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PROCESSING AND STORAGE IMPACT ON CAROTENOID CONTENTS AND FUNCTIONAL PROPERTIES OF YELLOW CASSAVA TRADITIONAL FOOD PRODUCTS

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ABSTRACT

This study determined the carotenoid content, functional properties and sensory qualities of seven cassava products (Dried chips, Attieke, Chickwangue, Fufu, Gari, Lafun and Pupuru) obtained from yellow fleshed biofortified cassava varieties (TMS 01/1371, TMS 01/1412 and TMS 01/1368) before and after processing over a 3months period of storage. Cassava products obtained from the three varieties were analysed and compared with non biofortified products. Bulk density was highest at 0.92 $g^{-1}ml$ in variety TMS01/1412 and lowest at 0.57 $g^{-1}ml$ in TMS 01/1371. Swelling capacity ranged from 25.67-51.33% while Water absorption capacity ranged from 19.33-75.33% across all the biofortified products. Carotenoid content decreased after processing and even much more after storage but modest retention recorded in variety TMS 1368. Retention of total carotenoid after the storage period was highest in Chickwangue (95%) and Fufu (92%) for variety TMS01/1368 and lowest in lafun from TMS 01/1371(25%). Overall acceptance of food products from variety 01/1368 was significantly higher among the samples hence, have potential to be the choice of biofortified cassava variety for production of cassava based food products with high retention of total carotenoid content.

Contribution/Originality: This study contributes to literature on valorization of yellow fleshed biofortified cassava varieties by examining the retention of total carotenoids as well as the functional properties of traditional food products from these yellow varieties for possible industrial application.

1. INTRODUCTION

Many people in countries of sub-Saharan Africa are undernourished with high levels of micronutrient malnutrition threatening the lives of millions of poor households. Olapeju, Ibiyemi, and Sanni (2013). This is due to the fact that the major staples, such as conventional varieties of cassava, are deficient in micronutrients such as vitamin A, iron, and zinc. No continent depends as much on roots and tubers for feeding its population as does Africa (Hillocks, 2002). Consumption of cassava can be as high as 940 g/adult /day fresh weight among resource poor consumers (De Moura et al., 2015). Cassava (*Manihot esculenta* Crantz), grown mainly by small scale farmers, thrives in marginally fertile soils and can tolerate wide range of rainfall. Cassava roots are a rich source of carbohydrate, nutritionally, the root is starchy, and contains about 60-70% moisture and 32-35% total carbohydrate of which 80% is starch with greater proportion of amylopectin (Rawel & Kroll, 2003). It has varying amounts of fat

(0.1-0.3 %), protein (1-3%) and fibre (1.5%) depending on the age and variety (Charles, Sriroth, & Huang, 2005). The new biofortified cassava varieties released in Nigeria contain up to 15 mg/kg carotenoid content on fresh weight basis and has the potential of providing up to 25% of daily vitamin A required by the body thereby improving the nutritional status of the consumers and alleviating Vitamin A deficiency (Ferreira et al., 2008; Olapeju et al., 2013).

Cassava bio-fortified with provitamin A carotenoids could be a sustainable approach to control micronutrient malnutrition among African consumers by using some of the most popularly consumed cassava-based food products such as *Fufu*, *Attieke*, *Gari*, *Pupu*ru, *Chickwangue* and *Lafun* as a vehicle. However, the adverse effect of processing on carotenoid retention of cassava food products has been documented by different authors (Chavez et al., 2007; Lawal, Badejo, & Fagbemi, 2015; Taleon, Sumbu, Muzhingi, & Bidiaka, 2019). It is therefore imperative to investigate the impact of processing and storage on retention of carotenoids in newly released varieties of cassava when developed into popular African cassava food products that are gaining more acceptance as well as examine the sensory perception of the products by cassava consumers.

This study was thus carried out to determine the effect of processing and storage on carotenoid content, functional properties and sensorial acceptance of different food products developed from three yellow-fleshed biofortified cassava cultivars.

2. MATERIALS AND METHODS

2.1. Source of Materials

Three yellow-fleshed low cyanide pro-Vitamin A carotenoids bio-fortified cassava roots varieties: UMUCASS 36 (TMS 01/1368), UMUCASS 37 (TMS 01/1412) and UMUCASS 38 (TMS 01/1371) and white low cyanide root variety, TMS 30572 from the Teaching and Research farms of Federal University of Technology Akure (FUTA), Federal College of Agriculture (FECA) Akure and the International Institute of Tropical Agriculture (IITA) in Ibadan South-West, Nigeria were selected for this study.

2.2. Processing of Cassava

The yellow fleshed cassava tubers were washed, peeled and sliced to 5 mm thickness before being subjected to traditional processing techniques to produce seven different products: Dried chips, Attieke, Chickwangue, Fufu, gari, Lafun, and Pupuru. All sample were prepared under strict hygienic conditions according to the method of IITA research guide publication (Hahn, 1997). The flow chart of the different processing techniques is found in Figure 1.

Dried chips: The cleaned, washed and sliced cassava roots were dried for 24 hours at 60°c before being milled into flour.

Attieke: Freshly harvested cassava roots were peeled, cut into pieces, washed and milled. The milled mash was left to ferment for three days (Heuberger, 2005) then placed in jute sacks and pressed. The pressed cake was sieved to obtain a fine powder and the hard fibres were manually removed. The granules were formed by shaking and rotating the powder in a large bowl. The small particles agglomerate into round granules of up to 5 mm diameter. The granules were sun-dried for 30mins and steamed using a metallic sieve attached on a cauldron filled with boiling water for 25 minutes.

Chickwangue: Cassava roots were fermented by steeping them in water for five days. The soft roots were then mashed to a pulp and the shafts removed. After kneading, the smooth dough was precooked, wrapped in leaves and steamed to get the final product (Heuberger, 2005).

Fufu: Cassava tubers were peeled cut into small sizes, steeped in water to ferment for three days. At the end of the fermentation, the peels were manually removed. The fermented mass were mashed manually and sieved by adding water to the retted mass to remove the fibres using cheese cloth. After 24hrs the water on top of the sediment was decanted and the remaining mass was de watered using a press and the cake sun dried for 2 days (Lawal et al., 2015).

Gari: Freshly harvested cassava roots were washed, peeled and grated into mash. The mash was packed into sacks and left for 2 days in a fermentation trough to ferment. The fermented mash was placed under hydraulic press to remove the moisture until cake is formed. The fermented cakes were pulverized and sieved to separate the fibrous materials. The pulverized cake was then roasted in a large, shallow stainless steel pan with constant stirring until cream, free-flowing granules were obtained.

Lafun: Fresh cassava roots were manually peeled and cut into chunks before steeping in water for 3days to ferment. The fermented roots were then broken up into small pieces and sun dried for 3 days. The dried pieces were milled into flour. Unlike fufu, the fibres in the retted roots for *Lafun* were dried along with the mash and later sieved out. Thus, *lafun* has more coarse particles than *fufu*.

Pupuru: The cassava roots were peeled, washed, cut into chunks, and steeped in water to ferment for 4 days. The fermented cassava mash was removed from the water into a jute bag to de-water by pressing. The de-watered mass was sifted and later fried on a hot ceramic clay pot before being milled into *pupuru* flour.

Storage of Cassava: The processed cassava products from the pro-Vitamin A cultivars were packaged in separate air tight sealed plastic containers under aseptic conditions for 12 weeks. Samples were taken from each treatment for analysis every 2 weeks until 12-week duration.

2.3. Experimental design

All samples were prepared in triplicates. Reagents were of analytical grade and all experiments were performed in triplicates. The total carotenoids were determined using a spectrophotometer.

2.4. Determination of Functional Properties of cassava food products

2.4.1. Bulk Density

The bulk density was determined using the procedure of Narayana & Narasinga with slight modification. An empty calibrated measuring cylinder was weighed and the weight recorded as W1. Cassava flours were then added to the measuring cylinder and the volume occupied was measured as V while the new weight was recorded as W2. The Bulk density was calculated as shown in the equation below.

The bulk density (g/ml) was computed as:

BD =Mass/Volume

Bulk Density (g/ml) = $\frac{w2-w1}{v}$

2.4.2. Water Absorption Capacity

Each sample (1g) was dispersed in 10ml distilled water. The content was then stirred for 2-3mins using a magnetic stirrer. The sample was then poured into a 50ml centrifuge tube and then centrifuged at 1500rpm for 30mins.

At the end of the centrifuging the sample in the tubes were allowed to stabilize and the supernatant of each tubes were carefully drained into a graduated measuring cylinder of 10ml. The volume of the supernatant was noted, the density of water was then assumed to be 1g/ml.

2.4.3. Swelling Index Determination

The swelling index of the samples was determined as described by Ukpabi and Ndimele (1990). Each sample (25g) was put in a 210ml measuring cylinder, stirred with 150ml of cold water and allowed to stand for four hours before observing the level of swelling.

2.4.4. Determination of Total Carotenoid Content of Cassava Food Products

The total Carotenoid content of the samples was determined using the extraction method described by Rodriguez-Amaya with some modifications. Each sample was homogenized and 10 g of sample mixed with 3 g of Celite and 25 mL of acetone was pounded with a pestle for 3 min before transferring into a filter funnel. Complete removal of carotenoids from the filter

Funnel was done by addition of 30 mL of acetone. Filtered extract was placed into a 500 mL separating funnel with 40 mL of petroleum ether. Acetone was separated from the petroleum ether by slowly adding 50 mL of deionized water. Further removal of acetone from the petroleum ether phase was done by adding 50 mL of water (10 g kg−1 sodium chloride) four times. The resulting extract was filtered with 15 g of anhydrous sodium sulfate and placed into a 50 mL graduated flask. Petroleum ether was added until carotenoid extract was diluted to 50 mL. An aliquot of the extract was placed in a quartz cuvette and read at 450 nm using a UV–visible spectrophotometer. To calculate the TC content, the following equation was used:

$$TC = \frac{A \times V \times 10^{-4}}{A^{1\%}/_{1\,cm} \times P}$$

where TC (μg g−1) is the TCs in the sample, A is the absorbance at 450 nm; V (mL) is the final volume of extract, A1% /1 cm = 2592 is the molar absorptivity coefficient of beta carotene in petroleum ether), and P (g) is the weight of sample.

2.5. Sensory Evaluation of Cassava Food Products

Sensory evaluation of the yellow cassava food products were conducted among semi-trained panelists made up of thirty members from the Federal University of Technology, Akure, Nigeria who were familiar and regular consumers of cassava-based food products. The panelists were provided with portable water for rinsing the mouth between evaluations. Attieke and gari samples were prepared and presented to panelists in granule forms while the Chickwangue, fufu, lafun and pupuru powders were prepared by stirring in hot water to make the gelatinized balls that could be eaten or swallowed. The samples were coded and served panelists. Each panelist was given coded samples to evaluate for taste, aroma, appearance and overall acceptability on a 9-point hedonic scale where '1' was used to denote 'Dislike extremely' and '9' 'Like extremely'.

2.6. Statistical Analysis

All determinations were carried out in triplicates and error reported as standard deviation from the mean. All data was subjected to analysis of variance and significance accepted at $p \leq 0.05$. The means were separated using Duncan Multiple Range Technique with SPSS package (version 17.0).

3. RESULTS AND DISCUSSION

The total carotenoid contents of the biofortified cassava varieties before processing ranged from 12.80 μg g^{-1}- 19.40 μg g^{-1} Table 1 but this reduced after processing and ranged as follows: Attieke: 5.23-10.10 μg g^{-1}; Chickwangue:10.13-13.27 μg g^{-1}; fufu: 10.37-14.17 μg g^{-1}; Gari: 7.33-7.57 μg g^{-1}; Lafun:4.80-12.20 μg g^{-1} and Pupuru: 8.67-10.63 μg g^{-1} Table 3. Cassava chips from TMS 01/1371 had initial carotenoid content of 19.40 μg g^{-1} and were significantly higher than all the other varieties. TMS 01/1412 had the lowest carotenoid content of 12.80 μg g^{-1} among the dried chips. Retention of total carotenoid after processing was highest in Chickwangue (95%) and Fufu (92%) for variety *TMS01/1368* while Lafun from TMS 01/11371 had the lowest (25%) retention after processing but the highest retention after storage for 3 months (75%). Gari retained an average 55% of carotenoid after storage in all the TMS varieties Table 2. Other authors reported significant loss in carotenoid for gari (with added palm oil) when in storage: Abu, Badifu, and Akpapunan (2006): 57% after 4 months, Uzomah, Ubbaonu, and Osuji (2005):50% by 3rd week of storage. Pupuru showed appreciable carotenoid retention across all varieties (<60).

Attieke, Chickwangue and Fufu of variety TMS 01/1368 had the highest retention after processing (80%, 93% and 91% respectively) while Gari from variety TMS01/1371 had the lowest retention (33%). The yellow bitter cassava studied by Oliveira, De Carvalho, Nutti, and De Carvalho (2010) showed carotenoid content of 3.65-18.92 µg g^{-1} and processing resulted in up to 50% degradation in the carotenoid contents. The sweet yellow cassava cultivars had carotenoid content ranging from 2.64-14.15 µg g-1 Carvalho et al. (2012). When yellow sweet potato was processed by cooking for 20-30 min, carotenoid retention was found to range between 83% and 92% (Van Jaarsveld, Marais, Harmse, Nestel, & Rodriguez-Amaya, 2006). Aman, Carle, Conrad, Beifuss, and Schieber (2005) also reported that food processing can cause losses of carotenoid due to degradation, isomerization, and oxidation. The relatively good retention of total carotenoid upon the processing and storage of the various cultivars used in this study provides experimental support for the feasibility of cassava biofortification as a means to alleviate vitamin A deficiency.

Results of the functional properties of the biofortified cassava products Table 4 showed that Attieke, from variety TMS 01/1412 had highest Bulk density (0.92 g-1ml) while Lafun from variety TMS01/1368 had the lowest (0.55 g-1ml). A study by Ukenye, Ukpabi, Chijoke, Egesi, and Njoku (2013) recorded lower figures than these, with a range between 0.51±0.02 and 0.59±0.03. Gari samples from TMS 01/1371 had highest swelling capacity (60.33%) followed by Pupuru and Gari from variety TMS01/1368 (58.33%).

The sensory attributes of biofortified cassava variety TMS 01/1368 were most acceptable to the panelists. The panelists recorded significantly higher preference for all the products from variety TMS 01/1368 and the highest score in taste, appearance, aroma and overall acceptability was recorded in the gari samples confirming gari's status as most preferred cassava food product in Nigeria.

4. CONCLUSION

This study shows a good acceptance of biofortified cassava products by consumers thus the barrier to acceptance of novel nutritious food from yellow cassava is expected to be low especially when they are of acceptable sensory characteristics. From these results, variety 01/1368 may likely be most acceptable to the people. Furthermore, information on retention of carotenoid shows Fufu, Chickwangue and Attieke had better retention than Gari ,Lafun and Pupuru. But results indicated a detrimental effect of storage on the carotenoid contents of the yellow cassava food products. This study therefore suggests that yellow biofortified cassava varieties can be utilized in production of nutritious cassava foods and this may serve as a guide to consumers in deciding which cassava products to consume as well as contribute to knowledge about utilization of yellow cassava.

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Table-1. Retention of total carotenoid contents in yellow cassava food products (fresh weight).

Cassava products	TMS 01/1371		TMS 01/1412		TMS 01/1368	
	Carotenoid content	Retention	Carotenoid content	Retention	Carotenoid content	Retention
	(µg g-1)	(%)	(µg g-1)	(%)	(µg g-1)	(%)
Dried Cassava chips	19.40±0.15b	100	15.07±0.21a	100	12.80±0.10c	100
Attieke	7.00±0.00b	36%	5.23±0.06c	35%	10.10±0.10a	79%
Chickwangue	10.13±0.15b	52%	13.27±0.15a	88%	12.16±0.10b	95%
Fufu	10.37±0.06c	53%	14.17±0.06b	94%	11.78±0.21b	92%
Gari	7.33±0.12d	38%	7.36±0.15c	49%	7.57±0.21b	59%
Lafun	4.80±0.10c	25%	12.20±0.10a	81%	7.63±0.06b	60%
Pupuru	8.67±0.15b	45%	8.83±0.11b	59%	10.63±0.21a	83%

Note: Values of carotenoid are mean±SEM fresh weight. Values with different alphabets across the row on carotenoid contents are significantly different P<0.05.

Table-2. Total carotenoid contents (µg g-1) and retention (%) of cassava food products after 12-weeks storage.

Cassava products	TMS 01/1371		TMS 01/1412		TMS 01/1368	
	Carotenoid content	Retention	Carotenoid content	Retention	Carotenoid content	Retention
	(µg g-1)	(%)	(µg g-1)	(%)	(µg g-1)	(%)
Attieke	4.40±0.10a	63%	1.70±0.15c	34%	3.57±0.06b	35%
Chickwangue	2.63±0.07b	26%	4.67±0.06a	35%	2.60±0.10c	22%
Fufu	3.03±0.06c	29%	5.27±0.12a	38%	3.20±0.06b	27%
Gari	4.23±0.15b	58%	3.67±0.15c	50%	4.30±0.30b	57%
Lafun	3.60±0.10b	75%	4.87±0.06a	40%	4.37±0.06c	57%
Pupuru	5.70±0.10b	66%	3.53±0.15c	40%	7.09±0.12a	67%

Note: Values of carotenoid are mean±SEM. Values with different alphabets across the row on carotenoid contents are significantly different P<0.05

Table-3. Effect of processing on the total carotenoid contents of biofortified cassava products.

Products from Cassava	TMS 01/1371		TMS 01/1412		TMS 01/1368		TMS 30572	
	Carotenoid content (µg g-1)	Retention post processing	Carotenoid content (µg g-1)	Retention post processing	Carotenoid content (µg g-1)	Retention post processing	Carotenoid content (µg g-1)	Retention post processing
Cassava chips	19.40±0.15b		15.07±0.21a		12.80±0.10c		2.00±0.10d	
Attieke	7.00±0.00b	36%	5.23±0.06c	35%	10.10±0.10a	79%	1.90±0.10d	79%
Chickwangue	10.13±0.15b	52%	13.27±0.15a	88%	12.16±0.10b	95%	1.16±0.10d	95%
Fufu	10.37±0.06c	53%	14.17±0.06b	94%	11.78±0.21b	92%	1.78±0.21d	92%
Gari	7.33±0.12d	38%	7.36±0.15c	49%	7.57±0.21b	59%	15.20±0.27a	159%
Lafun	4.80±0.10c	25%	12.20±0.10a	81%	7.63±0.06b	60%	1.67±0.06d	60%
Pupuru	8.67±0.15b	45%	8.83±0.11b	59%	10.63±0.21a	83%	1.40±0.44d	83%

Note: Values of carotenoid are mean±SEM. Values with different alphabets across the row on carotenoid contents are significantly different P<0.05.

Table-4. Bulk Density (g/ml), Swelling Capacity (%) and Absorption Capacity (%) of Products of biofortified cassava products.

Products	Bulk Density			Swelling Capacity			Water Absorption Capacity		
	TMS 01/1371	TMS 01/1412	TMS 01/1368	TMS 01/1371	TMS 01/1412	TMS 01/1368	TMS 01/1371	TMS 01/1412	TMS 01/1368
Attieke	0.57±0.02c	0.92±0.01a	0.82±0.01b	51.33±1.53a	25.67±1.15c	44.00±1.00b	40.33±0.58c	56.00±1.00b	19.33±0.58d
Chickwangue	0.67±0.02c	0.91±0.01a	0.70±0.01b	30.33±0.58b	25.00±1.73d	46.00±1.00a	20.67±0.59d	75.33±0.58a	48.67±0.58c
Fufu	0.56±0.01d	0.62±0.01b	0.71±0.01a	34.33±0.58a	17.67±0.58d	33.33±0.58b	30.00±0.01d	57.67±0.58a	37.33±0.58c
Gari	0.89±0.02a	0.91±0.01a	0.72±0.01b	60.33±0.58a	32.00±1.00b	58.00±7.21a	41.33±0.58a	40.33±0.57b	29.01±0.02d
Lafun	0.65±0.01a	0.60±0.01b	0.55±0.01c	34.33±1.53a	19.00±1.00c	31.67±0.58b	27.33±1.80d	49.00±1.01a	38.00±0.25c
Pupuru	0.60±0.01c	0.82±0.01a	0.77±0.01b	27.00±1.01d	28.33±0.58c	58.33±0.59a	40.67±0.58c	57.33±0.58b	19.67±0.58d

Note: Values are Mean± SEM. Values with different alphabet across the row are significantly different P<0.05.

Table-5. Sensory evaluation of attieke, chickwangue, fufu, garri, lafun and pupuru made from biofortified cassava products.

Products/Parameters	TMS 01/1371	TMS 01/1368	TMS 01/1412
Attieke (Taste)	7.03±0.03d	7.32±0.02b	7.21±0.02c
Attieke (Appearance)	7.49±0.04a	7.20±0.01c	7.21±0.12c
Attieke (Aroma)	6.50±0.03d	7.60±0.02a	7.00±0.01c
Attieke (Ov. Accept.)	7.30±0.01b	8.09±0.02a	6.50±0.02c
Chickwangue (Taste)	7.10±0.06b	7.20±0.02a	6.71±0.02c
Chickwangue (Appear*)	7.61±0.10a	6.91±0.02b	6.70±0.01c
Chickwangue (Aroma)	7.40±0.06a	7.20±0.02b	7.00±0.01c
Chickwangue (O. Accept.)	7.70±0.06b	8.09±0.15a	7.10±0.10c
Fufu (Taste)	7.20±0.12a	7.10±0.01a	6.70±0.01b
Fufu (Appearance)	7.10±0.01c	7.90±0.01a	6.30±0.01d
Fufu (Aroma)	6.80±0.00c	7.40±0.01a	6.40±0.01d
Fufu (OA*)	6.80±0.01b	7.60±0.20a	6.57±0.12c
Gari (Taste)	7.80±0.00c	7.90±0.15b	7.80±0.00c
Gari (Appearance)	6.50±0.20d	8.00±0.01b	7.80±0.01c
Gari (Aroma)	7.90±0.01b	7.40±0.10c	8.00±0.01a
Gari (OA*)	8.31±0.01b	8.40±0.01a	8.00±0.00c
Lafun (Taste)	7.10±0.03b	6.50±0.01c	7.10±0.01b
Lafun (Appearance)	7.30±0.01b	6.80±0.02d	7.60±0.03a
Lafun (Aroma)	7.20±0.02a	6.50±0.23b	7.20±0.02a
Lafun (OA*)	7.31±0.01a	7.30±0.02a	7.61±0.01a
Pupuru (Taste)	6.90±0.01 b	7.20±0.01a	6.60±0.01d
Pupuru (Appearance)	6.90±0.01d	7.50±0.01b	7.70±0.01a
Pupuru (Aroma)	7.51±0.01b	6.70±0.02d	7.30±0.01c
Pupuru (OA*)	7.20±0.01a	7.00±0.00a	7.00±0.03a

Note: Values are Mean±SEM.Values with different alphabet within the row are significantly different P<0.05
OA*.- Overall Acceptability.

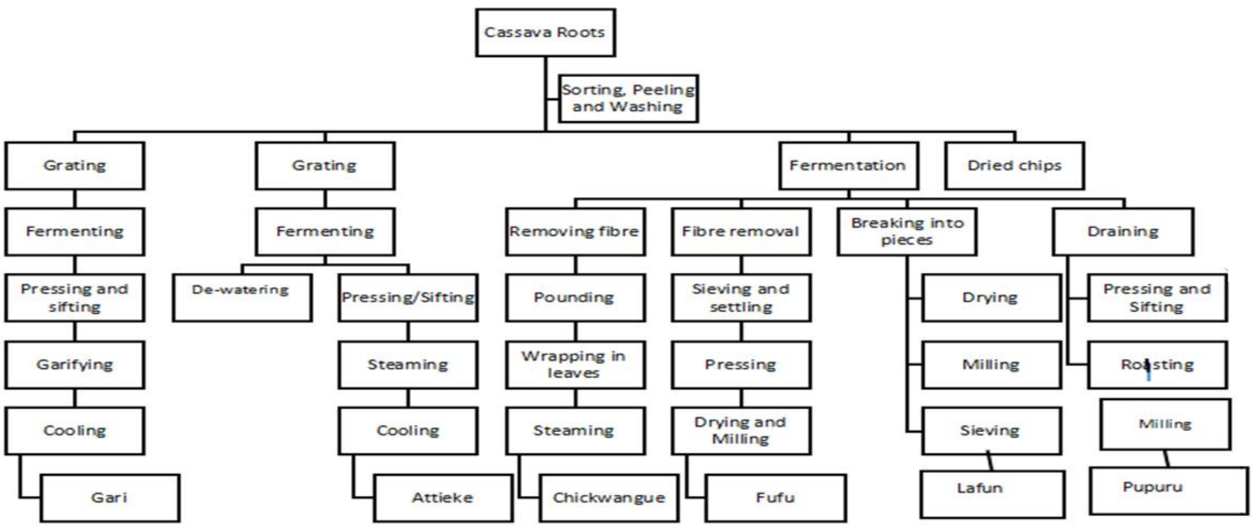

Figure-1. Flow chart for the processing of Dried chips, Attieke, Chickwangue, Gari, Fufu and Pupuru.
Source: Adapted from Lawal et al. (2015).

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