Original Research Article

Comparative Analysis on the Proximate Composition of Processed Cassava Products

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ABSTRACT

The extensive applicability of cassava and its derivatives in various industries in Nigeria is constantly increasing, thus the necessity to evaluate the chemical composition in order to ascertain the nutritional value of these products. This study investigated and compared the proximate composition of eight samples of processed cassava products (Niji® Foods Cassava Flour, IFGREEN® Odourless Fufu Flour, Ayoola® Fufu Flour, Aiteefills® Fufu flour, Niji® Foods Garri, Golden Penny Garri, GGEE® foods Ijebu Garri and local brand cassava starch) obtained from supermarkets and local markets in Lafia town using standard official methods for proximate analysis. The results were analyzed by Minitab version 20.0 by one way ANOVA and pair-wise comparison was made post hoc using Tukey t-tests. The moisture, ash, crude protein, crude fibre, crude fats and carbohydrate ranged from 4.34 – 12.70 %, 0.34 – 1.63 %, 1.30 – 10.06 %, 0.02 – 0.81 %, 4.01 – 12.53 % and 70.83 – 85.73 %. The study revealed that the results of the proximate composition in all the samples varied significantly ($P \le .05$). Crude protein and Crude fibre contents in all the samples agreed with the recommended limits by FAO/WHO and SON. The high moisture content in Aiteefills Fufu Flour may impart a shorter shelf life on the product. Findings from the study also suggested the possibility of formation of metal-ion pigment complexes in GGEE® foods Ijebu Garri, Ayoola® Fufu Flour, Niji® Foods Cassava Flour and Local Brand Cassava Starch due to high ash contents. However, all samples meet the basic nutritional requirements for crude protein, crude fibre, fats and carbohydrate contents in cassava products. The study recommended regular routine proximate composition checks on new and existing products available to consumers to further maintain high nutritional standards in processed cassava products.

Keywords: [Cassava, proximate composition, processed, nutritional value}

1. INTRODUCTION

Cassava, *Manihot esculanta* Crantz, now widely grown in the Pacific is a domesticated plant derived from one or more species of the Genus *Manihot* in the Euphorbiaceae family [1]. The plant parts used are the storage root (tuber) and leaves. The *Manihot* genus is reported to have about 100 species, among which the only commercially cultivated species is *Manihot esculenta* Crantz. There are two distinct types of cassava plants: erect, with or without branching at the top type and the spreading type [2]. The plant is characterized by palmate lobed leaves, inconspicuous flowers and a large, starchy, tuberous root with a tough papery brown bark and white to yellow flesh [3]. It is one of the most perishable tuber crops with a high postharvest loss [4, 5].

Being a drought-tolerant crop, cassava can be grown in areas with uncertain rainfall patterns which usually results in unsuccessful cultivation of many other crops. Recently, the world cassava production stands at 302.66 million metric tonnes with leading countries like Nigeria, Congo DR, Thailand and Indonesia ranked 1st, 2nd, 3rd and 4th respectively [6]. In Africa, production of cassava stands at 193.62 million metric tonnes in 2020 and is regarded as the world's largest cassava growing region and unarguably Nigeria remains the highest producer of cassava in the world with about 60 million metric tonnes in 2020 [6]. Cassava is a starchy staple whose roots are very rich in carbohydrates, a major source of energy. Apart from sugarcane, cassava has the highest carbohydrate contents amongst the crop plants [7]. In the aspect of food sufficiency and food crisis alleviation in Africa, the role of cassava cannot be over emphasized [8]. Based on the huge instrumentality of Cassava in this regard, it has been recognized as Africa's food security crop.

Food processing involves the transformation of food from its raw form into a new form by the application of varying techniques [9]. Food processing is vital since it ensures the improvement of shelf life of the products, reduce spoilage and increase the availability and accessibility of the food products to people. Fresh cassava roots contain about 70 % moisture content thereby increasing its bulkiness and this poses serious transportation problems which may affect the availability of the food crop to users. Additionally, studies have confirmed the high health risks associated with the consumption of cassava in its raw form owing to the presence of high level of toxic Hydrogen cyanide in the fresh roots. In recent years, the processing of cassava into various products has gained significant attention due to its versatility, cyanide reduction capacity, long shelf life, and potential for value addition thus ensuring food security. The processed forms of cassava finds wide applications both as food and useful industrial products. Tapioca, farina, garri, fufu, starch etc. are some of the product often gotten from processing of cassava tuber locally. The different processed forms are the cheapest source of staple food in Africa and Nigeria in particular. Nigeria consumes nearly all that it produces, regardless of the high level of cassava production [10, 11]. The processing of cassava into various forms involves the application of different techniques, each of which affects significantly the chemical composition of the final products. Traditionally, soaking, fermentation, cooking, steaming and chipping, frying, drying and roasting are the different processing steps employed in the processing of the cassava roots. The factors affecting the chemical composition of processed cassava products include the cultivar, geographical location, maturity stage of the plant, environmental conditions and processing methods [12, 13].

Proximate composition refers to the basic components of a food product, including moisture, protein, fat, fibre, ash, and carbohydrates. Over the years, research efforts have been directed towards characterizing the proximate composition of various species of cassava roots and derived products to unravel the effects of processing methods, environmental factors, and genetic diversity on their nutritional profiles [14, 15, 16]. Recent advances in analytical techniques and innovative research have provided valuable insights into the proximate composition of processed cassava products. In 2020, significant contributions were made to this field, shedding light on the nutritional content and potential health benefits of cassava-based foods. Findings from a study conducted by Okonkwo *et al.* [15] where advanced spectroscopic techniques were used to analyze the starch composition of cassava chips, revealed correlations between processing parameters and starch characteristics. Meanwhile, the work of Nzuta *et al.* [16] explored the nutritional variations of cassava flours derived from different cultivars and regions, revealing distinctive nutrient profiles among products.

Processed cassava products have been reported by several researchers to possess high carbohydrate content and low protein and fat content. In a study by Nwaliowe *et al.* [17], the proximate composition of cassava flour and its derived products was evaluated. The researchers reported that cassava flour contained approximately 80% carbohydrates, 2% protein, and negligible amounts of fat, making it a valuable source of energy. Similarly, Sajeev *et al.* [18] investigated the proximate composition of cassava chips and found that they contained about 80-85% carbohydrates, 1-2% protein, and low levels of fat. Additionally, research has focused on the nutritional attributes of other cassava-based products, such as cassava starch and tapioca pearls. A study by Nzuta *et al.* [16] analyzed the proximate composition of tapioca pearls commonly used in bubble tea. The researchers found that tapioca pearls contained approximately 85% carbohydrates, 1% protein, and negligible amounts of fat, further emphasizing the predominance of carbohydrates in processed cassava products. This quality of cassava products makes it a common household food in Nigeria generally and Lafia town in particular.

Recently, the increased production of processed cassava products locally, poses a necessity for detailed evaluation of the chemical composition of the final products as a basis for ascertaining the safety of these products for consumption. Studies on the proximate composition of fresh cassava roots have been done, but none has been done on the different processed cassava products obtained from local markets and supermarkets in the city of Lafia, Nassarawa State, Nigeria. Being a low-income town, many households in Lafia depend on the processed cassava products available in the local markets and supermarkets such as Gari, Fufu flour, Cassava flour and starch for their nutritional needs since they are the cheapest sources of carbohydrate. The present work reports on the proximate composition of eight different processed cassava products including Garri (Niji® Foods Garri, Golden Penny Garri, GGEE® foods Ijebu Garri), Fufu flour (IFGREEN® Odourless Fufu Flour, Ayoola® Fufu Flour, Aiteefills® Fufu flour), high quality cassava flour (Niji® Foods Cassava Flour) and starch (Local Brand Cassava starch) obtained from local markets in Lafia town. The study also compares the concentration of cyanide and the proximate composition of different processed cassava products to ascertain which product is the safest, considering the standard health rating index.

2. MATERIAL AND METHODS

2.1 Study Site and Sample collection

The present study was conducted in Lafia town. Lafia town is the headquarters of the Lafia local government area, and also the capital city of Nassarawa State in the Guinea Savanna vegetation of north central Nigeria. It is located between latitudes 80 28’ N and 80 30’ N to longitudes 80 29’ E and 80 32’ E. The local government area has a population of 361 000 [19], and is bordered by three local government areas; Wamba in the north, Nassarawa Eggon in the north-west, Obi in the south, Doma in the south-west, and Plateau state in the east (Figure 1). Lafia is geologically a part of the lower Benue trough and the major occupations of the inhabitants are civil service, farming, mining, artisanry, and fishing. Products containing cassava as primary ingredients were obtained directly from supermarkets and local markets in Lafia town. The eight samples of processed cassava products were divided into three groups based on the method of processing: garri samples, fufu flour, high quality composite flour and locally processed starch. The samples include Niji® Foods Cassava Flour, IFGREEN® Odourless Fufu Flour, Ayoola® Fufu Flour, Aiteefills® Fufu flour, Niji® Foods Garri, Golden Penny Garri, GGEE® foods Ijebu Garri and local brand cassava starch. They were designated as NFCF, IGFF, AYFF, ATFF, NFG, GPG, GIG and LBCS respectively. The samples were obtained randomly and transported directly to the Chemistry laboratory, Faculty of Agriculture, Nassarawa State University, Shabu Campus, for analysis.

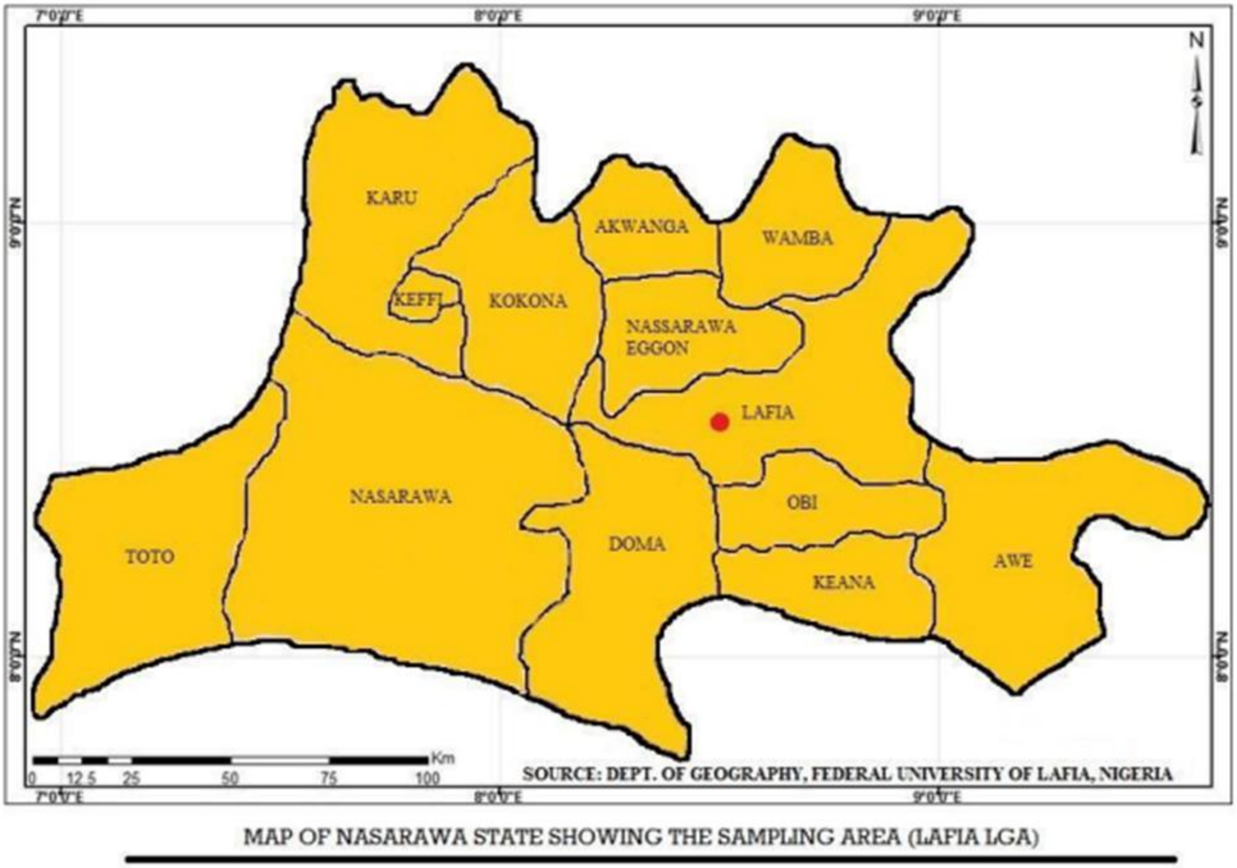

Figure 1: Map of Nassarawa state showing Lafia Local Government Area [20]

2.2 Preparation of samples

100g of each processed cassava product sample was put in tightly sealed envelopes and kept in field cellophane bags before analysis to prevent environmental contamination.

2.3 Proximate analysis

Proximate composition, namely, moisture, crude protein, crude fibre, crude fats, ash and nitrogen free extract (carbohydrate contents) in portions of the various samples were measured according to the standard methods as described in AOAC [21] and other standard techniques obtained from the literature.

2.3.1. Moisture Determination (% MD)

The moisture content was determined according to AOAC [21] method 925.10. 2 g of the samples was accurately weighed into a pre-labelled, preweighed beaker and transferred to a vacuum dry oven to dry at a temperature of 130 °C. The samples were heated within a time range of 1 h, 1 h -30 min, 2 h, 2 h -30 min, and 3 h respectively, and weighed till constant weight was achieved. All sampling and analysis were done in triplicate [13]. The formula used for the calculation of moisture content and dry matter can be seen below:

Sample weight – moisture content = dry matter

$$\% \text{ moisture content} = \frac{dry\ matter}{weight\ of\ sample} \times 100 \quad \text{……………} \ 2.1$$

2.3.2. Ash (% Ash)

The ash content was determined according to AOAC [21] method 923.03. Prepared samples were weighed into preweighed, porcelain crucibles. The samples were transferred to a muffle furnace (J M Ney furnace, model 2-525) and ashed at 550°C for 8 h. The crucibles were allowed to cool in desiccators and then weighed [22]. The formula that was used for the calculation of ash content can be seen below:

$$\% \text{ Ash} = \frac{Wt\ of\ Ash}{weight\ of\ sample} \times 100 \quad \text{…………………..} \ 2.2$$

2.3.3. Fat (% Fat)

The fat content in the samples were determined according to 920.39 of AOAC [21] by dissolving 8 g of the cassava samples in a 200 cm^3 beaker containing 8.4 cm^3 of hydrochloric acid and heated in a water bath for 1 h. After heating, the sample solution were allowed to cool and then extracted with petroleum ether in a separating funnel. After extraction, the sample solution were heated to dryness and the weight collected after cooling [22]. The formula that was used for the calculation of fat content can be seen below:

$$\% \text{ Fat} = \frac{Weight\ loss\ of\ sample\ \ (extract\ )}{weight\ of\ sample} \times 100 \quad \text{…………….. } 2.3$$

2.3.4. Crude protein (% C.P)

The crude protein content was determined as described in Nuwamanya *et al.* [23] using Dumas combustion method of nitrogen content analysis (Leco Truspec Model FP-528, St Joseph Mi, USA) by taking about 0.3 g of sample and using the conversion factor:

$$\% \text{ protein} = \% \text{ N} \times 6.25. \quad \text{…………………..} \ 2.4$$

2.3.5. Crude fibre content (% C.F)

The crude fibre content was determined using the method 962.09 of AOAC [21]. About 0.5 g of the sample was boiled in 50 mL of 0.3 M H_2SO_4 under reflux for 30 min, followed by filtering through a 75 mm sieve under suction pressure. The residue was washed with distilled water to remove the acid. The residue was then boiled in 100 mL, 0.25 M sodium hydroxide under reflux for 30 min and filtered under suction. The insoluble portion was washed with hot distilled water to free the alkaline. The insoluble portion was dried to the constant weight in the oven at 100 ℃, for 2 h, then cooled in the desiccator. The dried sample was ashed in a muffle furnace to subtract the mass of ash from the fibre after then the % of fibre was determined.

2.3.6. Nitrogen Free Extract (% NFE) as Carbohydrate content

NFE was determined by mathematical calculation. It was obtained by subtracting the sum of percentages of all the nutrients already determined from 100.

$$\% \text{ NFE} = 100 - (\% \text{ moisture} + \% \text{ CF} + \% \text{ CP} + \% \text{ EE} + \% \text{ Ash}) \quad \text{…………………} \ 2.5$$

% NFE represents soluble carbohydrates and other digestible and easily utilizable non-nitrogenous substances in the samples.

2.4 Data Analysis

Data was analyzed using a one-way analysis of variance (ANOVA). The mean differences were determined using the Tukey’s Least Significance Difference test at 5% significant level. Values of $p \leq 0.05$ were considered statistically significant. All data were expressed as the mean ± standard deviation (SD) of three observations. All calculations were done using the Minitab version 20 software.

3. RESULTS AND DISCUSSION

The proximate composition of the cassava products is shown in Figure 2. Eight samples of different processed cassava products were randomly selected from the supermarkets and local markets in Lafia town, Nassarawa State, Nigeria and analyzed for their proximate composition using the standard methods as described by AOAC [21].

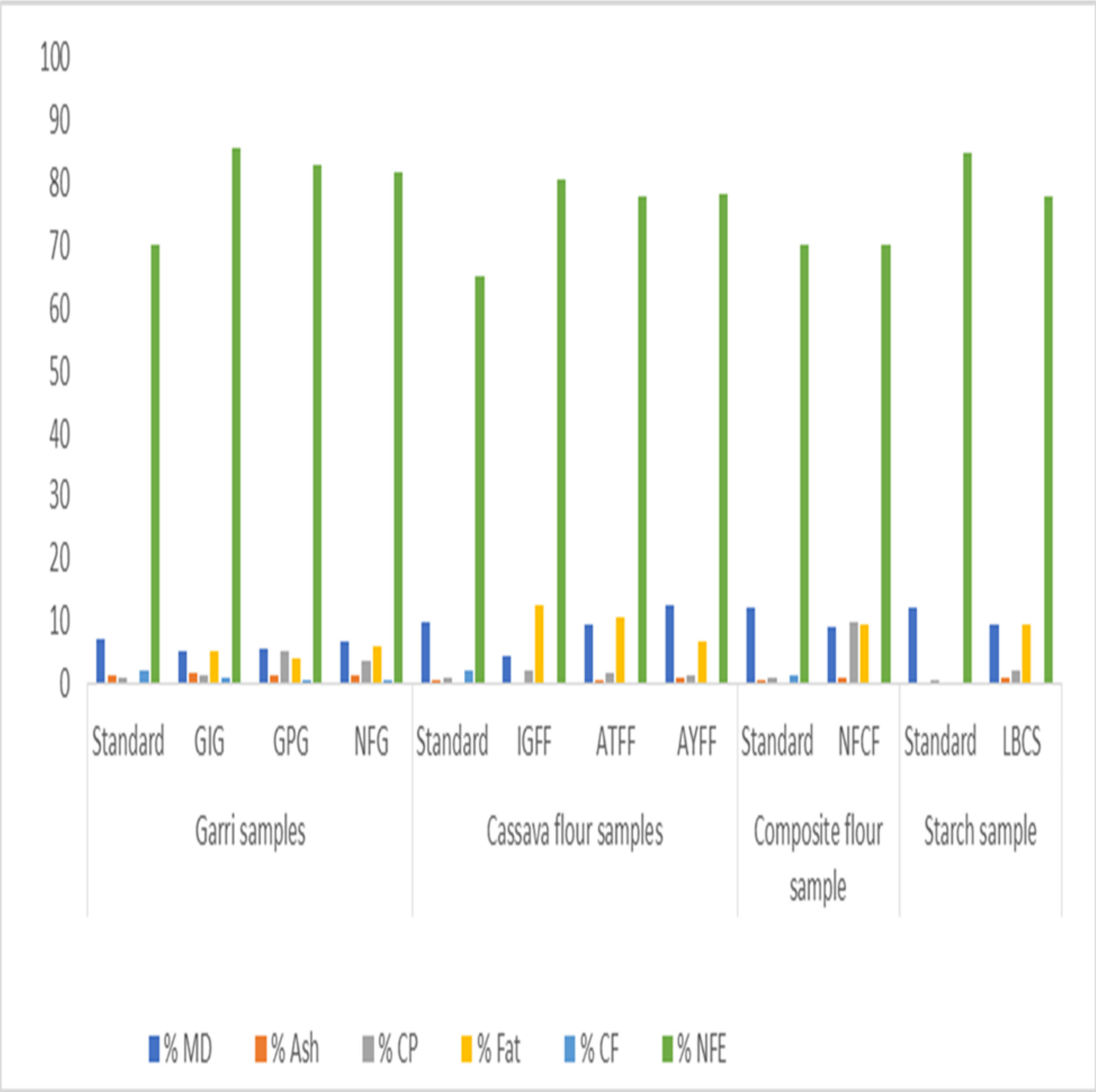

Figure 2: Proximate composition of the eight processed cassava products

3.1 Moisture Content (% MD)

The moisture content of the processed cassava samples ranged from 4.34 - 12.70 % and varied (*P* = .05) among the products (see Figure 3). LBCS and AYFF were not significantly different (*P* > .05). ATFF, AYFF, NFCF and LBCS gave relatively higher moisture content compared to NFG, GPG, GIG and IGFF. As expected, the garri samples (NFG, GPG and GIG) had low values of moisture content due to the roasting stage involved during their processing stage. Conversely, the moisture content in IGFF was lower than ATFF and AYFF. The moisture content of Aitefills Fufu flour (ATFF) was significantly the highest (*P* = .05). This is followed by LBCS, AYFF, NFCF, NFG, GPG, GIG and IGFF being the least. Manano *et al.* [25] reported moisture contents of cassava varieties in Uganda in the average range 5.43–10.87% which is similar to results obtained from the current study. The differences in moisture contents could be attributed to differences in chemical constituents and processing methods. Moisture is an important parameter in the storage of cassava flour. Very high levels greater than 12 % allow for microbial growth and thus low levels are favourable and give relatively longer shelf life [26]. The low content of moisture in IGFF may be attributed to the effect of commercial production considerations and shelf life where the intention of the producers must have been to provide products that can store for a longer duration before purchase by consumers or before spoilage. The effect of insufficient drying during the processing stage may have contributed to the high moisture content in ATFF (12.70%). All the fufu flour samples (AYFF and IGFF) except ATFF had moisture contents within the permissible limit as stipulated by the Standard Organization of Nigeria (SON) and FAO/WHO limits. Similarly, all the garri samples, (GIG, GPG and NFG), cassava flour (NFCF) and cassava starch (LBCS) showed moisture contents that were within the standard limits of SON and FAO/WHO.

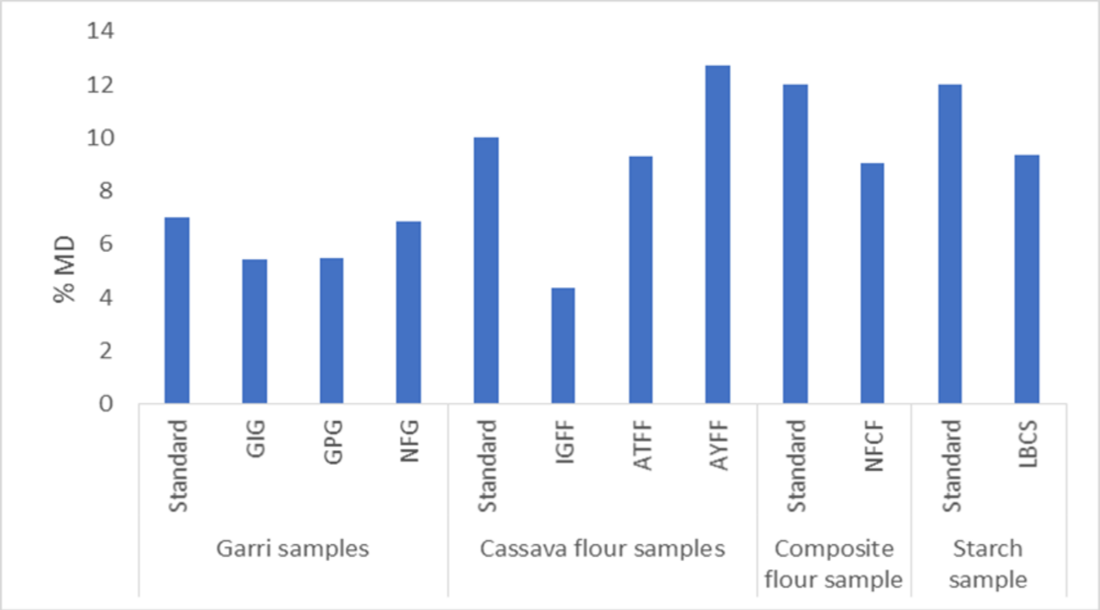

Figure 3: Moisture contents of the eight processed cassava products

3.2 Ash contents (% Ash)

The ash contents were in the average range of 0.34 % – 1.63 % and varied (*P* = .05) among the samples (see Figure 4). GIG (1.63%) had the highest ash content while IGFF (0.34 %) had the lowest. Ash contents of the cassava fufu flour samples (IGFF, AYFF, ATFF) except the high quality cassava flour sample (NFCF) were relatively lower than the garri samples (GIG, GPG, NFG). However, the ash contents of IGFF, AYFF, GPG and NFG were within the standard limits of SON while NFCF, AYFF, LBCS and GIG had values beyond the standard limits of SON and FAO/WHO. Crude ash content is usually indicative of inorganic constituents (minerals such as K, Zn and Ca) and generally including cassava, it ranges from 1% to 2%. Ash contents represent the total mineral content in food after it has been burnt at a very high temperature. The ash contents reported in previous studies: 1.46 – 2.71% [27], 1.90 – 2.84 % [28] and 1.44 – 2.35 % [29] are relatively higher as compared to the result obtained in the current study. Omowonuola *et al.* [30] also reported ash content in samples of cassava flour as 3.49 % which is significantly higher than that obtained in this study. The differences in reported ash contents could be attributed to differences in dry matter contents, genotypic form of the raw cassava roots and their proximate composition. It has been reported that higher dry matter contents were associated with lower ash contents [30]. This could also be attributed to higher fibre contents in GIG (0.81 %) as shown in Table 1. Fibre was a major contributor to ash contents in the samples. In a related study, wheat flour varieties with higher fibre contents had higher ash contents [31]. In the food industry, ash contents may influence the quality of flours. High ash contents can impact the whiteness of flours. Since ash content is also an indicator of mineral contents, increased mineral content may promote metal chelating activities to form metal-ion pigments complexes [32] which can confer greenness/redness or yellowness colour on the final product. Justifiably, the possibility of formation of metal ion-pigment complexes in NFCF, AYFF, LBCS and GIG is high since the product samples had ash contents above the recommended limits.

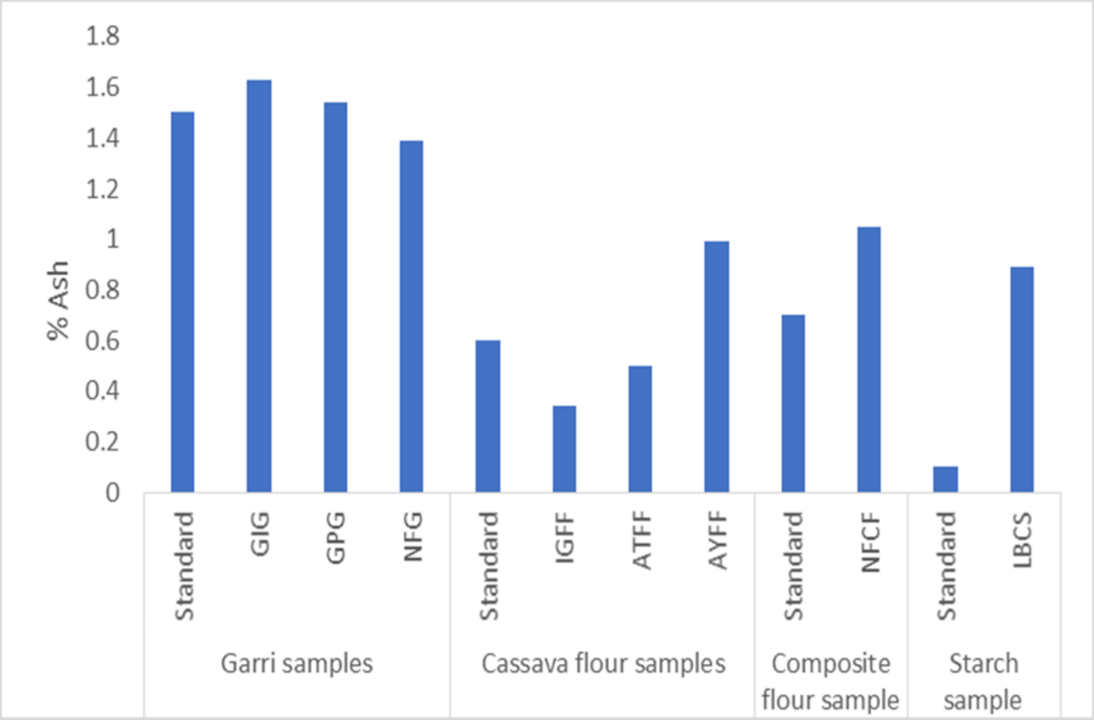

Figure 4: Ash contents of the eight processed cassava products

3.3 Crude Protein (% CP)

The protein contents were in the range of 1.30 % – 10.06 %. IGFF and LBCS as well as ATFF and GIG were comparable (*P* > .05) (see Figure 5). The protein in other samples were significantly different (*P* = .05). The composite flour sample, NFCF (10.06 %) had the highest crude protein content significantly, shortly followed by GPG (5.25 %), a garri sample. GIG had the least crude protein content in this study. The introduction of palm oil during the roasting stage is likely to be responsible for the value of the protein content in GPG. Manano *et al.* [25] reported protein in the range 0.74 % - 1.52 %. Emmanuel *et al*. [28] reported in the range 1.76 % - 3.46 % protein. Other authors have reported lower protein values in the range 0.3 % - 0.6 % protein [34, 35] and 0.72 % protein [36]. The differences in protein contents can be accounted for in terms of environmental conditions such as soil fertility [13, 12] from which the cassava tubers used in making the products were obtained from. The application of nitrogen rich fertilizer to the soil contributes to the increased protein contents in cassava as shown by Shittu *et al.* [37] where the protein range increased from 4.3 % - 19.30 % in unfertilized cassava varieties to 9.6 – 20.9% in fertilized varieties. However, these results are alarmingly too high levels for protein in cassava flours, garri and fufu. The high levels however, could be attributed to additional nitrogen from cyanides during alkaline distillation of acid-digested samples. While it is not completely and clearly understood, the nitrogen in cyanide compounds can contribute to the crude content of nitrogen levels attributed to proteins. During drying, saccharides replaces water molecules bonded to proteins. The elimination of water may alter the binding sites of proteins which affect their activities, and presumably decreasing the protein contents. In the current study, all samples had protein contents above the minimum values (0.5% for starch and 1.0% for other cassava products) as recommended by SON.

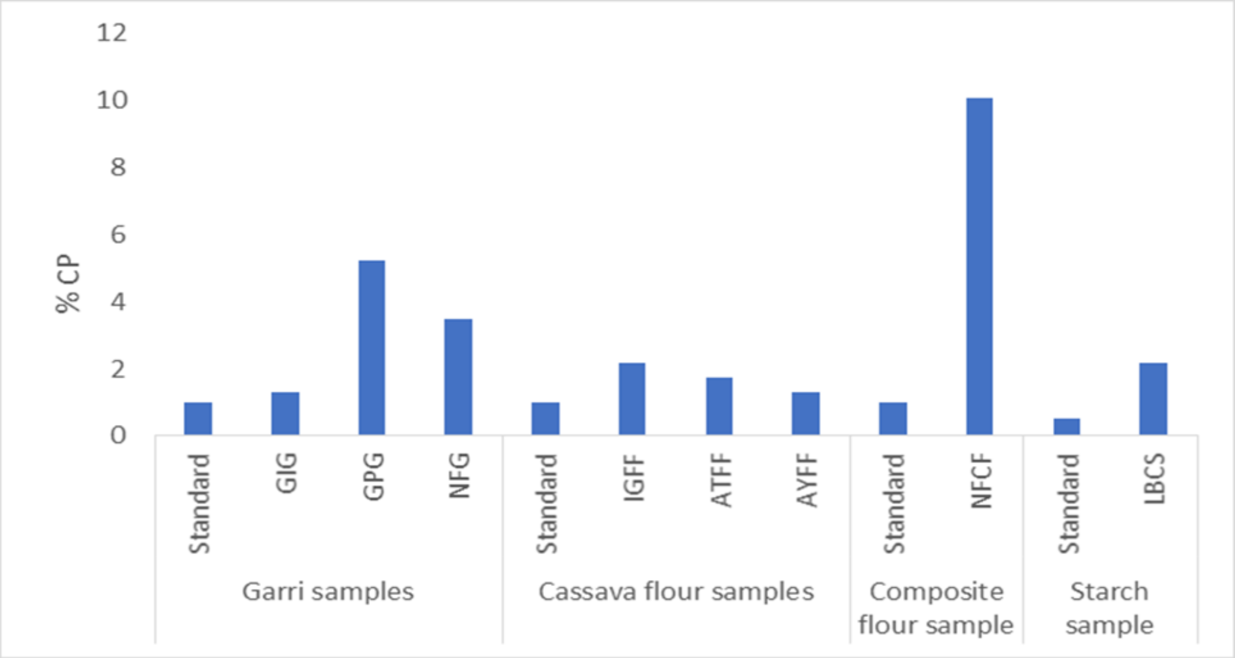

Figure 5: Crude protein contents of the eight processed cassava products

3.4 Crude fats (% Fats)

The crude fats contents were in the range of 4.01 % - 12.53 % and varied significantly (*P* = .05) among the samples (see Figure 6). All fufu flour samples (IGFF and AYFF) recorded high fat contents except ATFF. NFCF and LBCS also had high fat contents. All the garri samples (GIG, GPG and NFG) had relatively lower fat contents. Previous studies have reported fats in the range 0.1 % - 0.3 % [38, 35], 0.74 % - 1.49 % [28], 0.41 % [36] which are significantly lower than results obtained in the present study. Fat can act as an alternative energy source. Studies have shown that lower fats had decreased moisture contents which proximately increases dry matter contents, and subsequently total carbohydrates. Fats such as monoglycerides and phospholipids can form liquid-crystalline phase with water through hydrophilic (polar-heads) or hydrophobic (methyl) groups. The high fats contents in the cassava fufu flour samples may be due to microbial metabolism spin off associated with the fermentation period. Most of the garri samples were not yellow garri indicating that the samples might not have been fortified with palm oil which are rich in β-carotene as well as fat matter during the processing stage.

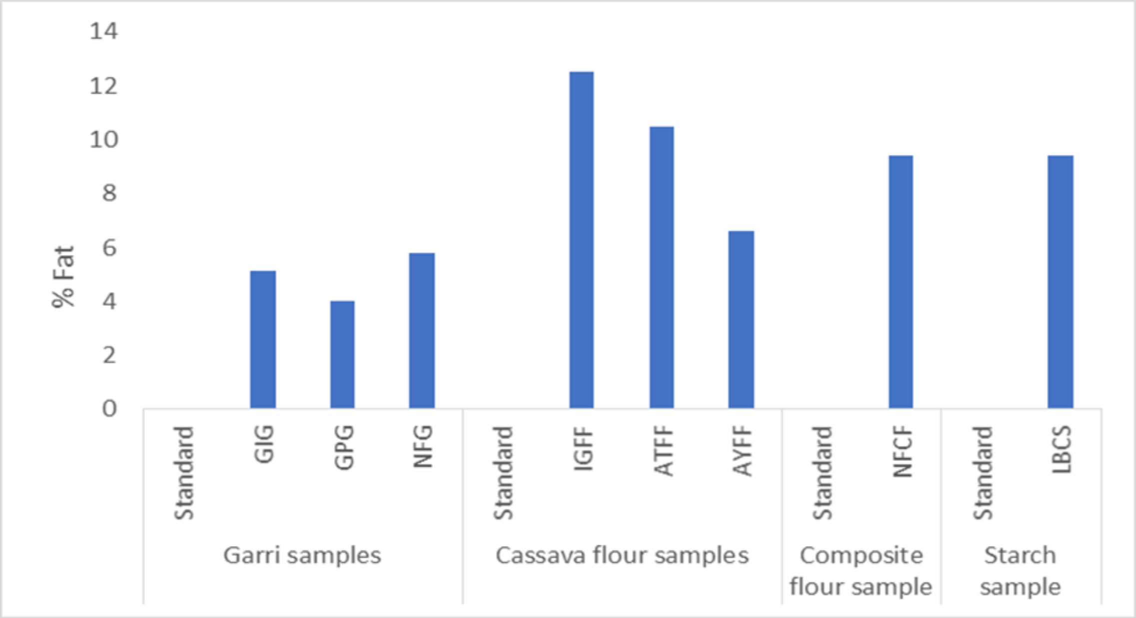

Figure 6: Fat contents of the eight processed cassava products

3.5 Crude fibre (% CF)

The fibre contents ranged from 0.02 % - 0.81 %. Fibre contents of NFCF, ATFF, AYFF and LBCS are significantly (*P* > .05) comparable (see Figure 7). Expectedly, the fibre contents of the garri samples (GIG, GPG and NFG) was relatively higher compared to LBCS, NFCF, IGFF, AYFF and ATFF. There was a relative comparability amongst NFCF-ATFF-AYFF and LBCS-AYFF-NFCF. High fibrous cassava would be characteristically coarse while less fibrous is likely to be finer. Higher dry matter contents are likely to be associated with high amounts of fibre and larger flour particle size. Fibre contents is related to ash contents. High fibrous cassava roots during dewatering process could indicate loss of mineral contents. There could also be increased rate of nutrients release (loss) in highly permeable fibres during processing [39]. Edible fibres are mainly composed of polysaccharides such as cellulose, hemicellulose and pectins. Fibre can take up water easily like a wick, however this water is loosely bound in the fibre structure and can easily be lost during drying resulting in decreased moisture contents. When fibre is present along with starch, it competes for the limited amount of water available in food system. Pectin functions as a plasticizer and control porosity [40], and depending on porosity, there could be differential moisture responses among the product samples. The proximate increase in fibre resulted in decreased protein and lipid contents of flour samples. Fibre contents in cassava flours were observed to increase while protein and lipid contents decreased. This was similar to the results reported by Oluwaniyi and Oladipo [41]. The variation in fibre can be alluded to differential genetic varieties of cassava. Excess fiber in the diet will increase fecal nitrogen, cause intestinal irritation and reduce protein digestibility used for production [42].

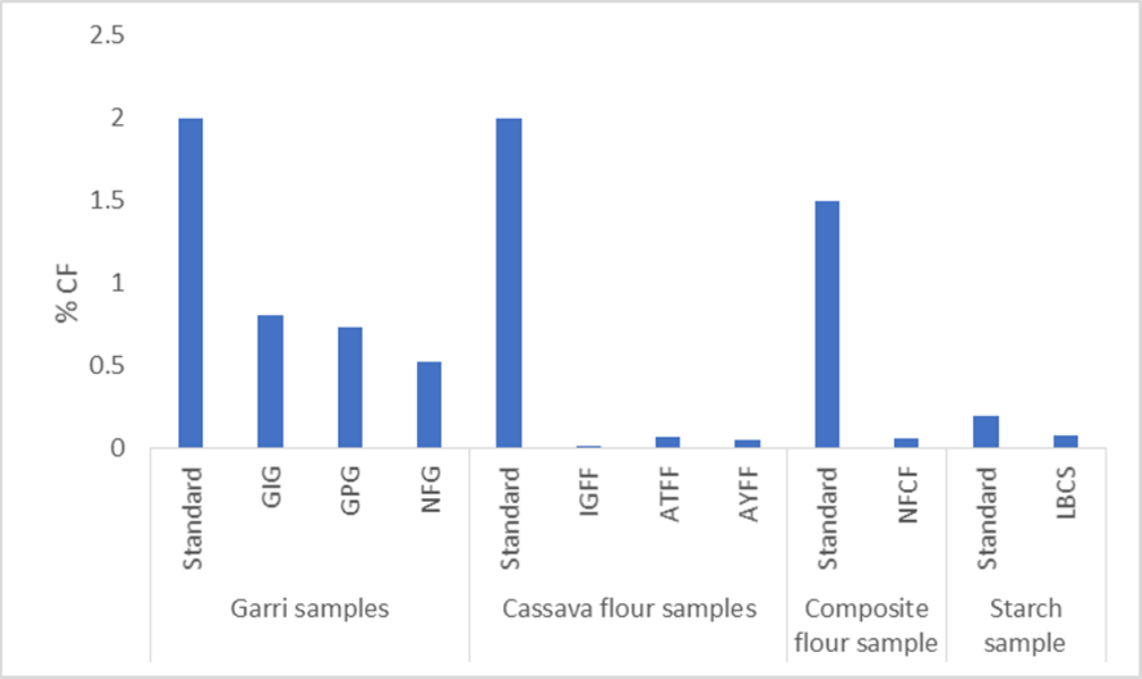

Figure 7: Crude fibre contents of the eight processed cassava products

3.6 Total carbohydrates (% NFE)

The total carbohydrate content was expressed in form of % NFE and was obtained by difference. Carbohydrate contents ranged from 70.38 % - 85.73% (see Figure 8). The total carbohydrate contents were high in all the garri samples (GPG, GIG and NFG) compared to the flour samples. However, one of the fufu flour samples, IGFF, had a high carbohydrate content of 80.59 % which was close to the range of the carbohydrate content in the garri samples. All samples were significantly different (*P* = .05). Similar results were reported by Charles *et al.* [43] in the range 80.1 - 86.3 % carbohydrate and 84.32 - 86.57 % [44]. Protein, lipids and moisture contents are the major components impacting carbohydrates and decrease in these molecules would lead to significant increase in the total carbohydrates [14]. Carbohydrates binds proteins through hydrogen bonding via hydroxyl group on saccharides and amine group on proteins [43] which may result in highly carbonyl substituted carbohydrate and subsequently loss of protein activity and availability. Carbohydrate interact with lipids to form glycolipids through glycosidic bond [44] which reduces free lipids. The carbohydrates binds water molecules through hydrogen bonding [45] hence limiting water mobility which justifies the inverse relationship between moisture and carbohydrates as shown in Table 1

Tharise *et al.* [46] showed that composite cassava flour had 8.51 % moisture, 10.6 % ash, 4.98 % protein, 0.65 % fat as well as 2.62 % fibre in its composition which were quite different as compared to values obtained in this current study. The difference in the values may be attributed to the fact that the composite flour contains a mix of other blends which will impact additional nutritive value to the flour as opposed to the cassava flour in the current study (NFCF) which is purely high quality cassava flour and contains no mix. It may be argued that the results obtained by the researchers was due to the non-processing effects, since current research only involved processed samples.

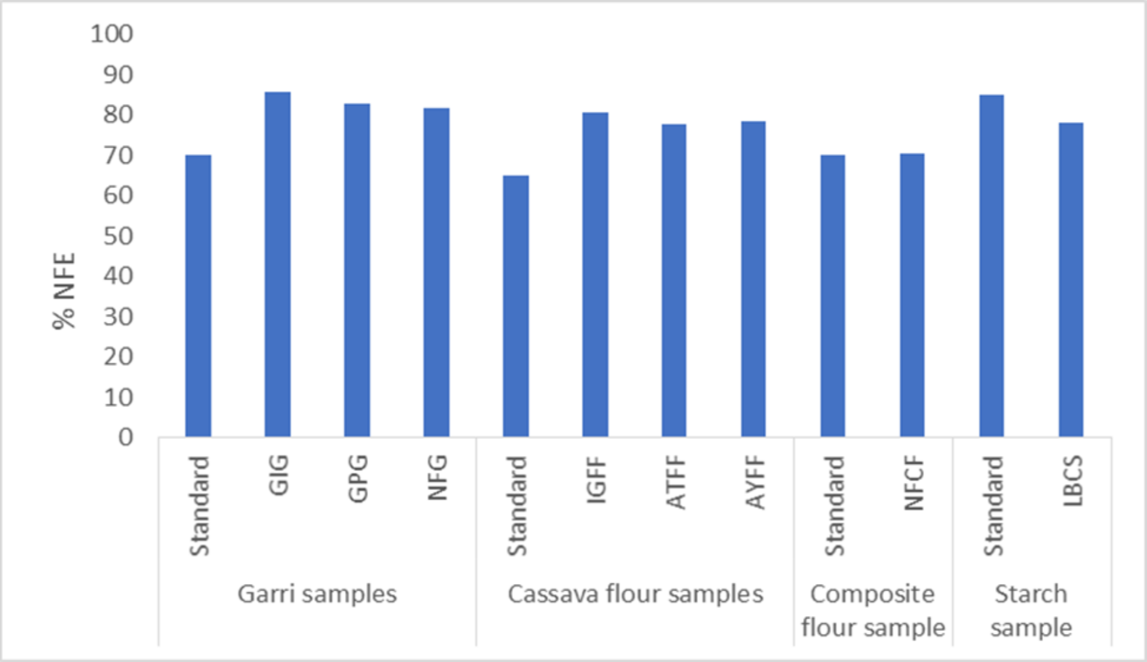

Figure 8: Nitrogen Free Extract (Carbohydrate content) of the eight processed cassava products.

4. CONCLUSION

The eight processed cassava products showed more comparable results with each other based on the analyzed nutritional composition implying that the various methods of processing and genotypic nature of the raw forms of the cassava samples affected the nutritional contents of the products respectively. All samples showed crude fibre contents within the recommended levels and protein contents above the recommended limits of SON. The moisture contents of all the samples except that of ATFF were within the standard limits of SON and FAO/WHO implying that the products will all have a longer shelf life except ATFF which may have a shorter shelf life since the moisture content is greater than 12 % as recommended by CODEX Alimentarius and SON. The present study also revealed that the possibility of formation of metal ion-pigment complexes in GIG, AYFF, NFCF and LBCS is high due to high ash contents and may affect the primary desirable quality of flours and starch (AYFF, NFCF and LBCS) suitable for use in the food and non-food industry. Furthermore, IGFF, AYFF, NFCF and LBCS had high fat contents while GIG, GPG and NFG had relatively lower fat contents. The carbohydrate contents of all samples were within acceptable ranges except for LBCS which had a carbohydrate content lower than the minimum carbohydrate level recommended by the benchmark used in this study.

5. RECOMMENDATIONS

i. Enhanced and strategic effort should be made by the relevant agencies of the government in Nigeria such as National Agency for Food and Drug Administration Control (NAFDAC) to educate the local manufacturers on the modern techniques of cassava processing and the health risk posed to the consumers for adopting short-cut processing techniques.

ii. Regular routine monitoring of proximate composition and cyanide levels in cassava products should be conducted to avoid sharp practices.

iii. Studies should be carried out on new and existing processed cassava products available in other local markets in Nigeria.

iv. Researches on modern ways to completely eliminate cyanide in processed cassava products should be aggressively undertaken and funded adequately.

v. Enlightenment and awareness campaigns should be carried out to sensitize farmers who cultivate cassava on the need to use more improved varieties and cultivation methods to further minimize the production of raw cassava roots with poor nutritional quality and high cyanide content.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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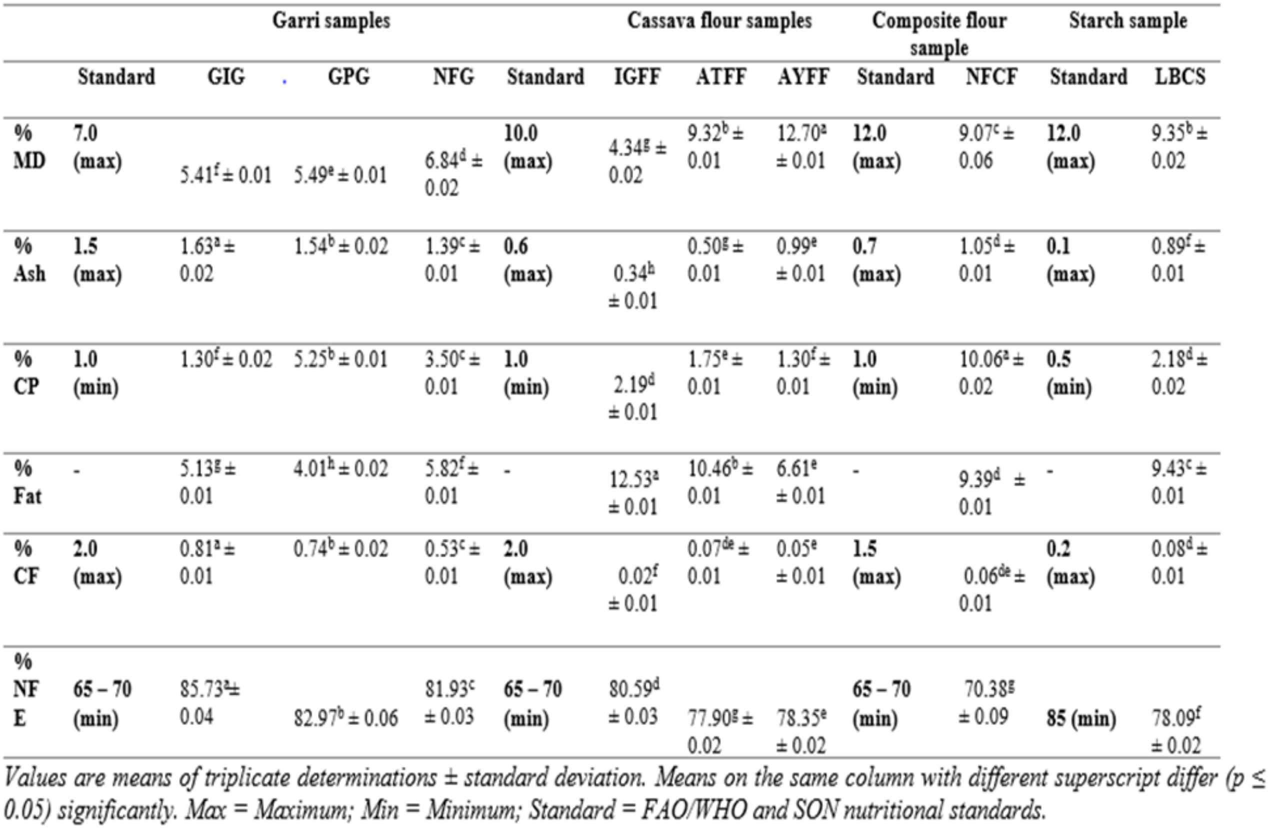
APPENDIX

Table 1. Proximate composition of the processed cassava products



	Garri samples				Cassava flour samples				Composite flour sample		Starch sample	
	Standard	GIG	GPG	NFG	Standard	IGFF	ATFF	AYFF	Standard	NFCF	Standard	LBCS
% MD	**7.0 (max)**	$5.41^{f} \pm 0.01$	$5.49^{e} \pm 0.01$	$6.84^{d} \pm 0.02$	**10.0 (max)**	$4.34^{g} \pm 0.02$	$9.32^{b} \pm 0.01$	$12.70^{a} \pm 0.01$	**12.0 (max)**	$9.07^{c} \pm 0.06$	**12.0 (max)**	$9.35^{b} \pm 0.02$
% Ash	**1.5 (max)**	$1.63^{a} \pm 0.02$	$1.54^{b} \pm 0.02$	$1.39^{c} \pm 0.01$	**0.6 (max)**	$0.34^{h} \pm 0.01$	$0.50^{g} \pm 0.01$	$0.99^{e} \pm 0.01$	**0.7 (max)**	$1.05^{d} \pm 0.01$	**0.1 (max)**	$0.89^{f} \pm 0.01$
% CP	**1.0 (min)**	$1.30^{f} \pm 0.02$	$5.25^{b} \pm 0.01$	$3.50^{c} \pm 0.01$	**1.0 (min)**	$2.19^{d} \pm 0.01$	$1.75^{e} \pm 0.01$	$1.30^{f} \pm 0.01$	**1.0 (min)**	$10.06^{a} \pm 0.02$	**0.5 (min)**	$2.18^{d} \pm 0.02$
% Fat	-	$5.13^{g} \pm 0.01$	$4.01^{h} \pm 0.02$	$5.82^{f} \pm 0.01$	-	$12.53^{a} \pm 0.01$	$10.46^{b} \pm 0.01$	$6.61^{e} \pm 0.01$	-	$9.39^{d} \pm 0.01$	-	$9.43^{c} \pm 0.01$
% CF	**2.0 (max)**	$0.81^{a} \pm 0.01$	$0.74^{b} \pm 0.02$	$0.53^{c} \pm 0.01$	**2.0 (max)**	$0.02^{f} \pm 0.01$	$0.07^{de} \pm 0.01$	$0.05^{e} \pm 0.01$	**1.5 (max)**	$0.06^{de} \pm 0.01$	**0.2 (max)**	$0.08^{d} \pm 0.01$
% NFE	**65 – 70 (min)**	$85.73^{a} \pm 0.04$	$82.97^{b} \pm 0.06$	$81.93^{c} \pm 0.03$	**65 – 70 (min)**	$80.59^{d} \pm 0.03$	$77.90^{g} \pm 0.02$	$78.35^{e} \pm 0.02$	**65 – 70 (min)**	$70.38^{g} \pm 0.09$	**85 (min)**	$78.09^{f} \pm 0.02$

Values are means of triplicate determinations ± standard deviation. Means on the same column with different superscript differ ($p \leq 0.05$) significantly. Max = Maximum; Min = Minimum; Standard = FAO/WHO and SON nutritional standards.