

Effect of Local Processing Techniques on the Nutrients and Anti-Nutrients Content of Bitter Cassava (*Manihot Esculenta Crantz*)

Ismaila A R^{1,*}, Alakali J S², Atume T G²

¹Department of Food Science and Technology, Federal University Dutsin-Ma, Nigeria
²Department of Food Science and Technology, University of Agriculture Makurdi, Nigeria
*Corresponding author: aismaila1@fudutsinma.edu.ng

Abstract The effects of local processing techniques on the nutrients and anti-nutrients content of bitter cassava were investigated. Raw bitter cassava tubers were boiled to produce (Rogo), sundried to produce (chips), roasted to produce (roasted chips), fried to produce (Kuese), partially fermented and sun dried to produce (Elubo), fermented by submersion to produce (Akpu) and finally, fermented by solid state to produce (yellow and white Gari). All these locally processed cassava products were subjected to proximate, mineral and anti-nutrient analysis using standard methods. The result of the proximate showed that, raw bitter cassava is composed of 1.85% ash, 64.38% moisture, 4.11% crude fibre, 1.03% crude protein, 0.66% lipids and 30.88% total carbohydrate. Mineral analysis of the raw bitter cassava tuber contained 32.00mg/100g Calcium, 12.55mg/100g Magnesium, 1.38mg/100g Iron and 80.17mg/100g Phosphorous. Even though all processing techniques significantly expose more of the the mineral content, fermentation had highest effect. The anti-nutrients analysis showed that the raw peeled tuber contained 98.16mg/100g cyanide, 44.00mg/100g oxalate 304.20mg/100g phytate and 73.00mg/100g saponin. In general all the processing techniques showed a significant reduction of the phytate, oxalate and saponin content of the cassava. However, only fermentation, sun drying and garification were able to reduce the cyanide content of bitter cassava below the safe level (10mg/100g) recommended by Standard Organization of Nigeria. Yellow gari(with the addition of palm oil) showed low cyanide content (1.10 mg/100g) than white gari (3.51 mg/100g). This also emphasis that processing methods involving fermentation reduce cyanide and other anti-nutrients in the cassava to levels that are safe for consumption and should be widely practiced.

Keywords: bitter cassava, local processing, fermentation, proximate, anti-nutrient

Cite This Article: Ismaila A R, Alakali J S, and Atume T G, "Effect of Local Processing Techniques on the Nutrients and Anti-Nutrients Content of Bitter Cassava (*Manihot Esculenta Crantz*)." *American Journal of Food Science and Technology*, vol. 6, no. 3 (2018): 92-97. doi: 10.12691/ajfst-6-3-1.

1. Introduction

Cassava (*Mainihot esculenta Crantz*) is one of the most important food plants in the world. It is grown throughout South America, Africa and Asia. In Africa, cassava was the crop with the highest total production with 118 million metric tons of productions across the continent in 2010, contributing significant energy input to the population, with an average of 196 kcal/capita/day in 2008 [1].

Cassava is processed into variety of products which are widely consumed in Nigeria. Its products are also consumed in many parts of the world such as the Asian and Latin American countries. It is a major component in Nigerian diet and an excellent source of dietary energy, being a primary and typical source of carbohydrates [2].

The nutrients composition of cassava and some cassava products have been well documented. Although cassava is of lower nutritional value than cereals, legumes, and even some other root and tuber crops such as yams, Cassava root contains significant amount of iron,

phosphorus, calcium and vitamin C, but is a poor source of protein [3].

One major factor which limits or affects the utilization of cassava as a food for man and animal is its content of the toxic hydrogen cyanide in both free and bound forms. The bound forms, known as cyanogenic glycosides, occur as linamarin and lotaustralin. When subjected to an appropriate processing technique, these glycosides release hydrogen cyanide. If this reaction takes place in the human system, cyanide toxicity results, the degree of which depends on the quantity of cyanide released. The outcome of cyanide toxicity can be instant death or it may be manifested by several diseases and disorders which may also result in death if untreated [4].

In order to avoid and mitigate dietary cyanide exposure, the glycosides and their metabolites, collectively known as cyanogens, must be removed by processing before consumption. Effective cassava processing methods disintegrate the root tissue completely by releasing an endogenous enzyme, linamarase; this endogenous β -glucosidase enables the hydrolysis of linamarin into glucose and ace-tone cyanohydrins [5]. These chemical

components will decompose above p^H 6 into volatile hydrogen cyanide (HCN) that is rapidly lost from the system [6]. Some of the processing techniques generally adopted in Nigeria include boiling, roasting, sun drying, frying, grating, and fermentation. In the production of certain cassava products such as gari, a combination of two or more processing techniques is required [7].

The ability of these processing techniques to remove the cyanide content of cassava roots varies greatly, some techniques remove nearly all residual cyanogens [8] but many techniques leave appreciable amounts of cyanogens behind [9]. Therefore, there is great need for development of improved processing methods for adequate detoxification of cassava, especially for populations feeding mostly on cassava products. To standardize the techniques, it is necessary to start by evaluating the effectiveness of the traditional and simple methods that are used by local cassava products producers. Therefore, the aim of this research is to evaluate the effect of local processing techniques on the nutrients and anti-nutrients content of bitter cassava.

2. Materials & Methods

2.1. Source of Materials

Twelve (12) months fresh Ya Kpe bitter cassava tubers were collected from a farm in Atule-Nor village of the Turan district in Kwande local government of Benue State, Nigeria.

2.2. Reagents

The following reagents were used in this project: distilled water, orthophosphoric acid (H_2PO_4), ammonia solution, potassium Iodide (KI), silver nitrate ($AgNO_3$), Hydrochloric acid (HCl), Ammonium Thiocyanate solution, iron chloride solution, diethyl ether, acetic acid, aqueous acetone, sodium carbonate solution calcium chloride and potassium tetraoxomagnese (vi) ($KMnO_4$).

2.3. Samples Preparation

100kg raw bitter cassava tubers were peeled and washed with tap water and allowed to dry. 2kg of cleaned fresh cassava was fetched from the whole lot to serve as control while 2kg each from the remaining cleaned fresh cassava was further subjected to varying processing condition and the product obtained therein were prepared for analysis.

2.4. Boiling

The cassava root was peeled, washed, sliced and boiled for 40 minutes at a temperature range of 86 – 100°C using tap water.

2.5. Frying

A cassava product that is locally consumed in the district (Kuese), was prepared here. The cassava tuber was peeled, washed, grated, partially dehydrated, molded into a desired shape and was fried using palm oil. However, no other ingredient was added.

2.6. Gari Production

Gari production involves several processing unit operations and the effect of each processing operation on the cyanide and anti-nutrient content was evaluated.

The cassava root was peeled, washed and grated using a 10mm size grater. The grated cassava was allowed to ferment for 72 hours (3 days) after which it was divided into two (2) equal portions of 10Kg. palm oil was added to one of the portions to produce yellow gari while none was added to the other portion to yield white gari. The two gari portions were separately dehydrated by continuous pressing until little or no water was observed coming out of the cassava. The dehydrated cassava was then sieved using a 0.1mm sieve before toasting.

2.7. Partial Fermentation and Sun Drying

The cassava tuber was peeled, sliced, washed and fermented in a closed plastic bucket for 24 hours. The partially fermented cassava was then sundried for two three weeks.

2.8. Submerged Fermentation (Akpu Production)

The cassava product was peeled, cut into smaller sizes of about 2cm, washed and fermented in a covered plastic bucket using tap water. After 72 hours of spontaneous fermentation, the fermented cassava was sieved with a 0.5mm size plastic basket. The filtrate was collected after the coagulation and decantation of the supernatant water.

3. Analytical Methods

3.1. Proximate Composition

Proximate analysis was done to determine nutrient composition of Ya kpe bitter cassava. The Moisture, Ash, Protein, Crude fiber, fat and carbohydrate content of the tuber was determined using the analytical method described by [10].

3.2. Mineral Analysis

The method described by [10] was adopted for analysis of minerals.

3.3. Anti-nutrient Analysis

3.3.1. Determination of Cyanide

The alkaline titration method of analyzing cyanide as described by [10] was adopted.

3.3.2. Determination of Phytate

The phytic acid was determined using the procedure described by [11].

3.3.3. Determination of OXALATE

Oxalate was determined using the method of [12].

3.3.4. Determination of Saponins

The method described by [11] was adopted.

3.5. Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA) and means of data found to be significantly different ($P < 0.05$) were separated using least significant difference as recommended by [13] using SPSS version 17.0.

4. Results & Discussion

The result of proximate analysis of locally processed bitter cassava products is as presented in Table 1. The components determined were: moisture content, protein, lipids, ash, carbohydrate and crude fibre. The moisture content of the raw bitter cassava was $64.38 \pm 0.00\%$ which is in range with the moisture content of raw bitter cassava tubers as reported by [14]. The result showed that, the solid state fermentation method used in the production of gari had the highest moisture reduction effect on the cassava. The addition of palm oil had no significant effect on the moisture content reduction as yellow and white gari had moisture contents of $5.00 \pm 0.00\%$ and $6.01 \pm 0.00\%$. This result compares reasonably well with the 12% maximum moisture content recommended for shelf stable gari as reported by [15]. Partially fermenting the bitter cassava before sun drying and sun drying the cassava without fermenting showed a reasonable reduction in the moisture content of the cassava to $7.06 \pm 0.01\%$ and $7.09 \pm 0.01\%$ respectively which are not significantly different. This result also showed that, bitter cassava chips fermented partially before sun drying and that which is sun dried without fermenting can be safely stored as they compare reasonably well with the 11.4% maximum moisture recommended for safe storage of cassava chips [16]. Frying and roasting reduces the moisture content of bitter cassava to levels that are significantly different ($13.08 \pm 0.001\%$ and $17.60 \pm 0.04\%$ respectively). [7] had earlier reported that frying is a more effective method of moisture removal than roasting. [18] defined ash content of food as an indication of the mineral content of the food product. The result showed that, bitter cassava contains low ash ($1.05 \pm 0.00\%$), compared with the 2.30% of the sweet cassava variety reported by [18]. This signifies the low mineral content of bitter cassava varieties as reported by [19]. The result of ash content also agrees with [19], who reported that frying, roasting, and solid state fermentation (with or without the addition of palm oil) could not significantly affect the ash content of the bitter cassava. This could be attributed to the inability of these processing techniques to increase or reduce the bulk of the cassava tuber during processing. Cassava processed by submerged fermentation had decreased ash content. Partially fermented and sun dried cassava had the same ash content as cassava sun dried without fermenting ($2.01 \pm 0.01\%$). The yellow and white gari samples produced by solid state fermentation had increased ash content ($2.36 \pm 0.01\%$ and $2.35 \pm 0.00\%$) which were not significantly different. The increase in ash content of sundried, solid state fermented cassava products had been attributed to the loss of moisture content of the samples and an increased concentration of carbohydrate within the samples. The crude fibre content of raw bitter cassava was high (4.11 ± 0.01). This was as a result of high

cellulose content of the bitter cassava variety [20]. The result showed that, boiling, frying, roasting and sun drying of the Ya kpe bitter cassava does not significantly affect its crude fibre content. The results of the effects of these processing techniques on the crude fibre content of fresh bitter cassava tuber were within the normal range for bitter cassava varieties as reported by [20]. The crude protein content of the bitter cassava tuber ($1.03 \pm 0.00\%$) was higher than the 0.98% reported for bitter cassava varieties by [19]. This is an indication that, the ya kpe bitter cassava variety used for the analysis contains more nitrogenous substances than other bitter cassava varieties. The result indicated that, addition of palm oil to gari during fermentation was the only local processing technique that created a significant effect on the crude protein content of bitter cassava products as the protein content of yellow gari produced increased from $1.03 \pm 0.00\%$ to $1.22 \pm 0.01\%$. The lipid content of the bitter cassava was very low ($0.66 \pm 0.01\%$). This result agrees with the findings y (20) that bitter cassava is a poor source of lipid since the lipid content of several varieties of bitter cassava are less than 1%. The result showed that, processing techniques that involved the addition or interaction of the bitter cassava pulp with palm oil increased the lipid content of the cassava product significantly. Frying of grated cassava in palm oil increased its lipid content to a higher concentration ($1.04 \pm 0.03\%$) compared to the addition of palm oil to the grated cassava which increased the lipid concentration to a lesser level ($0.99 \pm 0.01\%$). This result agrees with that by [21] who reported that, the higher oil concentration and higher frying temperatures could be responsible for the higher lipid concentration in frying than in yellow gari where a little palm oil is added and garification is done at a comparatively lower temperature. As shown by the result, other local processing techniques such as boiling, frying, roasting and sun drying which does not involve fermentation had no significant effect on the lipid content of the bitter cassava. Like all other varieties of cassava, bitter cassava had a high total carbohydrate concentration of $30.88 \pm 0.00\%$. Local processing methods produced varying degrees of significant effects on the total carbohydrate content of the cassava. In submerged fermented cassava (Akpu), boiled cassava and solid state fermented cassava (gari), a considerable amount of starch is lost during processing and the total carbohydrate content of the products are lowered to significantly different levels of $46.56 \pm 0.00\%$, $51.23 \pm 0.01\%$ and $55.08 \pm 0.01\%$ respectively. However, Sun drying of the cassava chips promoted the removal of moisture, thus increasing the concentration of carbohydrates in the cassava chips to $85.15 \pm 0.01\%$. This explains why the total carbohydrate content of sun dried cassava increased significantly in the result above.

Table 2 showed the result of some mineral analysis of locally processed bitter cassava. Selected minerals that were analysed for are: Calcium, Magnesium, Iron and phosphorous. These minerals were selected because they are the dominant minerals in a cassava tuber [21]. The result showed that, the mineral composition of bitter cassava is low as compared to earlier reports by researchers. [22] reported that, the calcium, iron, phosphorous and magnesium content of most bitter cassava varieties

were 46.02mg/100g, 2.11mg/100g, 98.45mg/100g and 17.64mg/100g respectively which is much higher than the 32.00mg/100g, 1.38mg/100g, 80.17mg/100g and 12.55g shown by the result of the bitter cassava analysis in this study. This lower concentration of minerals in bitter cassava could be due to the higher concentration of anti-nutrients such as phytates, oxalates and saponins in the cassava which forms insoluble complexes with the minerals preventing their availability. [22] had earlier reported the nutrient binding activity of anti-nutrients such as oxalates, phytates and saponin. The calcium and magnesium content of the bitter cassava was low due to the high concentration of oxalate in the tuber. Oxalate is the major anti-nutrient that binds calcium and magnesium ions to form complexes. In this regard, the efficiency of any processing technique to significantly affect the concentration of magnesium and calcium in the cassava tuber depends on its ability to degrade or hydrolyze the oxalate-calcium and oxalate-magnesium complexes [18]. The result showed that, techniques involving the fermentation of cassava had the best degradation effect on the complexes, hence, the best calcium and magnesium increasing effect on the cassava. Complete fermentation of the cassava in tap water for three days (Akpu) had the highest calcium and magnesium increasing effect which was followed by the solid state fermented gari products (irrespective of the addition of palm oil). The differences in the ability of these processing techniques to hydrolyse oxalate have been earlier explained by [23] that, processing techniques involving fermentation had the best hydrolytic effect on the anti-nutrient complexes formed within the product and that the degree of hydrolysis of the anti-nutrient complex depends on the interval of fermentation. Other processing techniques also hydrolysed oxalate at lesser levels to release calcium and magnesium. Boiling is more efficient than roasting and sun drying. Iron is required for the synthesis of haemoglobin and myoglobin, which are oxygen carriers in the blood and muscles respectively [24]. The daily iron requirement for men and non-menstruating and pregnant women is 18mg (FAO). The iron content of cassava is low ($1.38\pm 0.01\text{mg}/100\text{g}$) which falls short of the 2.00 mg/100g reported to be present in other bitter cassava varieties by [20]. Submerged fermented cassava had the highest iron concentration ($2.80\pm 0.00\text{mg}/100\text{g}$). Solid state fermentation also increased the iron concentration of the cassava to $1.95\pm 0.03\text{mg}/100\text{g}$ while partial fermentation that was followed by sun drying increased the concentration of iron to $1.84\pm 0.03\text{mg}/100\text{g}$. Other processing techniques such as frying, roasting, sun drying and boiling had no significant effect on the iron content of the bitter cassava. The phosphorous content of bitter cassava was also low ($80.17\pm 0.04\text{mg}/100\text{g}$) due to the high concentration of phytate in the cassava. The result in table two (2) showed that, solid state fermentation of the cassava produced the highest increase in the phosphorous content of the cassava products ($91.10\pm 0.03\text{mg}/100\text{g}$) and that, the addition of palm oil to the cassava does not create a significant difference in the phosphorous content of the two gari samples produced. Submerged fermentation also showed significant increase in the phosphorous content of the cassava tuber ($90.77\pm 0.04\text{mg}/100\text{g}$) which signifies

the effectiveness of fermentation methods in hydrolysing phytate as earlier reported by [20]. Sun drying and boiling of the bitter cassava tuber increased its phosphorous content to a level that is significantly different from that of the fresh tuber but contrary to the findings by [20], the result showed that, frying and roasting of the cassava increased its phosphorous content to a level that is not significantly different from the fresh tuber.

The result of some anti-nutrients found in bitter cassava which were analysed is as shown in Table 3. The result showed that, the concentration of anti-nutritional substances such as cyanogenic glycoside, oxalate, phytate and saponin in bitter cassava was high. This explains why the mineral concentration of the bitter cassava variety is lower when compared to the sweet cassava variety and even other sub-varieties within the bitter cassava variety. The result also showed the ability of some processing techniques to effectively reduce the concentration of these anti-nutrients during processing. [25] and [26] in their separate works confirmed that, the concentration of anti-nutrients in consumable food stuffs is reduced to varying degrees by processing methods during processing. Cyanide, a toxic compound present in the bitter cassava was reduced to varying degrees by different local processing techniques. The result showed that, methods involving fermentation of the cassava had the highest cyanide reduction effect and were the only processing techniques that reduced the cyanide content of the cassava to a level that met the 10mg HCN equivalent per 100g maximum cyanide tolerated in consumable food products as stipulated by the standard organization of Nigeria (SON). [15] reported that, unlike gari products that were not adequately fermented, properly fermented gari sold in Makurdi had low cyanide content that meet the regulatory standards. The result of analyses indicates that, gari production which involved numerous processing techniques such as grating, fermenting, drying and frying had the highest cyanide reduction effect. Yellow gari which was produced with the addition of palm oil reduced cyanide to a lower concentration ($1.10\pm 0.02\text{mg}/100\text{g}$) than white gari which was produced without the addition of palm oil ($3.51\pm 0.01\text{mg}/100\text{g}$). This result is in agreement with published reports that the addition of palm oil to the pulp during gari processing facilitates the reduction in cyanide levels of the product [14] and [15]. The result also showed that, the concentration of cyanide in white gari ($3.51\pm 0.01\text{mg}/100\text{g}$) and Akpu produced by submerged fermentation ($3.62\pm 0.01\text{mg}/100\text{g}$) were not significantly different. Unlike other processing techniques involving fermentation, partial fermentation of the cassava tuber for one day followed by sun drying had a comparatively higher concentration of cyanide ($7.44\pm 0.03\text{mg}/100\text{g}$) which reflects the effect of fermentation time on the anti-nutrient content reduction of food products. [27] reported that, fermented products which had enough fermentation time had the opportunity for their bond cyanide to be hydrolysed and distributed to different forms and the volatile hydrocyanic acid which escapes freely to the atmosphere. [17] also reported that, the enzyme linamarase had more time to hydrolyze bond cyanide in a product when fermented for at least 3 days.

Table 1. The Proximate composition of locally processed bitter cassava products

Samples	Nutrient composition (%)					
	Ash	Moisture	Crude fibre	Crude protein	Lipids	Total CHO
A	1.05±0.00 ^b	64.38±0.00 ^e	4.11±0.01 ^c	1.03±0.00 ^a	0.36±0.01 ^a	30.88±0.00 ^c
B	1.14±0.01 ^b	13.08±0.01 ^c	4.10±0.01 ^c	1.04±0.03 ^a	1.04±0.03 ^c	72.81±0.04 ^e
C	1.15±0.01 ^b	17.60±0.04 ^d	4.10±0.01 ^c	1.04±0.01 ^a	0.65±0.01 ^a	70.68±0.01 ^d
D	1.01±0.01 ^c	7.09±0.01 ^b	4.21±0.00 ^c	1.04±0.01 ^a	0.65±0.00 ^a	87.15±0.01 ^f
E	0.75±0.00 ^b	60.05±0.01 ^f	4.19±0.00 ^c	0.94±0.01 ^a	0.15±0.01 ^a	51.23±0.01 ^b
F	1.03±0.03 ^a	26.51±0.01 ^e	4.54±0.03 ^a	1.06±0.01 ^a	0.64±0.01 ^a	46.56±0.03 ^a
G	2.01±0.01 ^c	7.06±0.01 ^b	3.89±0.01 ^b	1.06±0.01 ^a	0.65±0.01 ^a	85.20±0.01 ^f
H	2.36±0.01 ^d	5.00±0.00 ^a	4.20±0.01 ^d	1.22±0.01 ^b	0.99±0.01 ^b	58.31±0.01 ^e
I	2.35±0.00 ^d	6.01±0.01 ^a	4.20±0.01 ^d	1.06±0.01 ^a	0.64±0.01 ^a	58.42±0.01 ^e
LSD	0.03	1.06	0.03	0.02	0.03	0.05

Values are means ± standard deviation from triplicate determinations.

Means within the same column with same superscript are not significantly different (p<0.05).

KEY:

Sample **A**= fresh unprocessed tuber, **B**=grated and fried cassava (Kuese), **C**= Roasted cassava tuber, **D**=Sundried cassava chips, **E**= boiled cassava tuber, **F**= Submerged fermented cassava (Akpu), **G**=partially fermented and sundried cassava (Alubo), **H**=Solid state fermented, palm oiled and fried cassava (yellow gari), **I**=Solid state fermented and fried cassava (White gari).

Table 2. Effect of local processing techniques on the mineral content of bitter cassava products

Samples	Amount of mineral contained (mg/100g)			
	Calcium (Ca)	Magnesium (Mg)	Iron (Fe)	Phosphorous (P)
A	32.00±0.01 ^a	12.55±0.01 ^a	1.38±0.01 ^a	80.17±0.01 ^a
B	49.92±0.02 ^e	19.79±0.01 ^d	.39±0.01 ^a	82.06±0.01 ^b
C	47.20±0.03 ^c	18.91±0.00 ^c	1.38±0.01 ^a	82.09±0.03 ^b
D	46.01±0.01 ^b	17.30±0.01 ^b	1.41±0.01 ^a	84.16±0.01 ^c
E	49.86±0.02 ^d	18.99±0.01 ^c	1.38±0.00 ^a	84.20±0.01 ^d
F	63.72±0.01 ^h	35.06±0.01 ^g	2.80±0.00 ^d	90.77±0.04 ^f
G	54.39±0.01 ^g	29.00±0.05 ^f	1.84±0.03 ^b	86.00±0.02 ^e
H	52.11±0.01 ^f	23.86±0.01 ^e	1.95±0.03 ^c	91.10±0.00 ^e
I	52.10±0.01 ^f	23.84±0.01 ^e	1.93±0.02 ^c	91.11±0.01 ^e
LSD	0.04	0.53	0.04	0.05

Values are means ± standard deviation from triplicate determinations.

Means within the same column with same superscript are not significantly different (p<0.05).

KEY:

Sample **A**= fresh unprocessed tuber, **B**=grated and fried cassava (Kuese), **C**= Roasted cassava tuber, **D**=Sundried cassava chips, **E**= boiled cassava tuber, **F**= Submerged fermented cassava (Akpu), **G**= partially fermented and sundried cassava (Alubo), **H**=Solid state fermented, palm oiled and fried cassava (yellow gari), **I**=Solid state fermented and fried cassava (White gari).

Table 3. Effect of local processing techniques on the anti-nutrients content of bitter cassava products

Samples	Amount of Anti-nutrientretained (mg/100g)			
	Cyanide	Oxalate	phytate	Saponnin
A	98.16±0.01 ^h	44.00±0.01 ^g	304.20±0.09 ^h	73.00±0.01 ^g
B	67.86±0.07 ^f	16.85±0.01 ^d	211.60±0.03 ^g	34.03±0.05 ^d
C	74.59±0.01 ^g	18.98±0.02 ^e	209.00±0.01 ^f	35.45±0.04 ^e
D	18.86±0.03 ^d	19.09±0.02 ^f	101.03±0.01 ^d	43.20±0.00 ^f
E	59.48±0.02 ^e	16.83±0.01 ^d	135.06±0.02 ^e	32.10±0.04 ^c
F	3.62±0.01 ^b	6.20±0.00 ^a	24.84±0.03 ^b	18.78±0.02 ^a
G	7.44±0.03 ^c	13.02±0.02 ^c	57.07±0.03 ^c	20.99±0.01 ^b
H	1.10±0.02 ^a	7.46±0.01 ^b	18.99±0.01 ^a	19.04±0.02 ^a
I	3.51±0.01 ^b	7.48±0.00 ^b	19.02±0.01 ^a	20.89±0.02 ^b
LSD	0.21	0.03	1.13	0.56

Values are means ± standard deviation from triplicate determinations.

Means within the same column with same superscript are not significantly different (p<0.05).

KEY:

Sample **A**= fresh unprocessed tuber, **B**=grated and fried cassava (Kuese), **C**= Roasted cassava tuber, **D**=Sundried cassava chips, **E**= boiled cassava tuber, **F**= Submerged fermented cassava(Akpu), **G**= partially fermented and sundried cassava (Alubo), **H**=Solid state fermented,palm oiled and fried cassava (yellow gari), **I**=Solid state fermented and fried cassava (White gari).

Other processing techniques such as boiling ($59.48 \pm 0.02 \text{ mg}/100\text{g}$), frying ($67.86 \pm 0.07 \text{ mg}/100\text{g}$) and roasting ($74.59 \pm 0.01 \text{ mg}/100\text{g}$) also reduced the cyanide content of the cassava significantly but the level of cyanide in such products is not safe for consumption. Thus, while processing techniques involving fermentation such as solid state fermentation used for the production of white and yellow gari, submerge fermentation used for the production of Akpu and partial fermentation followed by sun drying used for the production of cassava flour (Alubo) reduced cyanide to levels that are safe for human consumption, processing techniques which does not involve fermentation (i.e boiling, frying, roasting and sundrying) does not reduce cyanide to safe levels and the consumption of such products is a source of danger to health as on there average, their cyanide levels are above the safe level of $10.00 \text{ mg HCN equivalent per } 100\text{g}$ recommended by the standard organization of Nigeria. Phytates, oxalates and saponins usually forms insoluble salts with mineral elements such as Zinc, calcium and iron preventing their utilization [21]. The result of analysis showed that, processing methods involving fermentation created the highest oxalate and phytate degradation effect. [23] explained that, processing techniques involving fermentation are very effective in lowering the anti-nutrient concentration of foods due to the hydrolytic activities of fermentation enzymes on the anti-nutrients and the complexes they form with mineral elements. Submerge fermentation had the highest oxalate, phytate and saponin reduction effects due to the fermentation time of its products. Other processing techniques such as boiling, frying, roasting and sun drying had also shown a significant degradation activity on these anti-nutrients. These processing effects is reflected in the release of various nutrients contained in the cassava tuber but were bounded as shown in Table 3.

5. Conclusion

The result of the study has shown that, high anti-nutrient and toxin content of bitter cassava are reduced at varying level by various local processing techniques employed. Processing techniques such as submerged fermentation for the production of Akpu, solid state fermentation used for gari production and partial fermentation before sun drying are the most effective methods of detoxifying cassava and increased its nutritional value. Other processing methods used such as boiling, frying, sun drying and roasting also reduced the cyanide and anti-nutrient content of the cassava but not to a level that meets the cyanide safety standard of $10 \text{ mg HCN equivalent}/100\text{g}$ in consumable food products set by the standard organization of Nigeria (SON). The study also confirms earlier claims by researchers that yellow gari produced with the addition of palm oil have a lower anti-nutrient content than white gari which is produced without the addition of palm oil.

References

- [1] Food and Agriculture Organization. FAOSTAT. 2010 Rome, Italy.
- [2] Osakwe J.A., Chuku E.C., Harry S.A. Relationship between cyanogens and foliar diseases in cassava (*Manihot Esculentus*). India J. Agric. Sci. 2008; 78: 997-999.
- [3] Charles A.L, Sriroth K, Huang T. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. Food Chem. 2005; 92: 615-620.
- [4] Onabolu, A.; Abass, A.; Bokanga, M. New food products from cassava. IITA: Ibadan, Nigeria. 1998; p 40.
- [5] Conn EE (1969). Cyanogenic glucosides. J. Agric. Food Chem. 1969; 17: 519-526.
- [6] Cooke, R.D. and E.N. Maduagwu, 1985. The Effect of Simple Processing on the Cyanide Content of Cassava Chips. J. Food Tech. 1985; 13: 299-306.
- [7] Nambisan B (2011). Strategies for elimination of cyanogens from cassava for reducing toxicity and improving food safety. Food Chem. Toxicol. 2011; 49: 690-693.
- [8] Nambiscan, B., Sundarsan, S. 1985. Effect of processing on the cyanoglucoside content of cassava. J Sci Food Agric. 1985; 36: 1197-1203.
- [9] Mlingi NLV, Bainbridge ZA, Poultefl NH, Rosling H. Critical stages in cyanogen removal during cassava processing in southern Tanzania. Food Chem. 1995 53: 29-33.
- [10] AOAC. Official Methods of Analysis 15th edn. Washington D. C U.S.A, 1990
- [11] Markkar, H.P.S., M. Blummer, N.K. Browy and K. Becker, 1993. Gravimetric of Tannins and their correlation with chemical and protein precipitation methods. J. Sci. Food Agr.1993; 61: 161-165.
- [12] Oke, O.L., 1969. Chemical studies on some Nigerian foodstuffs. Latum W. Afr. J. Biol. Appl. Chem.1969; 8: 53-56.
- [13] Duncan, D. B. Multiple Range and Multiple F tests. *Biometrics*,1955; 11
- [14] Ihekoronye, A.I. and Ngoddy P.O. Integrated Food Science and Technology for tropics. Macmillan publisher Ltd, London. 1985.
- [15] Abu J.O, Badifu G.T.O, Akpapunam M.A. Effect of Crude palm oil inclusion on some physicochemical properties of gari –A fermented cassava Food product. Nig. Food J. 2006; 24(1): 73-75.
- [16] Chijioke, A., A. Aderibigbe, T. O. Olarenwaju, A. M. Makusidi, and A. E. Oguntoyinbo. Prevalence and pattern of cystic kidney diseases in Ilorin, Nigeria. *Saudi J. Kidney Dis. Transplant*. 2010; 21: 1172-1178.
- [17] Asegbeloyin, J.N. and Onyimonyi, A.E. The effect of different processing methods on the residual cyanide of Garri .Pakistan. Journal of. Nutrition., 2007; 62: 163-166.
- [18] Adeleke, R. O., and J. O. Odedeji. Functional properties of wheat and sweet potato flour blends. *Pak. J. Nutr*. 2010; 9: 535.
- [19] Frederick, D.O. and H. Hominy. Soul Food from Africa to America, Columbia University Press, Chap: 1-2. 2008.
- [20] Kadashi, Y.D. Vitamin and Minerals Nutritional Foods in Nigeria. De-peak Publishers, Kaduna. 2005.
- [21] Sarkiyayi, S. and Agar, T. M. Comparative analysis on the nutritional and antinutritional contents of the sweet and bitter cassava varieties. *Advance Journal of Food Science and Technology*, 2010; 2 (6): 328-334.
- [22] Amira, P. O., Daramola, S.A and Atolani, S. T. Effect of drying on some anti-nutritional factors resent in Bitter Cassava (*Manihot utilisima*) and Sweet Cassava (*Manihot palmata*). *International Journal of Engineering Science and Innovation Technology*, 2014; 3(4): 368-372.
- [23] Gilani, G.S., K.A. Cockell and E. Sepehr. Effects of Antinutritional factors on protein digestibility and amino acid available in foods. *J. AOAC Int*. 2005; 88(3): 967-987.
- [24] Davidson, A.H. and G.M. Stanley. Human Nutrition and Dietetics, 6th Edn., Longman, London, pp: 208-305. 1975.
- [25] Aregheore, E.M. and O.O. Agunbiader. The toxic effects of cassava diet on human. *Vet. Hum. Toxicol*. 1991; 33: 274-275.
- [26] Agte VV, Tarwadi KV, Chipplonkar SA . Phytate Degradation during Traditional cooking: Significance of the phytic acid profile in cereal based Vegetarian meals. *J. Food Anal*. 1999; 12: 161-167.
- [27] Maduagwu, E. N. and Oben, D. H. E. (2007). Effects of processing of grated cassava roots by the 'screw press' and by traditional fermentation methods on the cyanide content of gari. *International Journal of Food Science & Technology*, 2007; 16(3): 299-302.