State Of Knowledge Report

# State Of Knowlegde (SoK) For *Gari*

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# OVERVIEW OF THE GARI SOK REVIEW

During the review of more than fifty publications/documents on gari, it was observed that more work has been done on the composition of raw cassava roots with some methods of preservations, composition of gari with or without some level of enrichment and the sensory evaluation of the roasted gari and gari reconstituted into eba. However, there is presently dearth of information on the following:

a. Comparing the physical, functional, physiochemical and chemical composition of gari produced from the traditional and mechanical methods, putting into consideration each of the unit operations/critical control points.,
b. The sensory attributes and consumer acceptability of gari produced from the traditional and mechanical methods, as well as the sensory and instrumental texture profile analysis of eba from the two methods,
c. Effect of storage root preservation such as ratooning and pruning on the composition of gari, as well as the sensory attributes and texture profile analysis of eba. Cassava varieties could be included as a factor
d. Sensory and instrumental texture profile analysis and sensory attributes of eba produced from yellow- and white- fleshed cassava varieties compared
e. The physical, physicochemical and chemical composition of eba from white and yellow fleshed varieties compared with their sensory attributes and consumer acceptability

# 1. COMPOSITION AND STRUCTURE OF RAW MATERIAL

## 1.1 Composition

The composition of cassava roots differs depending on cultural practices like pruning, ratooning, age and maturity of the root at harvest, storage environment, region, and post-harvest practices (Laya et al., 2018). The carbohydrate (starch), moisture and cyanogenic potential contents are the major constituent affecting cassava root in terms of processing and value addition.

The cassava root is a physiological energy reserve with high carbohydrate content, which ranges from 80% to 90% db (Montagnac, 2009; Zvinavasheet al., 2011). Laya et al. (2018) reported a carbohydrate content of between 75% and 90% db of some cassava varieties in Cameroon. The carbohydrate content of cassava roots in Uganda ranged from 84-91% db (Manano et al., 2018), Ghana 83-87% db (Emmanuel et al., 2012) and Côte d'Ivoire 93-94% db (Koko et al., 2014). The carbohydrate in the cassava root is made up of starch and some sugar. Starch content varies from one location to another depending on the varieties, age at harvest and season of the year among others. To this end, starch content of cassava root from Bolivia ranged from 72-84% db (Rojas et al., 2007), Colombia 87% db (Rodríguez-Sandoval et al., 2008), Uganda 67-84% db (Manano et al., 2018), Nigeria 70-78% db (Alamu at el., 2017), and Côte d'Ivoire 75-78% db (Koko et al., 2014) (Table 1).

Comparing the dry matter content of cassava varieties from Cameroon and Côte d'Ivoire, it was observed that cassava roots harvested in Côte d'Ivoire have more dry matter content than that of Cameroon (Table 1) (Koko et al., 2014 ; Laya et al., 2018). The variation in the dry matter content may be due to their differences in textural structures and constituent solutes among other factors (Manano et al., 2018).

All cassava varieties contain toxic cyanogenic glucosides, which are present in three different forms in the cassava roots; linamarin, lotaustralin and free hydrogen cyanide (Wheatley et al., 1993; Cardoso et al., 2005; Emmanuel et al., 2012). The linamarin and lotaustralin undergo a sequential enzymatic breakdown in the presence of linamarase, an enzyme present in cassava tissues, and the final form is a toxic free cyanide. Cassava root parenchyma of the bitter variety has a range of 10 to 500 mg HCN/kg dry matter (Arguedas et al., 1982; Siritunga and Sayre, 2003), which is higher than the FAO/WHO

(1991) recommendation of <10 mg HCN/kg. Manano et al. (2018) reported the values of the cyanogenic potential of different cassava varieties (sweet and bitter) in Uganda to range from 30-800 mg HCN/kg. These researchers than concluded that the levels of the cyanogenic glycosides were significantly higher in the local varieties compared to the improved varieties. However, much lower values have been reported by other researchers. For instance, Sarkiyayi and Agar (2010) reported 4.6 mg/kg for sweet cassava root and 6.5 mg/kg bitter varieties in Kaduna State Nigeria. In northern Cameroon, Laya et al. (2018) reported a range of between 0.88 mg HCN/kg and 1.56 mg HCN/kg, and in Ghana 0.08 – 0.12 mg HCN/kg was reported by Emmanuel et al. (2012). Charles et al. (2005) also reported a cyanogenic potential of bitter cassava varieties in Thailand to range from 26.90 - 28.00 mg HCN/kg in bitter roots and between 8.33 mg HCN/kg and 12.50 mg HCN/kg for sweet roots. Manano et al. (2018) then concluded in their work that since cyanogenic glucosides release the toxic cyanide as a breakdown product, bitterness of a cassava root is directly related to its toxicity. Higher values compared to the FAO/WHO (1991) recommendation was also reported by Koko et al. (2014) for cassava root from Côte d'Ivoire (Table 1). Although, studies have also shown that cyanide content of cassava root tends to increase during periods of droughts and or prolonged dry weather due to water stress on the plant (Bokanga et al., 1993; Bokanga, et al., 1994). Additionally, Splittstoesser and Tunya (1992) reported that cassava grown in wet areas contain relatively lower amount of cyanide than those grown in drier areas.

Human exposure to heavy metals causes serious adverse health effects, including reduced growth and development, cancer, organ damage, and in extreme cases—death (Dix, 1981). However, minerals iron such Fe, Cu, and Zn among others are also referred to as trace metals, which are naturally present in foodstuff and confer some nutritional benefits to human, but toxic when consumed in excess (Magomya et al., 2013). It is important to add that cassava varieties, maturity, genetics, age of the crops, soil fertilization, geographic location, season and water source among other factors affect the mineral composition of cassava roots (Charles et al., 2005; Manano et al., 2018). Out of all the minerals analyzed by Rojas et al. (2007) in six different cassava roots from Bolivia, Fe has the highest values, which ranged from 7-79 mg/kg, and Ca has the least (0.32-0.43 mg/kg). On the contrary, Manano et al (2018) reported higher values for the Ca content of both improved and local cassava roots in Uganda 132-181 mg/kg) and lower values for Fe (0.10 mg/kg) (Table 2). The major mineral found in cassava roots from Ghana was Mg (14-25 mg/kg), and the least was Mn (0.21-0.30 mg/kg). The cassava roots harvested in Côte d'Ivoire have the highest values of all the minerals; Fe (69-104 mg/kg), Mg (658-729 mg/kg), Zn (25.10-28.10 mg/kg), Ca (974.10- 1156.70 mg/kg) and P (1117.8-1404.30 m/kg) (Koko et al., 2018) (Table 2).

Table 1. Chemical composition of cassava roots from different locations

| Locations | Dry matter/ moisture (%) | Ash (%) | Fibre (%) | Protein (%) | Lipid (%) | Starch (%) | Sugar (%) | Amylose (%) | CHO (%) | CNP (mg/kg) | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bolivia | | | | | | | | | | | (a) |
| Range | - | 1.46-1.65 | 8.22-8.54 | 1.46-2.76 | 0.58-1.4 | 71.64-84.15 | - | - | - | - | |
| Mean (db) | - | 1.56 | 8.37 | 1.93 | 0.97 | 76.73 | - | - | - | - | |
| Methods | - | a* | a** | a*** | a* | a**** | - | - | - | - | |
| Cameroon | | | | | | | | | | | (b) |
| Range | 25.21-30.25 | 0.78-0.86 | 2.88-3.7 | 5.86-9.75 | 4.17-8.66 | - | 15.3-25.45 | - | 74.54-90.15 | 0.88-1.56 | |
| Mean (wb) | 27.01 | 0.84 | 3.15 | 7.14 | 6.36 | - | 18.87 | - | 80.96 | 1.26 | |
| Methods | b* | b* | b* | b** | b* | - | b*** | - | b*** | b**** | |
| Colombia | | | | | | | | | | | (c) |
| Mean (db) | - | 1.90 | 2.60 | 2.90 | 0.40 | 86.50 | - | 18.80 | - | - | |
| Methods | - | c* | c* | c* | c* | c** | - | c*** | - | - | |
| Uganda | | | | | | | | | | | (d) |
| Range | 5.43-10.96 | 1.05-2.39 | 1.06-1.18 | 0.74-1.52 | 0.39-0.63 | 66.72-84.42 | - | - | 83.86-91.33 | 30-800 | |
| Mean (db) | 8.79 | 1.90 | 1.09 | 1.16 | 0.51 | 75.32 | - | - | 86.83 | 222 | |
| Methods | d* | d* | d* | d** | d* | d*** | - | - | d**** | d***** | |
| Nigeria | | | | | | | | | | | (e) |
| Range | 10.78-12.72 | 0.96-1.43 | - | 0.6-1.26 | - | 69.6-77.8 | 2.04-5.66 | 15.7-19.1 | - | - | |
| Mean (db) | 11.7 | 1.24 | - | 0.79 | - | 74.2 | 3.05 | 17.1 | - | - | |
| Methods | e* | e* | - | e** | - | e*** | e*** | e**** | - | - | |
| Ghana | | | | | | | | | | | (f) |
| Range | 7.48-9.66 | 1.71-2.34 | 1.38-3.2 | 1.17-3.48 | - | - | - | - | 83.42-87.35 | 0.08-0.12 | |
| Mean (db) | 8.42 | 2.11 | 2.02 | 2.11 | - | - | - | - | 86.13 | 0.10 | |
| Methods | f* | f* | f* | f* | | | | | f** | f*** | |
| Côte d'Ivoire | | | | | | | | | | | (g) |
| Range | 37.82-39.64 | 2.29-2.67 | - | 1.95-2.27 | 0.58-1.04 | 75.36-77.70 | 2.1-2.64 | - | 92.52-93.65 | 20-106 | |
| Mean (wb) | 38.51 | 2.53 | - | 2.14 | 0.80 | 76.81 | 2.39 | - | 92.98 | 60.11 | |
| Method | g* | g* | - | g* | g* | g* | g** | - | g*** | g**** | |

wb-wet basis ; db-dry basis ; (a) Rojas et al., 2007; (b) Laya et al. 2018; (c) Rodríguez-Sandoval et al., 2008; (d) Manano et al., 2018; (e) Alamu et al., 2017; (f) Emmanuel et al., 2012; (g) Koko et al., 2014; CHO-Carbohydrate; CNP-Cyanogenic glucoside; a* AACC, method 44-15A (Tarleton, 1976); a**Enzymatic method (Asp et al., 1983); a***Kjeldahl method (Manual of operation tecator, 1981); a****Rapid method of starch analysis (Holm et al., 1986); b*AOAC, 1990; b**Acetyl acetone/formaldehyde method (Devani et al., 1989); b***Orcinol colorimetric method (Tollier & Robin, 1979); b****Picrate colorimetric method (Baltha and Cereda, 2006); c*AOAC (1995); c** Enzymatic method (Holm et al., 1986); c*** colorimetric method (Sowbhagya and Bhattacharya, 1979); d* AOAC, (1995); d** Micro Kjeldahl method ( AOAC, 1995); d*** Anthrone reagent (AOAC, 1995); d**** By difference (AOAC, 1995); d***** Alkaline pictrate method (Bradbury et al., 1999); e* AOAC (1990); e** Kjeldahl method (Foss, 2003); e*** Dubois et al. (1956); e**** Williams et al. (1958); f* AOAC (2005); f**By difference (AOAC, 2005); f*** Acid titration method (AOAC, 2005); g* BIPEA (1976); g** Dubois et al. (1956); g*** Bertrand (1913); g**** FAO (1956)

*NB: Some values in Table 1 are under revision for inconsistencies*

Table 2. Mineral composition of cassava roots from different locations

| Locations | Copper (mg/kg) | Iron (mg/kg) | Magnesium (g/kg) | Manganese (mg/kg) | Zinc (mg/kg) | Calcium (mg/kg) | Sodium (mg/kg) | Phosphorus (mg/kg) | References |
|---|---|---|---|---|---|---|---|---|---|
| Bolivia | | | | | | | | | (a) |
| Range | 1.49-3.2 | 6.8-78.88 | 0.49-0.67 | 4.28-6.21 | 7.28-11.06 | 0.32-0.43 | - | - | |
| Mean (db) | 2.144 | 34.484 | 0.56 | 5.376 | 8.752 | 0.38 | - | - | |
| Methods | a* | a** | a** | a** | a* | a** | - | - | |
| Uganda | | | | | | | | | (b) |
| Range | 0.02-1.40 | 0.10-0.10 | 35.80-38.80 | - | 5.60-8.70 | 131.50-180.90 | - | - | |
| Mean (db) | 0.60 | 0.10 | 37.02 | - | 6.62 | 153.92 | - | - | |
| Methods | b* | b* | b* | - | b* | b* | - | - | |
| Ghana | | | | | | | | | |
| Range | - | 1.60-2.40 | 13.50-25.20 | 0.21-0.30 | 0.40-1.30 | 6.00-16.00 | 2.50-3.70 | 10.60-21.30 | (c) |
| Mean(db) | - | 1.85 | 16.30 | 0.25 | 7.33 | 9.87 | 3.18 | 14.35 | |
| Methods | - | c* | c** | c** | c*** | c*** | c**** | c** | |
| Côte d'Ivoire | | | | | | | | | (d) |
| Range | - | 69.40-104.10 | 658.10-729.20 | - | 25.10-28.10 | 974.10-1156.70 | - | 1117.80-1404.30 | |
| Mean (wb) | - | 86.87 | 690.40 | - | 26.13 | 1084.13 | - | 1267.23 | |
| Methods | - | d* | d* | - | d* | d* | - | d* | |

wb-wet basis ; db-dry basis ; (a) Rojas et al., 2007; (b) Manano et al., 2018; (c) Emmanuel et al., 2012; (d) Koko et al., 2014; a* ICP-MS (Okkum et al., 1989); a** ICP-AES (Okkum et al., 1989); b* AAS (AOAC, 1995); c* Ortho-phenanthroline method (AOAC, 2005); c** AAS (AOAC, 2005); c*** AAS (AOAC, 2005); c**** Flame photometry (AOAC, 2005); d* AAS (IITA, 1981)

## 1.2 Structure

Cassava roots have different physiological and functional parts which exist in various colours and shapes. Peel colours of light, and dark brown; cortex colours of pink, yellow, purple, light brown, cream, and white; flesh colours of yellow, white, and red (Figures 1 & 2); and root shapes of conical, cylindrical and irregular (Nassar, 2007; Anggraini et al., 2009; Fukuda et al., 2010; Gu et al. 2013; Ayetigbo et al., 2018). Starch granules of seven Southern China varieties grown in eight different locations had essentially similar shapes and sizes among the white and yellow-flesh varieties, such as round, oval, and truncated shapes (Figure 3) as well as a wide range of dimension (5–40 μm) (Gu et al., 2013). All the granules were of unimodal distribution, with sizes from 10 to 15 m more frequently occurring than others. Granules with sizes above 30 μm were the fewest, thus, small- and medium-sized granules form the bulk class of granule types found in cassava starches (Ayetigbo et al., 2018). Figures 4 and 5 shows the cross sections of the middle third of the cassava tuberous root at different days of planting (30, 60 & 90 days), and the cross section of cassava root at 15 days after planting (Figueiredo et al., 2015). The macro-structure of the cassava root, and the cell organization and arrangement has been reported to influence the texture of cassava products (Charoenkul et al., 2006).

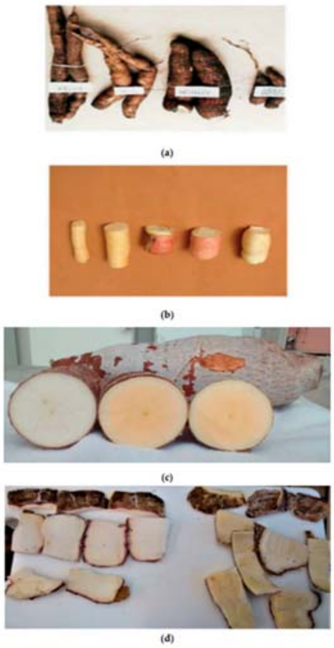


Figure 1. Visual differences in: (a) cassava root size and shape; (b) cassava cortex color; (c) flesh color; and (d) peel color. Source: Anggraini et al. (2009) (a & b); Ayetigbo et al. (2018) (c & d)

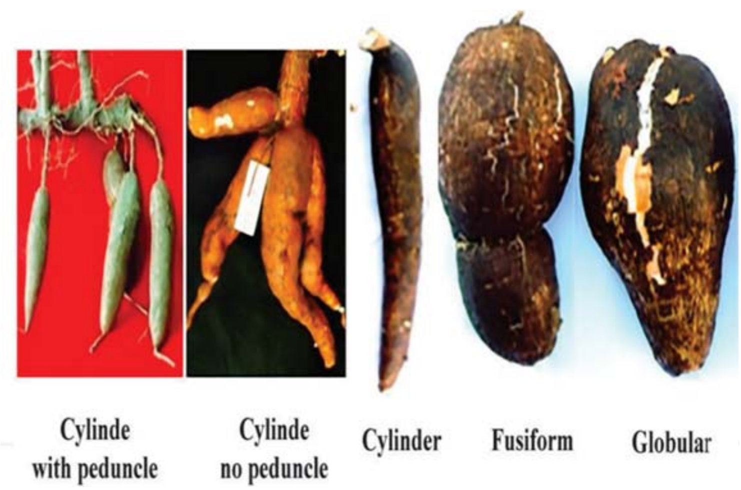


Figure 2. Cassava storage root morphological types (Carvalho et al., 2017)

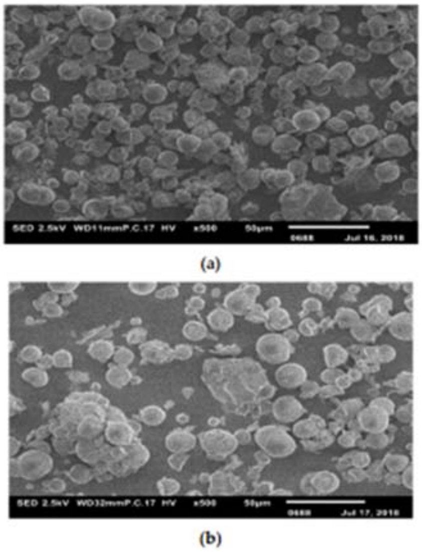


Figure 3. Emission scanning electron micrographs of starch granules showing shape and size of granules, and cell wall fragments of white cassava variety (a) and yellow cassava variety (b) (Ayetigbo et al., 2018)

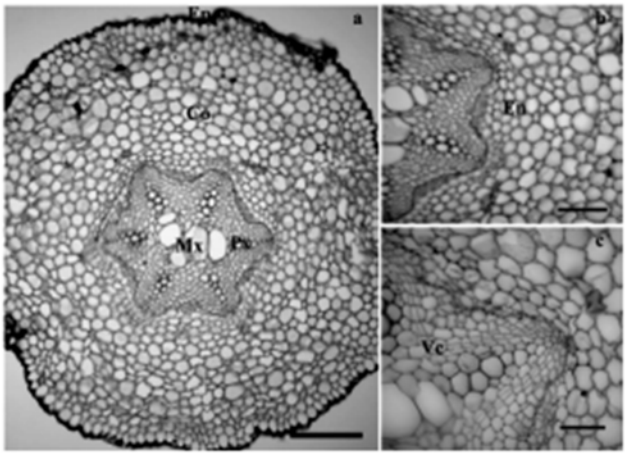


Figure 4. Cross sections of cassava root at 15 days after planting. a: General aspect of the root in early secondary growth (scale bar: 100 µm). b: Details of the endoderm (scale bar: 100 µm). c: Vascular cambium (scale bar: 50 µm). Ep, epidermis; Co, cortex; Pt, protoxylem; Mx, metaxylem; En, endoderm; Vc, vascular cambium (Figueiredo et al., 2015)

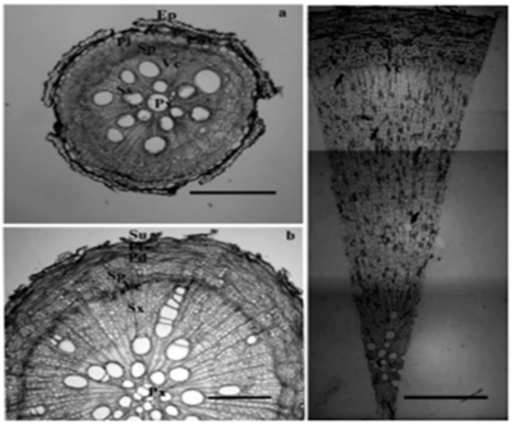


Figure 5. Cross sections of the middle third of cassava tuberous root at a: 30, b: 60 and c: 90 days after planting (arrows shows the vessel elements). Scale bar of a, b, c: 500 µm. Ep, epidermis; Co, cortex; Pl, phellogen; Px, primary xylem; Sp, secondary phloem; Vc, vascular cambium; Sx, secondary xylem; Cc, central cord (Figueiredo et al., 2015)

# 2. PROCESSING CONDITION

Gari is a dry, crispy, creamy- white/yellow and granular product, which is produced by crushing the cassava root into a mash, fermented (lactic fermentation, optional in some location), dewatered, and sieved into grits. The grits are then roasted manually or mechanically to make the gari (Awoyale et al. 2018). However, the processing of cassava roots into gari differs from one location to another. Some producers/consumers may prefer sour or bland taste gari, fine or coarse particle size gari, palm oil mixed gari or even gari enriched/fortified with different legumes or protein sources (Abass et al. 2012; Awoyale et al. 2018; Olaleye et al. 2018).

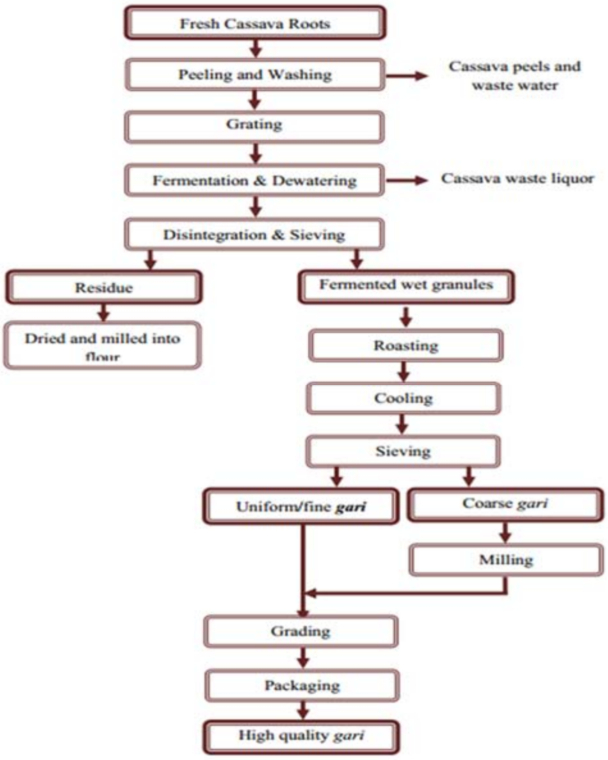


Figure 6. Standardized form of gari production (Abass et al. 2012)

Table 3. Processing of *gari* from fresh cassava roots in Liberia

| Type of gari | Processing method |
|---|---|
| White *gari* | Peeling, washing, grating, bagging, fermentation (optional as most consumers in Liberia prefer unfermented gari) and dewatering, granulation and roasting in earthenware pots. |
| Yellow *gari* | Same processing steps as above with mixing of palm oil to the granules before roasting |
| Coconut-fortified *gari* | Grating and roasting of matured coconut pulp before blending with white gari |
| Groundnut-fortified *gari* | Roasting and milling of groundnuts before mixing with white gari |
| Groundnut-moringa-fortified *gari* | Drying of fresh moringa leaves, milling and mixing with groundnut-fortified gari |

Source: (Awoyale et al., 2018)

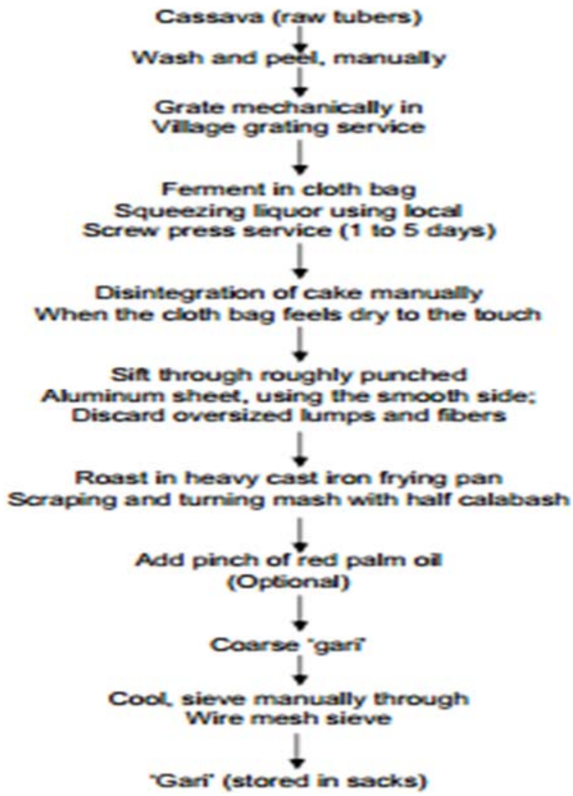


Figure 7. Production of gari in Nigeria (Olaleye et al., 2018)

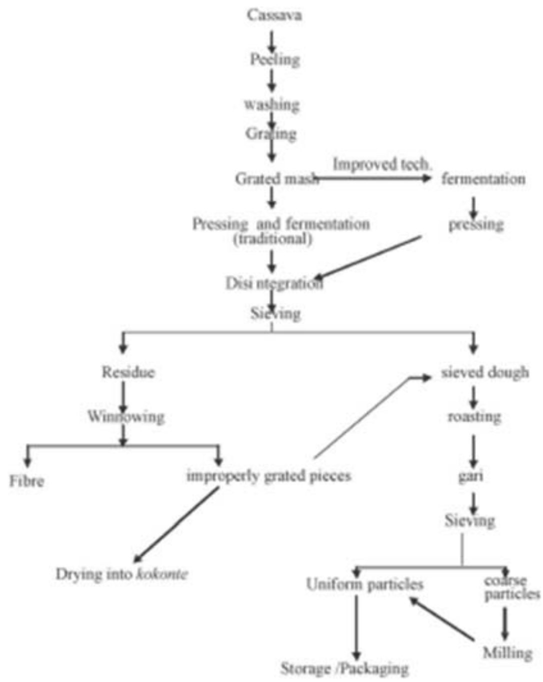


Figure 8. Production of gari in Ghana (Quaye et al., 2009)

From Figures 6 to 8 and Table 3, it is observed that gari is made by peeling fresh cassava roots, then washing and grating, fermenting (optional), dewatering or pressing, breaking of the cake, sifting, roasting, sieving or grading, and packaging.

Peeling of freshly harvested cassava roots manually with knife is most common, but mechanical peelers are now available in countries such as Nigeria and Ghana (Abass et al., 2012). The importance of the peeling operation is to remove the brown peel which might affect the gari color and increase its fiber content. Washing of the peeled roots is done to remove all extraneous materials, which could contaminate the gari. Grating of the washed cassava roots is done using a motorized cassava grater but hand graters, made by fastening the perforated grating sheets on woods are still used in some countries. Grating is done to increase the surface area of the cassava root, and free up the moisture so that dewatering of the mash can be done easily. The grated cassava mash is bagged using polypropylene/polyethylene woven bag or basket (lined with polypropylene sack) and left for between 1 and 5 days to ferment, depending on the taste preferred by the consumers. Apart from the taste, fermentation helps to reduce the cyanogenic potential of the product (Abass et al., 2012). The fermented mash is then dewatered by pressing with a manual screw or hydraulic press or even woods tied at both ends with rope, which is still common in most rural communities. Pressing is done to reduce the moisture content of the grated mash before roasting. The cake formed after dewatering is pulverized by a pulverizer/cake breaker or by hand and sieved with a manual woven sieve or rotary sieve, to remove the fiber and lumps.

The sieved grit is then roasted. Earthenware stove and a frying pan made of molded aluminum or stainless steel are used for roasting on a wood fire. In some communities, the roasting pan is smeared with a small amount of palm oil prior to roasting, to produce yellow gari. However, mechanical roasters are now available in Nigeria and Ghana. The roasting process develops the gari flavor, improves digestibility and the extent of drying determines the crispiness and storability of the product. It is important to add that in some communities, the grit is partially toasted and finally dried under the sun, which is not very good as the product will be contaminated. The gari is then cooled for some hours, graded (sieved) depending on the particle sizes preferred by the consumers and packaged depending on the distribution outlet. However, most rural communities packaged in 50kg bags for retail.

# 3. SENSORY ANALYSIS AND CONSUMER PREFERENCE

Sensory evaluation has been reported not to be the only most important hurdle after all the necessary agronomic characteristics have been developed but also a major determinant of acceptability of the variety, and the subsequent adoption and use of the variety for different products (Otoo and Asiedu, 2009). There are some differences in the processing of cassava roots into gari and subsequent consumption, which will lead to variants in the final product to meet local preferences and traditions. These variations in the process may have impact on the sensory attributes of the gari and later its consumer preference or acceptability (Bechoff et al., 2018).

Since gari is consumed dry, soaked in water, smoked with milk, sugar and salt, or reconstituted in hot water to form *eba* and consumed with preferred soups (Udofia et al., 2011); the sensory attributes is determined by the level of fermentation, roasting temperature, quantity of palm oil added or use of yellow-fleshed cassava roots, post-harvest storage of cassava roots before processing, method of grating, and rate of dewatering of cassava mash during fermentation, as well as the age of cassava plant at harvest, cassava variety, soil quality/location of farm and storage condition of gari before consumption (Collard and Levi, 1959; Okafor and Uzuegbu, 1987; Wayne et al., 1997; Oduro et al., 2000; Udofia et al., 2011). For instance, in Nigeria, gari quality varies along traditional/cultural lines. Red coloured and sweet gari produced with the addition of palm oil and short fermentation time is preferred by the east; and the west prefers creamy to slightly-golden coloured and sour gari imparted by longer period of fermentation (Udofia et al., 2011). Both the east and the western part of Nigeria preferred either the fine or coarse form of gari. Therefore, the major sensory attributes for gari are appearance, texture, colour, flavor, taste and overall acceptability. However, it is important to add that human perception of sensory attributes is derived from a combination of food chemical properties and food structural properties (Bart, 2006).

Table 4 showed the sensory attributes of different gari types and the cooked paste. The main sensory attributes evaluated on the dry gari are appearance, colour, taste, acidity, sweetness, flavour/aroma and graininess/crispiness (Owuamanam et al., 2011; Apea-Bah et al., 2011; Makanjuola et al., 2012; Udoro et al., 2014; Laya et al., 2018). Similarly, appearance, colour, texture, taste, flavour/aroma, mouldability and drawability were the sensory attributes assessed on the cooked paste (eba) (Udoro et al., 2014 ; Eje et bal., 2015 ; Oluwamukomi, 2015 ; Olaleye et al., 2018). Gari fermented for 48h was reported to be generally accepted by the consumers (Owuamanam et al., 2011). The acceptance of the 48h fermented gari may be attributed to the sour taste, as a positive but not significant correlation (r=0.57, p>0.05) exist between consumer acceptability and the gari taste (Table 5). This is very interesting as the research was conducted in Owerri; South-East Nigeria, where it is believed that consumer preferred unfermented gari.

Gari produced from Abasafitaa local variety in Ghana was more acceptable compared to other local varieties (Apea-Bah et al., 2011) (Table 4). This may be attributed to the taste and crispiness of the gari (r>0.70, p>0.05) (Table 5). Crispiness was defined by the researchers as a measure of the extent of gelatinization of starch during the gari roasting process. The consumer acceptability of gari collected from different processing centers across South West, Nigeria showed that all the samples were generally preferred (p<0.01) based on colour (r=0.98), taste (r=0.96) and flavour (r=0.99) (Makanjuola et al., 2012).

Gari produced from different improved and local cassava varieties in northern region of Cameroon, harvested at 12 (dry season) and 15 (rainy season) months after planting were soaked in 10% sucrose (i.e. gari consumed in the form of a drink) and evaluated using five-point hedonic scale (Laya et al., 2018). The result of this study showed that the consumers preferred gari from cassava harvested at 12 month to that harvested at 15 month, which may be linked with the colour and flavour/odour of the gari. This is because a significant positive correlation (r=0.84, p<0.01) exist between consumer acceptability and the colour and flavour/odour of the gari (Table 5).

Eje et al. (2015) worked on the sensory acceptability of gari produced from different improved varieties of fresh cassava roots stored in layers in moist saw dust of 80% moisture content (wb), in a rectangular wooden boxes (100cm x 60cm x 60cm x 40cm), and reported that there was no significant difference in the drawability of the cooked paste (eba) from all the varieties, which was attributed to undegraded starch in the cassava root stored in the moist saw dust. However, gari produced from all the cassava varieties with no storage produced the most acceptable product in terms of colour (r=0.85), taste (0.71) and aroma (r=0.87). This is because a positive and significant (p<0.01) correlation exist between the consumer acceptability and the colour, taste and aroma of the gari samples (Table 5).

The enrichment of gari with defatted and full fat sesame seed flour at different ratios showed that 10% defatted sesame seed flour enriched gari cooked into eba was more acceptable and compared favourably with the control sample (Oluwamukomi, 2015). The acceptability of this eba sample may be attributed to the colour, texture, taste and flavour, as a significant positive correlation (r>0.90, p<0.05) exist between consumer acceptability and these sensory attributes (Table 2).

Table 4. Sensory attributes of different types of gari and cooked paste (*eba*)

| Samples | Appearance | Colour | Texture | Taste | Acidity | Sweetness | Flavour/ Aroma | Mouldability | Drawability | Graininess/ crispiness | Acceptance | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gari evaluated in dry form** | | | | | | | | | | | | |
| Nwanyi bekee local variety (0h fermented) | 5.80 | - | - | 5.70 | - | - | - | - | - | - | 5.70 | Owuamanam et al., 2011** |
| Nwanyi bekee local variety (12h fermented) | 5.70 | - | - | 5.70 | - | - | - | - | - | - | 5.60 | Owuamanam et al., 2011** |
| Nwanyi bekee local variety (24h fermented) | 6.30 | - | - | 6.20 | - | - | - | - | - | - | 5.50 | Owuamanam et al., 2011** |
| Nwanyi bekee local variety (36h fermented) | 6.00 | - | - | 6.00 | - | - | - | - | - | - | 5.50 | Owuamanam et al., 2011** |
| Nwanyi bekee local variety (48h fermented) | 5.60 | - | - | 5.60 | - | - | - | - | - | - | 5.70 | Owuamanam et al., 2011** |
| Nwanyi bekee local variety (72h fermented) | 5.20 | - | - | 5.00 | - | - | - | - | - | - | 5.10 | Owuamanam et al., 2011** |
| Afisiafi local variety | 6.03 | 6.10 | - | 6.40 | - | - | 6.45 | - | - | 6.62 | 6.08 | Apea-Bah et al., 2011** |
| Tekbankye local variety | 5.75 | 6.58 | - | 6.23 | - | - | 6.53 | - | - | 5.99 | 5.94 | Apea-Bah et al., 2011** |
| Abasafitaa local variety | 5.64 | 6.47 | - | 6.33 | - | - | 6.23 | - | - | 6.43 | 6.19 | Apea-Bah et al., 2011** |
| Gblemoduade local variety | 5.69 | 6.26 | - | 6.22 | - | - | 6.28 | - | - | 6.07 | 5.94 | Apea-Bah et al., 2011** |
| Processing center 1 | 0.00 | 5.43 | - | 4.57 | - | - | 5.17 | - | - | - | 5.40 | Makanjuola et al., 2012** |
| Processing center 2 | 0.00 | 6.50 | - | 5.83 | - | - | 5.67 | - | - | - | 5.93 | Makanjuola et al., 2012** |
| Processing center 3 | 0.00 | 4.90 | - | 5.03 | - | - | 4.83 | - | - | - | 4.80 | Makanjuola et al., 2012** |
| Processing center 4 | 0.00 | 6.45 | - | 6.37 | - | - | 6.27 | - | - | - | 6.23 | Makanjuola et al., 2012** |
| Processing center 5 | 0.00 | 5.37 | - | 5.08 | - | - | 5.17 | - | - | - | 5.07 | Makanjuola et al., 2012** |
| Processing center 6 | 0.00 | 7.13 | - | 7.13 | - | - | 7.18 | - | - | - | 7.38 | Makanjuola et al., 2012*** |
| Processing center 7 | 0.00 | 6.00 | - | 5.72 | - | - | 5.50 | - | - | - | 5.92 | Makanjuola et al., 2012*** |
| Processing center 8 | 0.00 | 8.00 | - | 7.93 | - | - | 7.70 | - | - | - | 8.10 | Makanjuola et al., 2012*** |
| Bitter cassava | 0.00 | 6.85 | - | 6.45 | - | - | 6.60 | - | - | 6.50 | 6.70 | Udoro et al., 2014** |
| TMS92/0326 (12months) | 0.00 | 3.45 | - | - | 2.80 | 2.55 | 3.40 | - | - | - | 3.75 | Laya et al., 2018* |
| TMS96/1414 (12months) | 0.00 | 2.85 | - | - | 2.65 | 2.65 | 3.20 | - | - | - | 3.80 | Laya et al., 2018* |
| IRAD4115 (12months) | 0.00 | 2.75 | - | - | 2.20 | 2.50 | 3.05 | - | - | - | 2.75 | Laya et al., 2018* |
| EN local variety (12months) | 0.00 | 4.50 | - | - | 1.60 | 2.60 | 3.50 | - | - | - | 4.30 | Laya et al., 2018* |
| AD local variety (12months) | 0.00 | 3.55 | - | - | 1.65 | 2.30 | 2.95 | - | - | - | 3.10 | Laya et al., 2018* |
| TMS92/0326 (15months) | 0.00 | 2.50 | - | - | 1.90 | 2.30 | 1.80 | - | - | - | 2.55 | Laya et al., 2018* |
| TMS96/1414 (15months) | 0.00 | 2.15 | - | - | 2.00 | 2.25 | 2.50 | - | - | - | 2.75 | Laya et al., 2018* |
| IRAD4115 (15months) | 0.00 | 2.40 | - | - | 1.85 | 3.00 | 2.35 | - | - | - | 2.40 | Laya et al., 2018* |
| EN local variety (15months) | 0.00 | 2.20 | - | - | 1.95 | 3.35 | 2.55 | - | - | - | 2.50 | Laya et al., 2018* |
| AD local variety (15months) | 0.00 | 3.40 | - | - | 1.65 | 2.05 | 2.95 | - | - | - | 3.00 | Laya et al., 2018* |
| Commercial gari dry form | 0.00 | 3.90 | - | 2.50 | 2.50 | 2.95 | 3.15 | - | - | - | 3.55 | Laya et al., 2018* |
| **Gari evaluated in cooked form (eba)** | | | | | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bitter cassava | 0.00 | 6.80 | 6.50 | 6.55 | - | - | 6.55 | 6.60 | - | - | 6.60 | Udoro et al., 2014** |
| TMS 30572 (0week storage) | 0.00 | 5.09 | - | 4.73 | - | - | 5.27 | - | 5.27 | - | 5.18 | Eje et al., 2015** |
| TMS 50395 (0week storage) | 0.00 | 5.27 | - | 5.37 | - | - | 4.82 | - | 5.09 | - | 5.00 | Eje et al., 2015** |
| TMS 4(2)1425 (0week storage) | 0.00 | 5.18 | - | 5.73 | - | - | 5.27 | - | 4.91 | - | 5.18 | Eje et al., 2015** |
| TMS 91934 (0week storage) | 0.00 | 5.00 | - | 4.64 | - | - | 5.00 | - | 5.00 | - | 5.00 | Eje et al., 2015** |
| TMS 30572 (3week storage) | 0.00 | 5.18 | - | 4.27 | - | - | 4.55 | - | 4.73 | - | 4.09 | Eje et al., 2015** |
| TMS 50395 (3week storage) | 0.00 | 4.45 | - | 4.55 | - | - | 4.18 | - | 4.18 | - | 4.00 | Eje et al., 2015** |
| TMS 4(2)1425 (3week storage) | 0.00 | 5.09 | - | 5.64 | - | - | 6.00 | - | 4.36 | - | 4.55 | Eje et al., 2015** |
| TMS 91934 (3week storage) | 0.00 | 4.27 | - | 4.45 | - | - | 4.73 | - | 4.64 | - | 4.64 | Eje et al., 2015** |
| TMS 30572 (6week storage) | 0.00 | 5.36 | - | 4.27 | - | - | 5.18 | - | 4.27 | - | 5.00 | Eje et al., 2015** |
| TMS 50395 (6week storage) | 0.00 | 5.09 | - | 5.00 | - | - | 5.09 | - | 4.73 | - | 5.00 | Eje et al., 2015** |
| TMS 4(2)1425 (6week storage) | 0.00 | 4.82 | - | 4.64 | - | - | 5.64 | - | 4.18 | - | 4.55 | Eje et al., 2015** |
| TMS 91934 (6week storage) | 0.00 | 5.18 | - | 4.55 | - | - | 4.73 | - | 5.00 | - | 5.00 | Eje et al., 2015** |
| TMS 30572 (9week storage) | - | 4.64 | - | 4.00 | - | - | 4.36 | - | 4.18 | - | 4.73 | Eje et al., 2015** |
| TMS 50395 (9week storage) | - | 5.00 | - | 4.36 | - | - | 4.00 | - | 4.45 | - | 4.00 | Eje et al., 2015** |
| TMS 4(2)1425 (9week storage) | - | 5.00 | - | 5.27 | - | - | 5.27 | - | 4.00 | - | 4.82 | Eje et al., 2015** |
| TMS 91934 (9week storage) | - | 4.55 | - | 4.45 | - | - | 4.00 | - | 4.82 | - | 4.36 | Eje et al., 2015** |
| TMS 30572 (12week storage) | - | 4.91 | - | 3.86 | - | - | 5.00 | - | 5.00 | - | 4.70 | Eje et al., 2015** |
| TMS 50395 (12week storage) | - | 4.64 | - | 4.55 | - | - | 4.55 | - | 5.36 | - | 3.96 | Eje et al., 2015** |
| TMS 4(2)1425 (12week storage) | - | 4.80 | - | 3.55 | - | - | 4.18 | - | 3.27 | - | 3.96 | Eje et al., 2015** |
| TMS 91934 (12week storage) | - | 4.70 | - | 3.82 | - | - | 2.73 | - | 5.40 | - | 2.45 | Eje et al., 2015** |
| TMS 30572 (15week storage) | - | 1.91 | - | 3.85 | - | - | 3.18 | - | 4.00 | - | 1.18 | Eje et al., 2015** |
| TMS 50395 (15week storage) | - | 3.55 | - | 3.80 | - | - | 3.95 | - | 5.18 | - | 3.45 | Eje et al., 2015** |
| TMS 4(2)1425 (15week storage) | - | 1.27 | - | 2.18 | - | - | 2.45 | - | 3.27 | - | 2.09 | Eje et al., 2015** |
| TMS 91934 (15week storage) | - | 2.18 | - | 2.73 | - | - | 2.55 | - | 5.36 | - | 2.36 | Eje et al., 2015** |
| 100% cassava | - | 7.23 | 6.56 | 7.13 | - | - | 7.02 | - | - | - | 7.43 | Oluwamukomi, 2015*** |
| 5% Full fat sesame | - | 4.30 | 3.55 | 3.00 | - | - | 4.05 | - | - | - | 4.30 | Oluwamukomi, 2015*** |
| 10% Full fat sesame | - | 3.00 | 3.80 | 3.50 | - | - | 4.40 | - | - | - | 3.60 | Oluwamukomi, 2015*** |
| 5% defatted sesame | - | 3.90 | 4.95 | 3.90 | - | - | 5.05 | - | - | - | 4.70 | Oluwamukomi, 2015*** |
| 10% defatted sesame | - | 5.30 | 5.10 | 5.35 | - | - | 5.80 | - | - | - | 5.35 | Oluwamukomi, 2015*** |
| Bitter cassava | 5.73 | 6.00 | 6.20 | 5.73 | - | - | 5.53 | - | - | - | 6.20 | Olaleye et al., 2018*** |
| Sweet cassava | 6.47 | 6.07 | 6.53 | 7.00 | - | - | 6.53 | - | - | - | 7.20 | Olaleye et al., 2018*** |

*5-point hedonic scale; **7-point hedonic scale; ***9-point hedonic scale

Texture: texture of the dried gari is the crispiness/graininess, while that of the eba is the hand feel before consumption.

Taste: This is the combination of sweetness or sourness of the gari

Table 5. Pearson correlation of sensory attributes and consumers acceptability

| Sensory evaluations | Colour | Taste | Acidity | Sweetness | Flavour/aroma | Texture | Appearance | Graininess | Drawability | Acceptability |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Effect of length of fermentation on sensory acceptability of gari*** | | | | | | | | | | |
| Appearance | - | 0.98** | - | - | - | - | 1.00 | - | - | 0.47 |
| Taste | - | 1.00 | - | - | - | - | 0.98** | - | - | 0.57 |
| Acceptance | - | 0.57 | - | - | - | - | 0.47 | - | - | 1.00 |
| ***Effect of varieties and period of harvest on sensory acceptability of soaked gari*** | | | | | | | | | | |
| Colour | 1.00 | - | -0.13 | -0.25 | 0.74* | - | - | - | - | 0.84** |
| Acidity | -0.14 | - | 1.00 | -0.00 | 0.343 | - | - | - | - | 0.27 |
| Sweetness | -0.25 | - | -0.00 | 1.00 | -0.027 | - | - | - | - | -0.21 |
| Flavour | 0.74* | - | 0.34 | -0.03 | 1.00 | - | - | - | - | 0.84** |
| Acceptance | 0.84** | - | 0.27 | -0.21 | 0.84** | - | - | - | - | 1.00 |
| ***Effect of different processing centres on the sensory acceptability of gari*** | | | | | | | | | | |
| Colour | 1.00 | 0.96** | - | - | 0.97** | - | - | - | - | 0.98** |
| Taste | 0.96** | 1.00 | - | - | 0.97** | - | - | - | - | 0.96** |
| Flavour | 0.97** | 0.97** | - | - | 1.00 | - | - | - | - | 0.99** |
| Acceptance | 0.98** | 0.96** | - | - | 0.99** | - | - | - | - | 1.00 |
| ***Effect of local cassava varieties on the sensory acceptability of gari*** | | | | | | | | | | |
| Appearance | -0.70 | 0.67 | - | - | 0.58 | - | 1.00 | 0.59 | - | 0.02 |
| Colour | 1.00 | -0.55 | - | - | 0.09 | - | -0.70 | -0.60 | - | -0.08 |
| Taste | -0.55 | 1.00 | - | - | -0.00 | - | 0.67 | 0.99* | - | 0.75 |
| Flavour | 0.09 | -0.00 | - | - | 1.00 | - | 0.58 | -0.17 | - | -0.48 |
| Crispiness | -0.60 | 0.99* | - | - | -0.17 | - | 0.59 | 1.00 | - | 0.80 |
| Acceptance | -0.08 | 0.75 | - | - | -0.48 | - | 0.02 | 0.80 | - | 1.00 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Effect of cassava varieties & storage on sensory acceptability of eba*** | | | | | | | | | | |
| Colour | 1.00 | 0.75** | - | - | 0.77** | - | - | - | 0.27 | 0.85** |
| Taste | 0.75** | 1.00 | - | - | 0.82** | - | - | - | 0.25 | 0.71** |
| Aroma | 0.77** | 0.82** | - | - | 1.00 | - | - | - | 0.07 | 0.87** |
| Drawability | 0.27 | 0.25 | - | - | 0.07 | - | - | - | 1.00 | 0.19 |
| Acceptance | 0.85** | 0.71** | - | - | 0.87** | - | - | - | 0.19 | 1.00 |
| ***Effect of sesame enrichment on the sensory acceptability of eba*** | | | | | | | | | | |
| Colour | 1.00 | 0.92* | - | - | 0.90* | 0.87 | - | - | - | 0.98** |
| Texture | 0.87 | 0.95* | - | - | 0.98** | 1.00 | - | - | - | 0.94* |
| Taste | 0.92* | 1.00 | - | - | 0.99** | 0.95* | - | - | - | 0.95* |
| Flavour | 0.90* | 0.99** | - | - | 1.00 | 0.98** | - | - | - | 0.95* |
| Acceptance | 0.98** | 0.95* | - | - | 0.95* | 0.94* | - | - | - | 1.00 |

-Not evaluated, *p<0.05, **p<0.01

# 4. PRODUCT CHARACTERIZATION AND RELATIONSHIP WITH SENSORY EVALUATION

## 4.1. EVOLUTION OF COMPOSITION AND STRUCTURE WITH PROCESSING

Processing of cassava roots into product often result to reduction of nutrients, or conversion to other forms than the original nutrients. For instance, Aloys and Zhou (2005) find out that longer fermentation of raw cassava is associated with higher yield of the gari process, density of gari, dispersibility, crude fiber, and pasting temperature, but lower pH, starch, cyanide content, peak viscosity, paste viscosity, and water retention of the gari. About 80% of the dry mater in cassava root has been reported to be carbohydrate, which consist of starch, mucilage and sugars (Kim et al., 1995; Huang et al., 2007; Goddard et al., 2015). The starch itself consist of amylose (straight chain polymer of glucose units) and amylopectin (branched chain of glucose units). These two components of starch are arranged in a semi-crystalline granule, and their ratios in starchy foods may explain the textural traits of food products (Goddard et al., 2015), and the pasting properties. In addition, Maieves et al. (2011) reported that cassava varieties whose starch granules are more deeply related with parenchyme tissues, pectin and cellulose tend to be harder in texture, both in raw and in cooked cassava roots. These researchers further added that starch and fiber quantification can help to predict the use of cassava roots for production of either flour or starch, especially when considering that the age of the plants can influence the starch and fiber contents. Aryee et al. (2006) on their own part, stated that cassava varieties of poor cooking quality and high cyanogenic potential can be used for production of starch, glucose, adhesives, fuel alcohol and other industrial materials.

Grating yellow-fleshed cassava root retained 97.68-98.48% of the original total carotenoid of between 6.26-7.76 µg/g. Subsequent fermentation of this mash lead to 94.68-96.66% retention of carotenoid (Omodamiro et al., 2012). The retention of zinc, iron and total carotenoid was studied in the processing of TMS 01/1371, TMS 01/1235, and TMS 94/0006 into gari, and the result showed that fermentation significantly increased the average carotenoid content of the roots from 4.9 µg/g to 8.64 µg/g (wb) (Maziya-dixon et al., 2015). The increase in carotenoid content was attributed to the fact that as major compositions of cassava (carbohydrates, moisture, and fiber) reduce by hydrolysis during fermentation, the proportion of other minor compositions such as carotenoids apparently increase. However, Ortiz et al. (2011) believed that dry basis measurements of the carotenoid content would give a more accurate trend of what transpired during fermentation of the cassava mash. Maziya-dixon et al. (2015) also added that fermentation significantly reduced the iron content from 7.47 mg/kg to 7.13 mg/kg, and the zinc content from 8.95 mg/kg to 5.58 mg/kg. (wb). Fermentation has been reported to leach minerals due to the acidic nature of fermentate, and oxidative activities of microbes that use the micronutrients for development and growth (Ayetigbo et al., 2018). The subsequent roasting of the fermented, dewatered and sieved mash from TMS 01/1371, TMS 01/1235, and TMS 94/0006 cassava varieties lead to an increase in average carotenoid content from 4.9 µg/g to 10.6 µg/g, and iron content from 7.5 mg/kg to 8.2 mg/kg (Maziya-dixon et al., 2015). Though, this increase may not be an actual increase as the analyses was done in wet basis (wb) and not dry basis (db). Production of gari from yellow-fleshed cassava varieties has been reported to retain the least β-carotene viz: oven dried cassava chips (71.9%) > shadow dried cassava chips (59.2%) > boiled cassava roots (55.7%) >sun dried cassava chips (37.9%) > gari production (34.1%) (Chavez et al., 2007). Diallo et al. (2014) used three cassava varieties from Senegal to produce gari and found out that the product retained between 0% and 1.8% of the cyanide concentration (wb).

The viscosity of cassava-based products has been positively correlated with starch granule shape and sizes, swelling power, and the amylose and amylopectin ratios (Sanchez et al., 2010). On the contrary, Charoenkul et al. (2006) reported that the molecular structure of starch was not related to textural appearance. However, this study relied on a visual assessment of texture rather than an instrumental method. In addition, a positive correlation between particle sizes and moisture content of gari was reported by Makanjuola et al. (2012). This implied that gari with large particle sizes will be associated with higher moisture content and thus, problem with storage stability. A significant positive correlation was established by Saka et al. (1998) between the cyanogenic glucoside level and the bitter taste after evaluating 246 cassava samples from the 10 most common cultivars grown in Nkhata Bay District, Malawi. In addition, variation in cassava root cortex or peel thickness also affects the amount of extractable starch, since the peel has lower starch content than the root flesh (Kawiki, 2009).

## 4.2. Instrumental Texture assessment and relationship with sensory evaluation

The sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinaesthetic, is known as texture (Civille & Ofteda, 2012; Szczesniak, 2002). Thus, understanding the textural properties of foods allows for the control of food operations such as cooking, heating, frying and drying, to attain the desired quality attributes of the product (Chen and Opara 2013). The most important factor influencing cassava product texture is the quantity and quality of starch (Charoenkul et al., 2006). Texture assessment of food can be done using either human senses (sensory texture profile analysis-STPA) or instrument (instrumental texture profile analysis-ITPA). For the STPA, consumers are asked to rate the textural attributes of different varieties, allowing the researcher to identify consumer-preferred textural attributes and to isolate different varieties with consumer-preferred characteristics (Tomlins et al., 2004), while the ITPA uses equipment designed to imitate the mastication or chewing process, providing standardized data through which a wide range of food texture properties including hardness, springiness, adhesiveness, resiliency, fracturability, wateriness, gumminess, sliminess, and chewiness can be analyzed (Chen & Opara, 2013a; Goddard et al., 2015). This means that the ITPA can greatly expedite the testing process and allow for repeat testing of the same sample over time, and thus, seems to be the best texture assessment method for foods. Maieves et al. (2011) observed that the use of a texturometer to determine the hardness of the cooked roots can significantly facilitate the decision on which cassava varieties are softer for industrial processes involving heat treatment of raw materials. There is a paucity of research on the ITPA of eba produced from cassava gari, though work has been done on the texture analysis of different cassava products (Asaoka et al., 1992; Perez et al., 1998; Defloor et al., 1998; Oyewole and Afolami, 2001; Aryee et al., 2006; Tomlins et al., 2007; Anggraini et al., 2009; Sanchez et al., 2010; Franck et al., 2011; Makanjuola et al., 2012).

## 4.3. Relationship between composition and sensory evaluation

Cassava processing and consumption patterns and preferences differ among regions, thereby influencing the type of cassava varieties adopted by farmers. In Nigeria, a preference for early maturing varieties with good shelf-life during storage was preferred to produce gari (Onyenwoke and Simonyan, 2014). Consumers look for a sour taste (the strength of the sourness will depend on regional preferences) which is characteristic of lower pH value linked with proper fermentation (Nweke, 1994).

Cassava variety also influences the flavour of gari and its consumer acceptability (Jones, 1959). Cassava starch aids the solidifying process when gari is cooked into a stiff paste called eba and gives it a sticky consistency, which is a quality preferred by some consumers (Udoro et al., 2014). Infante et al. (2013) reported that the presence of pectic substances (salts of pectinic and pectic acids, and protopectin) in cassava root may contribute to the texture and hardness of cassava, which in turn could be responsible for the mouth feel of cooked or processed foods. This was corroborated by Eggleston and Asiedu (1994), who reported that a positive correlation exists among texture, final dry matter content and intercellular adhesion, when cubes of several cassava cultivars were compressed after being cooked for 20 min. The effect of pectic substances on processed cassava roots is a function of the age of the root and the season of harvest.

In addition, Marcon et al. (2007) observed that softening of cassava roots also depends on the swelling of their starch granules, which occurs due to disruption of hydrogen bonds between amylose and amylopectin in intact starch granules. Thus, further studies need to be carried out on pectic substance as it affects the sensory texture profiling and consumer acceptability of different cassava products such as gari from different varieties in Africa, where cassava is one of the major staples.

Table 6 showed the relationship between chemical composition and sensory evaluation of gari. From Laya et al. (2018) study on the effect of varieties and period of harvest of cassava roots on the sensory evaluation of gari, it was found through correlation that the acceptability of gari had a significant ($p<0.05$) negative correlation with moisture content (r= -0.85) and the lipid content (r= - 0.83), but positive for the carbohydrate content (r= 0.92, $p<0.01$) (Table 6). In addition, the moisture content of the gari has a negative significant correlation with colour (r= -0.85, $p<0.05$), taste (r = – 0.98, $p<0.01$), aroma (r = - 0.94, $p<0.01$) and crispiness (r= - 0.98, $p<0.01$), but a positive correlation with acidity (r=0.86, $p<0.05$) and sweetness (r 0.98, $p<0.01$). The ash content was significant and positive only with the acidity (r=0.86, $p<0.05$). The protein content had a negative and significant correlation with taste (r = - 0.86, $p<0.05$) and crispiness (r = - 0.86, $p<0.05$), and a positive correlation with sweetness (r= 0.86, $p<0.05$). All the sensory attributes of the gari have a negative and significant correlation with the lipid content, except for acidity and sweetness (Table 6). Similarly, the fiber content has a significant correlation with all the attributes except for acceptability. The correlation of the fiber content was positive for colour (r = 0.88, $p<0.05$), taste (r= 0.95, $p<0.01$), aroma (r=0.92, $p<0.05$) and crispiness (r=0.95, $p<0.01$), but negative for acidity (r= -0.95, $p<0.01$) and sweetness (r = - 0.97, $p<0.01$). Furthermore, the carbohydrate content has significant positive correlations with all the attributes except acidity and sweetness, which are negative. The cyanogenic potential was negatively correlated with taste (= - 0.92, $p<0.01$), aroma (r = - 0.86, $p<0.05$) and crispiness (r = - 0.92, $p<0.01$), but positive for sweetness (r=0.92, $p<0.01$). The taste (r= -0.93, $p<0.01$), aroma (r = -0.88, $p<0.05$) and crispiness (r = -0.93, $p<0.01$) of the gari have a significant negative correlation with the pH, but the correlation of the sweetness and the pH was positive and significant (r=0.94, $p<0.01$) (Table 6)

The effect of different processing centers on the sensory evaluation of gari as reported by Makanjuola et al. (2012) showed that there was no significant correlation between the chemical composition and sensory evaluation of the gari samples. Though, ash, lipid and fiber contents have a negative correlation with all the sensory attributes evaluated, while moisture content has a positive correlation (Table 6).

The enrichment of gari with defatted and undefatted Sesame flour and subsequent reconstitution in hot water to form eba (Oluwamukomi, 2015), revealed that lipid content has a significant negative correlation with texture (r= - 0.89, $p<0.05$) and the acceptability (r = - 0.91, $p<0.05$). Taste of the eba has a positive and significant correlation with the fiber and cyanogenic potential contents (r = 0.92, $p<0.05$). Similarly, the correlation between aroma and the fiber (r = 0.88, $p<0.05$) and cyanogenic potential (r=0.96, $p<0.05$) contents are positive and significant. The cyanogenic potential also had a significant positive correlation with the texture of the eba (r = 0.98, $p<0.05$) (Table 6).

The correlation of the data generated by Olaoye et al. (2015), on the effect of varieties and length of fermentation on the sensory evaluation of gari showed that the acceptability of the gari had a significant ($p<0.05$) positive correlation with ash and fiber (r=0.59), and the carbohydrate (r = 0.69) contents, but a negative correlation with moisture (r= - 0.67, $p<0.05$). In addition, the ash, fiber and carbohydrate contents of the gari have significant positive correlations with all the sensory attributes, and that of moisture content was negative for all the attributes. The protein content had a significant positive correlation with the gari appearance (r = 0.60, $p<0.05$), and the cyanogenic potential content had a significant negative correlation with the aroma (r = - 0.71, $p<0.05$) (Table 6).

Table 6. Pearson correlation of chemical composition and sensory evaluation of gari

| | Moisture | Ash | Protein | Lipid | Fiber | CHO | CNP | pH |
|---|---|---|---|---|---|---|---|---|
| **Effect of varieties and period of harvest on sensory acceptability of gari (Laya et al., 2018)** | | | | | | | | |
| Colour | -0.85* | -0.69 | -0.60 | -0.95** | 0.88* | 0.91* | -0.71 | -0.73 |
| Taste | -0.98** | -0.66 | -0.86* | -0.81* | 0.95** | 1.00** | -0.92** | -0.93** |
| Acidity | 0.86* | 0.86* | 0.69 | 0.87* | -0.95** | -0.87* | 0.80 | 0.79 |
| Sweetness | 0.98** | 0.66 | 0.86* | 0.82* | -0.97** | -0.99** | 0.92** | 0.94** |
| Aroma | -0.94** | -0.64 | -0.79 | -0.85* | 0.92* | 0.99** | -0.86* | -0.88* |
| Acceptance | -0.85* | -0.60 | -0.63 | -0.83* | 0.81 | 0.92** | -0.72 | -0.74 |
| Crispiness | -0.98** | -0.66 | -0.86* | -0.81* | 0.95** | 1.00** | -0.92** | -0.93** |
| **Effect of different processing centers on the sensory acceptability of gari (Makanjuola et al., 2012)** | | | | | | | | |
| Colour | 0.28 | -0.13 | NA | -0.67 | -0.37 | NA | NA | NA |
| Taste | 0.06 | -0.24 | NA | -0.51 | -0.19 | NA | NA | NA |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Aroma | 0.12 | -0.05 | NA | -0.54 | -0.40 | NA | NA | NA |
| Acceptance | 0.19 | -0.04 | NA | -0.61 | -0.40 | NA | NA | NA |
| **Effect of Sasame enrichment on the sensory acceptability of eba (Oluwamukomi, 2015)** | | | | | | | | |
| Colour | 0.57 | -0.31 | -0.47 | -0.86 | 0.80 | 0.81 | 0.78 | -0.52 |
| Texture | 0.47 | 0.00 | -0.34 | -0.89* | 0.81 | 0.67 | 0.98** | -0.73 |
| Taste | 0.40 | -0.18 | -0.35 | -0.79 | 0.92* | 0.69 | 0.92* | -0.54 |
| Aroma | 0.40 | -0.08 | -0.31 | -0.83 | 0.88* | 0.66 | 0.96** | -0.60 |
| Acceptance | 0.61 | -0.23 | -0.50 | -0.91* | 0.83 | 0.83 | 0.87 | -0.66 |
| **Effect of varieties and length of fermentation on sensory acceptability of gari (Olaoye et al., 2015)** | | | | | | | | |
| Appearance | -0.93** | 0.91** | 0.60* | -0.76** | 0.83** | 0.91** | -0.54 | NA |
| Texture | -0.93** | 0.93** | 0.58 | -0.77** | 0.79** | 0.93** | -0.55 | NA |
| Taste | -0.94** | 0.93** | 0.55 | -0.77** | 0.79** | 0.95** | -0.56 | NA |
| Aroma | -0.91** | 0.95** | 0.45 | -0.69* | 0.78** | 0.95** | -0.71** | NA |
| Acceptance | -0.67* | 0.59* | 0.33 | -0.46 | 0.59* | 0.69* | -0.58 | NA |

*p<0.05, **p<0.01, NA-Not available, CHO-Carbohydrate, CNP-Cyanogenic potential

In conclusion, the main sensory parameters identified repeatedly in different studies that are essential to describe gari are colour, taste, texture and aroma/flavour. Texture attributes of particular importance are crispiness and graininess in the case of dried gari, and hand feel before consumption in the case of eba. Taste attributes of particular importance are sweetness and sourness, and the combination (balance) thereof.

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