

Effect of fermentation periods and storage on the chemical and physicochemical properties of biofortified cassava gari

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Abstract

Gari (cassava flake) is a fermented, roasted cassava product, and a major staple food in Nigeria. Yellow flesh cassava (TMS 1358) variety was processed into *gari* and the chemical and physicochemical properties of the *gari* and reconstituted paste were determined. Ash, lipid, and carbohydrate contents decreased with fermentation days while the protein and fiber contents increase with fermentation days in the *gari*. Starch contents decreased gradually while the sugar contents of the *gari* increased with fermentation days. Cyanide contents of all the *gari* samples were less than 1 mg/CN⁻¹. Color of the *gari* samples were brighter in early fermentation periods but became darker with prolonged fermentation periods. Carotene contents decreased with storage time while pH values increased slightly at 6 months. Reconstituted *gari* paste fermented for 0 to 2 days was more acceptable in appearance, moldability, and in overall acceptability. Fermentation of cassava (TMS 1358) for 0–2 days and storage of *gari* product for up to 2 months are desirable for human consumption.

Practical applications

This study is about the use of improved breed cassava in making cassava flakes (*gari*). The biofortified cassava was used and studied over 6 months to know the effect of storage on the cassava flake. Cyanide content of the cassava variety was low and reduced with fermentation periods. Carotene contents also diminished after 2 months of storage. Utilization of biofortified cassava flakes (*gari*) is encouraged within 1–2 months of production and at 2nd day of fermentation. This study enables the consumers and processors to know the characteristics of this cassava variety, the best fermentation periods, and storage of the product at ambient temperature.

1 | INTRODUCTION

Cassava (*Manihot esculenta* Cranz) tuber is a tropical and perishable crop with high levels of cyanogenic glycosides which are toxic to man and can result in death (Akinrele et al., 2000). Processing of cassava tubers to shelf stable foods eliminate or reduce the toxic compound in the food. Akintonwa et al. (1994) stated that processing methods used to reduce cyanide in foods include soaking, fermentation, drying, frying, pressing etc. Cassava tubers had been made into varieties of cassava products among which are *gari* (cassava flakes), *lafun* (fermented

cassava flour), *fufu* (steeped cassava starch dough), cassava flour etc. *Gari* is a popular product from fermented cassava which is consumed by both children and adult with other products such as groundnut, sugar, coconut etc. Sanni et al. (2008) described *gari* as creamy white flour or yellow colored flakes made from fresh, grated, and fermented cassava tubers while Oluwafemi and Udeh (2016) describe *gari* as a cheap, convenient, and easy to store product. *Gari* consumption is not limited to the low income earners alone but also consumed by medium and high income families due to low cost and more convenient to cook than grains (Nweke, 2005). It could be eaten when reconstituted at any

time of the day in Nigeria. The quality of *gari* depends on the cassava varieties used, fermentation periods, roasting temperature, and particle size. Fermentation process had been reported to play a major role in acceptability of *gari*. Aworh (2008) reported fermentation as the oldest traditional food processing methods used in producing a shelf stable products from cassava. Azam-Ali et al. (2003) were of the opinion that fermentation improves and gives the sour taste of *gari*. *Gari* had been made from different varieties of sweet and bitter cassava tubers which lack vitamin A (Irtwange & Achimba, 2009; Oduah et al., 2015; Oluwafemi & Udeh, 2016). *Gari* is consumed by high percentage of children and adult in Nigeria, thus, constituting a major problem in the society as *gari* is predominantly made up of carbohydrate, therefore, resulting in protein-energy malnutrition, vitamin A deficiency etc. United Nations Children Education Fund (UNICEF, 2018) reported that 48% of children between ages 6 and 59 months have vitamin A deficiency with highest value in Sub-Saharan Africa. However, fortification of cassava with vitamin A is essential to reduce the incidence of vitamin A deficiency in Nigeria. Vitamin A biofortified cassava is produced and is available in research Institutes to reduce vitamin A deficiencies in infants and adults. There are dearth of information on the effect of fermentation, processing, and storage of yellow cassava *gari*. Studying the properties of biofortified cassava *gari* product will enable the consumers to be aware of the best fermentation periods of the cassava mash and the keeping quality of the product. Therefore, this paper studied the effect of fermentation and storage periods on the chemical and physicochemical properties of biofortified cassava *gari*.

2 | MATERIALS AND METHODS

The freshly harvested yellow fleshed cassava (TMS 1358 variety) was obtained in Root and Tuber expansion programs, Ajase-Ipo, Kwara State, Nigeria.

2.1 | Processing of cassava tuber to cassava flakes (*gari*)

Freshly harvested cassava tubers were peeled, washed, and milled using motorize fabricated cassava grinder. The cassava mash was packed in five bags and fermented for 0, 1, 2, 3, and 4 days. Each day, the cassava mash was dewatered using hydraulic press, sieved, roasted, and cooled. *Gari* flakes were sieved (5 mm) to obtain uniform particle sizes and stored in plastic containers at room temperature for 6 months.

2.2 | Chemical and physicochemical analyses of *gari*

The proximate composition of each sample was determined by the Association of official Analytical chemist (AOAC, 2000) official method of analysis. The pH (10%) weight per volume suspension of the sample in distilled water was prepared and measured according

to Nelson (2002). Determination of water absorption capacity, swelling index, and solubility were carried out according to the method of Iwuoha (2004). The method used by Udensi and Okaka (2000) was adopted for bulk density. The color attributes (L^* , a^* , and b^* values) of the *gari* were measured using standard $L^* = 53.24$, $a^* = 7.96$, and $b^* = 53.66$ values (Hsu et al., 2003). Beta-carotene was determined using methanolic extract according to Kumara et al. (2011) method.

2.3 | Viscosity Determination

Reconstituted *gari* (1:3 w/v) was used for this analysis. After heating, the paste was cooled and kept in a water bath at 30°C. The viscosity of the sample was determined using the viscometer (Model RV-1T) (W&J INSTRUMENT CO., LTD). The viscosity was recorded at the spindle speed of 6 rpm using rotor 4.

2.4 | Hydrogen cyanide determination

Method of Onwuka (2005) was used for the extraction of cyanide in the sample. Sample (2 g db) was made into paste in 20 ml of distilled water in a corked conical flask overnight, the extract was filtered and the filtrate was used for the analysis. Cyanide test kit Quantofix (7070-1EA) was supplied by Bristol Scientific Company Limited, Nigeria. The test vessel was filled with extracted sample to the 5 ml mark. One level spoon of Reagent CN-1 was added, dissolved by swirling and five drops of Reagent CN-2 was added. Immediately the test strip was immersed in the reaction zone of the measurement sample for 30 s. The strip was removed, allow excess liquid to run off via the long edge of the strip onto an absorbent paper towel, and, within 10 s, determine with which color field on the label the color of the reaction zone coincides most exactly.

2.5 | Sensory analysis

Sensory analysis was conducted on the reconstituted *gari* paste (*eba*). *Eba* was prepared by adding hot boiling water to *gari* in ratio 1:3 (w/v) and stirred constantly to form a smooth thick paste. The reconstituted dough samples were coded and subjected to organoleptic evaluation using a 20 man panel (Students of the Department of Home-economics and Food science, University of Ilorin, Ilorin, Kwara state) with the aid of questionnaires based on a 9-point hedonic scale (9 like extremely and 1 dislike extremely). The panelist assessed the coded samples for appearance, aroma, taste, moldability, and over-all acceptability.

2.6 | Statistical analysis

All analyses were carried out in triplicates. The mean and standard deviation of the data obtained were calculated. The data were evaluated for significant differences in their means with Analysis of

Variance (ANOVA) ($p < .05$). Differences between the means were separated using Tukey's test as packaged by SPSS software (version 17.0).

3 | RESULTS AND DISCUSSION

3.1 | Chemical composition of biofortified cassava tuber

Chemical composition of the cassava tuber is shown in Table 1. Moisture content of the cassava tuber was 82.20% indicating low dry matter in the biofortified cassava tuber. Ash, crude fiber, and fat contents of the biofortified cassava tuber were within the range reported by Eleazu and Eleazu (2012) and Ayetigbo et al. (2018). Starch, sugar, and cyanide contents in the tuber were 38.30%, 1.1%, and $<10 \text{ mg/L CN}^{-1}$. Starch contents reported by Aniedu and Omodamiro (2012) for two varieties of yellow cassava (NR 07/0427) and (TMS 30572) ranged from 11.69% to 29.16%. Likewise, Atwijukire et al. (2019) also reported the starch yield of 8.4%–33.2% for yellow cassava tubers. Charles et al. (2005) reported the cyanide contents ranging from 8.33 to 28.8 mg HCN/kg dry weight basis in five cassava genotypes. Cyanide content of the cassava tuber used in this study was low when compared to other cassava varieties.

3.2 | Effect of fermentation on the proximate composition of gari using yellow flesh cassava varieties

Moisture contents of the *gari* samples ranged from 7.81% to 7.95% (Table 2). Moisture content was found to be higher on day 4 while day 0 had the least value. Moisture content was below the recommended level (10.0%–12.13%) stated by Makanjuola et al. (2012). The ash contents of the *gari* were found to be low and it decreased with an increase in the fermentation periods. The decrease in ash content may be due to the leaching of soluble mineral elements into fermenting medium. The ash value obtained for *gari* in this study was higher than the value recommended (1.5% max) by NIS (2004). However, higher ash contents observed in this study may be due to the improved and biofortified cassava variety used.

TABLE 1 Chemical composition of biofortified cassava tuber

Parameters	Values
Moisture (%)	82.20 ± 0.21
Ash (%)	1.76 ± 0.10
Fat (%)	2.06 ± 0.17
Crude fiber (%)	1.22 ± 0.08
Starch (%)	38.30 ± 0.41
Sugar (%)	1.10 ± 0.0
Cyanide (mg/L CN^{-1})	<10

TABLE 2 Effect of fermentation time on chemical composition of *gari*

Fermentation days	Moisture content (%)	Ash (%)	Crude protein (%)	Lipid content (%)	Fiber content (%)	Carbohydrate (%)	Starch (%)	Sugar (%)	Cyanide (mg/L CN^{-1})
0	7.81 ± 0.01^{ab}	2.15 ± 0.01^a	2.05 ± 0.01^{ab}	0.87 ± 0.01^a	0.89 ± 0.01^b	86.51 ± 0.01^a	20.05 ± 1.20^a	2.20 ± 0.40^d	<1
1	7.84 ± 0.07^{ab}	2.11 ± 0.14^a	2.20 ± 0.14^a	0.74 ± 0.01^b	0.92 ± 0.07^b	86.39 ± 0.01^a	18.20 ± 0.20^b	3.50 ± 0.17^c	<1
2	7.92 ± 0.01^a	1.96 ± 0.01^b	2.16 ± 0.01^a	0.75 ± 0.01^b	0.96 ± 0.01^b	86.34 ± 0.01^a	14.10 ± 0.45^c	4.10 ± 0.21^b	<1
3	7.95 ± 0.01^a	1.93 ± 0.01^b	2.18 ± 0.01^a	0.71 ± 0.01^b	1.72 ± 0.01^a	85.53 ± 0.01^b	11.20 ± 0.36^d	4.20 ± 0.23^b	<1
4	7.90 ± 0.08^a	1.90 ± 0.12^b	2.25 ± 0.01^a	0.68 ± 0.01^{bc}	1.86 ± 0.00^a	85.65 ± 0.04^b	8.20 ± 0.27^e	5.20 ± 0.20^a	<1

Note: Value with the same letter within the same column are not significantly different ($p > .05$).

TABLE 3 Effect of fermentation time and storage on the color of *gari*

Fermentation days	L*					a*				
	0	2	4	6	6	0	2	4	6	6
0	66.21 ± 3.20 ^a	67.13 ± 1.70 ^b	77.68 ± 2.60 ^a	74.72 ± 1.70 ^b	74.72 ± 1.70 ^b	3.80 ± 0.70 ^c	2.51 ± 0.70 ^c	8.45 ± 0.20 ^c	12.92 ± 0.70 ^b	12.92 ± 0.70 ^b
1	66.80 ± 2.50 ^a	69.92 ± 1.50 ^a	72.41 ± 1.20 ^e	77.22 ± 2.80 ^a	77.22 ± 2.80 ^a	3.83 ± 0.40 ^c	1.87 ± 0.10 ^d	8.14 ± 0.20 ^c	12.83 ± 0.31 ^b	12.83 ± 0.31 ^b
2	60.04 ± 3.70 ^c	60.37 ± 0.80 ^d	74.54 ± 1.40 ^c	71.44 ± 1.40 ^d	71.44 ± 1.40 ^d	3.92 ± 0.40 ^c	2.95 ± 0.10 ^c	9.23 ± 0.20 ^b	13.94 ± 0.20 ^a	13.94 ± 0.20 ^a
3	65.16 ± 2.70 ^b	66.63 ± 1.00 ^c	76.33 ± 3.60 ^b	73.82 ± 2.40 ^c	73.82 ± 2.40 ^c	4.53 ± 0.50 ^b	3.70 ± 0.30 ^b	9.41 ± 0.20 ^{ab}	13.93 ± 0.20 ^a	13.93 ± 0.20 ^a
4	57.97 ± 3.60 ^d	57.39 ± 1.70 ^e	73.84 ± 1.60 ^d	68.26 ± 4.20 ^e	68.26 ± 4.20 ^e	5.98 ± 0.40 ^a	4.32 ± 0.20 ^a	9.90 ± 0.20 ^a	14.25 ± 0.50 ^a	14.25 ± 0.50 ^a
Fermentation days	b*					ΔE				
	0	2	4	6	6	0	2	4	6	6
0	27.13 ± 1.60 ^b	8.62 ± 0.50 ^a	2.91 ± 0.70 ^b	1.32 ± 0.50 ^b	1.32 ± 0.50 ^b	29.82	47.36	56.15	56.79	56.79
1	27.01 ± 1.60 ^b	3.84 ± 0.40 ^c	2.11 ± 0.50 ^b	1.23 ± 0.40 ^b	1.23 ± 0.40 ^b	30.19	52.89	55.00	57.86	57.86
2	26.75 ± 2.60 ^c	5.45 ± 0.40 ^b	3.52 ± 0.40 ^b	2.34 ± 0.70 ^a	2.34 ± 0.70 ^a	28.05	48.99	54.50	54.78	54.78
3	29.15 ± 2.10 ^a	8.85 ± 0.50 ^a	3.82 ± 0.10 ^b	2.54 ± 0.40 ^a	2.54 ± 0.40 ^a	27.47	46.96	54.77	55.28	55.28
4	28.31 ± 2.90 ^{ab}	8.71 ± 0.70 ^a	6.94 ± 0.70 ^a	2.93 ± 0.90 ^a	2.93 ± 0.90 ^a	25.86	45.29	51.10	53.28	53.28

Note: Value with the same letter down the column are not significantly different ($p > .05$).

There were slight increases in protein contents of *gari* with fermentation time but no significant differences ($p > .05$) were observed in the values from day 0 to day 4. Increase in crude protein contents with increase in fermentation days were also observed by Irtwange and Achimba (2009). Increase in protein content could be due to starch removal during processing. Generally, there was an increase in the fiber contents of *gari* as the fermentation day increased. This may be due to loss of soluble solids during fermentation thereby increasing the fiber contents. Although the fat content of the *gari* was low, there was a decrease in the fat contents as the duration of fermentation increased. Fat contents ranged from 0.68% to 0.87%. The values were higher than that reported by Oduah et al. (2015) but lower than that observed by Oluwafemi and Udeh (2016). Reduction in fat contents may be due to microbial hydrolysis and metabolism of carbohydrates and fats as source of energy as reported by Nkhata et al. (2018). The low fat content of the *gari* indicated that it could be stored for a long time without rancidity as stated by Bolarinwa et al. (2017).

The carbohydrate content of the *gari* was high since carbohydrate is the major nutrient in *gari*. It was higher on day 0 and gradually decreases as the fermentation days increased. This was due to the breakdown of the carbohydrate by microorganisms into simple sugars and the utilization of carbohydrate nutrient as a source of energy by fermenting microorganisms for growth metabolism (Omafuvbe et al., 2004). The starch content of the *gari* samples were low and ranged from 8.2% to 20.05%. There were reductions in starch contents of *gari* while the sugar contents increased as a result of hydrolysis of starch into sugars. Low starch contents in the *gari* would affect the textural quality (moldability) of the reconstituted dough.

3.3 | Effect of fermentation and storage on the cyanide content of *gari* made from yellow fleshed cassava

It was observed that the cassava variety had low cyanide content and upon processing and storage was found to be less than 1 mg/L CN⁻¹ (Table 2). But during storage, cyanide was not detected in the *gari*. The reduction in the cyanide content of the samples during storage may be due to the volatility of the hydrogen cyanide. Fermentation caused reduction in the cyanide content of *gari* from yellow cassava. Hydrogen cyanide of the cassava pulp was reduced as a result of leaching into the medium during the pressing process. Tetchi et al. (2012) further explained that fermentation caused the elimination of endogenous cyanide compound in cassava roots after 48 hr. Cassava variety (TMS 1358) used were low in cyanide contents and thus after roasting, cyanide content was observed in the *gari* was less than 1 mg/L CN⁻¹. According to NIS (2004), the cyanide contents of *gari* must not exceed 20.0 mg/kg. The cyanide values obtained for the cassava tuber and the product *gari* were lower than the standard value indicating the safety of the product for human consumption.

3.4 | The effect of fermentation and storage on the color and β -carotene of *gari*

The results showed that the L^* (Lightness) value increased with fermentation days while the yellowness (b^*) reduced with fermentation days (Table 3). Color differences increased with storage period indicating the deviation of the *gari* color from the standard color. This might be due to the depletion of β -carotene during fermentation as β -carotenoids are known to be majorly responsible for the yellow/orange pigments or color in foods (Uchechukwu-Agua et al., 2015). According to Bolarinwa et al. (2017) reduction in the β -carotenoids and color may be due to the leaching of β -carotenoids during processing. There was an increase in the redness (a^*) of the samples as fermentation days increased. As the storage period was prolonged, there was an increase in the lightness and redness of the *gari* while the yellowness was reduced. At month 6, all the *gari* samples had become light in color (Figure 1). The yellow color had faded due to the oxidation and degradation of carotenoids in the yellow cassava flour. Uchechukwu-Agua et al. (2015) also reported that the degradation of color could be as a result of the degree of exposure to light during processing and storage. But according to Bechoff et al. (2009) temperature and oxygen were the main factors that caused the loss in carotenoids while water activity only had a minor effect. β -carotenoids decreased upon fermentation and processing as a result of leaching (Bolarinwa et al., 2017) (Table 4). It was observed that the β -carotenoid decreased as fermentation days and storage time increased. Reduction in carotene during storage may be due to the oxidation which led to the production of hydroperoxide that caused fading and loss of carotenoids in *gari* color. Bechoff et al. (2015) also observed that carotenoid content and vitamin A activity of the bio-fortified *gari* products decreased with time and temperature.

3.5 | Effect of fermentation and storage on the pH of *gari* samples from yellow fleshed cassava

The pH of *gari* at day 0 decreased with an increase in fermentation periods (Table 4). The value obtained for day 0 was significantly different ($p < .05$) from other samples while there were no significant differences ($p > .05$) in values obtained from day 1 to 4 days in pH. pH values increased slightly during storage of the *gari*. According to Oyewole and Ogundele (2001), fermentation caused a reduction in pH value due to the increase in the level of acidification with increasing fermentation periods due to the accumulation of organic acids such as lactic and acetic acids produced by microbial activities during fermentation. pH has been attributed to be a critical factor in developing the flavor and aroma of foods (Tetchi et al., 2012). Hence, increasing the fermentation period increased the flavor and aroma of *gari* from yellow cassava. The increase in the pH observed during storage may be due to the rancidity that occurred in the *gari* as a result of the production of hydroperoxide which caused fading of the color and destruction of the carotenoid from month 2.

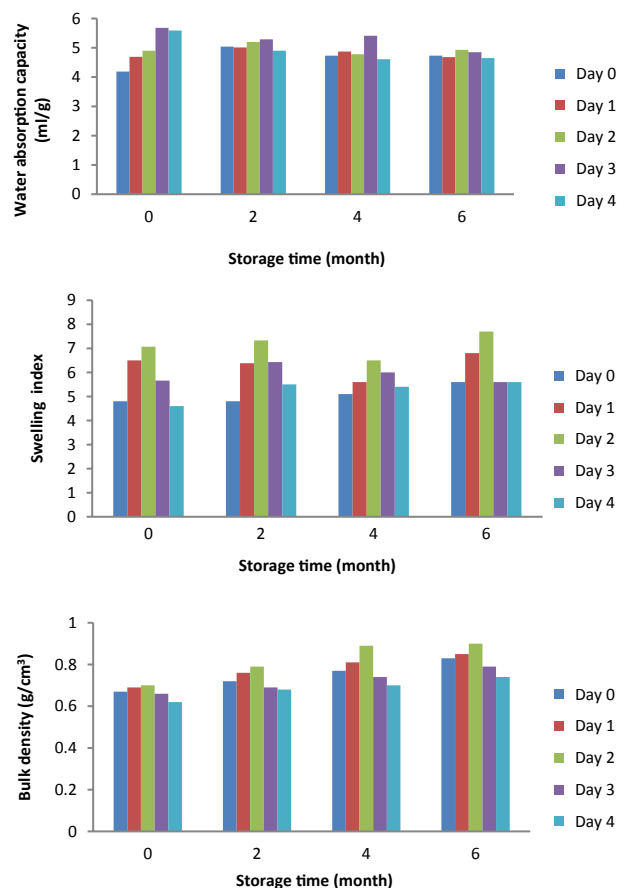


FIGURE 1 *Gari* processed before and after 6 months of storage

3.6 | Effect of fermentation and storage on the water absorption capacity of *gari*

Water absorption capacity increased gradually from days 0–2 while it decreased from day 3 and day 4 fermentation periods (Figure 2). This might be due to the low starch content and more sugar of the *gari* as a result of the breakdown of starch to simple sugars by fermentation. Oluwole et al. (2004) explained that at elevated temperature the molecules are subjected to random movement causing the intermolecular and intramolecular forces to be broken and the *gari* will imbibe greater volume of water. It was observed that the water absorption capacity decreased gradually with storage time and the least value was observed (4.65 ml/g) at 6 months. Water absorption capacity is the ability of a product to absorb water (Bolarinwa et al., 2017), and this depends majorly on the processing methods used.

3.7 | Effect of fermentation and storage on the swelling index of *gari*

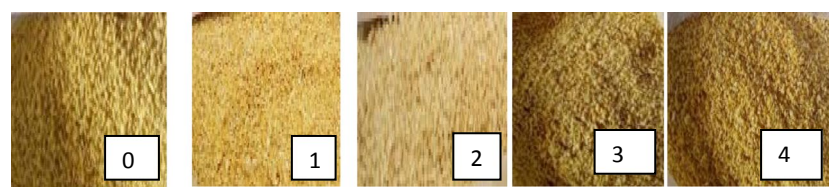
Swelling index of the *gari* samples ranged between 3.6% and 7.7% (Figure 2). It was observed that the swelling index increased with increasing fermentation days and it was higher at day 2 of fermentation while it gradually decreased from day 3 and day 4. The swelling

TABLE 4 Effect of fermentation time and storage on the beta-carotenoid (mg/100g) and pH of *gari*

Fermentation days	β -carotenoid (mg/100g)				pH			
	0	2	4	6	0	2	4	6
0	61.06 $\pm$ 0.19 ^a	41.26 $\pm$ 0.22 ^a	ND	ND	6.8 $\pm$ 0.0 ^a	7.0 $\pm$ 0.00 ^a	7.1 $\pm$ 0.00 ^a	7.1 $\pm$ 0.0 ^a
1	58.02 $\pm$ 0.32 ^b	39.14 $\pm$ 0.14 ^b	ND	ND	5.6 $\pm$ 0.0 ^b	6.1 $\pm$ 0.00 ^a	6.2 $\pm$ 0.00 ^{ab}	6.2 $\pm$ 0.0 ^{ab}
2	49.35 $\pm$ 0.24 ^c	29.16 $\pm$ 0.30 ^c	ND	ND	5.4 $\pm$ 0.0 ^b	6.0 $\pm$ 0.00 ^a	6.1 $\pm$ 0.00 ^{ab}	6.1 $\pm$ 0.0 ^{ab}
3	40.08 $\pm$ 0.27 ^d	29.23 $\pm$ 0.18 ^c	ND	ND	5.3 $\pm$ 0.0 ^b	5.9 $\pm$ 0.00 ^a	5.9 $\pm$ 0.00 ^{bc}	5.9 $\pm$ 0.0 ^b
4	38.12 $\pm$ 0.18 ^d	18.20 $\pm$ 0.21 ^d	ND	ND	5.2 $\pm$ 0.0 ^b	5.8 $\pm$ 0.00 ^a	5.9 $\pm$ 0.00 ^{bc}	5.9 $\pm$ 0.0 ^b

Note: Value with the same column are not significantly different ($p > .005$).

Abbreviation: ND, Not detected.



Before Storage



After storage

FIGURE 2 The effect of fermentation and storage on water absorption capacity, swelling index, and bulk density of *gari* from yellow flesh cassava

power is an indication of the presence of amylase which influences the quantity of amylose and amylopectin present in *gari*. Irtwange and Achimba (2012) further explained that prolonged fermentation periods (up to 3 days) caused proper degradation of starch which led to a higher absorptive/swelling of the *gari* upon reconstitution. According to Sanni et al. (2008) low swelling index may be due to samples being affected by drying temperature, degree of gelatinization, and moisture content.

3.8 | Effect of fermentation time and storage on the bulk density of *gari*

Increase in fermentation days increased the bulk density of *gari* from 0.67 g/cm³ on day 0 to 0.70 g/cm³ on day 2 with subsequent reduction from day 3 (0.66 g/cm³) to day 4 (0.62 g/cm³) (Figure 2). The result was in contrast to the report of Oluwafemi and Udey (2016) that observed an increase in bulk density with increasing fermentation days but comparable to findings of Komolafe and Arawande (2010). Storage period was observed to increase the bulk density of *gari* from the production day to 6 months. Bulk density is influenced by factors such as dryness and particle size distribution of samples (Komolafe & Arawande, 2010). Bulk density is reportedly influenced by the structure of starch polymers and loose structure of starch polymers result in low bulk density (Makanjuola et al., 2012). Sanni et al. (2008) observed that the lower the bulk density, the higher the floatation of *gari* on top of water which may result in poor soaking in water leading to rejection by consumers.

Hence, fermentation of this cassava variety may not exceed 2 days as fermentation beyond this led to reduction in bulk density.

3.9 | Effect of fermentation time and storage on the viscosity of reconstituted *gari* paste (*eba*)

Viscosity of the reconstituted *gari* paste (*eba*) was done over 6 months (Table 5). It was discovered that the viscosity of the *eba* reduced with increasing fermentation period from 23,365 mPa/s for day 0 to 22,066 mPa/s on day 4. There were no significant differences ($p > .05$) in the viscosities of *eba* made from *gari* in day 0 to day 2 of fermentation. These values decreased during storage but *eba* from day 0 had higher viscosities throughout the storage periods. The least viscosity value was observed in day 4 at 6 months of storage. As fermentation days increased, the starch contents are broken down by fermenting microflora thereby increasing the sugar contents of the product leading to reduced viscosity of the reconstituted *gari*.

3.10 | Effect of fermentation on the sensory properties of reconstituted *gari* paste (*eba*)

The appearance of the reconstituted *gari* paste (*eba*) from day 0 was more preferred and significantly different ($p > .05$) from other reconstituted *gari* paste (Table 6). There were no significant differences

TABLE 5 Effect of fermentation time and storage on the viscosity (mPa/s) of gari paste

Fermentation days	Storage periods (month)			
	0	2	4	6
0	23,365 ± 17.8 ^{ab}	23,329 ± 10.2 ^a	23,202 ± 5.5 ^a	23,185 ± 10.0 ^{ab}
1	23,226 ± 7.6 ^{bc}	23,167 ± 0.6 ^b	23,111 ± 17.1 ^b	23,107 ± 15.3 ^b
2	23,215 ± 2.1 ^{bc}	23,145 ± 0.6 ^b	23,106 ± 10.8 ^b	23,121 ± 6.0 ^b
3	23,185 ± 3.7 ^c	23,063 ± 2.9 ^c	23,070 ± 12.0 ^c	22,318 ± 2.0 ^c
4	23,166 ± 0.6 ^d	23,007 ± 6.4 ^d	22,167 ± 13.3 ^d	22,066 ± 4.0 ^d

Note: Values with the same letter within the column are not significantly different ($p > .05$).

TABLE 6 Sensory evaluation of reconstituted gari paste from yellow fleshed cassava

Fermentation days	Appearance	Taste	Moldability	Aroma	Overall Acceptability
0	7.67 ± 1.60 ^a	5.80 ± 1.70 ^b	8.07 ± 1.70 ^a	5.67 ± 2.10 ^c	6.92 ± 0.55 ^{ab}
1	7.13 ± 1.30 ^b	5.07 ± 1.90 ^c	7.73 ± 1.70 ^{ab}	6.13 ± 1.60 ^b	7.25 ± 0.87 ^a
2	7.20 ± 1.60 ^b	7.00 ± 2.04 ^a	6.67 ± 1.90 ^b	6.33 ± 1.60 ^b	7.64 ± 1.10 ^a
3	5.08 ± 1.90 ^c	7.13 ± 2.20 ^a	6.13 ± 1.40 ^c	7.40 ± 1.60 ^a	5.32 ± 0.59 ^b
4	4.67 ± 2.50 ^d	7.00 ± 2.10 ^a	4.28 ± 1.60 ^d	7.47 ± 1.70 ^a	4.29 ± 0.12 ^b

Note: Values with the same letter within the column are not significantly different ($p < .05$).

($p > .05$) in the values observed in *eba* fermented for 1 or 2 days in appearance while the values decreased further with fermentation days. As fermentation period was prolonged, the taste of *eba* became more acceptable. No significant differences ($p > .05$) were observed in reconstituted *gari* paste fermented for 2–4 days in their taste values. Moldability of the *eba* was preferred at day 0 and day 1 due to the firmness of the product. At the 4th day of fermentation, the *eba* could not be molded with hands due to low starch contents in the product. The *eba* aroma was perceived at day 3 and day 4 of fermentation periods. Prolonged fermentation of cassava paste for *gari* production improved the flavor of *gari* product. Reconstituted *gari* from yellow flesh cassava fermented for 0 to 2 days were more acceptable than others.

4 | CONCLUSIONS

This study examined the effect of fermentation and storage period on the physicochemical properties of the *gari* made from the yellow fleshed cassava (TMS1358 variety). The biofortified cassava tuber used had low cyanide contents and this reflected in the cyanide values of the finished product (*gari*) thereby making the product safe for human consumption. Carotene content of the *gari* was high at day 0 of fermentation but decreased with prolonged fermentation and storage. Higher swelling index was observed in the *gari* at day 2 while changes in color of the product were observed at 2 months. Taste, aroma, and moldability of *eba* were acceptable from day 0 to day 2 of fermentation. Storage and consumption of *gari* from this biofortified cassava tuber should be done within the first 2 months before the onset of rancidity.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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