

Effect of palm oil inclusion on the quality of garri produced from white and yellow cassava (*Manihot esculenta cranz*) roots

Ndife Joel^{1*}, Nwaubani Oluchi², Aniekpeno I Elijah³

^{1,2} Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Nigeria

³ Department of Food Science and Technology, University of Uyo, Uyo, Nigeria

Abstract

Cassava, a major staple crop is usually processed to reduce the cyanide content, improve palatability and shelf life. In this study, effect of palm oil inclusion at different production stages on the quality attributes and sensory acceptance of different garri types labeled A, B, C and D was studied. White and yellow root (β -carotene) cassava tubers were peeled, washed and grated to obtain uniform mash. Red palm oil was thoroughly mixed with the white tuber mash prior to fermentation and before toasting. The different garri samples were evaluated for their functional properties, nutrient composition, microbial-content and sensory evaluation. The results of the analysis showed the yield of the garri samples was in the range of 45.56 to 54.32 %. Sample B (3.10 %) and C (2.85 %) with oil additions had lower swelling index values. Sample A had the least moisture content (11.97%) among all the garri samples (11.97 - 17.31 %). There was increase in energy levels in samples B (350 Kcal) and C (339 Kcal). The pH values of the samples were in the range (3.83 - 4.06). The palm oil treated garri samples B (2.12 μ g/100g) and C (2.31 μ g/100g) had the highest vitamin A contents. There was significant ($p < 0.05$) reduction in HCN in samples B (4.25 mg/Kg) and C (5.05 mg/Kg). The total microbial count (2.91 to 4.01 log cfu/g) in the samples was low. Garri with palm oil addition B and C had the highest acceptability scores. Palm oil inclusion during garri production reduced the HCN content and improved the nutrient content and sensory attributes.

Keywords: Cassava tuber, carotene, functional properties, hydrogen cyanide, garri

1. Introduction

Cassava (*Manihot esculenta cranz*) is basically grown for its roots which contains a high concentration of starch when compared with other food crops. It is a major staple food for most Africans and those living within the tropics (Ajibola *et al.*, 1987; Ojo and Akande, 2013) [4, 19]. According to the Food and Agriculture Organization, more than 65 % of the total cassava production goes for human consumption and the rest goes for animal feed and industrial use (Asiedu, 1992; Onwuka, 2014) [4, 19].

Fresh cassava roots cannot be stored for long because deterioration begins upon harvest. They rot within 3 – 4 days of harvest. The roots are bulky with about 70 % moisture content, which makes transportation to the market difficult and expensive. More so, the roots contain cyanide in the form of cyanogenic glycosides (Chow and Ho, 2002; Abu *et al.*, 2006) [9, 11]. Consumption of cyanide-rich cassava or cassava-products could result in endemic goiter, cretinism and tropical ataxic neuropathy (Abu *et al.*, 2006; Wardlaw, 2004) [1, 27]. Hence the need for proper processing of the tubers before consumption.

Cassava is processed into various forms in order to increase the shelf life of the products, facilitate transportation and marketing, improve palatability and ultimately reduce cyanide content for safety of consumers. Traditional detoxification processes adopted with the intention of reducing the hydrocyanic acid (HCN) vary from country to country (Chow and Ho, 2002; Asegbeloyin, and Onyimonyi, 2007) [9, 7]

One of the different traditional methods for processing the

cassava tuber to reduce their cyanogenic potential and toxicity before consumption is by processing it into garri, a grain-like product that has been mashed, toasted and dried. The wide consumption of garri has been attributed to affordability and relatively long shelf life compared to other cassava products as well as its ease of preparation for eating (Makanjuola *et al.*, 2012) [14].

There are reported cases of poor quality garri with high residual cyanide which can have damaging effects on the body when consumed (Odoemelam, 2005; Ojo and Akande, 2013) [18, 19]. More so, the addition of palm oil, which on its own has an appreciable concentration of saturated and unsaturated fats, vitamins and antioxidants (Visakh, 2014; Ndife, 2016) [28, 16], during garri processing was reported to reduce or eliminate the cyanide content in the product and improve the nutrient and sensory quality (Chow and Ho, 2002; Abu *et al.*, 2006; Agwu and Ikechi, 2004) [9, 11]. The aim of this research work was to evaluate the effects of palm oil inclusion at different production stages on the quality attributes of functional properties, cyanide and nutrient contents and sensory acceptability of garri from yellow and white cassava varieties.

2. Materials and methods

2.1 Raw material sourcing

Yellow β -carotene cassava (TMS 01/14142) and white cassava (CMS 419) root tubers were obtained from National Root Crop Research Institute (NRCRI) Umudike. Palm oil was purchased from Ubani-Ibeku market in Abia State, Nigeria.

2.2 Production of garri

The white and yellow root (β-carotene) cassava tubers were manually peeled with a knife, washed with clean water and grated with a stainless steel grater to obtain uniform smooth mash and dewatered with a hydraulic press. The white cassava mash was then divided into 3 batches of 100 kg each. The first batch of white mash (sample A) which served as control was bagged directly. The second batch (sample B) was thoroughly mixed with 30 ml of red palm oil prior to bagging. To the third batch of the white cassava mash (sample C), 30 ml of red palm oil was added during toasting. No palm oil was added to the yellow cassava mash (sample D). All the cassava mashes were allowed to ferment for 3 days. After fermentation, woven screen (mesh size 3.2 mm) was used to sift the cake to remove the coarse fibre of the cassava roots. The mashes were subsequently toasted at a temperature range of 130 – 135 °C using toasting pan for 20 to 30 min. The toasted garri samples were allowed to assume room temperature (27 °C) and then sieved to obtain uniform granules, before packaging in cellophane bags and kept in a refrigerator prior to analysis.

2.3 Methods of Analysis

2.3.1 Physical properties of garri

The percentage yield of garri samples was determined as weight ratio of garri relative to the total cassava root used (Karim *et al.*, 2016) [13]. The pH was determined using a pH meter.

2.3.2 Functional properties of garri

Reconstitution properties of wettability, water absorption capacity (WAC), bulk density, swelling index, gelation temperature, and total viscosity were determined by methods described by Onwuka (2018) [24].

2.3.3 Chemical properties of garri

Dry matter content, moisture, ash, protein, fat and fiber contents were determined by methods described by Nielsen (2003) [17]. Carbohydrate content was determined by difference using the Atwater factors. Energy value was determined by burning the garri sample in Parr Adiabatic oxygen bomb calorimeter; the heat of combustion of the sample was calculated as the gross energy. The total

carotene content was determined by procedures described by AOAC (2005) [5] while hydrogen cyanide content was determined following the method described by Makanjuola *et al.* (2012) [14].

2.3.4 Microbial analysis

Microbial analysis (total bacteria, total fungi and total coliforms counts) of garri was performed by the method outlined in compendium of methods for the microbiological examination of foods (APHA, 1992) [6] with some modifications.

2.3.5 Sensory Evaluation

The protocol described by Iwe (2010) [12] was used. The organoleptic properties of garri samples were evaluated by 20-member semi-trained panelists. Quality attributes such as appearance, aroma, texture, taste, appearance, colour and general acceptability of the products were scored with a 9-point hedonic scale.

2.3.6 Statistical Analysis

Completely randomized experimental design was used. Data obtained were subjected to analysis of variance (ANOVA). Duncan Multiple Range Test was used for mean separation at 5% level of probability (SPSS, version 16).

3. Results and discussion

3.1 Yield of garri

The yield of garri obtained from the two varieties of cassava is presented in Table 1. The result showed that the yellow cassava roots (D) had higher garri yield (54.32 %) than the white cassava roots (45.56 – 47.88 %). Sample C with addition of palm oil during toasting had better garri yield (46.27 %) than sample B (45.56 %) with oil addition before fermentation. This showed that the stage at which palm oils was added during garri production is important. There was significant difference ($p < 0.05$) in the yields of garri from cassava roots. Yield increase with the dry matter content (85.97 - 88.03) of garri. Several researchers have reported the dry matter content of commercial garri to range from 85 to 91 % (Ukpabi and Ndimele, 1990; Okolie *et al.*, 2012; Olopade *et al.*, 2014) [26, 20, 21]

Table 1: Yield of garri after processing

Sample	Tuber weight (Kg)	After Peeling (Kg)	After grating (Kg)	After dewatering (Kg)	After sieving (Kg)	After toasting (Kg)	Garri Yield (%)
A	7.10±0.12	6.21±0.33	5.63±0.41	4.21±0.65	4.00±0.71	3.40±0.80	47.88 ^b ±0.02
B	6.65±0.23	5.80±0.41	5.22±0.22	3.80±0.41	3.62±0.80	3.03±0.78	45.56 ^d ±0.04
C	6.72±0.41	5.85±0.27	5.26±0.51	3.81±0.83	3.63±0.46	3.11±0.69	46.27 ^c ±0.06
D	7.05±0.31	6.53±0.34	6.25±0.42	4.82±0.51	4.61±0.77	3.83±0.82	54.32 ^a ±0.03

Values are mean ± standard deviation; Means in the same column with different superscript are significantly different ($p < 0.05$; Sample A-white garri; B-garri with oil addition before fermentation; C-garri with oil addition during toasting; D-yellow β-carotene garri

3.2 Functional properties

The result of the functional properties of the garri samples is presented in table 2. There were significant differences ($p < 0.05$) in the functional properties of the garri samples. The bulk density of the garri samples ranged from 0.56 to 0.65 g/ml. β-carotene garri (D) had the highest BD (0.56 g/ml) while white garri (A) had the least (0.65 g/ml). Functional properties of play an important role in the reconstitution of products as it explains the behavior in

different conditions of use (Adeleke and Odedeji, 2010) [2]. The addition of palm oil to samples B (0.57 g/ml) and C (0.59 g/ml) increased the bulk density of the sample. The lower the bulk density, the higher the floatation of garri samples on top of water and as a result may not soak properly in water which may lead to rejection by consumers (Sanni *et al.*, 2008). More so, the higher the bulk density the greater the quantity of material that can be packaged within a specified packaging space (Onwuka, 2018) [24]. The bulk

density was within the range (0.56 g/ml - 0.91 g/ml) reported by Ukpabi and Ndimele (1990) [26] for some commercial garri.

WAC of sample A was the highest (13.22 %), followed by B (12.64 %). There was decrease in WAC of the sample by the addition of palm oil to samples. Sample D had the lowest WAC (10.91 %). High WAC is attributed to lose structure of starch polymers while low values indicate the compactness of the structure (Okolie *et al.*, 2012) [26]. Increase in WAC implies increased digestibility of the product. The WAC of the samples was similar that of some commercial garri (10.2 - 14.1 %) reported by Okolie *et al.* (2012) [26].

There was significant ($p < 0.05$) difference in the swelling index of the garri samples. Sample B (3.10 %) and C (2.85 %) with oil additions had lower SI values. Addition of palm oil to sample B (3.10 %) and C (2.85 %) reduced the swelling index of the garri. The entrapped water by food molecule is responsible in making the food to swell (Onwuka, 2018) [24]. The swelling index values obtained was lower than the values (3.16 - 3.51 %) reported by Makanjuola *et al.* (2012) [14]. Ukpabi and Ndimele (1990) [26] reported that high quality garri has swelling power of up

to four times its original volume in water. A good swelling power is indicator of high quality garri, when it is soaked in water for direct consumption or reconstituted in hot water to form paste (Sanni *et al.*, 2008).

The wettability of the garri samples ranged from 3.55 to 4.22 min. This described the extent of water absorption by garri (Onwuka, 2018) [24]. It took sample B (3.44 min) more time than C (3.63 min) to become wet as a result of poor water absorption. Sample A had the fastest wettability (3.05 min) since it is devoid of oil and carotenoids which are non-polar components. Wettability improves with smaller particle size (Oluwamukomi and Adeyemi, 2013) [22].

The gelatinization temperature (67.50 - 81.00 °C) and the viscosity (1.99 - 3.10 NS/m²) were high in all the samples. This could be due to the food constituents and processing variables used. Addition of palm oil to samples B and C increased both the gelation temperature and viscosity, but reduced the flow rates. Sample D was the most viscous 3.10 NS/m². Viscosity determines the rheological compatibility with other food systems. The size of garri grains also influence gelation temperature and viscosity (Onwuka, 2014) [24].

Table 2: Functional properties of garri

Samples	BD (g/ml)	WAC (%)	SI (%)	WT (min)	GT (°C)	VC (NS/m ²)
A	0.56 ^a ±0.10	13.22 ^a ±0.13	3.34 ^a ±0.15	3.05 ^a ±0.18	79.20 ^a ±1.51	1.99 ^c ±0.65
B	0.57 ^b ±0.13	12.64 ^b ±0.15	3.10 ^a ±0.18	3.44 ^d ±0.20	81.00 ^a ±1.10	2.41 ^b ±0.80
C	0.59 ^b ±0.10	12.42 ^c ±0.13	2.85 ^b ±0.14	3.63 ^c ±0.21	83.10 ^a ±1.22	2.42 ^b ±0.74
D	0.65 ^a ±0.12	10.91 ^d ±0.11	2.15 ^d ±0.16	4.22 ^d ±0.17	67.50 ^b ±1.31	3.10 ^a ±0.60

Values are mean ±standard deviation. Means in the same column with different superscript are significantly different ($p < 0.05$); BD- Bulk density, WAC-Water absorption capacity, SI-Swelling index, WT-Wettability, GT-Gelation temperature, VC-Viscosity

3.3 Proximate and energy content

The proximate composition of garri is shown in Table 3. There was significant difference in the proximate composition of the garri samples. The moisture content of the garri samples ranged from 11.97 to 17.31 %, with A having the least value (11.97 %). The addition of palm oil to samples A (14.03 %) and C (15.31 %) increased their moisture contents. The moisture content of all the garri samples except the white garri (11.97 %) was higher than the value (12 %) recommended by Codex Alimentarius for shelf stability of garri (Abu *et al.*, 2006) [1]. The moisture in garri majorly depends on the degree of dryness after frying. B-carotene garri (D) had the highest protein (3.02 %) while white garri (A) had the least protein (1.68 %). Protein content increased with the addition of palm oil to sample B (2.29 %) and C (1.68 %). Similar result increase in protein content was reported by Asegbeloyin *et al.* (2007) [7] and Zhu *et al.* (2015) [29].

The crude fibre contents of the garri samples (0.45 – 0.54 %) were below the nutritional maximum level of 3 % recommended (Ibe,1981).There was no significant ($p > 0.05$) difference between sample A (0.45 %) and B (0.48 %). Codex standard on gari regulation of 1980 had

recommended not more than 2.0 % crude fibre for gari samples (Makanjuola *et al.*, 2012) Sample B (3.55 %) and C (3.36 %) to which palm oil was added had higher lipid content than sample A (0.31 %) and D (1.49 %). This is in agreement with the findings of Asegbeloyin *et al.* (2007) [7] that the addition of oil during garri production increased the lipid content. The ether extract contains fat soluble phytochemicals and vitamins (Onwuka, 2018) [24]

The addition of palm oil decreased the ash content of samples B (1.57 %) and C (1.60 %). The ash content of the gari samples (1.44 - 1.99 %) was lower than the recommended maximum of 2.75 % (Makanjuola *et al.*, 2012) [14]. β-carotene garri (D) had the least ash content (1.44 %). The ash contents values were higher than the values (0.69 – 0.78 %) reported by Makanjuola *et al.* (2012) [14]. Ash content of foods is an indication of the mineral content (Ndife *et al.*, 2011) [15]. Values up to 0.5 % ash content is a good representation of mineral content (Adeleke and Odedeji, 2010) [2].

Sample C had the least carbohydrate (75.55 %) while sample A had the highest (83.28 %). It was reported by Ojo *et al.* (2013) [19] and Karim *et al.* (2016) [13] that palm oil addition and enrichment led to the reduction of carbohydrate

in garri. The utilizable energy content of the samples ranged from 339 to 357 kcal/100g. An increase in energy level of

the garri resulted from addition of palm oil to samples B (350 Kcal) and C (339 Kcal).

Table 3: Proximate content and energy values of garri

Sample	MC (%)	CP (%)	CF (%)	EE (%)	ASH (%)	CHO (%)	EV (Kcal)
A	11.97 ^d ±0.11	1.98 ^c ±0.12	0.48 ^b ±0.11	0.31 ^d ±0.13	1.99 ^a ±0.15	83.27 ^a ±0.14	344 ^c ±0.21
B	14.03 ^b ±0.19	2.29 ^b ±0.11	0.48 ^b ±0.12	3.55 ^a ±0.15	1.57 ^d ±0.18	78.08 ^b ±0.12	350 ^a ±0.58
C	15.31 ^a ±0.15	1.68 ^d ±0.13	0.50 ^{ab} ±0.11	3.36 ^b ±0.18	1.60 ^d ±0.16	77.55 ^c ±0.11	339 ^d ±0.09
D	13.58 ^c ±0.12	3.02 ^a ±0.14	0.54 ^a ±0.10	1.49 ^c ±0.16	1.44 ^c ±0.15	79.93 ^b ±0.14	357 ^b ±0.16

Values are mean ± standard deviation. Means in the same column with different superscript are significantly different (p<0.05). MC-Moisture content, CP-Crude protein, CF-Crude-fibre, EE-ether extract, ASH-Ash, CHO-Carbohydrate, EV-Energy value.

3.4 Chemical properties of garri samples

Table 4 showed the chemical properties of garri samples. The pH values of the samples were in the range (3.83 - 4.06). White garri had the highest value of pH (4.06). Addition of palm oil led to reduction in pH of B (3.83) and C (3.85) garri samples. There was no significant (p> 0.05) difference in pH between sample B and C. Codex standard on acidity for high quality garri range from 0.6 % to 1.0% (Makanjuola *et al.*, 2012). The pH will affect palatability and discourage the growth of pathogenic bacteria and subsequent spoilage of the garri (Ezeama, 2007). pH is also a critical factor that influence the reconstitution characteristics of food products (Onwuka, 2018) [24].

Palm oil treated garri samples B (2.12 µg/100g) and C (2.31µg/100g) had higher vitamin A content than untreated sample A (0.24 µg/100g) but lower than beta-carotene garri-sample D (3.89 µg/100g) in vitamin A contents. This could be due to the amount of palm oil added during processing and the composition of the different samples. Vitamins A consumption is good for the eye sight (Wardlaw, 2004) [27]. According to Zhu *et al.* (2015) [29] palm oil added to cassava mash during garri production and the use of biofortified cassava improved both the aesthetic and vitamin A values. Therefore, yellow garri is more nutritious and

preferably cherished than white garri (Karim *et al.*, 2016) [13]. There was significant (p>0.05) difference in the cyanide content of the garri samples. The addition of palm oil to sample B (4.25 mg/Kg) and C (5.01 mg/Kg), led to reduction in the HCN content of the garri. Sample A (control) had the highest HCN (6.64 mg/Kg) while B-carotene cassava garri (D) had the lowest (3.05 mg/Kg). The HCN content of all samples were below 10 mg/Kg considered as safe level by the world health organization (Adindu *et al.*, 2003) [3]. Previous investigations revealed that cassava cakes and garri to which palm oil is added during processing had lower HCN content and finer granular texture than samples without palm oil (Okolie *et al.*, 2012) [20]. Odoemelam (2005) [18] also reported that the variations in the hydrogen cyanide (HCN) content in garri may be due to differences in cassava varieties, inadequate fermentation and toasting during production. In adequate processing of cassava roots may lead to the production of intermediate toxic compound called cyanohydrins which can cause dizziness, headache, nausea, stomachache, diarrhea, sometimes death when the garri is consumed (Adindu *et al.*, 2003; Wardlaw, 2004; Asegbeloyin *et al.*, 2007) [3, 27, 21].

Table 4: Chemical properties of garri

Sample	pH	Vitamin A (µg/100g)	HCN (mg/Kg)
A	4.06 ^a ±0.02	0.24 ^d ±0.11	6.64 ^a ±0.13
B	3.83 ^c ±0.01	2.12 ^c ±0.12	4.25 ^d ±0.15
C	3.85 ^c ±0.02	2.31 ^b ±0.11	5.01 ^c ±0.17
D	3.99 ^b ±0.01	3.89 ^a ±0.14	3.05 ^b ±0.14

Values are mean ± standard deviation. Means in the same column with different superscript are significantly different (p<0.05);

HCN- Hydrogen cyanide.

3.5 Microbial content of garri samples

There were significant differences (p<0.05) in the total bacterial (2.91 – 4.01 log cfu/g) and total fungi (0.88 – 1.01 log cfu/g) counts of the garri samples (Table 5). The β-carotene garri (D) had the highest total bacteria (4.01log cfu/g) while the white garri (A) had highest total fungi (1.01log cfu/g) and total coliform (0.24 log cfu/g). The microbial values were found to be low. Ready to eat foods with total microbial counts greater than 10⁶ are unacceptable (Olopade *et al.*, 2014) [21]. This suggests that good hygienic

practice was employed during the garri production; hence it was safe for consumption. This could also be due fermentation and toasting techniques used in garri production (Edward *et al.*, 2012) [10]. Processing help to stop physiological and microbial spoilage as well as reduce the cyanogenic glucoside content (Asiedu, 1992; Ezeama, 2007) [8, 11]. Edward *et al.* (2012) [10] reported that lactic acid bacteria (LAB), *Aspergillus* sp. and *Candida* sp. were the most predominant microbes isolated from garri.

Table 5: Microbial content of garri samples

Sample	TBC	TFC (log cfu/g)	TCC
A	3.86 ^b ±0.11	1.01 ^a ±0.13	0.24 ^b ±0.12
B	3.31 ^c ±0.13	0.75 ^d ±0.11	0.11 ^a ±0.11
C	2.91 ^d ±0.11	0.88 ^b ±0.12	0.13 ^a ±0.12
D	4.01 ^a ±0.12	0.81 ^c ±0.11	0.10 ^a ±0.11

Values are mean ± standard deviation; Means in the same column with different superscript are significantly different (p<0.05); TBC-Total bacteria count, TFC-Total fungi count, TCC-Total coliform count

3.6 Sensory evaluation

The result of the sensory evaluation of garri samples is presented in Table 6. The values were significantly different at 5 % level in taste, appearance, texture, aroma and general acceptability of the garri samples. In all attributes, samples with addition of palm oil (B and C) had the highest sensory scores, which made them to be preferred to the untreated

samples (A and D). Samples B was the most preferred by the panelist as it had the highest score in all the attributes when compared to other samples. Sample B (with oil addition before fermentation) was rated higher than sample C; this may be due to its pronounced yellowish colour. Sample A may have been impacted by browning reactions that might have taken place during toasting.

Table 6: Sensory evaluation of garri samples

Sample	Taste	Appearance	Texture	Aroma	Acceptability
A	5.50 ^a ±0.76	5.65 ^c ±0.76	6.30 ^b ±0.58	5.65 ^c ±0.73	5.30 ^d ±0.53
B	7.70 ^a ±0.90	7.55 ^a ±0.85	7.55 ^a ±0.65	8.15 ^a ±0.88	8.25 ^a ±0.63
C	7.10 ^a ±0.86	7.50 ^a ±0.83	7.30 ^a ±0.88	7.20 ^b ±0.85	7.95 ^b ±0.76
D	6.10 ^b ±0.59	6.65 ^b ±0.91	6.65 ^b ±0.74	5.40 ^c ±0.56	6.80 ^c ±0.67

Values are mean ± standard deviation. Means in the same column with different superscript are significantly different (p<0.05)

4. Conclusion

This study has shown that the addition of palm oil to cassava during the fermentation and toasting stages in gari production is one of the effective ways of reducing the cyanide content of garri to a minimal or safe level. There was also improvement in the nutrient contents of the treated garri as well. It is therefore recommended that further studies be done on the effects of palm oil addition on the shelf stability of garri.

5. References

- Abu JO, Badifu GO, Akpapunan MA. Effect of crude palm - oil inclusions on some physico chemical properties of gari, fermented cassava food product. *J. Food Sci. Technol.* 2006; 24:73-79.
- Adeleke RO, Odedeji JO. Functional properties of wheat and sweet potato flour blends. *Pak. J. Nutr.* 2010; 9:535-564.
- Adindu MN, Olayemi FF, Nze-Dike OU. Cyanogenic potential of some cassava products in Port Harcourt markets in Nigeria. *J. Food Composition Analysis*, 16:121-124.
- Ajibola OO, Ige MT, Makanjuola GA. Preliminary studies of a new technique of Cassava mash Gelation. *J. Agric. Eng. Res.* 1987; 36:97-100.
- AOAC. Official Method of Analysis (18th edn) Association of Analytical Chemist International, Gathers turg MD, USA, 2005.
- APHA. Compendium of Methods for the Microbiological Examination of Foods (4th edn) American Public Health Association, Washington, DC, USA, 1992.
- Asegbeloyin JN, Onyimonyi AE. The effect of different processing methods on the residual cyanide of gari. *Pakistan Journal of nutrition.* 2007; 6(2):163-166.
- Asiedu JJ. Processing of Tropical Crops. Macmillan Publishers, Ltd., London, 1992.
- Chow MC, Ho CC. Role of palm oil in cassava processing into garri. *Journal of Oil Palm Research.* 2002; 14(1):25-34.
- Edward V, Egounlety M, Huch M, Van Zyl P, Singh S., Nesengani N, Haakuria V, Franz C. Isolation and screening of microorganisms from a gari fermentation process for starter culture development. *Afri.J. Biotechnol.* 2012; 11(65):12865-12877.
- Ezeama CF. Food Microbiology: Fundamentals and Applications. Natural Prints Ltd. Lagos, Nigeria, 2007.
- Iwe MO. Handbook of Sensory Methods and Analysis. Rojoint Communication Services Ltd., Enugu, 2010.
- Karim O, Adebanye B, Akintayo A, Awoyale W. Physical, chemical and sensory properties of cassava (Manihot esculenta)- sweet potato (Ipomoea batatas) gari. *Ukrainian J. Food Sci.* 2016; 4(2):276-286.
- Makanjuola O, Ogunmodede A, Makanjuola J, Awonorin S. Comparative study on quality attributes of gari obtained from some processing centres in south west, Nigeria. *Adv. J. Food Sci.Technol.* 2012; 4(3):135-140.
- Ndife J, Abdurraheem LO, Zakari UM. Evaluation of the nutritional and sensory quality of functional breads produced from whole wheat and soya bean flour blends. *Afri. J. Food Sci.* 2011; 5(8):466-472.
- Ndife J. Functional Foods: Basics, Ingredients and Application. Amotees link Services and Publishers, Kaduna, Nigeria, 2016.
- Nielsen SS. Food Analysis Laboratory Manual (3rd edn) Kluwer Academic Plenum Publishers, New York, 2003.
- Odoemelam SA. Studies on residual hydrocyanic acid (HCN) in garri flour made from of cassava chips. *J. Food and Technol.* 2005; 13:299-306
- Ojo A, Akande EA. Quality evaluation of gari produced from cassava and sweet potato tuber mixes. *J. Food Sci.* 2013; 12(31):4920-4924.
- Okolie NP, Brai MN, Atoyebi OM. Comparative study on some selected garri samples sold in Lagos metropolis. *J. Food Studies.* 2012; 1(1):52-63.
- Olopade BK, Oranusi S, Ajala R, Olorunsola SJ.

- Microbiological quality of fermented cassava (gari) sold in ota ogun state Nigeria. *Int. J. Curr. Microbiol. App. Sci.* 2014; 3(3):888-895.
22. Oluwamukomi M, Adeyemi A. Physicochemical characteristics of gari semolina enriched with different types of soy-melon supplements. *Euro. J. Food Res. and Review.* 2013; 3(1):50-62.
 23. Onwuka GI. *Food Science and Technology.* Naphtali prints, Somolu Lagos, Nigeria, 2014.
 24. Onwuka GI. *Food Analysis and Instrumentation: Theory and Practice (2nd edn)* Naphtali prints, Somolu Lagos, Nigeria, 2018.
 25. Sanni LO, Adebawale AA, Awoyale W, Fetuga GO. Quality of gari (roasted cassava mash) in Lagos state, Nigeria. *Nigerian Food J.* 2008; 26(1):125-134.
 26. Ukpabi UJ, Ndimele C. Evaluation of the quality of gari produced in imo state. *Nigeria. Food J.* 1990; 8:105-110.
 27. Wardlaw GM. *Perspectives in Nutrition (6th edn)* McGram Hill Co., New York, USA, 2004.
 28. Visakh PM, Iturriaga L, Ribotta P. *Advances in Food Science and Nutrition.* Scrivener Publishing, Beverly MA, USA, 2014.
 29. Zhua C, Caia Y, Gertza E, La Franoa M, Burnetta D, Burri B. Red palm oil supplemented and biofortified cassava gari increase the carotenoid and retinyl palmitate concentrations of triacylglycerol-rich plasma in women. *Nutr Res.* 2015; 35(11):965-974.