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# EFFECTS OF DRYING METHODS AND REHYDRATION WATER TEMPERATURES ON PHYSICO-CHEMICAL AND PASTING PROPERTIES OF *GARI* PRODUCED FROM DRIED CASSAVA CHIPS

***Ogunlakin, G. O., Tunde-Akintunde, T. Y., Oke, M. O., Olaniyan, S. A. & Fadare, P. A***

*Research Scholar, Department of Food Science and Engineering, Ladoke Akintola University of Technology, P.M.B, Ogbomoso, Nigeria*

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***ABSTRACT***

*Freshly harvested cassava tubers were converted into cassava chips utilizing three different drying methods which include: sun, solar and cabinet drying. The dried cassava chips were coarse-milled and rehydrated to about 67% moisture content with water of three temperature levels (20, 30 and 40°C). The rehydrated mash was seeded with 5 % fresh cassava mash, fermented for 72 h and gari was produced. The gari produced were investigated for their physico-chemical and pasting properties. The following are the ranges of the various physico-chemical parameters evaluated: swelling capacity (3.56 - 4.14), water absorption capacity (493.85 - 542.15%), solubility index (3.5 to 9.4%), loose density (0.63 - 0.67 g/cm$^3$), bulk density (0.63 - 0.69 g/cm$^3$), pH (4.13 - 4.73), total titratable acidity (0.67 - 0.87 %), hydrogen cyanide content (0.023 - 0.03). The gari produced from cassava chips showed that pH and hydrogen cyanide (HCN) content were reduced significantly ($p<0.05$) compared to the control sample. Better results were observed in some physico-chemical properties such as water absorption capacity, swelling capacity, bulk density, and titratable acidity and pasting properties, particularly at lower temperature (20 °C) of rehydration water in all drying methods, used. At rehydration water temperature of 30 °C, sun and solar drying methods gave better results. Cabinet dried and rehydrated at 20°C sample has the highest peak viscosity value. Cabinet drying method and rehydration temperatures of 20 and 30°C produce the samples with the best pasting parameters.*

***KEYWORDS***: *Pasting, Physico-Chemical, Cassava Chips, Gari*

## INTRODUCTION

*Gari* is a granulated and roasted cereal-like cassava food product which is convenient for consumption in urban environments. It is preferred by urban consumers because it is a pre-cooked convenience food. It could be eaten with groundnut by soaking in cold water and adding sugar, or it could be prepared into dough (*eba*) with hot water and eaten with any form of soup. *Gari* is usually produced from fresh roots; however, when large quantities of cassava are harvested for the processing and not processed on time, the roots deteriorate. Generally, irrespective of the quantity, the roots would deteriorate or turn woody if left unharvested for some time (FAO, 2006). Producing chips during glut period (when a large quantity of cassava roots is harvested) can solve the problem of deterioration of roots as the chips can be used for further processing of the cassava products like *gari*.

Cassava chips are unfermented, dry products of cassava. Cassava roots are chipped into smaller sizes for fast drying that also helps the process of detoxification. Cassava can be dried naturally in the sun, or artificially in an oven (Irinkoyenikan *et al.,* 2008) to produce cassava chips. According to Sanni *et al.* (2007) and Taiwo and Okesola (2009), chips are mostly used in animal feed production but have a potential for human consumption which has not been fully explored. In some West African countries, chips are utilized in the production of flour and starch.

Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. Drying and dewatering plays a major role in food manufacturing or food processing activities worldwide. The aim of drying cassava is to reduce its moisture content to less than 15%. The recommended water content varies from the type of final product ranging from 9 to 15% (Wenlapatit, 2004). Meanwhile, according to IITA (2005) following some factors like temperature, airflow, humidity and tumbling frequency may influence drying of cassava products (chips, flour, and starch). Therefore this work aimed at studying the effects of different drying methods and rehydration water temperatures on physicochemical and pasting properties of *gari* produced from dried cassava chips

## MATERIALS AND METHODS

### Materials

Cassava (*Manihot esculenta*) roots (local sweet variety is also known as *oko-iyawo*) were obtained from LAUTECH (Ladoke Akintola University of Technology) Teaching and Research Farm, Ogbomoso, Nigeria.

### Sample Preparation

The freshly harvested cassava roots were sorted, washed, peeled and chipped using a chipping machine. The chips were packed in sacks and pressed with a hydraulic press in order to reduce the moisture content. The chips produced were dried using three different drying methods (sun, solar and cabinet drying), cooled and packaged in high-density polythene bags.

The dried cassava chips were coarse-milled using a milling machine. The dried cassava chips was then rehydrated to about 67 % moisture content to simulate the moisture level of fresh cassava mash. The amount of water added was calculated based on the mathematical expression according to Hammonds *et al*. (1977):

$$\boldsymbol{Q} = \left(\frac{(\boldsymbol{b}-\boldsymbol{a})}{(\mathbf{100}-\boldsymbol{b})}\right) \mathbf{x\ A}$$

where, **Q** is the amount of water to be used to rehydrate the cassava chips measure in liters; **A** is the initial mass of the cassava chips' sample measured in kg; **b** is the final moisture content of the sample taken to be 67 %; and **a** is the initial moisture content of the cassava chips' sample

The method of Oluwole*et al*. (2008) was utilized for producing *gari* after the rehydration of cassava chips. The chips were rehydrated and seeded with 5% fresh cassava mash (Akinwande*et al*., 2013). Seeding was done in order to induce fermentation in the rehydrated mash. The seeded mash was fermented for 72 h and dewatered with manually operated hydraulic jack. The solid cake obtained after dewatering was weighed, broken up and sifted to remove the large lumps. The broken up mash was roasted into the gelatinized product (*gari*) using traditional method in shallow cast-iron pans. The *gari* was scooped out and cooled by spreading it in a large bowl prior to weighing and packaging.

**Analyses of Samples**

Physico-chemical properties (loose and bulk densities) were determined using the method described by Balami*et al.* (2004), swelling capacity by using the method of Sathe and Salunkhe (1981), water absorption and water solubility index by using a method described by Malomo*et al.* (2012), pH using method by Oyewole and Odunfa (1989), Total Titratable Acidity (TTA) using a method described by Owuamanam *et al.* (2010), and Hydrogen Cyanide (HCN) content was determined by AOAC (2005).

The pasting profiles of the *gari* produced were studied using a Rapid Visco-Analyzer (RVA) (Newport Scientific, 1998) with the aid of a thermocline for windows version 1.1 software (1996).

**Statistical Analysis**

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 $p < 0.05$.

## RESULTS AND DISCUSSIONS

**Physico-Chemical Properties**

The result of physic-chemical analysis of *gari* produced from cassava chips is as shown in Table 1. The swelling capacity values ranged from 3.56 to 4.14. Solar-dried sample rehydrated at 20 °C, cabinet-dried sample rehydrated at 20 °C, sun-dried sample rehydrated at 30 °C, solar-dried sample rehydrated at 30 °C, solar-dried sample rehydrated at 40 °C is significantly different ($p<0.05$) from other experimental samples as shown in Table 1. The aforementioned samples were observed to have relatively high swelling capacities or indices. A good quality *gari* has been described as that which can swell to at least 3 times its original volume (Sanni *et al.,* 2008). The swelling capacity of *gari* indicates its starch content and the extent of its starch gelatinization since *gari* swells based on starch components. There were significant effects ($p<0.05$) on swelling capacity of *gari* samples in terms of drying method and rehydration water temperature (Table 1). But all the *gari* samples obtained in the study have a swelling capacity higher than three (3) which indicates that they are of good quality (Achinewhu *et al*., 1998).

The water absorption capacities ranged from 493.85 to 542.15%; with sun-dried sample rehydrated at 40 °C and solar-dried sample rehydrated at 40 °C having the lowest and highest water absorption capacities, respectively with no significant difference. Water absorption capacity which is the ability to absorb water through the food product is also an important characteristic of starch-based foods particularly those that need to be reprocessed to get another food. It was observed from this study that the *gari* produced from the dried cassava chips gave higher water absorption capacity than the control samples. This could be as a result of the fact that the drying of the chips was done at temperatures lower than its gelatinization temperature (< 70 °C). It was reported by Udoro *et al*. (2014) that there was pre-gelatinization or denaturation of the starch content during oven drying at 70 °C of dried chips as this could reduce the water absorption capacity of the product.

The solubility index range from 3.5 to 9.4%, with sun-dried sample rehydrated at 20 °C and solar-dried sample rehydrated at 30 °C having the lowest and highest solubility indices, respectively. Based on the results of the statistical, it was noted that solar-dried samples were significantly ($p<0.05$) different from those samples with obtained from other drying methods except at rehydration water temperature of 20 °C. The values were comparable to the ranges 4.25 – 5.96% obtained by Ikegwu *et al.* (2009) for starch isolates from 13 improved cassava cultivars and 3.34 – 5.07% by Oluwamukomi and Jolayemi (2012) for soy-melon enriched *gari* semolina.

The ranges of values for loose and bulk densities of *gari* samples are 0.61 - 0.67 g/cm$^3$ and 0.63 to 0.69 g/cm$^3$, respectively as shown in Table 2. Control sample had the lowest values in both loose and bulk densities but not significantly different from sun-dried sample rehydrated at 20 °C, The implication of high values of bulk density in most the samples produced from chips is that the volume will be reduced for a larger quantity of *gari* to be packaged or transported per volume of space (Singh and Heldman, 2008). This means, more quantity of *gari* produced from dried chips will be packaged than the *gari* produced from fresh cassava roots for the same specific volume (Oluwamukomi and Adeyemi, 2013). Apart from ease packaging with these higher values of bulk density, it is also observed by Udensi and Okaka (2000) that high bulk density increases the rate of dispersion of granules in water which is important in *gari* reconstitution for making *eba* (*gari* dough).

The pH of the *gari* obtained a range from 4.13 to 4.73 for the samples from dried chips while the pH of the *gari* obtained from fresh cassava roots was recorded as 5.58. The values were significantly different from each other for both drying methods and rehydration water temperature except for the values obtained for samples rehydrated at 20 °C in all drying methods. The highest value observed in the control sample indicates that the *gari* obtained from dried chips are acidic as this might not predispose the product to bacterial spoilage. The high values of pH of *gari* in this study contribute to the sourness of *gari* as this is desirable to most consumers particularly in South-West Nigeria (Adebayo, 2012).

The total titratable acidity (TTA) values ranged from 0.57 to 0.87 % with *gari* produced from fresh cassava roots having the lowest value. According to Oghenechavwuko *et al.* (2013), the increased values of TTA suggests that organic acids were produced during fermentation of the cassava chips that have been seeded with fresh cassava mash; and this was probably due mainly to the increased activities of the fermenting microorganisms native to fresh cassava mash and other organisms present at ambient temperature under which the fermentation was carried out.

The residual cyanide in the *gari* samples ranged from 0.02 to 0.03 with the sample the control sample having the highest value which was significantly ($p<0.05$) different from others. The reduction in the HCN content of *gari* produced from fresh cassava roots compared to *gari* produced from dried chips from the same variety can be attributed to the combined action of chipping, dewatering and drying (Mayaka, 2012). According to FAO/WHO (1991), the safe level of cyanide is below 10 mg/kg (1 mg/100 g); a value above this can pose the health risk to the consumers. The values obtained in this study are far below the values 1.36 – 2.15 mg/100 g reported by Komolafe and Arawande (2010) for *gari*. The low values obtained in this work indicate that the *gari* from dried cassava chips is safe for consumption.

**Pasting Properties**

The result of the analysis of the pasting profiles of the *gari* produced from cassava chips is shown in Table 2. The peak viscosity results which ranged from 66.10 to 332.82 RVU, obtained in this study were generally lower when compared with other cassava products like starch. This is because *gari* is a partially gelatinized product, but the results were comparable to the values 227.50 – 300.92 RVU, and 119.67 – 322.67 RVU obtained by Oluwamukomi and Jolayemi (2012) and Nwancho *et al.* (2014) for *gari*. The rehydration water temperatures of 20 and 30 °C were observed to have given higher peak viscosity values compared to control samples in all the drying methods used. It has been reported according to Sanni *et al.* (2001) that the peak viscosity is closely associated with the degree of starch damage and high starch damage results in high peak viscosity. More starch granules with a high swelling capacity also result in a higher peak viscosity. This implies that damage was done to the starch content of mash when rehydration was done with water temperatures of 20 and 30°C. Sample-cabinet dried and rehydrated at 20°C has the highest peak viscosity value.

The trough viscosity is also known as holding strength is the ability to paste to withstand breakdown during cooling. The range of values (62.06 - 239.15 RVU) obtained in this study is comparable to the findings of Nwancho *et al.* (2014) who reported the values of 70.92 - 239.17 RVU for trough viscosity of *gari* from cassava chips. The significant differences observed might be attributed to the different drying methods and the variation in the temperature of rehydration water used. The values of breakdown viscosity of *gari* from dried chips and fresh roots are ranged 0.58 - 41.52 RVU. The higher the breakdown viscosity of starch-based food, the lower is its ability to withstand the shear stress during cooking (Adebowale *et al.*, 2005). Shimelis *et al.* (2006) also reported that less stability of starch paste is commonly accompanied by the high value of breakdown. Though the values obtained in this study were comparable to the values of breakdown viscosity reported by Nwancho *et al.* (2014), 30.92 – 177.67 RVU and Otegbayo *et al.* (2013), 91.25 – 144.67RVU for *gari* obtained from dried chips and fresh roots and soy-substituted *tapioca*, respectively. However, the values are generally low compared to values reported by Olatunde *et al.* (2013) who reported 149.50 – 566.25 RVU for cocoyam-*gari* and Oluwamukomi and Jolayemi (2012) who reported 136.17 – 202.58 RVU for soy-melon enriched *gari* semolina. The lower values obtained in this breakdown viscosities in this study indicated that *gari* obtained from cassava chips will have a higher ability to withstand stress during heating.

The range of results of final viscosity is 129.720 – 420.720 RVU, with the control sample having the lowest values while solar-dried, rehydrated with 20 °C water temperature *gari* had the lowest value. This variation observed in final viscosity might be due to the simple effect of cooling on viscosity and re-association of starch molecules in the *gari* samples (Ikegwu *et al.,* 2009). This could be attributed to the different drying methods used and the variation in temperature of water used for rehydration. Maziya-Dixon *et al.* (2007) reported that the increase in final viscosity has been found to favor the ability of starch to form a viscous paste or gel after cooking and cooling. This implies that *gari* from cassava chips can give a stable product after cooking and cooling. The values (50.81 - 191.88 RVU) of setback viscosity obtained in this study were found lower than the ranges of 1297.75 – 2425.75 RVU and 915.5 – 2252.5 RVU reported by Olatunde *et al*. (2013) and Akinoso and Olatunde (2014), respectively for *gari*. The low setback value obtained during the cooling of the paste indicates a lower tendency for retrogradation (Sandhu *et al*., 2007). This is an indication that the *gari* samples from dried chips will produce the pastes with better characteristics which will have higher stability against retrogradation due to their lower setback viscosity.

The values of peak time ranged from 5.410 to 6.940 min, The values were found significantly ($p \leq 0.05$) different from each other which means both drying methods and the variation in temperature of rehydration water have significant effects on the peak time. Though the values were found significantly different, the highest values were obtained in a control sample. This signifies that more energy will be required to cook or form the paste with a control sample and the *gari* samples from dried chips will take a shorter time to form the paste. The pasting temperature is the temperature at which the peak value of RVA is measured which gives an indication of the temperature of gelatinization during processing (Chinma *et al*., 2009). The values of pasting temperature in this study ranged from 80.53 from 93.33 °C for *gari* from dried chips and fresh roots. The control samples were found to have the highest values while lowest values were found for samples obtained from solar-dried chips rehydrated with water at 30 °C. This indicates that *gari* produced from chips will cook faster and less energy will be consumed, thereby saving cost and time compared to the *gari* samples produced from fresh roots because their pasting temperature is lower than those of control sample. Colonna *et al*. (1992) reported that a high starch concentration leads to a low pasting temperature. This means the drying of chips had led to high starch concentration in the chips which is responsible for having lower pasting temperature and peak time compared to samples obtained from fresh roots.

## CONCLUSIONS

From the result, it could be concluded that production of *gari* from cassava chips improve the quality of *gari*. It also reduced the hydrocyanic acid content, thereby producing *gari* of higher quality with better safety. *Gari* samples produced from cassava chips were found to give high swelling indices which is good news for consumers of soaked *gari*. Cabinet drying method and rehydration temperatures of 20 and 30 °C produce the samples with the best pasting parameters.

**Table 1: Physico-Chemical Properties of *Gari* Produced from Dried Cassava Chips**

| Sample (%) | SC | WAC(%) | SI (%) | LD(g/cm$^3$) | BD(g/cm$^3$) | pH | TTA | HCN |
|---|---|---|---|---|---|---|---|---|
| **Sun$_{20}$** | 4.00$^{ab}$ | 534.50$^a$ | 3.50$^b$ | 0.61$^b$ | 0.63$^b$ | 4.68$^c$ | 0.67$^c$ | 0.02$^b$ |
| **Solar$_{20}$** | 4.14$^a$ | 514.50$^a$ | 3.55$^b$ | 0.66$^a$ | 0.68$^a$ | 4.67$^c$ | 0.77$^b$ | 0.02$^b$ |
| **Cabinet$_{20}$** | 4.14$^a$ | 521.40$^a$ | 4.45$^b$ | 0.66$^a$ | 0.69$^a$ | 4.68$^c$ | 0.70$^c$ | 0.02$^b$ |
| **Sun$_{30}$** | 4.10$^a$ | 531.35$^a$ | 3.80$^b$ | 0.66$^a$ | 0.68$^a$ | 4.24$^f$ | 0.77$^b$ | 0.02$^b$ |
| **Solar$_{30}$** | 4.11$^a$ | 510.70$^a$ | 9.40$^a$ | 0.67$^a$ | 0.69$^a$ | 4.73$^b$ | 0.70$^c$ | 0.01$^c$ |
| **Cabinet$_{30}$** | 3.80$^{bc}$ | 525.75$^a$ | 5.30$^b$ | 0.63$^{ab}$ | 0.65$^{ab}$ | 4.38$^d$ | 0.67$^c$ | 0.02$^b$ |
| **Sun$_{40}$** | 3.70$^{cd}$ | 493.85$^a$ | 5.75$^b$ | 0.64$^{ab}$ | 0.68$^{ab}$ | 4.13$^g$ | 0.87$^a$ | 0.02$^b$ |
| **Solar$_{40}$** | 4.09$^a$ | 542.15$^a$ | 8.65$^a$ | 0.63$^{ab}$ | 0.65$^{ab}$ | 4.26$^e$ | 0.83$^a$ | 0.02$^b$ |
| **Cabinet$_{40}$** | 3.56$^d$ | 509.75$^a$ | 4.25$^b$ | 0.64$^{ab}$ | 0.66$^{ab}$ | 4.23$^f$ | 0.73$^c$ | 0.02$^b$ |
| **Control** | 3.68$^{cd}$ | 504.80$^a$ | 4.25$^b$ | 0.61$^b$ | 0.63$^b$ | 5.58$^a$ | 0.57$^d$ | 0.03$^a$ |

Mean along the row with the different alphabet(s) are significantly different ($p < 0.05$)

Subscripts 20, 30 and 40 stand for rehydration water temperatures.SC: Swelling capacity; SI: Solubility Index; WAC: Water Absorption Capacity; LD: Loose Density; BD: Bulk Density; TTA: Titratable Acidity; HCN: Cyanide content.

**Table 2: Pasting Properties of *Gari* Samples from Dried Cassava Chips**

| Sample (RVU) | Peak (RVU) | Trough (RVU) | Breakdown (RVU) | Final Viscosity (RVU) | Setback (RVU) | Peak Time (minutes) | Pasting Temperature (°C) |
|---|---|---|---|---|---|---|---|
| **Sun$_{20}$** | 208.62$^d$ | 140.71$^e$ | 67.91$^c$ | 226.11$^h$ | 85.40$^g$ | 5.55$^g$ | 83.50$^e$ |
| **Solar$_{20}$** | 315.53$^b$ | 236.88$^b$ | 78.64$^b$ | 420.72$^a$ | 183.84$^b$ | 5.86$^f$ | 82.57$^f$ |
| **Cabinet$_{20}$** | 332.82$^a$ | 165.30$^c$ | 40.52$^a$ | 257.28$^d$ | 64.99$^i$ | 6.91$^b$ | 92.41$^c$ |
| **Sun$_{30}$** | 179.57$^e$ | 167.73$^d$ | 11.85$^f$ | 249.04$^e$ | 81.32$^h$ | 5.41$^i$ | 81.36$^h$ |
| **Solar$_{30}$** | 133.57$^f$ | 128.34$^f$ | 5.23$^g$ | 228.66$^g$ | 100.32$^d$ | 5.56$^g$ | 80.53$^i$ |
| **Cabinet$_{30}$** | 278.16$^c$ | 239.16$^a$ | 39.00$^e$ | 331.41$^b$ | 92.26$^f$ | 6.09$^e$ | 81.40$^h$ |
| **Sun$_{40}$** | 128.52$^g$ | 87.41$^g$ | 41.11$^d$ | 186.41$^i$ | 99.00$^e$ | 5.45$^h$ | 81.88$^g$ |
| **Solar$_{40}$** | 74.77$^i$ | 70.61$^i$ | 4.15$^h$ | 262.49$^c$ | 191.88$^a$ | 6.35$^d$ | 92.53$^b$ |
| **Cabinet$_{40}$** | 66.10$^j$ | 62.06$^j$ | 4.05$^i$ | 235.41$^f$ | 173.35$^c$ | 6.94$^a$ | 84.76$^d$ |
| **Control** | 179.19$^h$ | 78.61$^h$ | 0.58$^j$ | 129.72$^j$ | 50.81$^j$ | 6.87$^a$ | 93.33$^a$ |

Mean along the row with the different alphabet(s) are significantly different ($p < 0.05$)
Subscripts 20, 30 and 40°C stand for rehydration water temperatures.

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