<https://doi.org/10.36293/sfj.2019.0030>

EFFECTS OF DRYING METHOD AND REHYDRATION CONDITION ON SOME QUALITY ATTRIBUTES OF GARI FROM DRIED CHIPS OF DIFFERENT VARIETIES

Ogunlakin, G.O.*, Tunde-Akintunde, T.Y., Oke, M.O. and Olajire, A.S.

Department of Food Science and Engineering,
Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Abstract

Two indigenous (odongbo and oko-iyawo) and two improved (arubielu- TMS 30572 and egefunfun- TMS 23576) cassava varieties were processed into chips (length 4–5 cm, thickness 1.5 cm) and drying using direct sun, solar and cabinet (60 °C) methods. The chips were coarse-milled and rehydrated with water (at 20, 30 and 40 °C) to mash of 67% moisture content (wet basis). The rehydrated mash seeded with 5% fresh cassava mash and freshly prepared mash (control) were naturally fermented for 72 h for the production of gari. The influence of drying method and rehydration condition on some physico-chemical and chemical properties of gari samples was investigated. The mean values of swelling capacity, 3.68 - 4.45; water absorption capacity, 496.10 - 640.10%; and bulk density, 0.58 - 0.72 g/cm³ of gari produced from chips for the varieties considered were found significantly ($p < 0.05$) higher than those of control samples with swelling capacity, 3.56 - 3.77; water absorption capacity, 471.87 - 507.43%; and bulk density, 0.53 - 0.63 g/cm³. The values of swelling capacity, water absorption capacity, bulk density and titratable acidity which are favourable for gari were observed at lower rehydration water temperature of 20 °C in all drying methods used. Almost all properties of gari from sun-dried chips were significantly ($p < 0.05$) higher than gari obtained from solar and cabinet drying methods.

Keywords: Gari, Quality, Drying methods, Rehydration,

*Correspondence author e-mail: googunlakin@lautech.edu.ng

Introduction

Cassava (*Manihot esculenta* Crantz) is one of the prominent and high yielding root crops which originated from South American (Kamukondiwa, 1996). Cassava is an important carbohydrate food crop in Nigeria with low protein and fat (FAO, 2008). The local varieties of cassava are classified as sweet (*Manihot utilisima*) and bitter (*Manihot palmata*), depending on the level of

toxic Cyanogenic glucosides. The limitation of local varieties includes low yield, high susceptibility to diseases and long maturity period (Awotide *et al.*, 2014), thus the improved cassava varieties were developed based on attributes such as disease and pest resistance, low cyanide content, drought resistance, early maturity and high yield (Agwu and Anyaeche, 2007; Obiazi and Ojor, 2013). It has been revealed that in

Nigeria, the introduction of improved varieties has provided food for millions of people (IITA, 2009).

The main reasons for processing cassava roots are to increase shelf-life and facilitate transportation. Processing the tubers into products with low moisture content makes it more stable and less volume that makes transportation easier (Ugwu, 1996). Cassava roots are processed into products like cassava chips, cassava flour, *gari*, *fufu*, *pupuru*, *tapioca* etc, but the most well known among these products is *gari*. *Gari*, a starchy staple food with high dietary energy supply is an important food product in the diet of millions of people both in Nigeria and West Africa at large (Odoemelam, 2005, Afoakwa *et al.*, 2010).

Cassava chips are made from fresh roots by peeling and sun drying or hot-air drying the roots (Hahn, 1989). Drying as a unit operation has been reported to significantly affect the quality of dried food products, as there may be bio-chemical changes and thereby contaminating and spoiling the chips (Tunde-Akintunde and Afon, 2010). Different drying methods have been reported to significantly affect the drying kinetics and food products quality (Methakhup *et al.*, 2005; Bechoff *et al.*, 2009). Thus, the most important unit operation in producing cassava chips is drying as it can have a greater influence on the product quality.

Gari can only be produced from cassava chips by rehydrating the chips to reproduce the moisture of fresh cassava mash. The condition at which the rehydration is done can also have significant effect on quality of *gari* to be produced. Oluwole *et al.* (2008) and Akinwande *et al.* (2013) suggested the inclusion of some level of fresh cassava mash (about 5%) at the point of rehydration of dried cassava chips to produce *gari*. This is an indication of introducing fermenting

organisms which can only function in water-medium. Getting this condition right by the *gari* processors will ensure the retaining the accepted quality of *gari* usually induced as a consequent of fermentation. It is therefore necessary to conduct a study to determine the influence of drying on chips obtained from cassava of different varieties and to determine appropriate rehydration water temperature that will result in high quality *gari* that will compare favourably with that obtained from fresh cassava roots.

Materials and Methods

Materials

Four varieties (two indigenous- *odongbo* and *oko-iyawo*; two improved- *arubielu* (TMS 30572) and *ege-funfun* (TMS 23576)) of cassava (*Manihot esculenta*) were obtained from Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomosho, Nigeria. The varieties of cassava were choosing based on their availability and they are also commonly used varieties for the production of *gari* in this locality.

Preparation of sample

The freshly harvested cassava tubers were washed, peeled manually and sliced into chips of uniform slices (length 4 – 5 cm, thickness 1.5 cm). A locally fabricated chipping machine was used in order to obtain uniform sizes and to stimulate uniform drying of chips. Drying was done using different methods (sun, solar and cabinet at 60 °C). The method of Tunde-Akintunde *et al.* (2005) was modified to dry cassava chips by sun, solar and cabinet drying methods.

Rehydration of cassava chips

Cassava chips were coarse-milled and rehydrated to have cassava mash of about 67% moisture content with water at temperatures of 20, 30 and 40 °C. The

quantity of water added was calculated using the mathematical expression according to Hammonds *et al.* (1977):

$$q = \left(\frac{(b-a)}{(100-b)} \right) \times A$$

where, A, a, b and q are the initial mass of the sample (g); the initial moisture content of the sample (% wet basis); the moisture content of the sample at the point of interest (% wet basis) and the quantity of water to be used for rehydration (g), respectively.

Production of *Gari*

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 mash was stirred occasionally during fermentation for 72 h; the mash was then put into sack and pressed with manually operated hydraulic jack. The solid cake obtained after dewatering was weighed, sifted and roasted into gelatinized product (*gari*) using traditional method in shallow cast-iron pans. The *gari* was cooled by spreading it in a large bowl prior to weighing and packaging.

Quality Parameters Determination

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

Statistical Analysis

Data reported are averages of three determinations. Analysis of variance (ANOVA) was performed using the procedure of Statistical Package for Social Sciences (SPSS, Version 16). Mean values were separated using Duncan Multiple Range test at 5% level of probability as described by Lyocks (2013).

Results and Discussion

Physicochemical and chemical properties of *gari* produced from cassava chips of different varieties- *odongbo*, *oko-iyawo*, *arubielu* (TMS 30572) and *ege-funfun* (TMS 23576) as affected by the drying method and rehydration temperature are as shown in Tables 1 - 4, respectively.

The values of swelling capacity of *gari* ranged from 3.62 to 4.45; 3.56 to 4.14; 3.66 to 4.14 and 3.77 to 4.33 for *odongbo*, *oko-iyawo*, *arubielu* and *ege-funfun*, respectively. Swelling capacity is an important characteristic in determining the quality of *gari*. The higher the value of swelling capacity, the greater is its suitability in making dishes like *eba* (Apea-Bah *et al.*, 2009). It reflects the extent of associative forces within the flour granules (Moorthy and Ramannjam, 1986). The variation in the swelling capacity is as a result of different drying methods, rehydration water temperatures and the different varieties considered. Suresh and Samsher (2013) reported that swelling capacity of a food material depends on some factors like types of variety, processing methods or unit operations involved. In this study, solar dried samples rehydrated with water at 30 °C gave the highest values of swelling capacity in all the varieties. There were significant effects ($p < 0.05$) on swelling capacity of *gari* samples in terms of drying

method and rehydration water temperature in all varieties considered. But all the *gari* samples obtained in the study have swelling capacity higher than three (3) which is an indication of good quality of *gari* produced (Achinewhu *et al.*, 1998).

The solubility index of *gari* samples for *odongbo*, *oko-iyawo*, *arubielu* and *ege-funfun* ranged from 1.26 (cabinet-dried sample rehydrated with water at 40 °C) to 7.67% (cabinet-dried sample rehydrated with water at 20 °C); 3.80 (solar-dried sample rehydrated with water at 30 °C) to 9.40% (sun-dried sample rehydrated with water at 30 °C); 1.30 (sun-dried sample rehydrated with water at 30 °C) to 5.67% (solar-dried sample rehydrated with water at 40°C); and 3.40 (control sample) to 9.17% (cabinet-dried sample rehydrated with water at 20 °C), respectively. The values were significantly ($p < 0.05$) different for both drying method and rehydration water temperature used in all the varieties considered. The values obtained all within the range (5.15-20.77) obtained by Eriksson *et al.* (2014). 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 values of water absorption capacity for *gari* obtained from *odongbo*, *oko-iyawo*, *arubielu* and *ege-funfun* varieties ranged from 483.37 to 640.10%, 492.20 to 584.50%, 471.87 to 597.53% and 507.42 to 585.77%, respectively with control sample having the lowest values in all varieties. The results of water absorption capacity were significantly ($p < 0.05$) different except for those of *arubielu* variety that had no significant difference for both drying method and rehydration water temperature. 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 bulk density is an important factor used for the determination of the packaging material requirement and the handling of the food material (Karuna *et al.*, 1996). It is also an important to determine the suitability of foods for easy transportation (Shittu *et al.*, 2005). The value ranged from 0.55-0.62g/cm³, 0.63 to 0.69 g/cm³, 0.59 to 0.72 g/cm³ and 0.53 to 0.67 g/cm³. All control *gari* samples were found to have lowest values in all varieties and significantly ($p < 0.05$) different from all the *gari* obtained from dried chips. The implication of high values of bulk density is that the volume will be reduced for a larger quantity of chips 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. Findings of Oluwamukomi and Adeyemi (2013) reported a similar range of 0.620 to 0.670 g/cm³. Apart from ease packaging with these higher values of bulk density, it is also reported by Udensi and Okaka (2000) that the higher the bulk density, the higher the rate of dispersion of granules in water which is important in *gari* reconstitution for making *eba* (*gari* dough).

The pH of the *gari* ranged from 3.98 to 4.45 for *odongbo* samples; 4.13 to 5.58 for *oko-iyawo* samples; 4.40 to 4.70 for *arubielu*; and

4.09 to 4.52 for *ege-funfun*. It was observed that the control *gari* samples have the highest values in all. All the varieties considered were significantly ($p < 0.05$) affected by rehydration water temperature and drying method. This might be attributed to the different carbohydrate contents present in the cassava. The values obtained in this work were comparable to the findings of Achinewhu *et al.* (1998); Komolafe and Arawande (2010) who reported 3.4-4.0 and 3.6-4.0, respectively. However, the results obtained were found lower than the range (6.7-7.4) reported by Karim *et al.* (2009). This is an indication that the *gari* obtained from dried chips were acidic as this might not predispose the product to bacterial spoilage. The high values of pH of *gari* in this study contribute to sourness of *gari* as this is desirable to most consumers particularly in South-West Nigeria (Adebayo, 2012).

The values of total titratable acidity varied from 0.57-1.00%, 0.57-0.87%, 0.67-1.00% and 0.60-0.87% for *odongbo*, *oko-iyawo*, *arubielu* and *ege-funfun*, respectively with the control *gari* samples having the lowest values for each variety. The ANOVA shows that the results were significantly ($p < 0.05$) different for both drying method and rehydration temperature. The ranges of values for titratable acidity obtained in this work are comparable to the ranges 0.60-0.97 and 0.54-0.84 for *gari* reported by Olatunde *et al.* (2013) and Komolafe and Arawande (2010), respectively. It was also observed that the values of the total titratable acidity of *gari* (both from dried chips and fresh roots) are within the recommended values (0.6-1.0) given by Codex Alimentarius Commission (1989). This is an indication that fermentation period used for this study was adequate for *gari* production of using dried chips.

The residual cyanide in the *gari* samples

ranged from 0.01 to 0.15 mg/100 g in *odongbo* samples; 0.01 to 0.03 mg/100 g in *oko-iyawo* samples; 0.01 to 0.03 mg/100 g in *arubielu* samples and 0.011 to 0.03 mg/100 g in *ege-funfun gari* samples. Though there was no significant ($p \geq 0.05$) difference in residual cyanide content for all the *gari* samples obtained from dried chips. The control samples were significantly ($p < 0.05$) differed from *gari* samples produced from rehydrated cassava chips. This implies that drying of chips drastically reduced the cyanide content of cassava prior to other processes (fermentation, dewatering and roasting) that are meant to reduce the cyanide content in the production of *gari*. According to FAO/WHO (1991), the safe level of cyanide is below 10 mg/kg (1 mg/100 g); value above this can pose health risk to the consumers. The range of values obtained in this study are far below the range 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.

Starch content of any starch-based food possesses two types of molecules namely: linear amylose and highly branched amylopectin. The amylose content of the *gari* samples ranged from 16.46-17.19%; 16.52-17.21%; 16.55-17.08% and 16.55-17.33% for *gari* obtained from dried chips and fresh roots of *odongbo*, *oko-iyawo*, *arubielu* and *ege-funfun*, respectively. The values of amylose were significantly ($p < 0.05$) different for both drying method and rehydration water temperature used in all the varieties considered. Amylose affects the textural quality of starch-based foods and it is the key component involved in water absorption capacity, swelling capacity and starch gelation in food processing (Wittaya, 2012). The higher the amylose content, the more gelatinous paste obtained during

reconstitution (Otegbayo *et al.*, 2013). The highest values of amylose content were observed in *gari* samples obtained from chips dried with solar and sun drying methods at rehydration water temperature of 40 °C. This might be as a result of higher temperature (60 °C) used in cabinet drying method which is close to gelatinization temperature which would have caused the reduction in amylose content of the starch present in the chips.

The ranges of amylopectin of *gari* from dried chips and fresh cassava roots are 82.81-83.54%; 82.79-83.48%; 82.93-83.45% and 82.68-83.45% for *odongbo*, *oko-iyawo*, *arubielu*, and *ege-funfun*, respectively. There

were significant ($p < 0.05$) differences in terms of drying method, variety and rehydration water temperature. Many starch functionalities such as stabilizers, rheological and visco-elastic properties of foods depend on these two distinct structural polysaccharide fractions (amylose and amylopectin). Alteration on amylose/amylopectin ratio can also alter the functionality of the starch. It was also reported by Adegunwa *et al.* (2011) that the viscosity, gelatinization, textural quality, solubility, tackiness, gel stability, cold strength and retrogradation of starch-based food depend on its amylose/amylopectin ratio.

Table 1: Physicochemical and chemical properties of *gari* from *odongbo* chips at different drying methods and rehydration temperatures

Sample	SC	SI (%)	WAC (%)	BD (g/cm ³)	pH	TTA (%)	HCN (mg/100 g)	Amylose (%)	Amylopectin (%)
A _{su, 20}	4.39 ^{abc}	3.40 ^e	636.03 ^a	0.59 ^{ab}	3.98 ^h	1.00 ^a	0.02 ^b	16.46 ^h	83.54 ^a
A _{so, 20}	4.43 ^{ab}	3.97 ^{de}	596.23 ^c	0.61 ^{ab}	4.07 ^e	0.83 ^{bc}	0.02 ^b	16.49 ^{gh}	83.51 ^{ab}
A _{ca, 20}	4.32 ^{abcd}	7.67 ^a	612.00 ^{bc}	0.61 ^a	4.04 ^f	0.87 ^b	0.01 ^b	16.66 ^f	83.34 ^c
A _{su, 30}	4.13 ^{de}	2.37 ^f	640.10 ^a	0.62 ^a	4.12 ^d	0.77 ^{bcd}	0.01 ^b	16.85 ^{de}	83.15 ^{de}
A _{so, 30}	4.45 ^a	2.00 ^f	573.90 ^d	0.62 ^a	4.30 ^b	0.67 ^d	0.02 ^b	16.83 ^e	83.18 ^d
A _{ca, 30}	4.16 ^{cde}	4.87 ^c	624.93 ^{ab}	0.62 ^a	4.00 ^g	0.87 ^b	0.01 ^b	16.99 ^b	83.01 ^g
A _{su, 40}	4.00 ^e	5.73 ^b	578.90 ^d	0.60 ^{ab}	4.19 ^c	0.73 ^{cd}	0.02 ^b	16.96 ^{bc}	83.04 ^{fg}
A _{so, 40}	4.19 ^{bcd}	4.43 ^{cd}	557.37 ^e	0.60 ^{ab}	4.12 ^d	0.77 ^{bcd}	0.02 ^b	17.19 ^a	83.81 ^h
A _{ca, 40}	4.44 ^{ab}	1.20 ^g	599.77 ^c	0.59 ^{ab}	4.12 ^d	0.77 ^{bcd}	0.02 ^b	16.55 ^g	83.45 ^b
A _{control}	3.62 ^f	3.80 ^{de}	483.37 ^f	0.55 ^c	4.45 ^a	0.57 ^e	0.15 ^a	19.91 ^{cd}	83.09 ^{ef}

Mean values ($n = 3$) with different alphabet (s) in the same column are significantly different at $p < 0.05$.

A: *odongbo*; subscripts su, so and ca represent sun, solar and cabinet drying methods, respectively and 20, 30 and 40 stand for rehydration water temperatures.

SC: Swelling capacity; SI: Solubility Index; WAC: Water Absorption Capacity; BD: Bulk Density; TTA: Titratable Acidity; HCN: Cyanide content

Table 2: Physicochemical and chemical properties of *gari* from *oko-iyawo* chips at different drying methods and rehydration temperatures

Sample	SC	SI (%)	WAC (%)	BD (g/cm ³)	pH	TTA (%)	HCN (mg/100 g)	Amylose (%)	Amylopectin (%)
B_{su, 20}	4.00 ^{ab}	4.00 ^d	534.50 ^a	0.66 ^a	4.68 ^c	0.67 ^{cd}	0.01 ^b	16.63 ^c	83.37 ^b
B_{so, 20}	4.14 ^a	3.90 ^d	509.30 ^{bcd}	0.68 ^a	4.67 ^c	0.70 ^c	0.01 ^b	16.63 ^c	83.37 ^b
B_{ca, 20}	4.14 ^a	4.57 ^{cd}	521.73 ^{abc}	0.69 ^a	4.68 ^c	0.70 ^c	0.01 ^b	16.66 ^c	83.34 ^b
B_{su, 30}	4.10 ^a	3.80 ^d	531.77 ^{ab}	0.68 ^a	4.24 ^f	0.77 ^{abc}	0.01 ^b	16.96 ^b	83.04 ^c
B_{so, 30}	4.11 ^a	9.40 ^a	511.33 ^{bcd}	0.69 ^a	4.73 ^b	0.67 ^{cd}	0.01 ^b	16.52 ^d	83.48 ^a
B_{ca, 30}	3.80 ^{bc}	5.30 ^{bc}	524.67 ^{abc}	0.65 ^{ab}	4.38 ^d	0.73 ^{bc}	0.01 ^b	16.52 ^d	83.48 ^a
B_{su, 40}	3.69 ^{cd}	5.77 ^b	506.47 ^{cd}	0.68 ^{ab}	4.13 ^g	0.87 ^a	0.01 ^b	17.21 ^a	82.79 ^d
B_{so, 40}	4.09 ^a	8.60 ^a	542.17 ^a	0.65 ^{ab}	4.26 ^e	0.77 ^{abc}	0.01 ^b	16.66 ^c	83.34 ^b
B_{ca, 40}	3.68 ^{cd}	4.23 ^{cd}	509.83 ^{bcd}	0.66 ^{ab}	4.23 ^f	0.83 ^{ab}	0.01 ^b	16.63 ^c	83.37 ^b
B_{control}	3.56 ^d	4.23 ^{cd}	492.20 ^d	0.63 ^b	5.58 ^a	0.57 ^d	0.03 ^a	16.99 ^b	83.01 ^c

Mean values (n = 3) with different alphabet (s) in the same column are significantly different at $p < 0.05$.

B: *oko-iyawo*; subscripts su, so and ca represent sun, solar and cabinet drying methods, respectively and subscripts 20, 30 and 40 stand for rehydration temperatures.

SC: Swelling capacity; SI: Solubility Index; WAC: Water Absorption Capacity; BD: Bulk Density; TTA: Titratable Acidity; HCN: Cyanide content

Table 3: Physicochemical and chemical properties of *gari* from *arubielu* chips at different drying methods and rehydration temperatures

Sample	SC	SI (%)	WAC (%)	BD (g/cm ³)	pH	TTA (%)	HCN (mg/100 g)	Amylose (%)	Amylopectin (%)
C_{su, 20}	4.10 ^a	2.93 ^{cd}	499.30 ^a	0.65 ^{bc}	4.30 ^d	0.73 ^{def}	0.02 ^b	16.55 ^g	83.45 ^a
C_{so, 20}	3.90 ^{ab}	4.53 ^b	597.53 ^a	0.61 ^{cd}	4.46 ^b	0.67 ^f	0.01 ^{bc}	16.77 ^{de}	83.23 ^{cd}
C_{ca, 20}	4.14 ^a	3.50 ^{bc}	513.77 ^a	0.65 ^{bc}	4.42 ^c	0.73 ^{def}	0.01 ^{bc}	16.63 ^f	83.37 ^b
C_{su, 30}	4.14 ^a	1.30 ^e	558.90 ^a	0.63 ^c	4.22 ^g	0.87 ^{bc}	0.01 ^{bc}	17.07 ^a	82.93 ^g
C_{so, 30}	4.14 ^a	3.87 ^{bc}	558.53 ^a	0.61 ^{cd}	4.14 ^h	0.90 ^b	0.03 ^b	16.99 ^b	83.01 ^f
C_{ca, 30}	4.14 ^a	1.90 ^c	540.40 ^a	0.63 ^c	4.25 ^f	0.80 ^{cd}	0.01 ^{bc}	16.83 ^{cd}	83.18 ^{de}
C_{su, 40}	3.98 ^{ab}	2.30 ^{de}	507.83 ^a	0.68 ^{ab}	4.26 ^c	0.77 ^{de}	0.01 ^{bc}	17.08 ^a	82.93 ^g
C_{so, 40}	3.79 ^{ab}	5.67 ^a	513.90 ^a	0.65 ^{bc}	4.04 ⁱ	1.00 ^a	0.01 ^{bc}	16.96 ^b	83.04 ^f
C_{ca, 40}	3.82 ^{ab}	3.67 ^{bc}	496.10 ^a	0.72 ^a	4.42 ^c	0.70 ^{ef}	0.01 ^c	16.88 ^c	83.12 ^e
C_{control}	3.66 ^b	3.33 ^c	471.87 ^a	0.59 ^d	4.70 ^a	0.67 ^f	0.03 ^a	16.74 ^e	83.26 ^c

Mean values (n=3) with different alphabet (s) in the same column are significantly different at $p < 0.05$.

C: *arubielu* (TMS 30572); subscripts su, so and ca represent sun, solar and cabinet drying methods, respectively and subscripts 20, 30 and 40 stand for rehydration temperatures.

SC: Swelling capacity; SI: Solubility Index; WAC: Water Absorption Capacity; LD: BD: Bulk Density; TTA: Titratable Acidity; HCN: Cyanide content

Table 4: Physicochemical and chemical properties of *gari* from *ege-funfun* chips at different drying methods and rehydration temperatures

Sample	SC	SI (%)	WAC (%)	BD (g/cm ³)	pH	TTA (%)	HCN (mg/100 g)	Amylose (%)	Amylopectin (%)
D _{su, 20}	4.03 ^{abc}	8.83 ^{ab}	532.73 ^c	0.68 ^a	4.26 ^c	0.67 ^{def}	0.01 ^c	16.66 ^d	83.34 ^b
D _{so, 20}	4.06 ^{abc}	8.47 ^b	567.90 ^{ab}	0.61 ^{de}	4.19 ^e	0.77 ^{bc}	0.01 ^c	16.88 ^c	83.12 ^c
D _{ca, 20}	4.89 ^{ab}	9.17 ^a	554.17 ^{bc}	0.64 ^{bc}	4.15 ^f	0.77 ^{bc}	0.01 ^c	16.58 ^e	83.43 ^a
D _{su, 30}	3.86 ^{bc}	4.63 ^{de}	557.53 ^{bc}	0.63 ^{bcd}	4.19 ^e	0.77 ^{bc}	0.01 ^c	16.71 ^d	83.29 ^b
D _{so, 30}	4.09 ^{abc}	3.77 ^f	585.70 ^a	0.63 ^{bc}	4.27 ^b	0.63 ^{ef}	0.01 ^c	16.96 ^c	83.04 ^c
D _{ca, 30}	3.98 ^{abc}	4.07 ^{ef}	574.33 ^{ab}	0.59 ^e	4.15 ^f	0.80 ^{ab}	0.02 ^b	17.13 ^b	82.87 ^d
D _{su, 40}	4.25 ^a	4.93 ^{cd}	538.77 ^c	0.66 ^{ab}	4.19 ^e	0.73 ^{bcd}	0.01 ^c	16.88 ^c	83.12 ^c
D _{so, 40}	4.33 ^a	5.00 ^{cd}	555.47 ^{bc}	0.65 ^{abc}	4.23 ^d	0.70 ^{cde}	0.01 ^c	17.33 ^a	82.68 ^e
D _{ca, 40}	4.21 ^{ab}	5.40 ^c	573.73 ^{ab}	0.63 ^{cd}	4.09 ^g	0.87 ^a	0.01 ^c	16.55 ^e	83.45 ^a
D _{control}	3.77 ^c	3.40 ^f	507.43 ^d	0.53 ^f	4.51 ^a	0.60 ^f	0.03 ^a	16.91 ^c	83.09 ^c

Mean values (n=3) with different alphabet (s) in the same column are significantly different at $p < 0.05$.

D: *ege-funfun* (TMS 23576); subscripts su, so and ca represent sun, solar and cabinet drying methods, respectively and subscripts 20, 30 and 40 stand for rehydration temperatures.

SC: Swelling capacity; SI: Solubility Index; WAC: Water Absorption Capacity; BD: Bulk Density; TTA: Titratable Acidity; HCN: Cyanide content.

Conclusion

The effects of drying and rehydration condition on some quality parameters of *gari* produced from chips of four varieties (2 local and 2 improved) of cassava were investigated in this study. The values of swelling capacity, water absorption capacity, bulk density and titratable acidity which are favourable for *gari* were observed at lower rehydration water temperature of 20 °C in all

drying methods used. Significant effects were observed for the quality parameters determined among the varieties and drying methods used. But drying method was observed to have a more significant effect than variety. The data obtained showed that almost all evaluated parameters of the sun-dried chips were better than those from the other two drying methods.

References

- Achinewhu, S. C., Barber, L. I. and Ijeoma, I. O. 1998. Physicochemical properties and garification (*gari* yield) of selected cassava cultivars in Rivers state, Nigeria. *Plant Foods for Human Nutrition* 52, 133-140.
- Adebayo, B. A., Nanam, T. D., Bamidele, E. A. and Braima, D. J. 2012. Quality management manual for the production of *gari*. UPoCA Project © International Institute of Tropical Agriculture (IITA). pp. 6-8.
- Adegunwa, M. O., Sanni, L. O. and Maziya-Dixon, B. 2011. Effects of fermentation length and varieties on the pasting properties of sour cassava starch. *African Journal of Biotechnology* 10(42), 8428-8433.
- Afoakwa, E. O., Edem, K. J., Budu, A. S. and Annor, G. A. 2010. Souring and starch behaviour during co-fermentation of cassava and soybean into *gari* 'farina'. *Asian Journal of Food and Agro-Industry* 3(3), 371-385.
- Agwu, A. E. and Anyaeche, C. L. 2007. Adoption of improved cassava varieties in six rural communities in Anambra State, Nigeria. *African Journal of Biotechnology* 6(2), 89-98.
- Akinwande, B. A., Ngoddy, P. O., Olajide, J. O. and Fakolujo, A. D. 2013. Production and storage of cassava chips for reconversion into *gari*. *Innovative Systems Design and Engineering* 4(9), 68-72.
- AOAC. 2005. Official methods of analysis. Association of Official Analytical Chemist. Washington DC. 18th Edition, Revision 3

- Apea-Bah, F. B., Oduro, I., Ellis, W. O. and Kafo-Katanka, O. 2009. Principal components analysis and age at harvest effect on quality of *gari* from flour elite cassava varieties in Ghana. *African Journal of Biotechnology* 8(9), 1943-1949.
- Awotide, B. A., Abdoulaye, T., Alene, A. and Manyong, V. M. 2014. Assessing the extent and determinants of adoption of improved cassava varieties in Southwest Nigeria. *Journal of Development and Agricultural Economics* 6(9), 376-385.
- Balami, Y. A., Bolaji, P. T., Hamza, F., Bahago, E. J. Komolafe, G., Onyeiwu, S. C. and Hassan, A. 2004. Determination of bulk density. In: Laboratory Manual on Food Technology, Nutrition and Dietetics for Schools and Industries. 2nd Ed. National Science and Technology Forum, Kaduna. pp. 73-79.
- Bechoff, A., Dufour, D., Dhuique-Mayer, C., Marouzé, C., Reynes, M. and Westby, A. 2009. Effect of hot air, solar and sun drying treatments on provitamin A retention in orange-fleshed sweetpotato. *Journal of Food Engineering* 92(2), 164-171.
- Codex Alimentarius Commission. 1989. Codex standard for *gari*. *Codex stan 151-1989 (Rev. 1-1995)* 7, 1-6.
- Eriksson, E., Kosh, K., Tortoe, C., Akonor, P. T. and Baidoo, E. 2014. Physicochemical, functional and pasting characteristics of three varieties of cassava in wheat composite flours. *British Journal of Applied Science and Technology* 4(11), 1609-1621.
- FAO. 2008. FAOSTAT production database. Food and Agriculture Organization of the United Nation, downloaded from <http://faostat.fao.org/site/567/desktop,default.aspx?pageID=567#ancor> on 11 November 2008.
- FAO/WHO. 1991. Joint FAO/WHO Food Standards Programme. Codex Alimentarius Commission XII, Supplement 4, FAO, Rome, Italy. 1-10 July 1991
- Hahn, S. K. 1989. An overview of African traditional cassava processing and utilization. *Outlook on Agriculture* 18, 110-118.
- Hammonds, T. W., Aristee, G. D. and Wimbedlow, L. 1977. Handbook of shea processing using a manually operated bridge press. A Publication of National Resources Institute, Chatham, England. pp. 13
- IITA. 2009. Research to nourish Africa. In: Integrated Cassava Project. International Institute of Tropical Agriculture, Ibadan, Nigeria. 1-46.
- Ikegwu, O. J., Nwobasi, V. N., Odoh, M. O. and Oledinma, N. U. 2009. Evaluation of the pasting and some functional properties of starch isolated from some improved cassava varieties in Nigeria. *African Journal of Biotechnology* 8(10), 2310-2315.
- Kamukondiwa, W. 1996. Alternative food crops to adapt to potential climatic change in Southern Africa. *Climate Research* 6, 153-155.
- Karim, O. R., Fasasi, O. S. and Oyeyinka, S. A. 2009. *Gari* yield and chemical composition of cassava roots stored using traditional methods. *Pakistan Journal of Nutrition* 8(12), 1830-1833.
- Karuna, D., Noel, G. and Dilip, K. 1996. Food and Nutrition Bulletin, United Nation University 17, 2.
- Komolafe, E. A. and Arawande, J. O. (2010). Evaluation of the quantity and quality of *gari* produced from three cultivars of cassava. *Journal of Research in National Development* 8(1), 14-18.
- Lyocks, S. W. J., Tanimu, J., Dauji, L. Z. and Ogunleye, D. A. 2013. Evaluation of the effects of intra-row spacing on the growth and yield of maize (*Zea mays* L.) in maize-ginger intercrop in samaru, northern guinea savanna of Nigeria. *Agriculture and Biology Journal of North America* 4(3), 175-180
- Malomo, O., Ogunmoyela, O. A. B., Adekoyeni, O. O., Jimoh, O., Oluwajoba, S. O. and Sobanwa, M. O. 2012. Rheological and functional properties of soy-poundo yam flour. *International Journal of Food Science and Nutrition Engineering* 2(6), 101-107.
- Methakhup, S., Chiewchan, N. and Devahastin, S. 2005. Effects of drying methods and conditions on drying kinetics and quality of Indian gooseberry flake. *LWT- Food Science and Technology* 38(6), 579-587.
- Moorthy, S. N. and Ramanujam, T. 1986. Variation in properties of starch in cassava varieties in relation to age of the crop. *Starch/Starke* 38, 58-61.
- Obiazi, C. C. and Ojobor, S. A. 2013. Production

- challenges of cassava and prospects. *Journal of Biology, Agriculture and Healthcare* 3(14), 31-35.
- Odoemelam, S. A. 2005. Studies on residual hydrocyanide acid in *gari* flour made from cassava (*Manihot spp*). *Pakistan Journal Nutrition* 4(6), 376-378.
- Olatunde, S.T., Olatunde, S. J. and Ade-Omowaye, B. I. O. 2013. Production and evaluation of *gari* produced from cassava (*Manihot esculenta*) substituted with cocoyam (*Colocasia esculenta*). *Pakistan Journal of Food Science* 23(3), 124-132.
- Oluwamukomi, M. O. and Adeyemi, I. A. 2013. Physicochemical properties of *gari*-semolina enriched with different types of soy-melon supplements. *European Journal of Food Research and Review* 3(1), 50-62.
- Oluwamukomi, M. O. and Jolayemi, O. S. 2012. Physico-thermal and pasting properties of soy-melon enriched *gari* semolina from cassava. *Agricultural Engineering International CIGR Journal* 14(3), 105-116.
- Oluwole, O. B. Olatunji, O. and Odunfa, S. A. 2008. Development and evaluation of a process technology for conversion of dried cassava chips into *gari*. *Journal of Industrial Research and Technology* 2(1), 21-30.
- Otegbayo, B. O., Samuel, F. O. and Alalade, T. 2013. Functional properties of soy-enriched *tapioca*. *African Journal of Biotechnology* 12(22), 3583-3589. DOI: 10.5897/AJB.12.2654.
- Owuamanam, C. I., Iwouno, J. O., Ihediohanma, N. C. and Barber, L. I. 2010. Cyanide reduction, functional and sensory quality of *gari* as affected by pH, temperature and fermentation time. *Pakistan Journal of Nutrition* 9(10), 980-986.
- Oyewole, O. B. and Odunfa, S. A. 1989. Microbiological studies on cassava fermentation for *lafun* production. *Food Microbiology* 5, 125-133.
- Sathe, S. K., and Salunkhe, D. K. 1981. Functional properties of the great Northern bean (*Phaseolus vulgaris*) rotein: emulsion, foaming, viscosity and gelation properties. *Journal of Agricultural and Food Chemistry* 28, 1163-1166.
- Shittu, T. A, Sanni, L. O, Awonorin, S. O, Maziya-Dixon, B. and Dixon, A. 2005. Use of multivariate technologies in studying flour making characteristics of some cassava mosaic disease resistant cassava clones. African Crop Science Conference Proceedings, held at Kampala, Uganda, 5 - 9, December. 7, 621-630.
- Singh, R. P. and Heldman, D. R. 2008. Introduction to Food Engineering. Academic Press, Inc. pp. 258-262.
- Suresh Chandra and Samsher 2013. Assessment of functional properties of different flours. *African Journal of Agricultural Research* 8(38), 4849-4852.
- Tunde-Akintunde, T. Y. and Afon, A. A. 2010. Modelling of hot-air drying of pretreated cassava chips. *Agricultural Engineering International: CIGR Journal* 12(2), 34-41.
- Tunde-Akintunde, T. Y., Afolabi, T. J. and Akintunde, B. O. 2005. Influence of drying methods on drying of bell-pepper (*Capsicum annum*). *Journal of Food Engineering* 68, 439-442.
- Udensi. E. A. and Okaka, J. C. 2000. Predicting the effect of particle size profile, blanching and drying temperature on the dispersibility of yam flour. *Global Journal of Pure Applied Science* 6, 589-592.
- Udoro, E. O., Kehinde, A. T., Olusunkanmi, S. G. and Charles, T. A. 2014. Studies on the physicochemical, functional and sensory properties of *gari* processed from dried cassava chips. *Journal of Food Processing Technology* 5(293), 1- 9. DOI 10.4172/2157-7110.1000293.
- Ugwu, B. O. 1996. Increasing cassava production in Nigeria and prospects for sustaining the trend. *Outlook on Agriculture* 25(3), 179-185.
- Wittaya, T. 2012. Rice starch-based biodegradable films: properties enhancement. In: Structure and Function of Food Engineering edited by Ayman Amer Eissa, In Tech Publisher. <http://dx.doi.org/10.5772/47751>. pp. 103-134.