Agrosearch, 20(1): 118-132 (2020) https://doi.org/10.4314/agrosh.v20i1.11S

PHYSICAL, CHEMICAL AND SESNORY PROPERTIES OF FLAKES (*GARI)* PREPARED FROM REFRIGERATED CASSAVA ROOTS

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ABSTRACT

Cassava is a tropical crop that can be processed into a variety of products including flakes popularly called *gari*. *Gari* is a product obtained from cassava root by fermentation, but the root from which the *gari* is obtained spoils rapidly. Efforts have been made to extend the shelf life of the root through the use of traditional and improved storage techniques, for example storage in boxes, freezing and refrigeration. However, the quality of the products from refrigerated roots, such as *gari,* has not been reported. In this study, cassava roots were refrigerated for a period of three weeks and the physicochemical properties of *gari* from the stored roots were determined. With the exception of the carbohydrate content which was very similar (approx. 88%), refrigeration of cassava roots significantly ($p < 0.05$) affected the physical and chemical properties of the resulting *gari.* The cyanide content decreased from 2.96 to 1.90 mg/ kg with increase in refrigeration period, while the functional properties including bulk densities and swelling power were only slightly affected. Cassava roots can be refrigerated for a period of two weeks without substantial changes in the eating quality of the resulting *gari*, if the storage condition is closely monitored. Future studies are required to investigate the physicochemical properties of other valuable products from refrigerated cassava roots to determine their potentials in food and non-food applications.

Keyword: Cassava; Functional; *Gari*; Refrigeration; Pasting; Sensory

INTRODUCTION

Cassava (*Manihot esculenta)* is a major crop in the tropics grown for its edible root. It is the second most important tropical root crop in West Africa (Adisa *et al.*, 2015; Falola *et al.*, 2017). However, cassava spoils rapidly because of its high moisture content which may vary between 61.00 and 90.15% (Ibegbulem and Chikezie, 2018; Laya *et al*., 2018; Oyeyinka *et al*., 2020). Deterioration which sets in immediately after harvest is a major challenge limiting commercial production of cassava (Uchechukwu-Agua *et al.*, 2015). The rapid post-harvest deterioration of cassava roots, which usually prevents their storage in the fresh state for more than 2-3 days, is poorly understood. Several modern and traditional methods of storing cassava roots have been developed to control the deterioration of cassava roots. Modern methods include waxing, chemical treatment, controlled atmosphere, deep freezing and refrigeration (Uchechukwu-Agua *et al.*, 2015). Subsistence farmers leave cassava roots in the ground until needed, or if storage is required after harvesting as a traditional means, re-bury the roots in a trench (Karim et al., 2009). Due to its perishability, cassava root is rapidly processed into shelf-stable products such as *fufu, elubo* and *gari* (Balogun *et al.*, 2012; Oyeyinka *et al.*, 2019b) with low moisture content to enhance stability and long-term storage (Uchechukwu-Agua *et al.*, 2015). Among these products, *gari* appears to be consumed more due to its relatively longer shelf-life compared to other food products from cassava as well as its ease of preparation (Omueti *et al.*, 1993; Oyeyinka *et al*., 2019b).

Gari is a creamy-white, partially gelatinized, roasted free-flowing granular flour made from fermented cassava roots (Sanni *et al.*, 2008). During its production, fermentation plays an important role by hydrolyzing linamarin into hydrocyanic acid at reduced levels that may become harmless after roasting (Irtwange and Achimba, 2009; Laya *et al*., 2018). Production of *gari* involves peeling of cassava roots, followed by washing, and grating to produce cassava mash. The mash is bagged using a porous sack and then allowed to ferment for 3-5 days. Thereafter, the fermented mash is placed in an adjustable press machine for 1-3 hours to remove excess starchy water. The mash is then sieved and roasted (*garified*). As previously noted, the cassava root used in the preparation of *gari* and other fermented food products have a very short shelf-life of about three days. Hence, efforts have been made to reduce the rate of deterioration of the roots.

Several factors including age, season at which cassava storage roots are harvested, variety, type of storage and duration has been found to influence the physicochemical, functional, and sensory properties of *gari* (Laya *et al*., 2018; Oyeyinka *et al*., 2019b). Laya *et al*. (2018) reported that *gari* produced in the dry season were better in terms of physicochemical, functional, and sensory properties than that produced in the rainy season. Oyeyinka *et al.* (2019b) reported that *gari* may be produced from deep frozen cassava roots without substantial changes in the eating quality, but the functional properties i.e. swelling capacity was reported to reduce significantly. Furthermore, the authors hypothesized that the freezing conditions, which may generate ice-crystals could have resulted in high starch damage leading to greater reduction in granule size. This presumably resulted in the decrease ability of the samples to absorb moisture and swell. Hence refrigeration may be a better alternative to freezing in this regard. Therefore, this study investigated the physicochemical properties of *gari* prepared from refrigerated cassava roots for a period of three weeks.

MATERIALS AND METHODS

Materials

Fresh mature cassava roots of variety TME 419 were harvested from the University of Ilorin, Agricultural Research Farm. The cassava roots were immediately transferred to the food processing laboratory in the Department of Home Economics and Food Science, University of Ilorin for processing. All other chemicals used were laboratory-grade.

Storage of Cassava Roots

Cassava roots were washed in distilled water, drained and weighed. The washed samples, 10 kg each, were packaged in Ziploc bags and kept in a refrigerator operating at a temperature of 4 ^{o}C±2. The roots were stored for a period 1, 2 and 3 weeks. Cassava roots that were immediately processed after harvest served as the control.

Preparation of *Gari*

Gari was prepared from either fresh or stored cassava roots as reported previously (Oyeyinka *et al.*, 2019b). Briefly, cassava roots were peeled, washed and grated using a Lister Diesel (5-1 6HP 650RPM, UK) grating machine. The grated pulp was packed into a jute bag and pressed to remove water. The pulp was fermented for 5 days, sifted to remove coarse fibre and roasted to obtain *gari*.

Analyses

Colour

The tristimulus L, a, b parameters of the *gari* samples were determined after standardization with a white tile using a Colorflex-EZ bench top spectrophotometer (A60-1014-593, Hunter Associates, Reston, VA, USA). Digital color photos were taken in duplicate and values read directly from a digital print (Oyeyinka *et al.*, 2019a).

Particle Size Distribution

The particle size of the *gari* samples was determined as earlier reported (Oyeyinka *et al.*, 2019b). Briefly, fifty (50) grams of *gari* was sieved through a set of graded Tyler sieves of aperture sizes 5.00, 4.00, 3.0, 1.80, 1.40 and 1.00 mm using a Retsch Vibro shaker (Model 65056, W. Germany) set at frequency of 50 Hz for 10 min. Fractions retained on each sieve were then weighed.

Swelling Capacity

Swelling capacity was determined by filling *gari* samples into a 50 mL glass measuring cylinder. Distilled water was added at room temperature to give a total volume of 50 mL. The top of the cylinder was tightly covered and the contents mixed by inverting the cylinder. After 2 min, the cylinder was inverted again. The cylinder was then left to stand for additional 3 min and the final volume occupied by the *gari* was recorded. Swelling capacity was determined by dividing the volume of *gari* in water by the initial volume of *gari* (Oyeyinka *et al.*, 2019b).

Bulk Densities

Loose and packed bulk densities of *gari* samples were determined as earlier reported (Falade and Oyeyinka, 2015). Sample was filled to 100 mL mark of a measuring cylinder (100 mL) and the content weighed. Packed bulk density was also obtained by following the same procedure, but with additional tapping for 50 times prior to weighing. Bulk density was calculated as the ratio of the bulk weight and the volume of the container (g/mL).

Chemical Composition

Moisture, crude fat and total ash contents were determined using the standard method of the Association of official Analytical Chemists (2000). Protein content was determined using the Kjeldahl method (6.25×N) and total carbohydrate was calculated by difference. Crude fibre were determined by standard laboratory procedure (Olagunju *et al.*, 2018). The pH of the samples was determined using a pH meter (Jenway 3505, Bibby Scientific, London, UK), while cyanide contents were determined by the method of Nkoudou and Essia, (2017).

Pasting Properties

The pasting properties of the *gari* were determined using a Rapid Visco-Analyzer (Newport Scientific Australia) as previously reported (Nwancho *et al*., 2014).

Sensory Properties

Sensory evaluation of *gari* was carried out as using a multiple comparison test. Thirty (30) panelists, selected from student of the Department of Home Economics and Food Science, University of Ilorin, Nigeria were used for the evaluation. The selected students were those who consume *gari* regularly. Prior to the sensory analysis, they were screened with respect to their interest and ability to differentiate food sensory properties. The samples were evaluated for aroma, appearance, sourness, and overall acceptability using a 9-point hedonic scale, where 9 and 1 represent like extremely and dislike extremely, respectively.

Statistical Analysis

Duplicate samples were prepared and analyses done in triplicate. Data was analysed using one-way analysis of variance (ANOVA) and means were compared using the Fisher Least Significant Difference (LSD) test ($p \leq 0.05$) using the Statistical Package for the Social Sciences (SPSS) Version 16.0 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Colour

Refrigeration slightly affected the objective colour attributes of the *gari* samples (Table 1). In general, *gari* prepared from refrigerated cassava root showed lower lightness (L) values (64.40-70.30) compared with the one prepared from freshly harvested cassava root (70.48). The L value decreased with increasing refrigeration period. *Gari* prepared from cassava root refrigerated for 1 week had similar L value with the control. Beyond one week of storage, the L value decreased significantly ($P < 0.05$). Oyeyinka *et al.* (2019b), similarly reported decrease in L values for *gari* prepared from frozen cassava roots. The a and b values of the *gari* samples did not follow a particular trend. Redness value (positive a) ranged between 2.60 and 3.11, while the yellowness value (positive b) of the sample ranged between 11.28 and 13.07.

Table 1. Colour attributes, moisture and carbohydrate contents of *gari* from refrigerated cassava

Storage period (Weeks)	L	a	b	Moisture (%)	*CHO (%)
0	$70.48^{a} \pm 0.96$	$2.71^{b} \pm 0.11$	$12.83^{a} \pm 0.40$	$7.75^{a} \pm 0.04$	$87.80^{a} \pm 0.15$
1	$70.30^{a} \pm 2.04$	$3.11^{a} \pm 0.18$	$13.07^{a} \pm 0.97$	$7.37^{a} \pm 1.07$	$88.25^{a} \pm 1.07$
2	$65.64^{b} \pm 0.70$	$2.81^{b} \pm 0.20$	$12.30^{ab} \pm 0.51$	$7.68^{a} \pm 0.07$	$88.13^{a} \pm 0.11$
3	$64.40^{b} \pm 4.33$	$2.60^{b} \pm 0.21$	$11.28^{b} \pm 1.25$	$7.35^{a} \pm 0.18$	$88.08^{a} \pm 0.18$

Values are mean ± standard deviation. Mean with different superscripts along a column are significantly ($p < 0.05$) different

*CHO: Carbohydrate

Chemical Composition

The carbohydrate (average of 88%) and moisture (average of 7.5%) contents of the *gari* samples were very similar (Table 1), suggesting that the refrigeration condition did not alter the composition of cassava roots from which the *gari* samples were made. Carbohydrate content of the samples was very high and this could be because the bulk of cassava roots is carbohydrate (Oyeyinka *et al.*, 2019a). The carbohydrate and moisture values in this study are in agreement with earlier studies (Laya *et al*., 2018; Oyeyinka *et al.*, 2019b) and also within values that are known to be safe for storage between two and seven months (Ukpabi and Ndimele, 1990). Laya *et al*. (2018) found that the period of harvest of cassava influenced the carbohydrate contents of *gari*. *Gari* prepared from cassava harvested in the dry season at 12 months after planting (MAP) reportedly showed higher carbohydrate content (65.98-75.12%) compared with the one produced from cassava harvested in the raining season (49.58-68.47%) at 15 months MAP (Laya *et al*., 2018).

pH and Cyanide Content

The pH values of the *gari* sample decreased significantly ($p < 0.05$) from 5.40 to 4.30 (Figure 1). *Gari* is a fermented product with pH found to vary between 3.42 and 4.88 depending on processing methods (Oyeyinka *et al.*, 2019b; Sanni *et al.*, 2008). Cassava roots has a high pH, which may vary between 6.9 and 7.1 (Oyewole and Afolami, 2001). The reduction in pH is associated with fermentation period due to the production of organic acids. These acids contribute largely to the flavour and consequently the acceptability of *gari*. Furthermore, high acidity of *gari* has been associated with better stability of *gari* and the resulting products such as eba, when compared to other food products such as pounded yam (Ogunsua, 1980).

Cyanide levels (2.96 mg/kg) in the *gari* from freshly processed cassava roots were significantly ($p < 0.05$) higher than samples (1.90-2.38 mg/kg) obtained from refrigerated cassava roots (Figure 1). The cyanide contents decreased with increasing refrigeration period from 2.96 to 1.90 mg/ kg and the values are within the value (10 mg/kg) considered safe (Sanni et al., 2008). Oyeyinka *et al.* (2019b) reported higher cyanide levels (4.48-6.41 mg/kg) for *gari* prepared from frozen cassava roots compared to values (1.90-2.96 mg/kg) reported in this study. Laya *et al*. (2018) also reported varying cyanide contents (0.08–0.90 mg/kg) for cassava roots harvested at different periods. The variation in cyanide contents may be attributed to the variety of cassava used as well as the duration of fermentation used in the respective studies. Consumption of high levels of cyanide has been associated with serious health disorders, especially when consumed in quantities exceeding the recommended safe levels (Montagnac *et al.*, 2009).

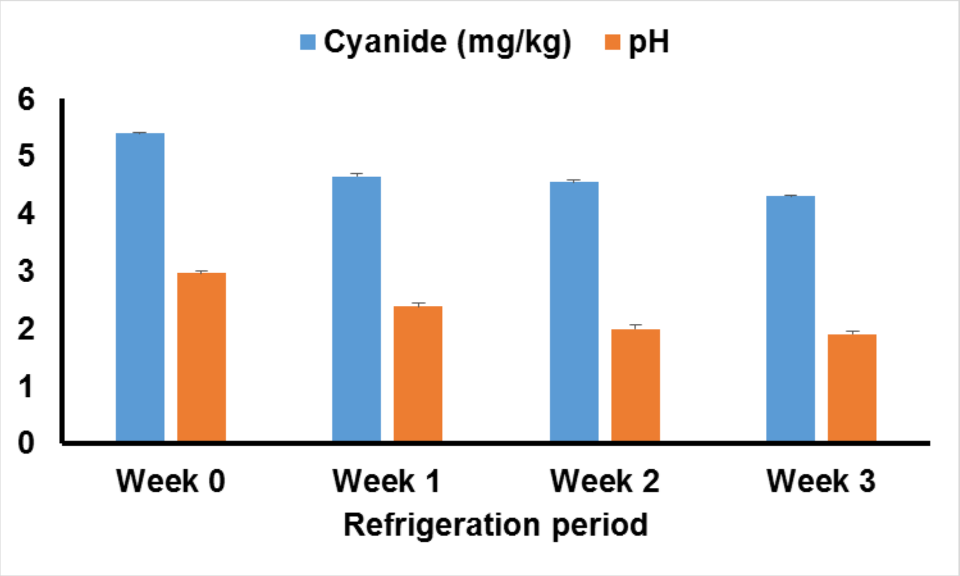

Figure 1: pH and cyanide contents of *gari* from refrigerated cassava
Error bars indicate standard deviation (N= 6)

Particle Size Distribution

The particle size of *gari* varied significantly ($p < 0.05$) among the samples, but did not follow any particular trend with weeks of refrigeration (Table 2). Oduro *et al.* (2000) suggested that differences in particle size distribution of *gari* samples could be as a result of varying grating procedures, roasting processes and the duration of fermentation. However, it is unlikely that any of the above-mentioned factors led to the observed variation in particle size in this study, since the samples were subjected to the same grating procedure, roasting process and period of fermentation. *Gari* obtained from freshly harvested cassava roots, which served as the control, had a lower amount (3.19) of fine particles compared with the *gari* (5.21-19.80) from refrigerated cassava roots. Our finding is in agreement with previous reports on *gari* from frozen cassava roots where *gari* from freshly harvested roots similarly had finer particles than stored roots (Oyeyinka *et al.*, 2019b). Several factors including the extent of starch damage may influence the particle size of *gari* samples (Akingbala *et al.*, 2005).

Table 2. Particle size distribution of *gari* from refrigerated cassava

Storage period (Weeks)	1mm	1.4mm	1.8mm	3mm	4mm	5mm	Fine particles
0	$0.28^{b}\pm0.01$	$2.44^{b}\pm0.01$	$24.99^{a}\pm0.01$	$52.99^{a}\pm0.04$	$10.75^{b}\pm0.08$	$5.48^{b}\pm0.03$	$3.19^{c}\pm0.01$
1	$0.10^{b}\pm0.01$	$2.95^{b}\pm0.07$	$16.15^{b}\pm0.08$	$53.29^{a}\pm0.01$	$15.16^{a}\pm0.08$	$6.92^{b}\pm0.12$	$6.37^{b}\pm0.19$
2	$0.85^{b}\pm0.06$	$1.07^{c}\pm0.37$	$14.06^{c}\pm0.01$	$74.78^{a}\pm1.13$	$10.49^{b}\pm3.08$	$6.78^{b}\pm1.70$	$5.21^{bc}\pm1.75$
3	$0.78^{a}\pm0.14$	$3.51^{a}\pm0.01$	$9.34^{d}\pm0.02$	43.36a±0.01	$18.49^{a}\pm0.02$	$12.24^{a}\pm0.01$	$19.80^{a}\pm0.28$

Values are mean ± standard deviation. Mean with different superscripts along a column are significantly ($p < 0.05$) different

Functional Properties

Swelling capacity is the ability of samples to absorb water and swell at room temperature. It is highly important as it measures the extent of gelatinization of the *gari* sample and a high swelling capacity is very important and desirable for good quality *gari.* The swelling capacity of *gari* varied significantly ($p<0.05$) among the samples and decreased slightly with increasing refrigeration period

(Figure 2). The swelling capacity recorded in this study is within the range (1.6-4.63) reported in the literature (Akingbala *et al.*, 2005; Nwancho *et al*., 2014). Differences in the swelling capacity of *gari* has been associated with variation in particle size, which largely depends on the associative forces between the particles (Sanni et al., 2008). Particles with low associative force between them will exhibit high swelling capacity. The swelling capacity of *gari* was found to decrease with reduction in the particle size (Nwancho *et al*., 2014).

The packed bulk densities (PBD) of the *gari* samples were higher than the loosed bulk density (LBD). The PBD and LBD significantly ($p<0.05$) decreased with increasing refrigeration period which agrees with previous research (Oyeyinka *et al.*, 2019b). Food samples with low bulk densities are advantageous as more economical packaging materials can be used for their distribution (Falade and Oyeyinka, 2015). The PBD and LBD values are in agreement with the literature (Nwancho *et al*., 2014; Oyeyinka *et al.*, 2019b).

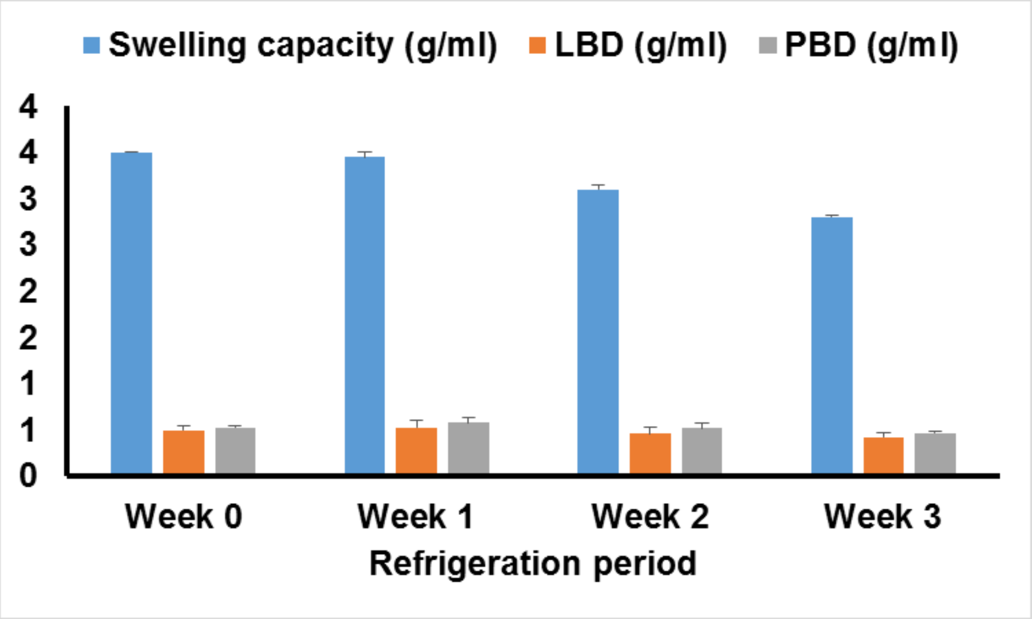

Figure 2. Selected functional properties of *gari* from refrigerated cassava
Error bars indicate standard deviation (N= 6)

Pasting Properties

Refrigeration of cassava roots significantly ($p < 0.05$) affected the pasting properties of the *gari* produced from the roots. The pasting curves of the samples are presented in Figure 3. *Gari* from freshly harvested roots displayed a lower peak viscosity (2562 cP) compared to samples from refrigerated cassava roots

(2897-6071 cP). High peak viscosity is an indication of high starch content and also relates to water binding capacity of starch (Oyeyinka *et al.*, 2019b). The variation in the peak viscosity of the *gari* samples may be linked with the differences in particle size (Table 2). *Gari* samples with greater proportion of small particles displayed higher peak viscosity. A previous study similarly found that the peak viscosity of *gari* samples was significantly affected by their particle size (Nwancho *et al*., 2014).

There was no significant difference ($p>0.05$) in the trough viscosity of the *gari* samples except for *gari* from roots refrigerated for 3 weeks. The values ranged from 2430.50 cP for *gari* from freshly harvested roots to 4640.50 cP for *gari* from roots refrigerated for 3 weeks. Breakdown viscosity, which measures the susceptibility of starch granules to disintegrate during heating (Oyeyinka *et al.*, 2019b) varied between 132 - 635.50 cP. *Gari* from refrigerated cassava roots generally showed higher breakdown viscosity compared to *gari* from freshly harvested cassava roots, suggesting that *gari* from freshly harvested roots is more stable to heat and mechanical shear than *gari* from refrigerated cassava roots. The impact of refrigeration on breakdown viscosity was only significant after the second week of storage. Final viscosity is commonly used to define the quality of a particular starch-based sample, as it indicates the ability of the material to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear force during stirring (Sanni *et al.*, 2008). Final viscosity values for the *gari* from refrigerated cassava were generally higher than the control, indicating that *gari* from refrigerated cassava roots will form a more viscous and stable paste after cooking and cooling. Setback viscosity values followed the same trend as observed for final viscosity. *Gari* from freshly harvested cassava roots had the lowest setback viscosity (1241 cP) compared to *gari* from refrigerated cassava roots which ranged from (1318 – 1924 cP). *Gari* samples showed significant ($p<0.05$) variations in their peak time (5.87- 7.00 mins). This implies that refrigeration affected the cooking time of the *gari* samples by reducing it significantly ($p<0.05$). The pasting temperatures (average of 86^{o} C) of *gari* from refrigerated cassava were generally lower than that of the control sample (91.23^{o} C) and is in agreement with the literature (Nwancho *et al*., 2014; Olanrewaju and Idowu, 2017; Awoyale et al., 2020). Pasting temperature measures the first detectable viscosity and as well depicts the maximum temperature taken to cook a given sample. Refrigeration reduced the pasting temperatures of the *gari* samples, suggesting that *gari* from refrigerated roots will cook at a lower temperature than the control.

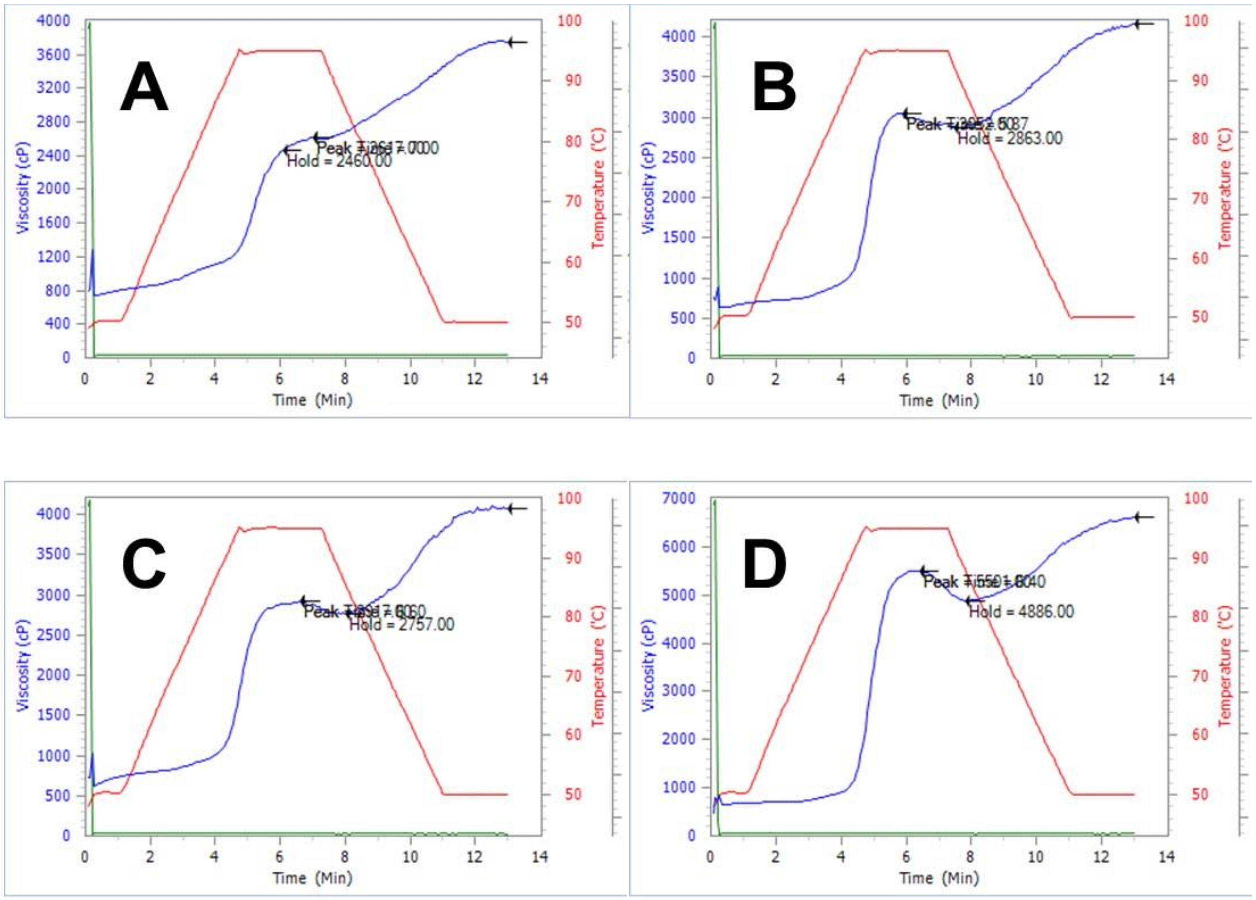

Figure 3. Pasting curve of *gari* from refrigerated cassava
A: *Gari* from cassava refrigerated for 0 week
B: *Gari* from cassava refrigerated for 1 week
C: *Gari* from cassava refrigerated for 2 weeks
D: *Gari* from cassava refrigerated for 3 weeks

Sensory Properties

Refrigeration significantly ($p < 0.05$) affected the sensory properties of the *gari* samples (Table 3). *Gari* prepared from cassava roots refrigerated for 3 weeks had substantially lower ratings in appearance, aroma, colour, sourness, texture and overall acceptability compared to other samples. The lower ratings recorded for sample prepared at the third week of refrigeration suggest that cassava roots should not be stored beyond 2 weeks to have acceptable sensory properties.

Other samples had similar ratings for all the measured sensory properties. Major parameters such as the appearance and sourness are important factors to be considered when determining the quality of *gari*. Although the preference for sourness of *gari* may vary depending on processing method used and individual perception, consumers most times determine their choice of *gari* from its appearance and sour taste. In this study, the control *gari* sample had slightly lower appearance ratings than *gari* from cassava roots refrigerated for 1 and 2 weeks.

Table 3. Mean sensory scores of *gari* from refrigerated cassava

Storage period (Weeks)	Appearance	Aroma	Colour	Sourness	Texture	Overall acceptability
0	$7.14^{b} \pm 0.97$	$6.60^{b} \pm 0.86$	$6.58^{c} \pm 0.70$	$7.06^{a} \pm 0.87$	$6.76^{b} \pm 0.82$	$6.80^{c} \pm 0.93$
1	$7.82^{a} \pm 0.69$	$7.34^{a} \pm 0.82$	$7.58^{a} \pm 0.86$	$7.52^{a} \pm 0.79$	$7.36^{a} \pm 0.89$	$8.30^{a} \pm 0.61$
2	$7.44^{ab} \pm 0.86$	$7.06^{a} \pm 0.77$	$7.16^{b} \pm 0.77$	$7.26^{a} \pm 0.72$	$7.22^{a} \pm 0.86$	$7.28^{b} \pm 0.81$
3	$3.02^{c} \pm 1.35$	$3.04^{c} \pm 1.56$	$2.40^{d} \pm 1.11$	$4.80^{b} \pm 2.13$	$5.18^{c} \pm 1.69$	$3.00^{d} \pm 1.07$

Values are mean ± standard deviation. Mean with different superscripts along a column are significantly ($p < 0.05$) different

CONCLUSION

Refrigeration of cassava roots did not have any influence on the proximate composition of *gari* obtained from refrigerated cassava roots. However, colour, sensory, pasting properties, loosed and packed bulk density as well as the swelling capacity of *gari* samples obtained from refrigerated cassava roots were substantially affected by refrigeration. Cassava roots can be refrigerated for a period of 2 weeks without substantial changes in the eating quality of the resulting *gari*. Future studies are required to investigate the physicochemical properties of starch from refrigerated cassava roots to determine their potentials in food and non-food applications.

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