Comparative Proximate Composition and Cyanide Content of Peeled and Unpeeled Cassava Roots Processed into Garri by Traditional Methods

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ABSTRACT

Investigations on the consequential effects of the presence of cassava peelings and palm oil on the proximate composition and cyanide content during the stages of processing cassava roots into gelatinized garri meal were carried out. The peeled and unpeeled cassava roots were processed into garri and preparation of gelatinized garri meals were according to standard traditional methods. The cassava roots and garri samples were stored at ambient room temperature and 30-55% relative humidity until used for analyses. Proximate composition and cyanide contents of the samples were measured using standard methods. The moisture content of the cassava roots was significantly ($p< 0.05$) higher than the processed garri samples. Protein and lipid contents of the samples were relatively low, whereas the ash value of unpeeled cassava roots was significantly ($p < 0.05$) higher than those of the peeled samples. The carbohydrate content of the unprocessed cassava roots was comparatively lower than those of the processed roots; $p< 0.05$. The cyanide content of garri sample produced from unpeeled cassava roots was 4.89 folds lower than that produced from peeled cassava roots ($p < 0.05$). Palm oil treated garri samples gave marginal low cyanide content, which was further lowered when processed into gelatinized garri meal. The presence of cassava peelings and the addition of palm oil to cassava mash during the production of garri caused critical readjustments of samples' physicochemical properties and impacted on the food value of the cassava-based meal.

Keywords: *Cassava; cyanide; garri; palm oil; proximate composition*

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an important root crop cultivated in the tropical countries of Africa, Asia and South America (Ihenkoronye and Ngoddy, 1985; Nweke, 2004; Navia and Villada, 2012). There are number of varieties of cassava plants that are generally categorized as 'bitter' or 'sweet' cassava depending on their cyanide content (Navia and Villada, 2012). Thus, the roots of 'bitter' cassava contain relatively high concentration of cyanide; the peels and pulps, on the average, contain about 650 ppm and 310 ppm total cyanide respectively, whereas the corresponding 'sweet' cassava peels and pulps contain less than 200 ppm and 38 ppm total cyanide respectively (http://www.fao.org/docrep/003/T0554E/T0554 E06.htm). The food value of cassava is greatly compromised by its cyanide content. Nevertheless, reports showed that Africa accounted for 45%, Asia 28% and Latin America and the Caribbean 19% of about 172 million tons of cassava roots produced worldwide in the year 2000 (FAO, 2001; FAO, 2012).

The crop has been noted for its capability to withstand adverse soil and climatic conditions in regions where the roots serve as a dependable staple food for millions of people (El-Sharkawy 2003; Ekwu *et al.,* 2012; Navia and Villada, 2012; Lukuyu *et al.,* 2014). Food products derived from the cassava plant provides about 70% of daily caloric intake for over 50 million Nigerians of diverse socio cultural standing (Oluwole *et al.,* 2004; OECD, 2009). Cassava roots can be processed into wide varieties of domestic meals, depending on local customs and preferences, for human consumption (CCDN News, 2006; OECD, 2009) as well as for livestock and aquaculture feeding programs (Okoli *et al.,* 2012; Lukuyu *et al.,* 2014). Some few notable processed cassava meals, known by their local names include *abacha*, *fufu*, *farinha*,

lio – lio, *tapioca*, and *garri*. Recent reports showed growing industrial demand for cassava roots as raw materials in the production of essential commodities, thermoplastic and biofuels (Jansson *et al.,* 2009; OECD, 2009; Navia and Villada, 2012; Adeniji, 2013; Ukwuru and Egbonu, 2013).

However, the cassava plant contains the potentially toxic compounds, cyanogenic gluco sides- linamarin and lotaustralin (Tewe and Iyayi, 1989; Mburu *et al.,* 2012), of which the amount of these toxic compounds varies according to cultivars, climatic and growing conditions (Mburu *et al.,* 2012). Anatomical survey showed that the cassava root is consist of brown outermost layer or husk (0.5-2.0% of the root weight; easily removed by simple scratching), the peels or cortical parenchyma (1-2 mm thick and 8-15% of the root weight; it contains most of the toxic cyanogenic glycosides) and the fleshy starchy parenchyma (83-92% of the root weight), which is the edible part of the root (http://www.fao.org/docrep/x5415e/x5415e01.htm; Tewe, 1992; Lebot, 2009).

Fresh cassava roots, particularly the high quality ones, deteriorate within two or three days after harvest, and therefore must be processed immediately to finished products (Tewe, 1992; Navia and Villada, 2012). Alternatively, cassava roots may be processed into the dried form to reduce moisture content, which converts the roots into more durable and stable product (IITA, 1990; Ugwu, 1996). The scheme used for the production of *garri* in households and villages as well as in large mechanized scale are essentially the same, whereas the complexity of processing technologies selected depend on the amount of cassava roots to be processed, the availability of capital and energy as well as labor cost (Hahn *et al.,* 1992; Adeniji, 2013). The scheme for the traditional production of *garri*has previously been described elsewhere (CCDN News, 2006; Kamalu and Oghome, 2012; Chikezie and Ojiako, 2013; Olaoye *et al.,* 2015).The two common varieties of *garri* in the Nigeria markets are the white and yellow *garri.* The yellow *garri* is produced by adding palm oil to the dewatered cassava cake prior to or during the roasting stage. *Garri* is often eaten in combination with nutritious soups and stews or snacks such as groundnuts, coconuts, dried fish/meat and vegetables, which enhances its nutritional value especially in terms of human and live stock daily protein, minerals and vitamins requirements.

Because peelings of cassava root prior to the production of cassava-based products consume man-hour with attendant impact on the environment by the generated waste (Cumbana *et al.,* 2007; Jyothi *et al.,* 2005; Oboh, 2006), alternative method to produce *garri* without the peeling operation was proposed in the present investigation. Accordingly, studies were carried out to ascertain the consequential effects of the presence of cassava peelings (peridermal and cortical regions) on the proximate composition and cyanide content during the stages of processing the cassava roots into gelatinized *garri* meal. The outcome of the present study will provide preliminary insights into the food value of cassava root and its products along the experimentally designed production chain.

MATERIALS AND METHODS

Collection and Preparation of Cassava Roots

Matured roots of the 'sweet' cassava variety were harvested twelve months after planting (Olaoye *et al.,* 2015) during the wet season, on the 16th of August, 2015 from Ofkaja Farm at Uruagu-Nnewi, Anambra State (Latitude 6°20′N; Longitude 7°00′E), Nigeria, which lies on the rainforest belt. The harvested roots were transported to the laboratory within 24 h, identified and authenticated by Dr. F.N. Mbagwu at the Herbarium, Department of Plant Science and Biotechnology, Imo State University, Owerri, Nigeria. Thereafter, the roots were washed under continuous current of tap water for 5 min to remove soil matter and air-dried at ambient room temperature ($T = 25 \pm 5$°C).

Unprocessed Cassava Roots

The cassava roots were divided into two groups of fairly equal sizes and weights using a triple beam balance (Model: OHAU 750-50; OHAUS Triple Beam Balance, Model TJ611, Burlington, NC, USA). The hard outer cover of one group of the cassava roots were manually removal using stainless kitchen knife. Thus the cassava samples were categorized as follows:

- Group 1: Unpeeled cassava roots (UPCR).

- Group 2: Peeled cassava roots (PCR).

The cassava root peelings were consisted of peridermal and cortical sections, whereas the

PCR was mainly composed of white starchy flesh and central vascular fiber.

Processing of Cassava Roots

The cassava roots were processed into *garri* according to standard traditional methods previously described (Oluwole *et al.,* 2004). The UPCR and PCR samples (500 g) were grated separately into fine pulp using a grating machine. Next, the pulp was packed into Hessian bags and compressed to drain and allowed to ferment for 3 days. The pressed cake of UPCR and PCR samples were sieved on a wire mesh screen (3×3 mm^2). A 200 g portion of the sieved cake of UPCR and PCR samples were mixed separately with 10 mL palm oil, whereas the remaining portions of the sieved cake of UPCR and PCR samples were not treated with palm oil. The sieved cakes of the various cassava roots were roasted separately in wide shallow cast iron pots until well baked into *garri.* The various types of *garri* samples (Type G1-G4) produced were categorized thus:

- Type G1: *Garri* produced from UPCR (UPCRG).
- Type G2: *Garri* produced from PCR (PCRG).
- Type G3: *Garri* produced from UPCR + palm oil (UPCRG+PO).
- Type G4: *Garri* produced from PCR + palm oil (PCRG+PO).

The *garri* samples were allowed to cool to ambient room temperature, packaged in labeled sterile cellophane bags and stored at ambient room temperature and 30-55% relative humidity until used for analyses.

Preparation of Gelatinized Garri Meal

Garri meal or *eba* was prepared according to established traditional methods of indigenous people of Nigeria. Ten grams (10g) portions of each of the experimental *garri* samples (Type G1-G4) were measured into a petri dish using a triple beam balance (Model: OHAU 750-50; OHAUS Triple Beam Balance, Model TJ611, Burlington, NC, USA). Next, 10 mL boiling distilled water was transferred into four separate 50 mL capacity beakers. The separate Type G1-G4 samples were poured into the corresponding beakers containing boiling distilled water, allowed to set and thereafter, mixed properly

using galvanized silver spoon. The gelatinized *garri* meals (Type GM1-GM4) were categorized in the following corresponding order thus:

- Type GM1: *Garri* meal produced from UPCR (UPCRGM).
- Type GM2: *Garri* meal produced from PCR (PCRGM).
- Type GM3: *Garri* meal produced from UPCR + palm oil (UPCRGM+PO).
- Type GM4: *Garri* meal produced from PCR + palm oil (PCRGM+PO).

The Type GM1-GM4 samples were allowed to cool to ambient room temperature and used for analyses.

Proximate Analyses

Proximate composition, namely, moisture, crude protein, crude fibre, ash, total lipids and carbohydrate contents, of 5.0 g portions of the various samples were measured according to the standard methods previously described (AOAC, 2006).

Cyanide Content

Measurement of cyanide contents of the various samples was according to alkaline titration method as described by Kamalu and Oghome, (2012) with minor modifications (Chikezie and Ojiako, 2013). A 15 g sample was measured into 800 mL Kjedahl flash containing 200 mL of distilled water and allowed to stand for 3 h at 25 $\pm$ 5°C. Autolysis was carried out with the apparatus connected to a distiller. A 150 mL of distillate was collected in 20 mL 25% of NaOH solution and further diluted to 250 mL with distilled water. Next, 100 mL of the diluted distillate was mixed with 8.0 mL of 6.0 N NH_4OH and 2.0 mL of 5% KI indicator solution and titrated against 0.02 N $AgNO_3$. The end point was indicated by a faint permanent turbidity appearance. The cyanide content (mg/100 g cassava wet weight) of the sample was evaluated from the expression: 1.0 mL 0.02 N $AgNO_3 \equiv$ 1.08 mg HCN.

Statistical Analyses

Data was analyzed using one-way analysis of variance (ANOVA). Values of $p < 0.05$ were considered statistically significant. All data were expressed as the mean $\pm$ SD of three observations.

RESULTS

The moisture contents of UPCR and PCR samples were within the range of 64.94-66.17% of total proximate composition of the cassava roots. Additionally, the moisture content of UPCR sample was not significantly ($p> 0.05$) higher than that of PCR sample (Figure 1). Conversely, the moisture content of PCRG sample was significantly ($p< 0.05$) higher than that of the UPCRG sample. UPCRG+PO sample gave a comparative moisture content that was 1.6 fold lower than that of PCRG+PO sample; $p< 0.05$. In the same corresponding order, moisture content of UPCRGM sample was lower than that of PCRGM sample, representing 2.33% lower moisture content; $p< 0.05$. Furthermore, moisture content of PCRGM+PO sample was significantly ($p< 0.05$) higher than that of the UPCRGM+PO sample.
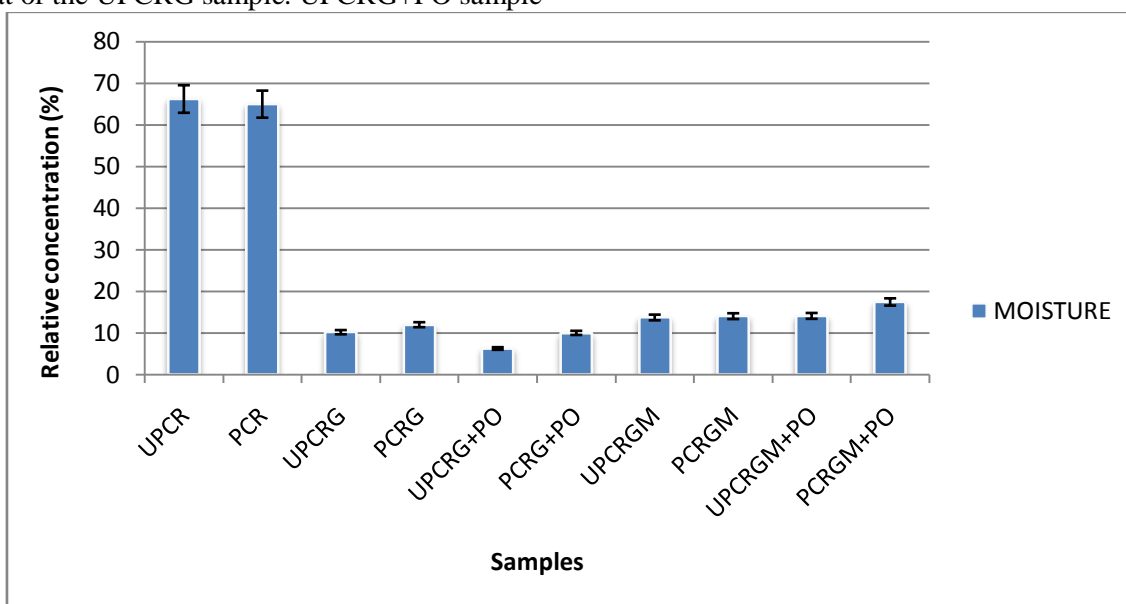

Figure 1. *Moisture contents of cassava roots, garri and garri meals*
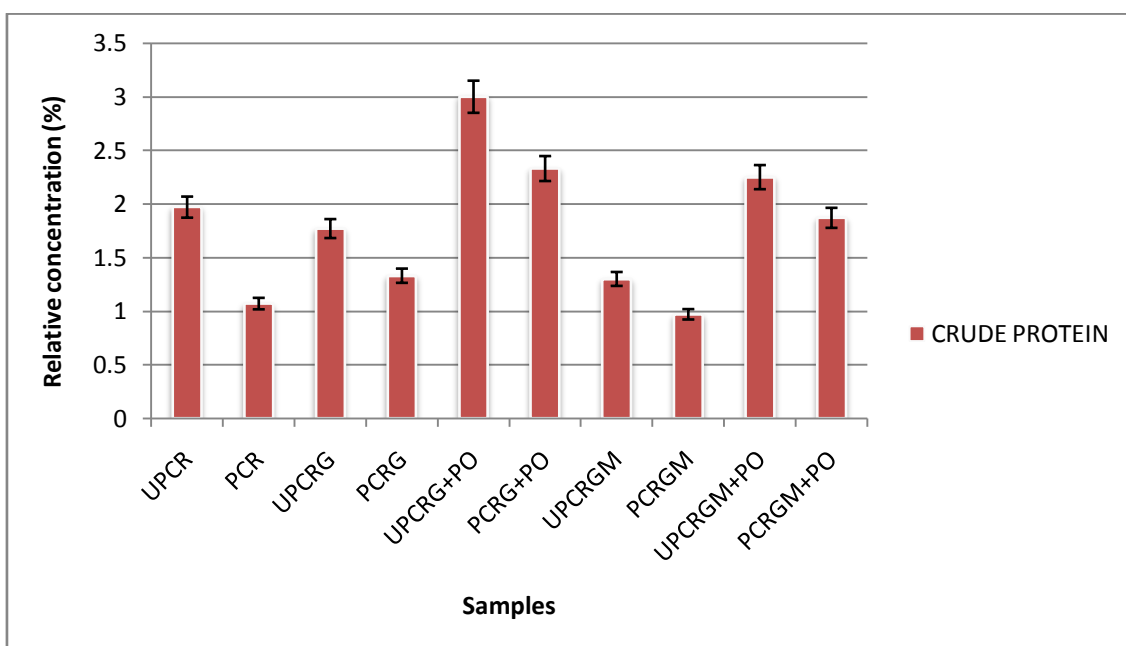

Figure 2. *Crude protein contents of cassava roots, garri and garri meals*

Crude protein content of UPCR sample was not significantly different ($p> 0.05$) from that of PCR sample (Figure 2). Likewise, UPCRG sample gave marginally higher crude protein content when compared with that of PCRG sample; $p> 0.05$. However, UPCRG+PO and PCRG+PO samples exhibited significantly ($p< 0.05$) higher crude protein contents compared

with the unprocessed cassava roots (UPT and PCR samples). The crude protein contents of UPCRGM and PCRGM samples were comparable with those of UPCRG and PCRG samples. In the same order, UPCRGM+PO and PCRGM+PO samples gave crude protein contents that were comparable with those of UPCRG+PO and PCRG+PO samples.
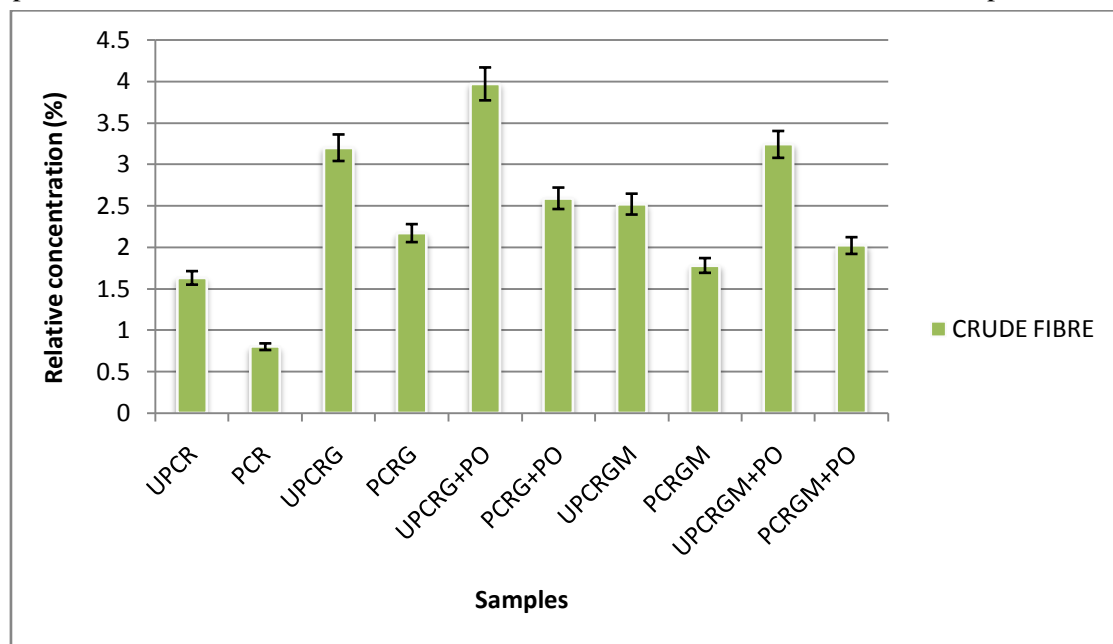

Figure 3. *Crude fiber contents of cassava roots, garri and garri meals*

Figure 3 showed that crude fiber contents of UPCR and PCR samples exhibited significant difference ($p < 0.05$). Likewise, the UPCRG, PCRG, UPCRG+PO and PCRG+PO samples gave variable crude fibre contents, such that UPCRG >PCRG samples and UPCRG+PO >PCRG+PO samples; $p < 0.05$. However, the crude fiber content of PCRG+PO sample was not significantly different ($p > 0.05$) from that of UPCRGM sample. On comparative terms, the order of crude fiber contents of UPCRGM and PCRGM samples followed the same pattern with that of the UPCRGM+PO and PCRGM+PO samples.
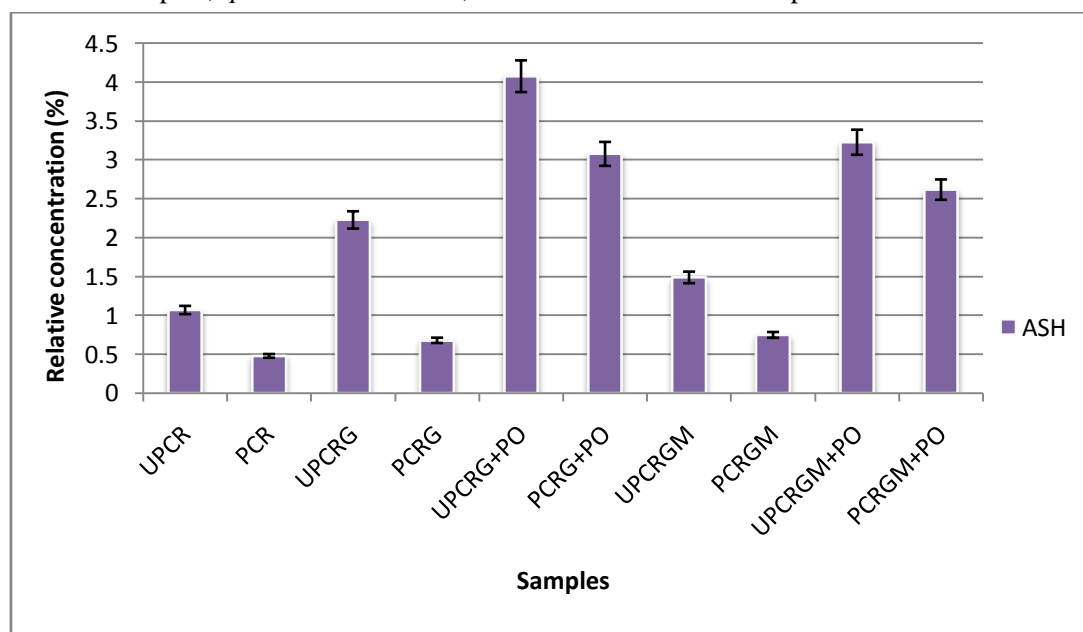

Figure 4. *Ash values of cassava roots, garri and garri meals*

The ash value of UPCR sample was significantly ($p < 0.05$) higher than that of the PCR sample. Furthermore, the ash values of UPCRG+PO and PCRG+PO samples were

significantly ($p < 0.05$) higher than their corresponding UPCRG and PCRG samples. The same pattern was observed in the order of ash values, such that UPCRGM >PCRGM samples and UPTGM+PO >PCRGM+PO samples; $p < 0.05$.
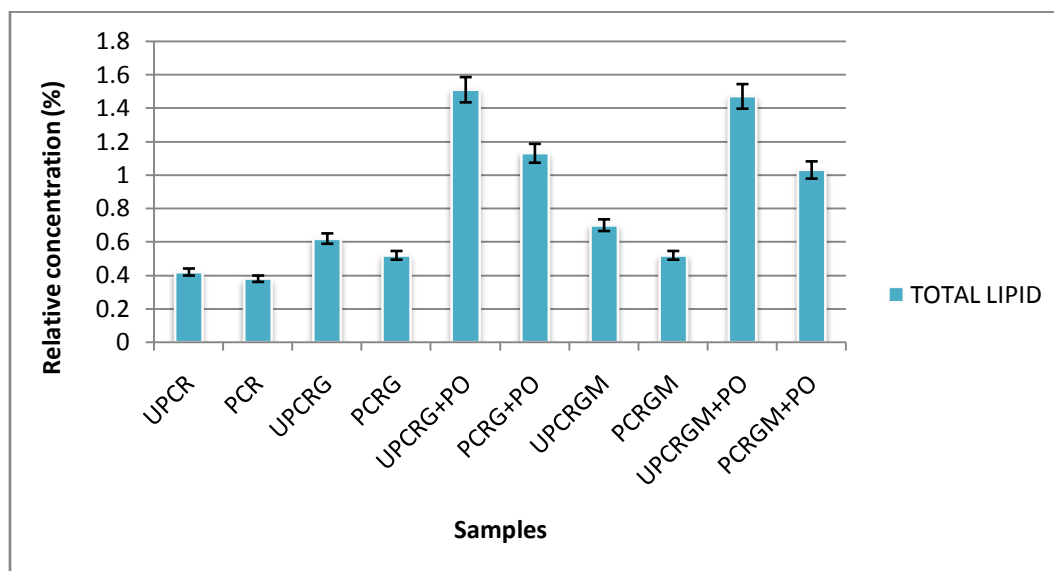

Figure 5. Total lipid contents of cassava roots, *garri* and *garri* meals

Figure 5 showed that the total lipid content in UPCR sample was not significantly ($p > 0.05$) different from that of PCR sample. Likewise, total lipid content of UPCRG sample was comparable with that of PCRG sample; $p > 0.05$. However, the total lipid contents of UPCRG and PCRG samples were significantly ($p < 0.05$) higher than those of UPCR and PCR samples.

Expectedly, UPCRG+PO, UPCRGM+PO and PCRGM+PO samples gave relatively higher total lipid contents compared with those of UPCRGM, PCRGM, UPCRG and PCRG samples. Overall, the total lipid contents of the samples were within the range of 0.33%-1.51% (Figure 5).
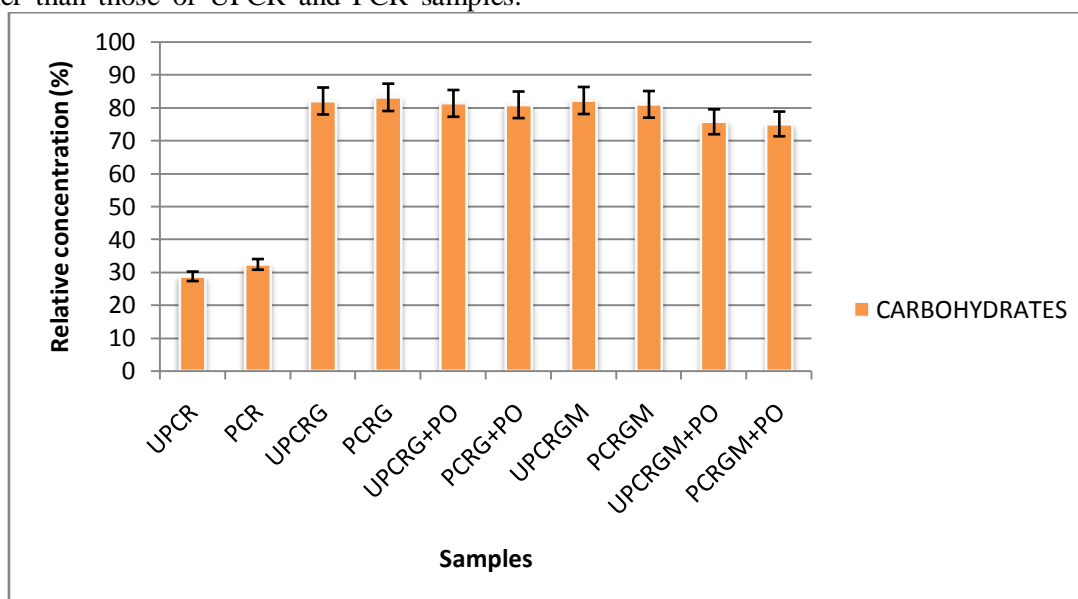

Figure 6. *Carbohydrate contents of cassava roots, garri and garri meals*

The carbohydrate content of the unprocessed cassava roots (UPCR and PCR samples) were comparatively lower than those of the processed roots; $p < 0.05$ (Figure 6). The carbohydrate content of UPCR sample was not significantly ($p > 0.05$) different from that of PCR sample. Furthermore, the carbohydrate contents of UPCRG, PCRG, UPCRG+PO, PCRG+PO, UPCRGM and PCRGM samples varied within relatively narrow range: 81.00 0.26%-83.13

0.05%; $p > 0.05$. The UPCRGM+PO sample gave carbohydrate content that was not

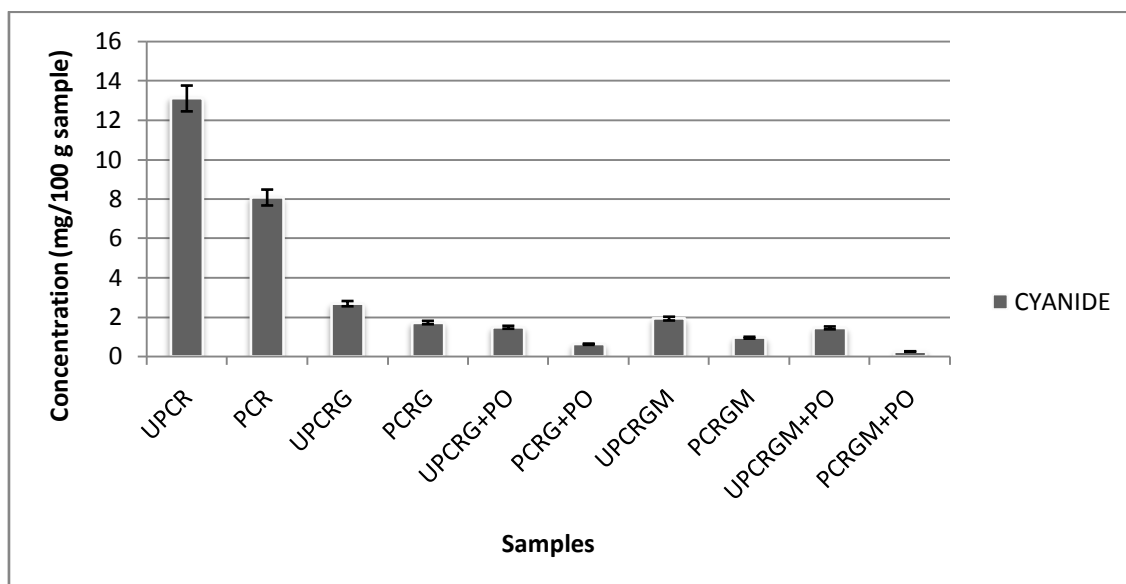significantly ($p > 0.05$) different from that of PCRGM+PO sample.

Figure 7. *Cyanide contents of cassava roots, garri and garri meals*

Figure 7 showed that the cyanide content of PCR sample was 1.62 fold lower than that of UPCR sample; $p < 0.05$. The cyanide content of UPCRG sample was 4.89 folds lower than that of UPCR sample ($p < 0.05$), whereas PCRG sample gave 4.69 folds lower than that of the corresponding PCR sample; $p < 0.05$. Additionally, the UPCRG+PO and PCRG+PO samples gave marginal lower cyanide content compared with their corresponding UPCRG and PCRG samples. The PCRGM+PO sample gave the lowest cyanide content compared with other experimental samples; $p < 0.05$.

DISCUSSION

The present study showed that unprocessed cassava roots (PCR and UPCR samples) contained comparatively high quantity of moisture and exhibited variable proximate composition. Collation of previous reports had shown wide variations of nutrient composition in several collections of cassava roots (OECD, 2009), which were linked to cultivar/variety differences, age of the plants, geographic location/climatic conditions, differences in soil conditions, rainfall distribution and, probably, analytic methods employed in those previous studies (Osei and Twumasi, 1989; Fasuyi and Aletor, 2005; OECD, 2009; Montagnac *et al.,* 2009).Also, significant variations in cyanide content amongst cassava roots of the same cultivar in different agro-ecological zones have been reported (Mburu *et al.,* 2012; Koko *et al.,*

2014). Other studies have linked wide variability of cyanide content in cassava roots to variety differences, growing conditions of plant, (i.e. soil type, humidity, temperature), maturity of plants, environmental conditions, and nutritional status of the plants, prevailing seasonal and climatic conditions during the time of harvest as well impact of environmental pollution and application of inorganic fertilizers (http://www.fao.org/docrep/x5415e/x5415e01.htm; Splittstoesser and Tunya, 1992; Bokanga *et al.,* 1994; Vetter, 2000; CIAT, 2007; Navia and Villada, 2012; Adeniji, 2013; Faezah *et al.,* 2013; Koko *et al.,* 2014).

From the outcome of the present investigations, comparatively high moisture content of the PCR and UPCR samples were evident and, to a large extent, conformed to previous reports (Ceballos, 2002; OECD, 2009; Montagnac *et al.,* 2009). Earlier studies had reported that the high moisture content and activation of molecular events leading to the poorly understood post-harvest physiological deterioration in cassava root were responsible for its relatively low stability during storage and accelerated rate of deterioration immediately after harvest (Ceballos, 2002; Reilly *et al.,* 2004; Salcedo *et al.,* 2010; Koko *et al.,* 2014). This drawback can be circumvented or minimized by converting the wet roots into intermediate dried chips that can further be processed into preferred cassava-based products when the need arises (Oluwole *et*

al., 2004; Ekwu and Ugwuonah 2007; Ekwu *et al.,* 2012; Udoro *et al.,* 2014).

Furthermore, traditional methods of processing cassava root into *garri* involved substantial elimination of water from the raw roots (Figure 1), resulting to a relatively more stable product with comparatively longer shelf-life (Oluwole *et al.,* 2004; Kamalu and Oghome, 2012). Between the two processed cassava roots (UPCRG and PCRG samples), the PCRG sample appeared to retain relatively more moisture than that of the UPCRG sample. The significant disparity in moisture content between the UPCRG and PCRG samples was an indication that the starchy parenchyma exhibited greater capacity to retain moisture than the peridermal and cortical regions of the cassava root. Also, the presence of peridermal and cortical regions in the cassava mash altered the water retention capacity of the starchy parenchyma following the processing of the cassava root into *garri*. The capability of the starchy parenchyma to retain water in the cause of processing cassava roots into *garri* was as a result of the peculiar physicochemical changes in cassava starch associated with the fermentation process and altered textural property as previously described (Numfor *et al.,* 1995) between UPCRG and PCRG samples. Similarly, previous investigation showed that the presence of palm oil in *garri* gave a finer granular texture than corresponding sample devoid of palm oil (Agbor, 2005; Odoemelam, 2005), which suggest disparity in water retention capacities between *garri* treated with palm oil (UPCRG+PO and PCRG+PO samples) and the corresponding sample devoid of palm oil (UPCRG and PCRG samples). Additionally, the presence of palm oil in the cassava mash facilitated rapid volatilization of moisture as it did to cyanohydrin and hydrogen cyanide during the roasting stage as earlier reported (Vasconcelos *et al.,* 1990; Olorunfemi and Afobhokhan, 2012). Thus, UPCRG+PO and PCRG+PO samples exhibited lower moisture content than those of corresponding UPCRG and PCRG samples. The presence of peridermal and cortical regions in palm oil treated cassava mash also interfered with the moisture retention capacity of the starchy parenchyma following roasting. The comparatively raised moisture content of gelatinized *garri* samples were obvious reflection of re-introduction of water during preparation of the various *eba* samples.

The cassava root is a poor source of protein (Montagnac *et al.,* 2009); exemplified by the relatively low crude protein contents of the unprocessed roots and their corresponding processed products (Figure2). However, the presence of peridermal and cortical regions as well as introduction of palm oil in the cassava mash caused marginal increases and improvement in the crude protein contents of the unprocessed roots and their corresponding processed products. Nevertheless, the crude protein contents of the various experimental samples, probably, were far lower than what was reported in the present study because the Kjeldahl methods have been noted to present 'false' raised levels of crude proteins in biological samples (OECD, 2009). In the Kjeldahl technique, non-protein nitrogen elements are captured in the analysis, particularly in the present study, where the nitrogen elements of cyanogenic glycosides and hydrocyanic acid (HCN) are relatively present in the cassava samples. Studies have also shown that differences in genetics/cultivar and growth conditions of cassava plants create wide variations in free amino acids content and non-protein nitrogen elements (Yeoh and Truong, 1996).

The present study showed that the combined crude fibre contents of the peridermal and cortical regions were high enough to alter the proportion of crude fibre contributed by the starchy parenchyma in the cassava mash; since crude fibre content of PCR sample was substantially greater than that of UPCR sample (Figure 3). Meanwhile, earlier reports had also showed that smaller sizes of unpeeled cassava roots contained more crude fiber than those of large roots (Gil and Buitrago, 2002; OECD, 2009; Montagnac *et al.,* 2009). The present investigation showed that the traditional methods leading to the processing of cassava roots into *garri* caused marginal increases in the proportions of crude fibre contents in the cassava-based products. Similarly, the ash value, which is a measure of the total amount of inorganic matter in the samples, was affected by the addition of palm oil and inclusion of peridermal and cortical regions to the cassava mash. Conversely, the level of lipids in cassava roots is relatively very low, which usually occur on the average of 0.25% (Lalaguna and Agudo, 1988). Consequently, the disparity in lipid content between the peels and the starchy parenchyma was not obviously profound; since

the lipid content of the PCR sample was not significantly different from that of the UPCR sample (Figure 5). However, marginal alterations and readjustments in lipid contents of the experimentally processed cassava products (UPCRG, PCRG, UPCRGM and PCRGM samples) occurred, probably, as a result of microbial metabolism spin off associated with the fermentation period. Contrary, the yellow *garri* samples (UPCRG+PO, PCRG+PO, UPCRGM+PO and PCRGM+PO samples) are fortified with palm oil and are rich in *β*–carotene as well as collections of lipid matter as previously reported (Orakpo, 2013; Chikezie and Ojiako, 2013).

The cassava root is often referred to as starchy root (Nweke, 2004; Montagnac *et al.,* 2009) in that the carbohydrate content is about 30-35% of fresh root (IITA, 1990; Tonukari, 2004; Montagnac *et al.,* 2009), which was in conformity with the present findings. Furthermore, the present study showed that carbohydrate content of the processed samples were proportionally higher than that of PCR and UPCR samples, which was not unconnected with the elimination of substantial quality of water during the course of processing the raw roots to corresponding finished products. For instance the carbohydrate contents of the processed cassava products were comparable with that of cassava flour (Charles *et al.,* 2005). However, the presence of peridermal and cortical sections of the root in the cassava mash did not substantially alter the starchy fraction of the parenchyma section; since the carbohydrate content of UPCR sample was not significantly higher than that of PCR sample (Figure 6). Aside the starchy content of the cassava root, Sanchez *et al.* (2009) had noted that the total and reducing sugars in cassava roots were within the range of 0.2-18.8% and 0.0-15.7%, respectively, on a dry weight basis.

Traditionally, the reduction and, possibly, elimination of cyanide from raw cassava roots have been achieved using a combination of several processing schemes (Odoemelam, 2005;Asegbeloyin and Onyimonyi, 2007).Investigations had shown that the final level of residual cyanide in cassava-based products depended on the initial cyanide load and methods applied in processing raw cassava roots (Omoike and Adediran, 1991; Cardoso *et al.,* 2005; Okoli *et al.,* 2012). All processing techniques involved operations that trigger the breakdown of cyano genic glycosides by

endogenous hydrolytic enzymes such as linamarase into hydrogen cyanide followed by the volatilization by heating, in form of roasting or boiling. In cases where the residual cyanide in cassava products cannot be totally eliminated, levels of less than 50 mg/kg are considered harmless (Mburu *et al.,* 2012; Lukuyu *et al.,* 2014). The FAO recommended maximum cyanide level in foods to be 10 mg CN equivalents/kg dry weight (OECD, 2009). Notwithstanding, chronic toxicity may ensue when the consumption of such cassava-based products are consumed over long period of time (FSN, 2005).

Studies have shown that the cortex parenchyma contains vast amount of the total cyanide in cassava root, whereas less concentration of the total cyanide is present in the starchy parenchyma (Onwueme, 1978). Therefore, peeling of the cassava husk ensures considerable reduction of cyanide levels in raw cassava root. Accordingly, the present study showed that the cyanide content of PCR sample was significantly lower than that of the UPCR sample (Figure 7), which confirmed substantial reduction of cyanide content, following the removal of the peridermal and cortical regions, in the raw cassava roots. The simultaneous process of dewatering and fermentation also promoted the reduction of cyanide contents in cassava mash by 50-80% as previously reported (Kemdirim *et al.,* 1995; Iyayi and Dosel, 2000; Oyewole and Ogundele, 2001; Cardoso *et al.,* 2005; Enidiok *et al.,* 2008). Furthermore, the roasting and drying procedures facilitated the reduction of cyanide contents to lower values in *garri* products. However, the presence of peridermal and cortical regions in the cassava mash caused the retention of relatively higher amount of cyanide in the *garri* samples as exemplified by the significant raised cyanide content of UPCRG sample compared with that of PCRG sample. This disparity was connected with initial cyanide load in the cassava husk based on previous suggestion (Cardoso *et al.,* 2005). In a similar corresponding order, the addition of palm oil to the cassava mash during the roasting stage caused moderate reduction in the cyanide contents of the finished products (UPCRG+PO and PCRG+PO samples). Previous studies had shown that roasting of cassava mash in the presence of palm oil engendered rapid volatilization of hydrocyanic acid (Vasconcelos *et al.,* 1990; Olorunfemi and

Afobhokhan, 2012; Aniebo, 2012) and may have also accounted for further reduction of cyanide content in gelatinized *garri* or *eba* (Figure 7), which was prepared by dispersing and soaking *garri* granules in boiling water, by causing volatilization of hydrocyanic acid. Accordingly, from toxicological standpoint, the consumption of *eba* is safer and should be preferred to intake of *garri* or *garri* dispersed and soaked in cold water, which is a common snacking habit among Nigerians.

CONCLUSIONS

The traditional methods of processing of cassava roots into *garri* caused substantial loss of water by the roots. The dehydrated *garri* produced from peeled and unpeeled cassava roots exhibited deferential capacities to retain moisture. Specifically, *garri* sample produced from peeled cassava roots appeared to retain relatively more moisture than that produced from unpeeled roots. Likewise, *garri* produced from unpeeled and peeled cassava roots treated with palm oil exhibited lower moisture content that their corresponding samples devoid of palm oil. Furthermore, the presence of peridermal and cortical regions in the cassava mash also interfered with the moisture retention capacity of the starchy parenchyma. The presence of cassava peels components as well as introduction of palm oil in the cassava mash caused marginal increases and improvement in the crude protein contents of the unprocessed roots and their corresponding processed products. Processing unpeeled cassava roots engendered marginal increases in the proportions of crude fiber in the cassava products, whereas the ash value of *garri* was affected by the addition of palm oil and inclusion of peridermal and cortical regions to the cassava mash. The lipid content of the cassava based products exhibited marginal alterations but were obviously produced in palm oil treated samples. The presence of cassava peels did not substantially alter the carbohydrate content, contributed by the starchy parenchyma section, in the cassava mash. Finally, the presence of cassava peels in the cassava mash caused retention of relatively higher amount of cyanide in the *garri* samples, whereas the addition of palm oil to the cassava mash caused moderate reduction of the cyanide contents in the finished products.

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