg quality indices, internal organ weights and haematological and serum biochemical indices of the laying hens.

Feed intake was determined by subtracting the weight of the left-over feed from the weight of the feed fed the previous day. Eggs were collected twice daily. At the end of each week, the eggs collected from each pen were weighed to determine the average egg weights. Feed conversion ratio was determined by dividing daily feed intake by daily egg weight (g feed/ g egg).

Hen-day egg production (%) was determined by dividing total egg production by the number of layers multiplied by 100.

Egg quality indices determined that included egg shell thickness, yolk index, albumen index and Haugh unit. Egg shell thickness was determined with a micrometer screw gauge after the membrane from each egg was removed. Measurements were taken from the three points on each shell. The shell thickness value for each egg was the average of the 3 measurements. Egg yolk index was determined according to Sharp and Powel (1930) as modified by Funk (1948). Albumen index was determined according to Heiman and Carver (1936), while Haugh unit was determined according to Haugh (1937), as modified by Brant *et al.* (1951).

At the end of the feeding trial, four birds were randomly selected from each treatment (one from each replicate) and used for determination of haematological/serum biochemical indices, carcass and internal organ weights. They were weighed before slaughter to determine their live weights. Blood was collected from each bird and about 2 ml of it put into well labeled sterilized bijon bottles containing EDTA as anticoagulant, while another 2 ml was put in bottles without EDTA, to produce serum for serum biochemical indices. Blood samples were analyzed within 3 hours of collection according to Monica (1984).

After blood collection, the carcasses were scalded in hot water and the feathers plucked manually. The carcasses were then eviscerated by cutting through the vent and the viscera removed. Thereafter, the dressed carcass weight was obtained. The weights of the internal organs (heart, liver, kidney and gizzard) as well as the abdominal fat were recorded and expressed as percentage of live weight.

Data generated were subjected to analysis of variance (ANOVA) using SPSS (2004). Where ANOVA detected treatment effects, means were compared using Duncan's New Multiple Range Test (Snedecor and Cochran, 1978).

Results and discussions

Physico-chemical nature of the processed cassava tubers

The fermented peeled and gelatinized cassava tuber meal (PFGC) looked like milled polished rice, devoid of dustiness and could store as long as the owner may want to keep it. The fermented unpeeled and gelatinized cassava tuber meal (UFGC) looked like milled unpolished rice, brownish in colour and also non-dusty. The brownish colour was believed to have been imparted on it by the brown colour of the peels. PFGC appeared like the sun-dried cassava *fufu* meal produced by Okere (2011), but different from the one produced by

Udedibie *et al.* (2008), which had golden colour, possibly due to the variety of cassava tubers used.

The proximate and HCN composition of the fresh and processed cassava tubers are presented in Table 2. The fresh unprocessed cassava tuber meals (peeled and unpeeled) used in the trial contained about 800 ppm HCN. After fermentation and gelatinization, the HCN of the peeled batch dropped to 0 ppm, while that of the unpeeled batch dropped to 50 ppm. Montaldo (1977) reported that cassava peels have the highest concentration of HCN among cassava parts. This possibly explains the existence of 50 ppm HCN in UFGC. The zero ppm HCN in PFGC was in agreement with the reports of Udedibie *et al.* (2008) and Okere (2011) on sun-dried cassava *fufu* meal.

The crude protein, crude fibre, ether extract and ash contents of UFGC were relatively higher than those of PFGC. This is understandable because cassava peels contain more of these nutrients than the pulp. Nitrogen-free extract was relatively higher in PFGC. The values were in agreement with the values obtained by Odukwe (1994) in his studies with composite cassava tuber meals. The proximate composition of PFGC was in agreement with the values reported by Udedibie *et al.* (2008) on sun-dried cassava *fufu* meal.

Table 2. Proximate and HCN composition of fermented and gelatinized peeled and unpeeled cassava tuber meals

Parameters (%)	RPCT*	PFGC	RUCT**	UFGC
Moisture (%)	75.22	9.84	75.81	9.72
Crude protein (% DM)	2.78	2.82	3.62	3.78
Crude fibre (% DM)	3.43	3.16	4.83	4.92
Ash (% DM)	3.14	3.26	4.34	4.40
Ether extract (% DM)	1.06	1.08	1.25	1.22
Nitrogen free extract (% DM)	89.59	88.88	85.96	87.18
HCN (ppm)	800.00	0.00	800.00	50.00

* Raw peeled cassava tuber meal

** Raw unpeeled cassava tuber meal

Performance of the laying hens

Data on performance of the experimental laying hens are presented in Table 3. There were no significant differences in body weight changes of the groups ($P > 0.05$). Similar observations had earlier been reported by Udedibie *et al*. (2008) and Enyenihi *et al.* (2009) on layers fed dried cassava *fufu* meal and those fed wetted and unwetted sun-dried cassava tuber meals. There were also no significant differences among the groups in feed intake. This also was in agreement with the report of Udedibie *et al.* (2008) with dried cassava *fufu*

meal. Earlier report by Ngoka *et al.* (1982) showed that laying hens and broilers had lower feed intake when cassava-based diets were fed in mash form. PFGC and UFGC appeared in pellets as against the powdery nature of sun-dried cassava tuber meal.

There were also no differences in hen-day egg production among the groups ($P > 0.05$) but the groups on PFGC and UFGC diets recorded significantly ($P < 0.05$) heavier egg weights. This is contrary to the reports of Aina and Fanimo (1997) and Enyenihi *et al.* (2009), who reported no differences in egg weights with ungelatinized cassava tuber meal. The group on UFGC diet had significantly ($P < 0.05$) superior feed conversion ratio as a result of the low feed intake and heavier eggs of the group. Udedibie *et al.* (2008) and Enyenihi *et al.* (2009) did not observe significant differences in feed conversion ratio of layers fed dried cassava *fufu* meal or wetted and unwetted sun-dried cassava tuber meal.

Table 3. Performance of the experimental laying hens

Parameters	Experimental diets			
	Control	PFGC diet*	UFGC diet**	SEM
Av. initial body wt. (kg)	1.59	1.58	1.57	0.008
Av. final body wt. (kg)	1.66	1.65	1.65	0.018
Av. body wt. change (kg)	0.07	0.07	0.08	0.017
Av. feed intake (g/day)	142.94[a]	140.82[a]	133.51[b]	1.90
Av. hen-day egg production (%)	68.44	69.33	68.90	0.64
Av. egg weight (g)	59.82[b]	63.97[ab]	67.88[a]	2.48
Feed conversion ratio (g feed/g egg)	2.40[a]	2.21[ab]	1.97[b]	0.87

[ab] Means within a row with different superscripts are significantly different ($p<0.05$)
*PFGC = peeled, fermented and gelatinized cassava tuber meal.
**UFGC = unpeeled, fermented and gelatinized cassava tuber meal.

Egg quality indices and internal organ weights

Data on egg quality indices and the internal organ weights of the layers are presented in Table 4. There were no significant differences in Haugh unit, albumin index and yolk index of the groups ($P > 0.05$). PFGC group, however, had significantly ($P < 0.05$) thicker egg shell. Similar observations had earlier been made by Aina and Fanimo (1997), Udedibie *et al.* (2008) and Enyenihi *et al.* (2009).

Dressing percentages of the groups were not affected by the treatments ($P > 0.05$). Similarly, the weights of the livers and hearts were not affected by the treatments ($P > 0.05$). However, UFGC produced significantly $P < 0.05$) heavier gizzards, while PFGC produced significantly ($P< 0.05$) more abdominal fat. Enlarged gizzards are associated with structural components of the diets such as large particles (Hetland and Sribus, 2001; Amerah *et al.* 2009). UFGC had more fibrous component than PFGC as a result of the peels. That also may explain the less abdominal fat developed by the group on UFGC diet. Udedibie *et al.* (2008), Enyenihi *et al.* (2009) and Okere (2011) had reported similar observation when peeled cassava tuber meals were fed to laying hens and broilers. UFGC also resulted in smaller kidneys. Obioha and Anikwe (1982) blamed smaller kidneys of grower pigs fed cassava tuber meal on HCN content of the diet. UFGC diet contained about 25 ppm HCN.

Table 4. Effect of the experimental diets on egg quality indices and internal organ weights

Parameters	Experimental diets			
	Control	PFGC diet*	UFGC diet**	SEM
Haugh unit	88.99	97.79	93.61	3.94
Albumin height (mm)	6.76	6.94	8.02	0.52
Albumin diameter (mm)	77.12	77.08	75.56	1.43
Albumin index	0.09	0.09	0.11	0.008
Yolk height (mm)	16.88	16.77	17.04	0.41
Yolk diameter (mm)	38.49	41.41	42.53	1.12
Yolk index	0.44	0.41	0.40	0.013
Shell thickness (mm)	0.36^{b}	0.42^{a}	0.39^{ab}	0.015
Internal Organs (% of LW)				
Live weight (kg)	1.83	2.04	1.94	0.096
Dressed weight (kg)	1.00	1.08	1.00	0.053
Dressing percentage	54.62	52.90	51.56	2.02
Liver	3.15	3.15	2.16	0.35
Gizzard	3.14^{a}	1.90^{b}	2.39^{ab}	0.21
Heart	0.88	0.83	0.59	0.13
Kidney	0.50^{a}	0.47^{a}	0.35^{b}	0.023
Abdominal fat	2.00^{b}	6.65^{a}	2.03^{b}	0.66

[ab] Means within a row with different superscripts are significantly different ($p<0.05$)
*PFGC = peeled, fermented and gelatinized cassava tuber meal.
**UFGC = unpeeled, fermented and gelatinized cassava tuber meal.
LW = live-weight

Haematological/serum biochemical indices

Data on haematological/serum biochemical indices of the laying hens are presented in Table 5. The haematological indices of the groups (PCV, RBC, MCV, MCHC, Hb, platelets, lymphocytes and neutrophyls) were not affected by the treatments ($P > 0.05$) and the values were within the ranges recommended by Mitruka and Rawnsley (1997) as normal for poultry. Similar observations had earlier been made by Udedibie *et al.* (2008), Enyenihi *et al.* (2009) and Okere (2011). However, WBC was significantly ($P < 0.05$) reduced by the cassava diets but the values were within the range recommended by Mitruka and Rawnsley (1997).

Most of the serum biochemical components were not affected by the treatments ($P > 0.05$). However, the cassava diets tended to reduce the levels of bilirubin and cholesterol of the laying hens. UFGC significantly ($P < 0.05$) reduced glutamate pyruvate transaminase (GPT). The similarity in almost all the serum biochemical components of the groups was an indication that the diets were adequately tolerated by the birds (Frandson, 1974).

Table 5. Effect of the experimental diets on the haematological and serum biochemical indices of the laying hens

Parameters	**Experimental diets**			
	Control	PFGC diet*	UFGC diet**	SEM
Haematological Indices				
WBC (x 10^3/µl)	8.55 x 10^{7a}	7.71 x 10^{7b}	7.27 x 10^{7b}	2.03 x 10^6
HB (g/dl)	11.10	10.27	9.60	0.64
RBC (x 10^6/µl)	2.62 x 10^6	2.75 x 10^6	2.50 x 10^6	1.18 x 10^5
PCV (%)	32.63	32.17	31.17	1.52
Platelets (x 10^3/µl)	2.70 x 10^7	3.10 x 10^7	2.47 x 10^7	1.25 x 10^5
MCV (fl)	117.47	117.23	118.70	5.95
MCHC (g/dl)	33.20	31.17	29.17	1.43
MCH (pg)	40.90	37.27	36.27	2.06
Lymphocytes (%)	86.33	82.67	87.00	3.07
Neutrophils (%)	13.67	17.33	13.00	3.07
Serum Biochemical Indices				
Urea (mg/dl)	32.00	29.00	29.33	0.97
Creatine (mg/dl)	$^{0.70}$	0.63	0.67	0.07
Na^+ (Mmol/l)	150.57	153.20	145.83	2.61
K^+ (Mmol/l)	3.71	4.00	3.63	0.16
Cl^- (Mmol/l)	116.43	117.83	109.50	2.11
HCO_3^- (Mmol/l)	28.67	28.67	25.93	0.99
pH	6.67	6.73	6.87	0.14
TB (mg/dl)	0.81^a	0.77^{ab}	0.50^b	0.10
CB (mg/dl)	0.40	0.37	0.24	0.05
ALT (iu/l)	516.33	559.00	380.67	176.20
GPT (iu/l)	16.33^a	16.00^a	9.33^b	1.20
GOT (iu/l)	162.82	175.03	166.07	12.41
Chol. (mg/dl)	194.33	173.67	105.33	29.34
TG (mg/dl)	738.33	770.67	671.00	35,67
Calcium (mg/dl)	8.99	8.94	7.54	0.57
Phosphorus (mg/dl)	6.66	6.22	5.82	0.61
TP (g/dl)	4.00	3.60	3.70	0.26
ALB (g/dl)	2.54	2.24	2.36	0.08
Glo B (g/dl)	1.46	1.36	1.34	0.183
Uric Acid (g/dl)	4.98	5.41	2.17	1.10
Glucose (g/dl)	152.00	140.00	144.33	10.74

[ab] Means within a row with different superscripts are significantly different ($P < 0.05$)
*PFGC = peeled, fermented and gelatinized cassava tuber meal.
**UFGC = unpeeled, fermented and gelatinized cassava tuber meal.

Conclusion and recommendation

The results of the trial have shown that 4-day fermentation followed by gelatinization of cassava tubers resulted in non-dusty product that was HCN-free if peeled and with about 50 ppm HCN if unpeeled. Both PFGC and UFGC

enhanced hen-ay egg production and egg weight but PFGC promoted development of excessive abdominal fat in the laying hens, which is not desirable. Egg quality indices as well as most haematological and serum biochemical indices were not affected by the diets.

It is therefore recommended that both PFGC and UFGC can be used to completely replace maize in the diets of laying hens, but UFGC is preferable because it promoted more egg production and egg weight and reduced abdominal fat. The labour involved in peeling the tubers is also eliminated. However, in replacing maize with the products, the diets should be balanced for protein in view of the disparity in crude protein content between maize and cassava. Although the process may appear tedious and laborious, it is hoped that technology can be developed to mechanize and make it commercializable.

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