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

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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 (*eba*).

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 chips 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].

Oluwole 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

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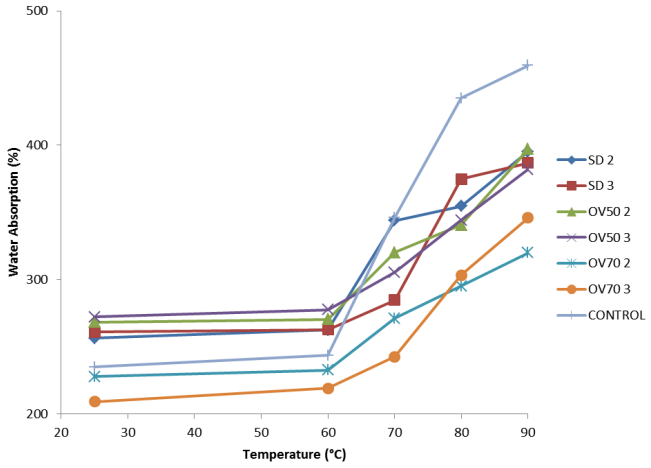

Figure 1: Effect of temperature on water absorption of *gari* samples.

(DK- 500WT, MRC LTD, Israel) at 50°C and 70°C, respectively for 48 h to a moisture content of about 10 ± 2%. The cassava chips obtained were allowed to cool, packed in polythene bags and sealed.

The method described by Irinkoyenikan et al. [6] was employed with slight modifications in preparation of the fermenting medium, four day old liquor (4DOL). Fresh cassava tubers were peeled, washed and cut. 1 kg of peeled tubers was put into 10 litres of tap water in a bucket, covered and allowed to stand for four days at room temperature. The liquor obtained is known as four day old liquor (4DOL) and was used to initiate fermentation of chips.

The method of Taiwo and Okesola [13] was employed with some 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 at room temperature (1 kg of milled chips in 5 litres of 4DOL) and the sacks were later transferred to a laboratory hydraulic press (32 tons) for dewatering (which allowed fermentation to continue for another 48h or 72 h). The second portion was soaked in a similar manner in 4DOL for 4 days and pressed for two days. The implication of this was that all the samples were subjected to the same duration of fermentation (6 days) and at room temperature (28 ± 2°C). The dough obtained was sieved using a loosely knit sieve (local raffia mat) to disintegrate coarse lumps and remove large particles of cassava tubers in the dough. The semi-dry cassava flour obtained was dried by constant stirring in a heated wrought iron pan until it was dried to about 10% moisture content. The *gari* obtained (experimental samples) was cooled, sieved again using the local raffia sieve, and stored in plastic bags. The method of Ene [14] was used to process *gari* from fresh cassava tubers which served as the control.

Physicochemical and functional Analysis

The proximate chemical composition of the *gari* samples was determined using standard AOAC [15] methods.

Water absorption: Capacity of the *gari* samples was determined by a modification of the method described by Sathe and Salunkhe [16]. Approximately 1 g of the sample was weighed into a tared 20 ml centrifuge tube and 15 ml of distilled water at different temperatures (60°C-90°C) added. The mixture was stirred with a glass stirring rod for 60 s and allowed to stand for 10 min. The suspension was then centrifuged at 3500g for 15 min. The supernatant was decanted and the tube allowed to drain at 45° angle for 10 min and then weighed. Water absorption was expressed as percentage increase of the sample weight.

Solubility and swelling power: 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 *gari* 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 3500g for 15 min, the supernatant decanted and the swollen granules were weighed. Swelling 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 according to the method of 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/cm^3).

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, this was followed by rapid cooling under running cold tap water. 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 procedure of Sudarmadji et al. [18] on the *gari* samples. 10 g of each sample (ground into flour) was put into a Kjeldahl 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 NH_4OH and 2ml of 5% KI were added to 100ml of the distillate. Finally, the distillate was titrated against 0.02 N $AgNO_3$. Endpoint was faint but permanent turbidity was easily recognized against a black background.

HCN content was calculated using the equations below:

$$HCN(mg) = \frac{ml\ titrate(sample - blank) * 20 * Normality\ of\ AgNo_3 * 0.54}{ml\ titrate\ of\ blank * 0.02} \quad (1)$$

$$HCN\% = \frac{HCN(mg) \times 100\%}{mg\ sample} \quad (2)$$

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 was 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

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:

$$\frac{Weight\ of\ sample\ on\ sieve * 100}{Starting\ Weight} \quad (3)$$

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:

$$Sample\ Weight = \frac{A * 100}{100 - M} \quad (4)$$

Where M is the moisture content of the sample

A = 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 panelists 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. Irinkoyenikan 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/cm^3) ranged from 0.50-0.65 (g/cm^3) and 0.62-0.78 (g/cm^3) 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/cm^3). According to Ukpabi and Ndimele [29] good quality *gari* should have bulk density of 0.56 to 0.908 ($g/cm^{3)}$. 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

Samples	Moisture (%)	Ash (%)	Protein (%)	Crude Fat (%)	Crude Fibre (%)	Carbohydrate (%)	HCN (mg/kg)
SD2	8.39 ± 0.57^{ab}	1.56 ± 0.10^{b}	1.52 ± 0.09^{a}	1.36 ± 0.23^{b}	2.49 ± 0.31^{a}	84.61 ± 1.20^{ab}	1.14 ± 0.23^{b}
SD3	9.74 ± 0.20^{bc}	1.54 ± 0.05^{b}	1.23 ± 0.71^{a}	1.37 ± 0.64^{b}	2.43 ± 0.07^{a}	83.69 ± 1.67^{ab}	0.71 ± 0.13^{a}
OV 50.2	7.31 ± 2.02^{a}	1.64 ± 0.03^{b}	1.22 ± 0.06^{a}	1.01 ± 0.75^{ab}	2.34 ± 0.56^{a}	86.48 ± 3.42^{b}	1.18 ± 0.15^{b}
OV50.3	11.04 ± 0.00^{c}	1.55 ± 0.13^{b}	1.63 ± 0.15^{a}	1.03 ± 0.78^{ab}	2.37 ± 0.09^{a}	82.38 ± 1.15^{a}	0.82 ± 0.11^{ab}
OV70.2	9.24 ± 0.61^{b}	1.70 ± 0.21^{b}	1.31 ± 0.48^{a}	0.34 ± 0.02^{a}	2.26 ± 0.17^{a}	85.15 ± 1.49^{ab}	1.19 ± 0.16^{b}
OV70.3	9.35 ± 0.28^{b}	1.70 ± 0.14^{b}	1.69 ± 0.26^{a}	0.53 ± 0.04^{ab}	2.45 ± 0.52^{a}	84.28 ± 1.24^{ab}	1.02 ± 0.18^{ab}
Control	9.05 ± 0.14^{b}	1.33 ± 0.02^{a}	1.61 ± 1.21^{a}	1.40 ± 0.10^{b}	2.47 ± 0.82^{a}	84.14 ± 1.29^{ab}	1.06 ± 0.04^{ab}

SD2, Sun dried chips (soaked three days and pressed three days)
SD3, Sun dried chips (soaked four days and pressed two days)
OV 50 2, Oven dried chips at 50°C (soaked three days and pressed three days)
OV 50 3, Oven dried chips at 50°C (soaked four days and pressed two days)
OV 70 2, Oven dried chips at 70°C (soaked three days and pressed three days)
OV 70 3, Oven dried chips at 70°C (soaked four days and pressed two days)
Control, Processed from fresh cassava tubers
Value with similar letters in the same column are not significantly ($p < 0.05$) different.

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

Sample	WAC (%)	LBD (g/cm^3)	PBD (g/cm^3)	pH	Solubility (%)
SD2	256.32 ± 13.62^{bc}	0.60 ± 0.01^{b}	0.71 ± 0.01^{b}	6.80 ± 0.07^{f}	0.26 ± 0.06^{ab}
SD3	261.00 ± 9.90^{bc}	0.61 ± 0.02^{b}	0.74 ± 0.01^{e}	4.03 ± 0.00^{b}	0.30 ± 0.05^{abc}
OV50 2	268.41 ± 0.31^{c}	0.65 ± 0.01^{c}	0.78 ± 0.01^{f}	4.80 ± 0.00^{d}	0.11 ± 0.09^{a}
OV50 3	272.08 ± 8.86^{c}	0.61 ± 0.02^{b}	0.72 ± 0.02^{cd}	4.55 ± 0.07^{c}	0.22 ± 0.03^{ab}
OV70 2	227.71 ± 3.43^{a}	0.61 ± 0.01^{b}	0.73 ± 0.01^{de}	5.95 ± 0.07^{e}	0.44 ± 0.03^{bc}
OV70 3	209.06 ± 7.71^{a}	0.60 ± 0.02^{b}	0.71 ± 0.00^{bc}	4.10 ± 0.00^{a}	0.46 ± 0.03^{bc}
Control	234.96 ± 32.88^{ab}	0.50 ± 0.01^{a}	0.62 ± 0.01^{a}	4.00 ± 0.00^{a}	0.54 ± 0.12^{c}

SD 2, Sun dried chips (soaked three days and pressed three days)
SD 3, Sun dried chips (soaked four days and pressed two days)
OV 50 2, Oven dried chips at 50°C (soaked three days and pressed three days)
OV 50 3, Oven dried chips at 50°C (soaked four days and pressed two days)
OV 70 2, Oven dried chips at 70°C (soaked three days and pressed three days)
OV 70 3, Oven dried chips at 70°C (soaked four days and pressed two days)
Control, Processed from fresh cassava tubers
LBD, Loose bulk density
PBD, Packed bulk density
WAC, Water absorption capacity at room temperature
Values with similar letters within the same column are not significantly ($p < 0.05$) different.

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

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 (SD_2) 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.

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 (60-90C) 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

suggests 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.

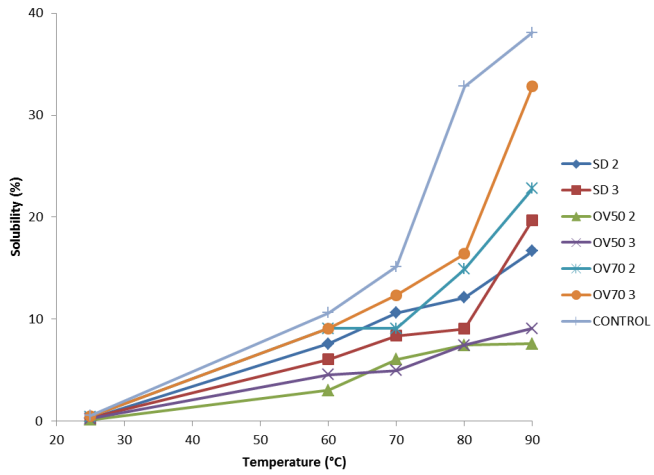

Figure 2: Effect of temperature on solubility of *gari*.

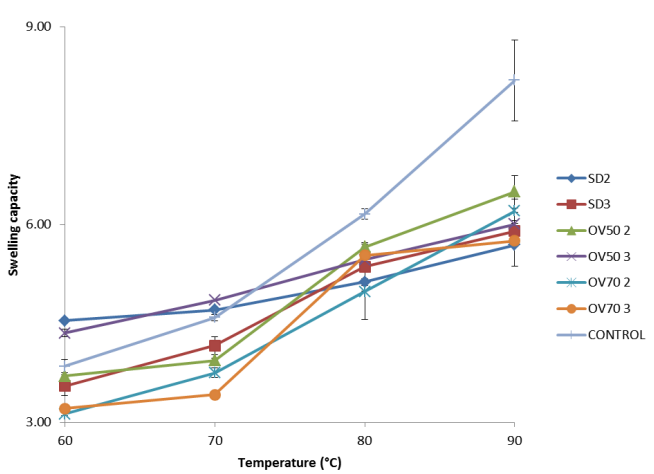

Figure 3: Effect of temperature on swelling capacity of *gari*.

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 ($p>0.05$) 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 amylose 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 amylose 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

Percentage (w/v)	SD2	SD3	OV50.2	OV50.3	OV70.2	OV70.3	Control
1	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
7	-	±	±	±	±	±	-
9	+	+	+	+	+	+	±
11	+	+	+	+	+	+	+
13	+	+	+	+	+	+	+
15	+	+	+	+	+	+	+
17	+	+	+	+	+	+	+
19	+	+	+	+	+	+	+

SD2, Sun dried chips (soaked three days and pressed three days)
SD3, Sun dried chips (soaked four days and pressed two days)
OV50.2, Oven dried chips at 50°C (soaked three days and pressed three days)
OV50.3, Oven dried chips at 50°C (soaked four days and pressed two days)
OV70.2, Oven dried chips at 70°C (soaked three days and pressed three days)
OV70.3, Oven dried chips at 70°C (soaked four days and pressed two days)
Control, Processed from fresh cassava tubers
- Not gelled
± Partially gelled
+ Completely gelled

Table 3: Gellation of gari samples.

Property	SD2	SD3	OV50.2	OV50.3	OV70.2	OV70.3	Control
PV (cP)	93.67 ± 0.47^{b}	163.38 ± 4.42^{d}	193.58 ± 3.54^{e}	147.25 ± 4.24^{c}	88.92 ± 1.59^{a}	95.50 ± 2.23^{b}	145.92 ± 0.83^{c}
TV (cP)	89.67 ± 0.23^{b}	158.79 ± 4.65^{d}	177.42 ± 0.23^{e}	141.33 ± 4.83^{c}	70.50 ± 3.78^{a}	93.17 ± 1.53^{b}	138.38 ± 4.18^{c}
BV (cP)	4.00 ± 0.71^{ab}	4.59 ± 0.23^{ab}	16.17 ± 3.77^{c}	5.92 ± 0.59^{ab}	18.42 ± 2.18^{c}	2.33 ± 0.71^{a}	7.55 ± 3.36^{ab}
FV (cP)	164.42 ±0.23^{b}	245.21 ± 9.49^{d}	275.12 ± 2.65^{e}	219.29 ± 7.13^{a}	90.04 ± 7.13^{a}	152.17 ± 1.65^{b}	214.83 ± 2.00^{c}
SV (cP)	74.75 ± 0.00^{b}	86.42 ± 4.83^{c}	97.71 ± 2.89^{d}	77.96 ± 2.53^{b}	54.80 ± 3.36^{a}	59.00 ± 0.11^{a}	76.46 ± 6.19^{b}
P_{Temp} (°C)	61.68 ± 0.18^{a}	62.08 ± 0.35^{a}	61.70 ± 0.14^{a}	61.53 ± 0.11^{a}	62.10 ± 0.00^{a}	61.68 ± 0.11^{a}	62.28 ± 0.88^{a}

SD.2, Sun dried chips (soaked three days and pressed three days)
SD.3, Sun dried chips (soaked four days and pressed two days)
OV 50.2, Oven dried chips at 50°C (soaked three days and pressed three days);
OV 50.3, Oven dried chips at 50°C (soaked four days and pressed two days)
OV 70.2, Oven dried chips at 70°C (soaked three days and pressed three days)
OV 70.3, Oven dried chips at 70°C (soaked four days and pressed two days)
Control, Processed from fresh cassava tubers
PV, Peak viscosity
TV, trough viscosity
BV, breakdown viscosity
FV, final viscosity
SV, setback viscosity
PTemp, pasting temperature
Values with different letters in the same row are significantly ($p< 0.05$) different

Table 4: Pasting properties of gari processed from dried cassava chips.

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 61.53-62.28°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_2) 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

Aperture size	SD2	SD3	OV50.2	OV50.3	OV70.2	OV70.3	Control
1mm	57.17 ± 4.58^{e}	34.29 ± 0.43^{b}	32.17 ± 0.42^{b}	40.00 ± 0.64^{cd}	38.65 ± 0.76^{c}	42.57 ± 0.71^{d}	24.82 ± 0.57^{a}
425–630 µm	36.90 ± 1.02^{b}	34.81 ± 0.89^{a}	38.67 ± 0.76^{ab}	41.05 ± 0.30^{ab}	42.62 ± 0.40^{ab}	38.36 ± 0.25^{ab}	60.65 ± 0.97^{c}
150-315 µm	5.95 ± 0.78^{a}	30.83 ± 1.26^{e}	29.18 ± 0.33^{d}	18.98 ± 0.39^{c}	18.76 ± 0.21^{c}	19.07 ± 0.40^{c}	14.56 ± 0.15^{b}
APS µm	662.50 ± 3.54^{d}	514.00 ± 5.66^{a}	525.00 ± 7.07^{a}	585.00 ± 7.07^{c}	567.50 ±10.61^{c}	575.00 ± 7.07^{c}	535.00 ± 7.07^{b}

SD2, Sun dried chips (soaked three days and pressed three days)
SD3, Sun dried chips (soaked four days and pressed two days)
OV50.2, Oven dried chips at 50°C (soaked three days and pressed three days)
OV50.3, Oven dried chips at 50°C (soaked four days and pressed two days)
OV70 2, Oven dried chips at 70°C (soaked three days and pressed three days)
OV70.3, Oven dried chips at 70°C (soaked four days and pressed two days)
Control, Processed from fresh cassava tubers
APS, Average particle size
Values with similar letters in the same column are not significantly ($p < 0.05$) different.
*Starting weight = 50g

Table 5: Percentage weight on different size apertures and average particle size of *gari.*

Quality Attributes	SD2	SD3	OV50.2	OV50.3	OV70.2	OV70.3	Control
Color	1.40 ± 0.50^{a}	2.60 ± 1.10^{b}	3.90 ± 1.48^{c}	3.45 ± 1.05^{c}	4.60 ± 1.39^{d}	5.30 ± 0.98^{e}	6.85 ± 0.37^{f}
Aroma	2.35 ± 1.34^{a}	2.30 ± 0.98^{a}	3.75 ± 1.21^{b}	3.80 ± 1.11^{b}	3.60 ± 1.47^{b}	3.80 ± 1.24^{b}	6.60 ± 0.50^{c}
Taste	2.40 ± 1.19^{a}	2.65 ± 1.04^{a}	3.50 ± 1.24^{bc}	3.05 ± 1.05^{ab}	3.55 ± 1.54^{bc}	3.90 ± 1.33^{c}	6.45 ± 0.69^{d}
Graininess	2.50 ± 1.10^{a}	2.95 ± 1.32^{ab}	3.85 ± 1.46^{cd}	3.45 ± 1.36^{bc}	4.25 ± 1.71^{cd}	4.35 ± 1.46^{d}	6.50 ± 0.51^{e}
Overall Acceptability	2.05 ± 0.94^{a}	2.65 ± 1.04^{a}	3.85 ± 1.18^{b}	3.70 ± 0.80^{b}	4.35 ± 1.14^{b}	4.25 ± 1.07^{b}	6.70 ± 0.47^{c}

SD2, Sun dried chips (soaked three days and pressed three days)
SD3, Sun dried chips (soaked four days and pressed two days)
OV50.2, Oven dried chips at 50°C (soaked three days and pressed three days)
OV50.3, Oven dried chips at 50°C (soaked four days and pressed two days)
OV70.2, Oven dried chips at 70°C (soaked three days and pressed three days)
OV70.3, Oven dried chips at 70°C (soaked four days and pressed two days)

Table 6: Sensory evaluation of gari processed from dried cassava chips.

Quality Attributes	SD2	SD3	OV50.2	OV50.3	OV70.2	OV70.3	Control
Color	1.10 ± 0.45^{a}	3.65 ± 1.42^{b}	3.95 ± 1.28^{b}	3.75 ± 1.65^{b}	5.20 ± 1.11^{c}	5.15 ± 1.46^{c}	6.80 ± 0.41^{d}
Aroma	1.75 ± 0.72^{a}	3.00 ± 0.79^{b}	3.75 ± 1.25^{cd}	3.50 ± 0.24^{bc}	4.25 ± 1.41^{d}	4.40 ± 1.05^{d}	6.55 ± 0.69^{e}
Taste	1.95 ± 1.10^{a}	2.75 ± 0.97^{a}	3.40 ± 1.54^{bc}	3.50 ± 1.15^{bc}	3.75 ± 1.59^{c}	3.85 ± 1.63^{c}	6.55 ± 0.69^{d}
Texture	3.10 ± 1.41^{a}	3.75 ± 1.16^{ab}	4.15 ± 1.14^{b}	4.20 ± 1.36^{b}	4.25 ± 1.45^{b}	4.20 ± 1.32^{b}	6.50 ± 0.76^{c}
Mouldability	3.90 ± 1.80^{a}	4.45 ± 1.36^{ab}	4.40 ± 1.43^{ab}	4.45 ± 1.10^{ab}	4.00 ± 1.65^{ab}	4.95 ± 1.36^{b}	6.60 ± 0.68^{c}
Overall acceptability	2.25 ± 1.21^{a}	3.65 ± 0.93^{b}	4.20 ± 0.95^{bcd}	3.90 ± 0.97^{bc}	4.55 ± 1.15^{cd}	4.85 ± 1.14^{d}	6.60 ± 0.68^{e}

SD2, Sun dried chips (soaked three days and pressed three days)
SD3, Sun dried chips (soaked four days and pressed two days)
OV50.2, Oven dried chips at 50°C (soaked three days and pressed three days)
OV50.3, Oven dried chips at 50°C (soaked four days and pressed two days)
OV70.2, Oven dried chips at 70°C (soaked three days and pressed three days)
OV70.3, Oven dried chips at 70°C (soaked four days and pressed two days)
Control, Processed from fresh cassava tubers
Value with similar letters in the same column are not significantly ($p < 0.05$) different.

Table 7: Sensory evaluation of gari (in form of eba) processed from dried cassava chips.

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 obtained less than average scores but those oven dried had greater than average scores (i.e. above 3.5) and better scores were obtained on samples dried at 70°C. This trend was observed for all the characteristics tested– graininess, aroma, taste and overall acceptability. Above average 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 colours for *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.

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