Studies on the Physicochemical, Functional and Sensory Properties of Gari Processed from Dried Cassava Chips

Elohor O Udoro*, Kehinde AT, Olasunkanmi SG and Charles TA
Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

Abstract

This study investigated the effects of drying temperature of chips, time of soaking and pressing on the quality of gari processed from dried cassava chips. Fresh cassava tubers were sliced and by sun dried and oven dried at 50 or 70°C. The chips were processed to gari by milling and soaking in four day old liquor (4DOL) for 3 or 4 days, transferred to the hydraulic press for 3 or 2 days respectively. The mash was sieved, fried, cooled and packaged. The proximate composition, physicochemical and functional properties of the gari samples were determined. Sensory evaluation was carried out on the gari samples in dry granular form and the reconstituted dough form (ebi).

The ash (1.54–1.70%), protein (1.22-1.69%), crude fibre (2.26-2.49%) and carbohydrate (82.38-86.48%) contents of the gari samples were not affected by the processing variables. The pH (4.00 – 6.80) of the gari samples decreased with fermentation time. The samples gelled completely at 9% (w/v). The pasting temperature (61.53-62.28°C) of the gari samples were not significantly (p < 0.05) different from each other. Solubility (3.03 – 38.10%), swelling capacity (3.13 – 8.19) and water absorption capacity (209.06 – 459.31%) were significantly (p > 0.05) influenced by the drying temperatures of the chips with gari from chips dried at 50°C having the highest values. Samples obtained from chips dried at 70°C, fermented for four days and pressed for two days recorded the highest overall acceptability.

Keywords: Dried cassava chips; gari; Physic-chemical properties; Functional properties; Consumer acceptability

Introduction

Cassava (Manihot esculenta Crantz) belongs to the family Euphorbiaceae. It is a major carbohydrate staple consumed in various forms by humans. It forms a base for a wide variety of fermented foods, in Africa, Asia and Latin America [1,2].

Cassava tubers once harvested begin to deteriorate and cannot be stored for more than a few days. Thus, there is a need for rapid processing of the tubers into a more shelf stable form. Nigeria currently is the largest producer of cassava in the world. Processing the tubers into chips reduced the moisture content to a very low level and reduced postharvest losses [3,4]. Cassava can be dried naturally in the sun or artificially in the oven [5,6] to produce dried cassava chips. Chips are commonly used in animal feed production; however several studies have shown that cassava can be reconstituted and converted to desired products such as starch, flour [7,8], fufu [6] and gari. Gari is a fermented cassava product and is one of the major products obtained from cassava in the West African sub region [9-11].

Oluswole et al. [12] reported that chips can be converted into gari by seeding (0-20%) it with fresh root. They reported that almost all the gari samples from the seeded chips gelatinised totally at the same temperature (82.5°C) with the commercial sample except for the gari sample prepared with unseeded chips. They also reported that gari obtained from dried cassava chips did not swell as much as gari obtained from fresh cassava roots. These they attributed to the treatment the chips received during drying. Taiwo and Okesola [13] reported that the pH of the mash from dehydrated chips was similar to that processed from fresh cassava in the traditional method, the findings of Oluwole et al. [12] agrees with the afore with the pH (4.1 - 4.5) of gari from fresh tubers and those from cassava chips ranging from 4.0 to 4.6.

Taiwo and Okesola [13] fermented dried chips in 4DOL and reported that gari processed from cassava chips has little or no difference from traditionally processed gari from freshly harvested cassava tubers when considering factors like residual cyanide, texture, moisture content; but taking sensory evaluation into consideration, there was significant difference in colour, flavour and general acceptability. This indicates that the quality of gari from dried cassava chips is yet to be perfected.

This study explored some processing variables that could influence the quality of gari processed from dried cassava chips with a view to establishing the optimum processing condition(s) for production of gari, with optimal functional and sensory characteristics, from dried cassava chips.

Materials and Methods

Bitter variety (Manihot esculenta Crantz) of freshly harvested cassava tubers (10-12 months old) were purchased from the University Teaching and Research farm on Obafemi Awolowo University Campus, Ile-Ife. All chemicals used were of analytical grade. The method described by FIIRO [5] was used with slight modifications in the production of the chips as shown in Figure 1. The washed cassava tubers were weighed and then manually peeled using a sharp knife after which the weight was taken again. The peeled tubers were diced manually into chips of 2.0 ± 1.0 mm thickness using a sharp knife and thickness was measured using a vernier calliper. The diced cassava tubers were divided into three parts. The first part was sun dried by spreading it on perforated steel trays and left in the sun until the diced cassava tubers were dried (average of 3 days). The second and third parts were dried in the oven...
The method described by Irinkoyenikan et al. [6] was employed with slight modifications in the processing of chips to gari. The samples of dried cassava chips were coarsely milled using a Marlex Excella grinder (Marlex Appliances PVT, Daman) set at speed 1 for 15 sec. The coarsely milled chips were divided into two portions. The first portion of all the coarsely milled samples of chips were weighed into a sack (made of muslin cloth) and then immersed in 4-day old liquor (4DOL) for three days. The second portion was soaked in a similar manner in 4DOL for 4 days and pressed for two days. At different temperatures were determined on the gari samples according to a modified version of Sathe and Salunkhe [16] method. The gari samples were milled using attrition mill to pass through a 300 µm sieve. Approximately 1 g of the sample was weighed into a previously tared 20 ml centrifuge tube and 15 ml of distilled water was added and stirred for 60 s. The tube was slowly shaken to keep the gari sample agitated and the temperature (60-90°C) was maintained in a thermostated water bath (Julabo, SW22, Germany) for 30 min. The suspension was then centrifuged (0502-1 Centrifuge, HOSPIBRAND, USA) at 3500 g for 15 min, the supernatant decanted and the swollen granules were weighed. Solubility power was expressed as the weight of swollen granules (final weight) divided by the sample weight (initial weight). From the supernatant, 5 ml was dried in an air convection oven at 120°C; for 4 h in a crucible to constant weight. Solubility was calculated as percentage weight of dry matter in 5 ml of the supernatant after drying according to a modified version of Sathe and Salunkhe [16] method.

Bulk density: Bulk density of the gari samples was determined by a modification of the method described by Okezie and Bello [17]. A 10 ml graduated cylinder, was gently filled with the sample, the bottom of the cylinder was gently tapped on a laboratory bench several (about 50) times until there were no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/cm³).

The method of Sathe and Salunkhe [16] was employed in determining the least gelling concentration of the gari samples. Sample suspensions of 1, 3, 5, 7, 9, 11, 13, 15, 17 and 20 % (w/v) were prepared in 5 ml distilled water and the test tubes were heated in a boiling water bath for 1 h. The test tubes were further cooled for 2 h at 4°C in a refrigerator. Least gelling concentration was determined as that concentration when the sample from the inverted test tube did not fall down or slip.

Hydrogen cyanide content was determined according to the method of Sudarmadji et al. [18] on the gari samples. 10 g of each sample (ground into flour) was put into a Kjeldal flask; approximately 200 ml of distilled water was added and allowed to stand for 2-4 h. Thereafter it was steam distilled and about 150-160 ml of the distillate was collected over 2.5% NaOH solution. Thereafter 8 ml of NH4OH and 2 ml of 5% KI were added to 100 ml of the distillate. Finally, the distillate was titrated against 0.02 N AgNO₃, Endpoint was faint but permanent turbidity was easily recognized against a black background. HCN content was calculated using the equations below:

\[ HCN_{(mg)} = \frac{ml \ \text{titrate sample} - \text{blank}}{ml \ \text{titrate of blank} \times 0.02} \times 0.54 \]  

\[ HCN\% = \frac{HCN_{(mg)} \times 100\%}{\text{mg sample}} \]  

Particle-size determination: The particle-size distribution of the gari samples was determined according to the method of Ngoddy et al. [19] with slight modifications. 50 g of gari granules were placed on a tier of sieves (Endecotts LTD, England) arranged in decreasing order of the size of their apertures as follows: 1 mm, 630 µm, 500 µm, 425 µm, 315 µm, 212 µm, 150 µm and a collecting base pan. The 1 mm aperture

![Figure 1: Effect of temperature on water absorption of gari samples.](image-url)
sized sieve was on top and the base pan at the bottom. The sieve was covered with a tight fitted lid and placed on a shaker. The shaker was operated for 10 min after which gari sample retained on each sieve was weighed. The percentage weight on different sized aperture sieves was calculated as:

\[
\text{Weight of sample on sieve} \times 100
\]

\[
\text{Starting Weight}
\]

The average particle size was determined by plotting percentage weight against sieve size on a sieve analysis graph sheet.

The pasting characteristics were determined using a Rapid Visco Analyzer (RVA) (Newport Scientific Pty. Ltd). The RVA was connected to a PC where the pasting properties and curves were recorded directly. Gari suspension was prepared by addition of the equivalent weight of 3.0 g of gari to 25 ml distilled water to make a total of 28.0 g suspensions in the RVA sample canister. A paddle was placed inside the canister; this was placed centrally onto the paddle coupling and then inserted into the RVA machine. The measurement cycle was initiated by pressing the motor tower of the instrument. The profile was seen as it was running on the monitor of a computer connected to the instrument. The 12 minute profile of the time-temperature curve of the equipment used was as follows: starting temperature was 50°C for 1 min, heated from 50°C to 95°C for 2 min 30 s. The sample was subsequently cooled to 50°C for 3 min 45 s period followed by a period of 2 min where the temperature was controlled at 50°C. The equivalent sample weight (S) was calculated using the formula:

\[
\text{Sample Weight} = \frac{A \times 100}{100 - M}
\]

Where M is the moisture content of the sample

\[
A = \text{Initial weight of sample.}
\]

Sensory analysis: Sensory analysis was conducted on the gari samples in both the granular meal form and in the reconstituted form (eba). Eba was prepared by adding about 100 g of gari to 500 ml of hot boiling water and stirred constantly to form a smooth thick paste. Gari and eba samples were coded and separately subjected to organoleptic evaluation using a 20-man panel (students of the Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife,) with the aid of questionnaires based on a 7 point hedonic scale (7–like extremely and 1–dislike extremely). The prepared eba was served with egusi vegetable stew and served in random order. The panellists assessed the coded eba samples for color, aroma, taste, texture, mouldability and overall acceptability. The coded gari samples (chewed dry) were assessed for colour, aroma, taste, graininess and overall acceptability.

All experiments were conducted in triplicate. Data reported are averages of three determinations. Analysis of variance (ANOVA) was performed and differences in mean values were evaluated using Duncan’s test at p<0.05.

Result and Discussion

Proximate Composition and Cyanide Content of Gari

Results of the proximate analysis of gari samples in Table 1 shows that the moisture content of the samples ranged between 7.31% and 11.04%. The moisture content of food samples is an index of stability and quality and also is a measure of yield and quantity of food solids [20]. The moisture content for gari samples were within the values considered acceptable for dried foods and also within the values reported for gari and other dried samples by earlier workers [12,13,21,22]. Ikujenlola et al. [23] reported a value of 11.24% for gari processed from dehydrated cassava chips. Ash content, which is a measure of the mineral elements, was lowest in the control sample (1.33%) and highest in gari samples produced from chips dried at 70°C (1.70%). The protein content of gari samples varied from 1.22% - 1.69%. The crude fibre of gari samples ranged from 2.26 - 2.49% while the carbohydrate contents were within the range 82.38 ± 1.15% and 86.48 ± 3.42%. The analysis of variance showed no significant (p<0.05) difference in the moisture, ash, crude fibre and carbohydrate content amongst the samples. The results are comparable to the findings of earlier workers Komolafe and Arawande [24] and Ashaye et al. [21]. It can be deduced that the processing variables such as drying temperature for chips, fermentation time as well as dewatering period did not influence the proximate composition of the experimental gari samples which compares favourably with the control [25].

The cyanide content of the gari samples (Table 1) ranged between 0.71 ± 0.13 and 1.19 ± 0.16 (mg/kg) which is below the recommended value of 2.0 mg/kg HCN for gari and cassava starch [5,3,26,27]. The values obtained in this study are lower than the values (1.97–2.01 mg/kg) reported by Taiwo and Okesola [13]. This may be attributed to the difference in fermentation time. It was also observed that the cyanide content decreased with increase in fermentation time. This may be attributed to the prolonged action of micro-organisms (in 4DOL) responsible for fermentation of gari on the chips. Irinokoyenikan et al. [6] reported a decrease in cyanide of chips with increase in fermentation time and attributed this decrease to the breakdown of cyanogenic glucosides in cassava roots during fermentation.

Pressing may also contribute to reduction in cyanide content [28]. The cyanide content of gari processed from dried cassava chips was not significantly different (P>0.05) from that of gari processed from fresh cassava tubers (control). It can therefore be deduced that dried cassava chips can be used to process gari with safe cyanide content comparable to those from fresh cassava roots. The results also suggest that the various processing methods adequately reduced cyanide content to an acceptable level.

Physicochemical and functional properties of Gari

The results of Loose Bulk Density (LBD), Packed Bulk Density (PBD), pH, water absorption capacity and solubility of gari samples at room temperature are presented in Table 2. LBD and PBD (g/cm³) ranged from 0.50-0.65 (g/cm³) and 0.62-0.78 (g/cm³) respectively. Gari processed from fresh cassava tubers had the least packed bulk density value and was significantly (p>0.05) different from all the experimental samples. The bulk density either loose or packed is influenced by factors such as dryness and particle size distribution of samples. The values obtained in this study are comparable to that of Komolafe and Arawande [24] who reported the bulk density of gari to be between 0.55–0.82 (g/cm³). According to Ukpabi and Ndimele [29] good quality gari should have bulk density of 0.56 to 0.908 (g/cm³). High bulk density increases the rate of dispersion which is important in the reconstitution of flours in hot water to produce dough [30]. The bulk density of any product provides vital information on packaging. The processing conditions studied did not influence the PBD or LBD of the samples significantly (p>0.05). The PBD values were higher than those of the LBD but this was not unexpected as the samples were tapped during experimentation to eliminate air spaces during determination of PBD thus resulting in higher values.

The control sample obtained from fresh cassava tubers had the lowest pH value (4.00) and therefore showed the highest acidity. In
The solubility of gari samples at room temperature as shown in Table 2 varied between 0.11 ± 0.09% and 0.54 ± 0.12%. Generally, there was no significant difference in the solubility of all the experimental samples at room temperature. Solubility reflects the extent of intermolecular cross bonding between granules [31]. This indicates that the drying temperature of chips had no significant effect on the solubility of the gari samples at room temperature. There was significant difference (p<0.05) in the solubility values of the samples but no discernible consistent trend was observed in this difference as a result of the processing conditions.

The water absorption capacity of the gari samples at room temperature varied between 234.96 - 272.08% with samples from chips dried in the oven at 50°C having the highest values. That of the control sample was not significantly (p < 0.05) different from the water absorption capacities of gari processed from sun dried and 70°C oven dried chips. This result indicates that gari from chips will absorb water adequately for soaking (drinking gari) as well as gari from fresh tubers. The water absorption capacity of chips oven dried at 70°C were lower (p > 0.05) than the values for the other processed chips. The values obtained in this study are within the range (215 – 445%) reported by Arawande and Komolafe [24].

The water absorption of gari samples as influenced by temperature is shown in Figure 1. The gari samples from different processing conditions exhibited water absorption capacities ranging from 219.92 to 459.31%. Water absorption capacity is the ability of a flour to absorb water and swell for improved consistency in food. It is desirable in food systems to improve yield, consistency and give body to the food [32]. The water absorption capacity increased with increase in temperature. Oluwole et al. [12] explained that at elevated temperatures, the molecules are subjected to random movement causing the intermolecular and intramolecular forces to be broken and the material in question will imbibe greater volume of water. The gari samples processed from 70°C oven dried chips exhibited the least water absorption capacity at all of the temperatures (60-90°C) studied. This could be attributed to the possible pre gelatinization or denaturation of the starch content of fresh cassava tubers during oven drying at 70°C to dried chips. This

### Table 1: Proximate composition and Cyanide content of gari samples.

| Samples         | Moisture (%) | Ash (%) | Protein (%) | Crude Fat (%) | Crude Fibre (%) | Carbohydrate (%) | HCN (mg/kg) |
|-----------------|--------------|---------|-------------|---------------|-----------------|------------------|-------------|
| SD2             | 8.39 ± 0.57  | 1.56 ± 0.10 | 1.52 ± 0.09 | 1.36 ± 0.23   | 2.49 ± 0.31     | 84.61 ± 1.20    | 1.14 ± 0.23  |
| SD3             | 9.74 ± 0.20  | 1.54 ± 0.05 | 1.23 ± 0.71  | 1.37 ± 0.64   | 2.43 ± 0.07     | 83.69 ± 1.67    | 0.71 ± 0.13  |
| OV 50.2         | 7.31 ± 2.02  | 1.64 ± 0.03 | 1.22 ± 0.06  | 1.01 ± 0.75   | 2.34 ± 0.56     | 86.48 ± 3.42    | 1.18 ± 0.15  |
| OV50.3          | 11.04 ± 0.00 | 1.55 ± 0.13 | 1.63 ± 0.15  | 1.03 ± 0.78   | 2.37 ± 0.09     | 82.38 ± 1.51    | 0.82 ± 0.11  |
| OV70.2          | 9.24 ± 0.61  | 1.70 ± 0.21 | 1.31 ± 0.48  | 0.34 ± 0.02   | 2.26 ± 0.17     | 85.15 ± 1.49    | 1.19 ± 0.16  |
| OV70.3          | 9.35 ± 0.26  | 1.70 ± 0.14 | 1.69 ± 0.26  | 0.53 ± 0.04   | 2.45 ± 0.52     | 84.28 ± 1.24    | 1.02 ± 0.18  |
| Control         | 9.05 ± 0.14  | 1.33 ± 0.02 | 1.61 ± 1.21  | 1.40 ± 0.10   | 2.47 ± 0.62     | 84.14 ± 1.29    | 1.06 ± 0.04  |

### Table 2: Physicochemical and functional properties of gari.

| Sample         | WAC (%)       | LBD (g/cm³) | PBD (g/cm³) | pH       | Solubility (%) |
|----------------|---------------|-------------|-------------|----------|----------------|
| SD2            | 256.32 ± 13.62 | 0.60 ± 0.01 | 0.71 ± 0.01 | 6.80 ± 0.07 | 0.26 ± 0.06   |
| SD3            | 261.00 ± 9.90  | 0.61 ± 0.02 | 0.74 ± 0.01 | 4.03 ± 0.00 | 0.30 ± 0.05   |
| OV50 2         | 268.41 ± 0.51  | 0.65 ± 0.01 | 0.78 ± 0.01 | 4.80 ± 0.00 | 0.11 ± 0.09   |
| OV50 3         | 272.08 ± 8.86  | 0.61 ± 0.02 | 0.72 ± 0.02 | 4.55 ± 0.07 | 0.22 ± 0.03   |
| OV70 2         | 277.41 ± 3.43  | 0.61 ± 0.01 | 0.73 ± 0.01 | 5.95 ± 0.07 | 0.44 ± 0.03   |
| OV70 3         | 299.06 ± 7.71  | 0.60 ± 0.02 | 0.71 ± 0.00 | 4.10 ± 0.00 | 0.46 ± 0.03   |
| Control        | 234.96 ± 32.88 | 0.50 ± 0.01 | 0.62 ± 0.01 | 4.00 ± 0.00 | 0.54 ± 0.12   |

### Experimental values

Experimental samples, pH values varied from 4.03–6.80 with gari processed from sun dried chips, soaked for three days and pressed for three (SD3) having the highest pH of 6.8 (almost neutral). All the experimental samples showed a sharp drop in pH with increase in soaking time. Samples soaked for 4 days and pressed for 2 days had lower pH values compared to those soaked for 3 days and pressed for 3 days. This may be due to increased production of lactic and other organic acids due to enhanced activities of lactic acid bacteria responsible for fermentation of cassava in the fermenting medium. This is in agreement with the findings of Irinkoyenikan et al. [6] that the pH of cassava roots decreased with increase in steeping time. There was significant difference (p<0.05) in the pH values of the samples but no discernible consistent trend was observed in this difference as a result of the processing conditions.
suggested that the temperature at which chips are dried influences the water absorption capacity of gari processed from them. Gari processed from fresh cassava tubers (control) exhibited distinctly higher (435.15-459.31%) water absorption capacity at temperatures above 70°C. Ruales et al. [33] reported that the water retention capacity of a starch granule indicates the degree of exposure of the internal structure of the starch granules to water. The values obtained in this study are comparable to the results (256–388%) of Ankrah [34] for gari samples in Accra. He attributed the range of values to the difference in starch levels of cassava tubers. The swelling pattern of a flour suggest the level of crystalline packing of the starch granules present in the flour [35]. The results in this study showed that the processing of gari from dried cassava chips had a declining effect on the water absorption capacity at temperatures above 70°C. The time of soaking and pressing during fermentation did not influence the water absorption capacity of the samples.

The influence of temperature on the percentage solubility of gari samples is presented in Figure 2. The solubility of the samples ranged between 3.03–38.10% at temperatures of 60–90°C. Increase in temperature resulted in increase in solubility for all the samples. According to Hoover and Maunal [36] an increase in temperature facilitated the hydrolysis of starch leading to an improved solubility.

Solubility increased as the temperature increased because of increase in mobility of the starch granules which facilitated enhanced dispersion of starch molecules in water [37]. Water molecules readily penetrated the intermolecular spaces of carbohydrates resulting in enhanced solubility [38]. It was observed that the control sample exhibited the highest (10.61–38.10%) solubility at all the temperatures investigated. Sample OV70.3 (oven dried at 70°C, soaked for four days and pressed for two days) exhibited solubility values (9.09–32.80%) close to the control while gari samples from chips dried in the oven at 50°C had the least percentage solubility. The effect of fermentation time or pressing time was not consistent.

The swelling capacity as a function of temperature shown in Figure 3 varied between 3.13 and 8.19. Gari samples processed from oven dried chips at 70°C, fermented by soaking in 4DOL for three days and pressed for three days (OV70.2) exhibited the lowest (3.13–5.3) swelling capacity while gari processed from fresh cassava tubers (control) had the highest (4.8–8.19) swelling capacity. However, at lower temperatures (60–70°C), the gari samples exhibited low swelling capacities when compared to the high temperatures of 80–90°C where the samples swelled more than five times their initial dry weight. It was also observed that the swelling capacity of the control sample was significantly (>0.05) higher than all other samples at temperatures above 70°C. Gari samples from chips dried at 50°C exhibited water absorption and swelling capacities closest to the control. It therefore suggests that the drying temperature of fresh cassava tubers to chips had a reducing effect on the swelling capacity of gari produced from the chips at higher temperatures (80–90°C) when compared to gari from fresh tubers. Swelling capacity, the ability of gari particles to absorb water and swell, depends on the free amyllose and associative forces within the starch granules and moisture content [39]. As temperature increases, the starch granules imbibe water and swell. Further increase in temperature caused amyllose molecules to leach out from the granules into the cooking water which increased the viscosity and therefore resulted in decreased swelling capacity. The findings in this study partly agree with that of Oluwole et al. [12] that at temperatures of 80 – 90°C, gari obtained from dried cassava chips did not swell as much as gari obtained from fresh cassava roots but that at lower temperatures (60–70°C) the gari obtained from dried cassava chips swelled as much as that obtained from fresh cassava. This means gari from chips will swell adequately for soaking (drinking gari) but may not give as good a volume when used to make eba when compared to gari from fresh tubers. This was attributed to the treatment of chips during drying which may have resulted in the general weakening of the starch structure thus, lowering swelling capabilities. However the values obtained in this study are similar to those of Achinewu et al. [40], IITA [2], Achinewu et al. [39], Udofia et al. [22] and according to the IITA [2], good quality gari may swell to about three times its initial volume when placed in water.

The gelling concentration of the gari samples is presented in Table 3. All the experimental gari samples were fully gelled at 9% (w/v) and the control gelled fully at 11% (w/v).Gelling of the experimental samples occurred at a lower concentration than that of the control. It therefore implies that the variation in the processing (drying temperature) of gari from dried cassava chips had no effect on the gelling ability of the gari samples. Gelation is an important functional property of food materials which affects its texture. The gelatinization process is a property of the starch granule found in cereals and tuber crops. The least gelling concentration indicates the amount of gari per volume of water that will be required to prepare the gelatinized form ‘eba’. These results show that less quantity of the gari samples processed from dried chips will be required to prepare a stable gel when compared to gari samples produced.
from fresh tubers. This implies that the pre-processing conditions did not significantly adversely (p<0.05) alter the starch structure which means that good eba can be made from the experimental samples.

The pasting properties of the gari samples from different processing conditions are presented in Table 4. The pasting temperature which provides an indication of the minimum temperature required to reconstitute (in hot water) a given sample and also indicate energy costs ranged from 61.53-70.2°C. It is characterized by an initial change in the viscosity due to the swelling properties of the starch granules. Pasting temperature, which is a reflection of the swelling of the starch granules, is affected by the starch concentration. The gelatinization temperatures are usually characteristic of a particular starch and usually lie between 55-70°C [41]. There was no significant difference (p<0.05) in the pasting temperature of all the gari samples. This implies that the processing variables such as the drying temperatures of chips, the soaking and pressing time (fermentation) had no significant effect (p<0.05) on the amount of energy that would be required to cook any of the gari samples.

The particle size distribution of gari samples processed from dried cassava chips under varying conditions and fresh cassava tubers is shown in Table 5. The percentage weight of particles retained on 1 mm aperture sieve ranged between 24.82 and 57.17%. All of the experimental samples except gari processed from sun dried chips, soaked for 3 days and pressed for 3 days (SD 3) and the control sample had about 70–80% of their particles retained on 625 µm–1 mm sieves and this could be attributed to the crushing of chips before fermenting in 4DOL. There was no significant difference (p<0.05) in the weight of samples retained on 425-630 µm sieves. The control exhibited values significantly (p<0.05) different from all the experimental samples in all the investigated sieve ranges. The difference in particle size exhibited by the samples suggests that the different processing procedures such as the grating of fresh tubers to mash before fermentation had significant (p<0.05) effect on the particle size distribution of gari samples processed from it. The range of particle size in foods depends on the cell structure and the degree of processing [42]. On the basis of the particle size distribution and average particle size, the control sample could be described as having moderately fine texture. The particle size of foods in dry granular form such as gari influences sensory attributes
such as graininess, mouth feel, texture and consistency of the food when consumed dry, soaked or in dough form.

Results of sensory evaluation in their dry granular form and reconstituted dough form (eba) are shown in Tables 6 and 7 respectively. The results on both evaluations followed a similar trend, the overall acceptability increased with increase in fermentation time, the samples from sun dried chips had the least scores this could be attributed to their dark colour, followed by samples from chips dried in the oven at 50°C, the control had the highest scores which was followed by samples processed from chips dried in the oven at 70°C with about 70% overall acceptability. Colour – on a 7 point hedonic scale, sundried samples had their dark colour, followed by samples from chips dried in the oven at 50°C, the control had the highest scores which was followed by samples processed from chips dried in the oven at 70°C (soaked three days and pressed three days) with 19.07 ± 0.40 the highest scores for colour is an improvement compared to earlier results published by Taiwo et al. [13] and Oluwole et al. [12]. These studies reported poor values for colour in gari samples from dried chips.

**Summary and Conclusion**

The cyanide content, proximate composition, pasting temperature and water absorption at room temperature of gari processed from dried cassava chips compared favourably with gari from fresh tubers. The result of water absorption at room temperature indicates that gari from chips will absorb water adequately for soaking (drinking gari) as well as gari from fresh tubers.

The physicochemical, functional and sensory properties of the...
experimental samples were greatly influenced by the processing variables. Gari samples from dried chips gelled at a lower concentration than the control. The results on both sensory evaluations followed a similar trend, the overall acceptability increased with increase in soaking time. Gari from oven dried chips had better sensory attributes (70°C was most preferred) than gari from sun dried chips (appeared dark).

Conclusively, this study shows that gari with relatively good physicochemical, functional and sensory characteristics (which compares favourably with gari from fresh cassava tubers) could be processed from dried cassava chips.

Acknowledgement
The authors are grateful to Obafemi Awolowo University Research Committee for funding the research through project No: 11812AMX.

The first author acknowledges the Carnegie Corporation, New York, for a cash scholarship received in the course of this work.

References
1. Aloys N, Ming ZH (2006) Traditional cassava food in Burundi. Food Rev Int 22: 1-27.
2. Taiwo KA (2006) Utilization Potentials of Cassava in Nigeria: The Domestic and Industrial Products. Food Rev Int 22: 29-42.
3. IITA (1996) Cassava in Tropical Africa: A Reference Manual, International Institute of Tropical Agriculture.
4. Ugwu WO (1996) Cassava cultivation in West Africa. Outlook on Agriculture 18: 72-81.
5. Federal Institute of Industrial Research (2005) Cassava processing. FIIRO, Oshodi, Lagos, Nigeria.
6. Irinkoyenikan OA, Taiwo KA, Gbadamosi SO, Akanbi C T (2008) Studies of fufo Production From Cassava Chips, Proceedings of Humboldt – Kolleg Held At The Obafemi Awolowo University, Ile-Ife, Nigeria, sponsored by Alexander von Humboldt Foundation, Germany.
7. Fomukunya OE (1994) Production of dehydrated cassava chips for starch and flour (fufo). Unpublished B.Sc. Thesis in Food Science and Technology. Obafemi Awolowo University, Ile-Ife, Nigeria.
8. Olomo V, Aijbola O (2006) Processing factors affecting the yield and physiochemical properties of starch from cassava chips and flour. Starch-Starke 55: 476-481.
9. Eggleston G, Bokanga M, Jean YW (1992) Traditional African methods for cassava processing and utilisation and research needs. Proceedings 4th Triennial Symposium, International Society for Tropical Root Crops- Africa Branch, Kinshasa Zaire.
10. Onabolu AO, Oluwole OSA, Rosing H, Bokanga M (2002) Processing factors affecting the levels of residual cyanohydrins in gari. J Sci Food Agr 82: 966-969.
11. Nago CM (1995) Artisanal gari production in Benin. Technological and physico-chemical aspects. Cassava processing. Paris ORSTOM editions.
12. Oluwole OB, Olutunji OO, Odunfa SA (2004) A process technology for conversion of dried cassava chips into garri. Nigerian Food Journal 22: 65-77.
13. Taiwo KA, Okesola CO (2009) A study of some processing factors on the production of gari (A fermented product) from dehydrated Cassava Chips. AICHE.
14. Enie LSO (1992) Prospects for processing and utilisation of root and tuber crops in Africa. Proceedings 4th Triennial Symposium, International Society for Tropical Root Crops- Africa Branch.
15. AOAC (1990) Association of Official Analytical Chemists. Official methods of Analysis. 13th edition. Washington DC, USA.
16. Sathe SK, Salunkhe DK (1981) Isolation, partial characterization and modification of Great Northern Bean (Phaseolus vulgaris L.) starch. J Food Sci 46: 617-621.
17. Okzie BO, Bello AB (1988) Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. J Food Sci 53: 450-454.
18. Sudarmadji SB (1984) Prosedur analisa untuk bahan makanan dan pertanian. Edisi Ketiga. Liberty. Yogyakarta: 138.
19. Ngody PO, Enwere NJ, Onuorah VI (1986) Cowpea flour performance in akara and moin-moin preparations. Trop Sci 26: 101-119.
20. Joslyn MA (1970) Methods in Food Analysis, 2nd Edition. Academic Press, London. pp 67.
21. Ashaye OA, Couple AA, Fasoyiro SB, Adeniji AM (2005) Effect of location and Storage Environment on the Quality Attributes of gari in South-West Nigeria. World J Agr Sci 1: 52-65.
22. Uduofa PG, Uduondo PJ, Eyen NO, Udokpokwu NS (2010) Optimizing gari quality attributes for different groups of consumers with response surface methodology. J Agri Biotechnol Sustain Develop 3: 28-34.
23. Iwuokwu IA, Ajambo CO, Udegbunam AO (2009) Processing of Cassava Chips to Gari. Adv Mat Res 62-64: 203-207.
24. Komolafe EA, Aruwade JO (2010) Evaluation of the quantity and quality of gari produced from three cultivars of cassava. Journal of Research in National Development 8.
25. IITA (1989) Lowering Cyanide Levels in Cassava. International Institute of Tropical Agriculture. Research Briefs 9: 1-3.
26. Standard Organization of Nigeria (1983) Nigeria industrial standard for gari. SON Lagos, Nigeria.
27. Standard Organization of Nigeria (2004) Nigeria industrial standard for gari. SON Lagos, Nigeria.
28. Blanshard AFJ, Dahiya MT, Poultier NH, Taylor AJ (1994) Fermentation of cassava into fufoo: Effect of time and temperature on pressing and storage quality. J Sci Food Agr 66: 485-492.
29. Ukpai UJ, Ndimele C (1990) Evaluation of the quality of gari produced in Imo State. Nigeria Food Journal 8: 105-109.
30. Brennan SG, Butters JR, Cowell ND, Lielly AEV (1976) Effect of agglomeration on the properties of spray-dried rooibos tea. Int J Food Sci Technol 23: 43-48.
31. Numfor FA, Walter WM Jr, Schwartz SJ (1995) Physicochemical changes in cassava starch and flour associated with fermentation; Effect on textural properties. Starch-Starke 47: 86-89.
32. Osundahunsi OF, Fagbemi TN, Kesselman E, Shimoni E (2003) Comparison of the physicochemical properties and pasting characteristics of flour and starch from red and white sweet potato cultivars. J Agric Food Chem 51: 2232-2236.
33. Ruales J, Valensia S, Nair B (1993) Effect of processing on physico-chemical properties of quinon (chenopodium quinon). Starch 45: 13-19.
34. Ankrah EK (2000) Quality evaluation of samples of gari from Ghana. Ghana J Agric Sci 33: 111-113.
35. Muhammad AS, Haq N, Mazhar H, Beena Y (2011) Proximate composition and functional properties of rhizomes of lotus (Nelumbo Nucifera) from Punjab Pakistan. Pak J Bot 43: 895-904.
36. Hoover R, Maunal H (1996) Effect of heat moisture treatment on the structure and physicochemical properties of legumes starches. Food Res Int 29: 731-750.
37. Adebowale AA, Sanni LO, Awonorin SO (2005) Effect of texture modifiers on the physicochemical and sensory properties of dried fufo. Food Sci Technol Int 11: 373-382.
38. Hwang J, Kokini JL (1991) Structure and rheological function of side branches of carbohydrate polymers. J Textural Study 22: 123-167.
39. Achinewu SC, Barber LJ, Ijewem IO (1998) Physicochemical Properties and Gari yield of some selected cassava cultivars in Rivers State, Nigeria. Plant Foods for Human Nutrition 52: 133-140.
40. Achinewu SC (1990) Toxic components of food and their mode of removal. Public lecture Rivers State University of Science and Technology, Port Harcourt.
41. Coutlalpe TP (1989) Food the Chemistry of its Components. Burlington House, Piccadilly, London.
42. Sahin S, Sumnu SG (2006) Physical Properties of Food. Springer Science, New York, USA.