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COMPARATIVE ANALYSIS OF THE PHYSICOCHEMICAL AND ACCEPTABILITY OF ENRICHED *GARI* (FERMENTED CASSAVA PRODUCT)

Olayinka Ramota Karim*, Mutiat Adebanke Balogun, Samson Adeoye Oyeyinka, Remilekun Morenike Abolade

Department of Home Economics and Food Science, University of Ilorin, Ilorin, Nigeria
** olayinkakarim@yahoo.com; karim.or@unilorin.edu.ng*

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ABSTRACT

Different materials and levels have been suggested for the enrichment of staple foods like *gari* (a fermented and roasted cassava granule). The study was aimed at using the same method of production and evaluation of the physicochemical and acceptability of enriched *gari*, with soybean (90:10), melon (95:5), okra seed (95:5) and moringa leaf powder (99:1). A significant increase in crude protein content was recorded for all the enriched *gari* samples with *soy-gari* having the highest value (7.22%) and 100% *gari* the lowest value (1.52%). There was also a significant difference on the fat content with *melon-gari* having the highest value of 10.74% while 100% *gari* sample still had the lowest value of 6.34%. Similar variations and significant difference were also observed for the carbohydrate, moisture, ash and fibre contents. The enrichment materials significantly influenced the pasting characteristics of the samples in which peak, trough and back viscosities varied between 1016.50 to 2374.54, 926.00 to 1862.50 and 1666.00 to 2924.00 RVU respectively. The enriched *gari* samples also exhibited high setback and breakdown viscosity values indicating that their pastes will have lower stability against retrogradation than 100% *gari* sample. A slight difference in hydrogen cyanide, titrable acidity, swelling and water holding capacity contents were also recorded. Sensory evaluation of the *gari* showed that the 100% *gari* was most preferred for colour, taste and odour, although, melon-*gari* emerged the best in overall acceptability. Enrichment of *gari* using these food materials is therefore recommended.

1. Introduction

Cassava (*Manihot esculenta Crantz)* is a staple food for over 500 million people in tropical Africa with Nigeria being the largest producer in Africa and more than 50% of the total world production (Adebayo *et al.*, 2003, CBN, 2003). Traditional cassava products in Nigeria are *gari*, *lafun, fufu*, tapioca, starch, etc. The production have significantly improved with Nigeria as the largest producer (Mroso, 2003) and *gari* being the most consumed and traded of all the food products from cassava roots in Nigeria (Westby and Twiddy, 1992, Karim *et al.*, 2014). *Gari* is fermented and partially gelatinized roasted, free flowing granules (Sanni *et al.*, 2008). Its ability to store well and its acceptance as a "convenience food" are responsible for its increasing popularity in the urban areas of west and central Africa (FAO, 1998).

Reports indicate that the physiochemical properties of *gari* are moisture content between

10.3% to 12.4%, ash content ranging from 0.69% and 0.78%, fat content between 0.33% and 0.44%, crude fibre content of 0.48% to 0.66%, cyanide content of between 0.007% and 0.011%, total titratable acidity, calculated as lactic acid ranged from 0.03 and 0.04 for all samples while the pH values ranged from 4.3 and 4.5. (Sanni *et al.*, 2008, Makanjuola *et al.*, 2012, Karim *et al.*, 2014). *Gari* is low in protein, deficient in essential amino acids and therefore, have poor qualitative and quantitative protein content (Obatolu and Osho, 1992, Osho, 2003; Oluwamukomi *et al.*, 2005). There is therefore, a need to enrich *gari* with good quality protein sources that are readily available (Oluwamukomi, 2007). Several attempts have been made by enriching with soybean, (Osho, 2003; Oluwamukomi *et al.*, 2005), okra seed, (Oyelade *et al.*, 2003, Aminigo and Akingbala, 2004), melon seed (Fokou *et al*., 2004) and Karim *et al*., (2012), suggested the use of *Moringa oleifera.*

Soybean (*Glysine max*) is a legume, native to East Asia that is grown for oil and protein around the world (Alex, 2007). It is a rich pulse containing a high percentage of protein of good quality (Sanni and Sobaniwa, 1994, Kolapo and Sanni, 2005), fat and a reasonable amount of carbohydrate. It is a good source of some essential amino acids such as lysine, tryptophan and threonine. It could be consumed as a whole food or added to other food stuff to achieve a balanced meal (Alex, 2007). Results of previous studies on fortification of cassava products using soybean has shown that fortification improves nutritional quality of resulting meals Oke, 1972, Oshodi, 1985; Osho, 2003, Oluwamukomi *et al.*, 2005). Banjo and Ikenebomeh, (1996) reported an observed increase in the protein content and reduction in the swelling indices against the control sample of soybean fortified *gari*. According to Jimoh and Olatidoye, (2009) amala fortified with 10% soy flour produced not only a nutritionally balanced meal but was more stable against retrogradation and was generally more acceptable when compared to other fortification ratios.

Okra (*Abelmoschus esculentus* L.) is widely consumed as a fresh vegetable. The mature seed is known to have superior nutritional quality (Oyelade *et al.*, 2003; Aminigo and Akingbala, 2004). In an earlier study, Karakoltsides and Constantimides (1975) found that the Protein Efficiency Ratio (PER) of okra seed flour heated at 130°C for 3hrs was not different from the non-heated flour, indicating the absence of anti-nutritional factors. According to these authors, the amino acid composition of okra seed protein is similar to that of soybean and the PER is higher than that of soybean. Okra seed is known to be rich in high quality protein especially with regard to its essential amino acids relative to other plant protein sources (Oyelade *et al.,* 2003). Amingo and Akingbala, (2004) reported that okra seed-fortified ogi at 10 and 20% substitution levels were generally acceptable; okra seed is therefore a potential source of protein for the fortification of poor protein cassava products like *gari*.

Melon is a cucurbit crop that belongs to the *Cucurbitaceae* family with fibrous and shallow root system. Melon seed kernels are major soup ingredients and they are used as a thickener and flavor component of soups. Melon seeds are less expensive and widely distributed. They can contribute substantially towards obtaining a balanced diet (Fokou *et al*., 2004). They are generally a rich source of oil. Oil seeds are generally processed to yield condiments such as 'ogiri'. According to Badejo (2010) the substitution of wheat flour with defatted melon seed flour at 5% level did not indicate any significant difference in consumer acceptability on the other hand it beefed up the protein content by about 46%.

Moringa (*Moringa oleifera Lam*) tree is considered as one of the world's most nutritious crops and commonly found in most parts of sub-Saharan Africa (Borlaug *et al.*, 2006). Moringa leaves on dry weight basis contain up to 30% protein, 1% to 2% fat, 2.0g calcium and 30mg iron. Abiodun *et al.*, (2012) reported that the Moringa leaf has certain health benefits such as improving blood sugar level, blood pressure and prevention of certain diseases and is also suitable for consumption by children as well as the aged. It is expected that fortification of *gari* with *Moringa oleifera* will not only improve the protein content but also result in an increase in other micronutrients such as calcium and iron. According to Karim *et al*., (2012), *amala* fortified with moringa leaf powder at 2.5% fortification level resulted in a stable product with improved nutritional quality that was generally more acceptable. This was adopted for moringa-*gari*, however the limitation in the use of moringa at 2.5% substitution level resulted in a product with poor appearance which could result in poor acceptability therefore moringa fortification ratio was reduced to 1% fortification level for the purpose of this research.

Despite these reports, a comparative study on the impact and the optimal level of these suggested materials (soybean, melon seed, okra seed and *Moringa oleifera* leaf powder) is not available. The study therefore aimed at comparative of the physicochemical and acceptability of *gari* enriched with soybean, melon seed, okra seed and *Moringa oleifera* leaf powder.

2. Materials and methods

2.1. Sources of raw materials

Freshly harvested cassava roots and *Moringa oleifera* leaf powder were obtained from the teaching and research farm of the University of Ilorin, Ilorin, Nigeria. Soybean, melon and okra were purchased from Oja-Oba Market in Ilorin, Kwara State, Nigeria. They were sorted, packed and kept until used.

2.2. Production of Enriched *Gari* Products

The soybean seeds were cleaned and sorted before steam heating for 30-45 min at 100℃ and de-hulled after cooling by rubbing between palms to remove the seed coat by floatation. The de-hulled seeds were air dried at oven temperature of 70-80℃ until they were completely dried and then dry milled into powder using magnetic Blender (SHB- 515 model by Sorex Company Limited) to obtain the soy-flour. The melon and okra seeds were sorted, cleaned and toasted in a steel pan a temperature of 80-90℃. The toasted seeds were cooled, and milled into powder to obtain the melon and okra flour. *Moringa oleifera* leaf powder was prepared according to Karim *et al.*, (2012) method. The traditional processing method of *gari* production as described by Odunfa (1998) and Akingbala *et al*., (2005) was adopted (Fig.1). The enrichment materials (soybean, melon, okra seed and *Moringa oleifera*) were added after sieving of fermented cassava roots prior to roasting to ensure uniformity in treatment.

2.3. Chemical Analysis

Proximate analysis for moisture, protein (N x 6.25), fat, ash, and crude fibre of samples were determined according to AOAC (2000) procedures. Carbohydrate contents were calculated by difference. Titritable acidity (TTA) and pH were also determined according to AOAC (2000). Hydrogen Cyanide (HCN) was determined according to the method described by Cooke (1978)

2.4. Functional Properties

2.4.1 Determination of Water Holding Capacity (WHC)

The WHC was determined by weighing 1.0 g of each *gari* sample and mixed with 10ml of water. It was then shake in Gallenkamp shaker for thirty seconds. The sample was allowed to stand at room temperature for thirty minutes, and then centrifuged at 3,500 rpm for 30min a SORVALL GLC-1 centrifuge (Model 06470, USA). The clear supernatant was discarded and the centrifuge tube was weighed with the sediment. The amount of water absorbed by the sample was determined by difference and expressed in percentage.

2.4.2. Determination of Swelling Index

The swelling index was measured using the method of Ukpabi and Ndimele (1990). Fifty grams of each *gari* samples were put into a five hundred (500) ml measuring cylinders. Three hundred ml of water was added and allowed to stand for 4hrs before observing the level of swelling. The swelling index was then calculated as the multiple of the original volume.

2.5. Pasting Properties

Pasting characteristics were determined with a Rapid Viscometer Analyzer (RVA) (Model RVA 3D+, Newport Scientific Australia). The sample of 2.5g was weighed into a dried empty canister and mixed with 25ml of distilled water as the canister was well fitted into the RVA. The slurry was heated from 50^0C to 95^0C and cooled back to 50℃ within 12 min holding time rotating the can at a speed of 160 r/min with continuous stirring of the content with a plastic paddle. The rate of heating and cooling were at a constant rate of 11.25^0C per min. Pasting temperature (PT), peak viscosity (PV), minimum viscosity (MV), or trough viscosity (TV), final viscosity (FV), and peak time (PTime) were read from the pasting profile with the aid of thermocline for windows software connected to a computer (Newport Scientific, 1998). Breakdown viscosity (BV) was calculated as the difference between PV and MV, while total setback viscosity (TSV) was determined as the FV minus MV. All determinations were performed in triplicate.

2.6.Sensory Evaluation/Consumer Acceptability

The sensory evaluation and consumer acceptability tests were carried out using a multiple comparison test. Twenty panelists who are familiar with *gari* were selected from Faculty of Agriculture**,** University of Ilorin (both sexes, 22 to 45 years old). The products were evaluated for their sensory qualities (taste, colour,odour and overall acceptability). The panelists were made to wash their mouth with water after evaluating each product.

2.7. Statistical data analysis

All analyses with mean and standard deviations were determined in duplicates. Data were analyzed using the Analysis of Variance (ANOVA) statistical method (Statistical Analysis System version 9.2 program, SAS Inc., (2012), USA.). Means were separated using Duncan's multiple range test. Significant differences were established at $p \leq 0.05$.

3. Results and discussions

3.1. Chemical Composition of Enriched *Gari* Products

The result of proximate quality of enriched *gari* products is presented in Table I. Moisture content ranged between 8.14% and 11.96%. Soy-*gari* had the least value of 8.14% and moringa-*gari* recorded the highest value of 11.96%. The values compared favourably with the data reported by some researchers on *gari* production (Akingbala *et al.*, 2005). The optimum moisture content of *gari* has been recommended to be between 9% and 12% (Hahn, 1989). This implies that the moisture content of the enriched *gari* products fell within the recommended range and may therefore have shelf-life of over 6 months has reported for 100% *gari* ((Hahn, 1989, Akingbala *et al.*, 2005).The inclusion of the materials significantly influenced the protein content at ($p \leq 0.05$) with soy-*gari* recording the highest value (7.22%) and 100%-*gari* had the least value (1.52%). The increase in protein content may be attributed to the complementary quantity of proteins in the materials most especially the soybean. Similar results were reported on yam flour fortified with soybean (Adetuyi and Adelabu, 2011), on 'amala' fortified with moringa (Karim *et al.*, 2012) and on plantain flour enriched with okra seed flour (Jimoh *et al.*, 2009), and the findings of Aminigo and Akingbala (2004) on *ogi* fortified with okra seed flour. Similar trends were obtained for the crude fibre content which increased from 1.73% for 100%-*gari* to 2.04% for okra-*gari*. The high crude fibre content of okra-*gari* is similar to the report of Adetuyi *et al.*, (2011) on plantain flour enriched with okra seed flour and Aminigo and Akingbala (2004) on *ogi* fortified with okra seed flour. The carbohydrate content also varied significantly ($p \leq 0.05$) between 71.02% and 78.74%. The *gari* from 100% cassava root still recorded the highest value, while the addition of the materials influenced the value of the other products. The decrease in the carbohydrate level is expected to boost the nutritional value of the products. This corroborates with the findings of some researchers on indigenous foods fortification (Aminigo and Akingbala 2004; Oluwamukomi *et al.*, 2007; Jimoh *et al.*, Adetuyi and Adelabu, 2011; Karim *et al.*, 2012).

The titratable acidity of enriched *gari* products varied significantly at ($p \leq 0.05$) between 0.13 and 0.25. The increase in titratable acidity of the enriched *gari* products may be attributed to the increase in amino acid content of the products from the fortifying materials. The result is line with the report of Oluwamukomi *et al.*, (2007) on *gari* semolina fortified with full fat soy-melon blends. The pH value of *gari* obtained from 100% cassava roots recorded the highest value of 5.9 and soy-*gari* the lowest value of 5.3. Enrichment of *gari* also influenced the hydrogen cyanide. It was observed that the hydrogen cyanide decreased with increase in the quantity of fortifying material. The hydrogen cyanide values are within the permitted level of 10mgHCN/kg of *gari* as stated by Adindu *et al.*, (2003). The level of hydrogen cyanide is very important in describing the quality and acceptability of *gari*.

3.2. Pasting Properties

The results of the pasting characteristics are shown in Table 2. The pasting temperature of the *gari* was generally lower than the boiling temperature. The pasting temperature is a measure of the minimum temperature required to cook a given food, it can have implications on the stability of other components (Newport Scientific, 1998). Hence the *gari* could form a paste in hot water. The result shows that the peak viscosity which is the maximum viscosity varied significantly at ($p \leq 0.05$) between 1016.5 and 2374.5RVU. The highest value of 2374.5RVU was recorded for okra-*gari* and soy-*gari* had the lowest value of 1016.5RVU. Okra-*gari* recorded the highest trough value of 1862.5 RVU and soy-*gari* had the lowest value of 926 RVU**.** Oguntunde (1987) reported that the associative bonding of the amylose fraction is responsible for the structure and pasting behaviour of starch granule. Peak viscosity has been reported to be closely associated with the degree of starch damage and high starch damage results in high peak viscosity (Sanni *et al*., 2001). This could be inferred as an indication of the ability of the starch granules to swell or gelatinize in hot water. The break down viscosity ranges from 72 and 512RVU with okra-*gari* having the highest value of 512RVU and moringa-*gari* gave the lowest value of 72 RVU. Adebowale *et al.*, (2005) reported that the higher the break down viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. The final viscosity also varied significantly at ($p \leq 0.05$) with values between 1666 and 3018.5 RVU. According to Shimelis *et al*., (2006) final viscosity indicates the ability of starch to form various paste or gel after cooling. The 100% *gari* had the highest final viscosity compared to the enriched *gari* products due to the replacement of starch granule responsible for this behavior with protein food materials. The variation in the final viscosity might be due to the simple kinetic effect of cooling on viscosity and the re-association of starch molecules in the samples. The set-back viscosity revealed values between 740 and 1378.50 RVU with moringa-*gari* having the highest value of 1378.50 RVU and soy-*gari* revealed the lowest value of 740 RVU. Sanni *et al.*, (2001) reported that lower set back viscosity during the cooling of *gari* indicates higher resistance to retrogradation.

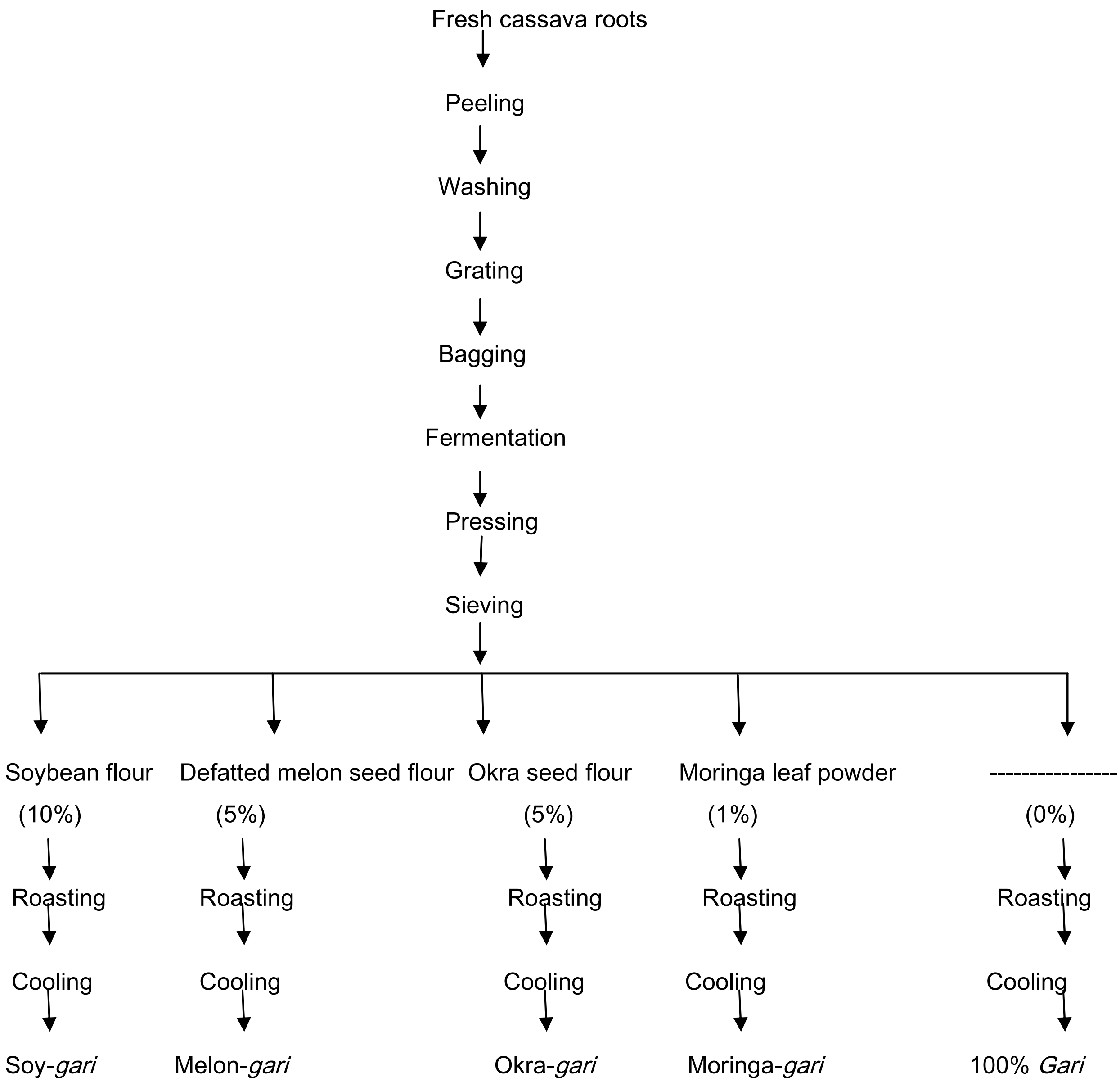

Figure 1. Flow chart for production of enriched *gari* products.

Table 1. Proximate Composition of Enriched *Gari* Products

Products	**Proximate Content (%)**					
	Moisture	**Protein**	**Fat**	**Crude Fibre**	**Ash**	**Carbohydrate**
100% *gari*	9.12^{c}±0.017	1.52^{e}±0.055	1.34^{d}±0.299	1.73^{c}±0.042	1.55c±0.030	84.74^{a}±0.242
Soy-*gari* (10%)	8.14^{e}±0.040	7.22^{a}±0.045	3.81^{b}±0.364	1.46^{d}±0.038	2.25^{ab}±0.021	77.02^{d}±0.512
Melon-*gari* (5%)	8.28^{d}±0.030	4.16^{b}±0.040	5.74^{a}±0.191	2.11^{e}±0.021	2.47^{a}±0.612	77.23^{c}±0.499
Okra-*gari* (5%)	10.26^{a}±0.026	3.54^{c}±0.118	2.61^{c}±0.332	2.04^{a}±0.079	1.76^{bc}±0.032	79.79^{c}±0.285
Moringa-*gari*(1%)	11.96^{b}±0.072	1.97^{d}±0.080	1.54^{d}±0.238	1.88^{b}±0.036	1.55^{c}±0.148	81.80^{b}±0.156

*Values represent mean of triplicates. Values with the same letter along the column are not significantly different (P≤0.05) according to Duncan's Multiple Range Test

Table 2. Hydrogen Cyanide, pH and Titratable Acidity of Enriched *Gari* products

***Gari* products**	**Hydrogen cyanide mg/Kg**	**pH**	**Titratable acidity %**
100%-*gari*	6.73±0.05 [a]	5.9±0.12[a]	0.13±0.02 [a]
Soy-*gari*	6.29±0.04 [a]	5.3± 0.08[a]	0.25±0.02 [a]
Melon-*gari*	6.51±0.04 [a]	5.5±0.10 [a]	0.21±0.04 [a]
Okra-*gari*	6.63±0.02 [a]	5.7±0.06 [a]	0.19± 0.01[a]
Moringa-*gari*	6.68±0.05[a]	5.7±0.12 [a]	0.14±0.04 [a]

*Values represent mean of triplicates. Values with the same letter along the column are not significantly different at (P≤0.05).

Table 3. Functional Properties of Enriched *Gari* Products

***Gari* products**	**Swelling index (%)**	**Water Holding Capacity (%)**
100%-*gari*	4.82± 0.02[a]	24.34±0.05[a]
Soy-*gari*	2.43±0.05[d]	19.22±0.03[c]
Melon-*gari*	2.22±0.04[d]	22.80±0.05[b]
Okra-*gari*	2.97±0.05[c]	23.05± 0.05[a]
Moringa-*gari*	3.93±0.02 [b]	20.54±0.02[c]

Mean values with the same letter along the column are not significantly different at (P≤0.05).

Table 4. Pasting Characteristics of Enriched *Gari* Products

***Gari* Samples**	**PT (°C)**	**PK (RVU)**	**TR (RVU)**	**BD (RVU)**	**FV (RVU)**	**SB (RVU)**	**PKT (Min.)**
100%-*gari*	79.05[a]	1902.50[b]	1789.50[ab]	113.00[b]	3018.50[a]	1229.00[ab]	6.10[bc]
Soy-*gari*	72.35[a]	1016.50[d]	926.00[c]	90.50[b]	1666.00[c]	740.00[c]	6.60[ab]
Melon-*gari*	81.97[a]	1595.00[c]	1510.50[b]	84.50[b]	2585.50[b]	1075.00[ab]	6.06[bc]
Okra-*gari*	89.97[a]	2374.50[a]	1862.50a	512.00[a]	2818.00[ab]	955.50[bc]	5.76[c]
Moringa-*gari*	92.00[a]	1617.50[c]	1545.50[ab]	72.00[b]	2924.00[ab]	1378.50[a]	6.96[a]

Mean values with the same letter along the column are not significantly different (P≤0.05)
PK-Peak viscosity TR-Trough Viscosity BD-Break Down Viscosity FV-Final Viscosity PKT-PeakTime SB-Set Back viscosity PT-Peak Temperature RVU-Rapid Viscometer Unit

Table 5. Sensory Characteristics of Enriched *Gari* Products

***Gari* products**	**Colour**	**Taste**	**Odour**	**Overall Acceptability**
100% *gari*	1.25[b]	1.80[b]	1.55[c]	1.70[b]
Soy-*gari* (5%)	1.80[b]	2.20[b]	2.30[ab]	2.00[b]
Melon-*gari* (5%)	1.30[b]	2.10[b]	1.95[bc]	1.55[b]
Okra-*gari* (5%)	3.65[a]	3.05[a]	2.80[a]	3.40[a]
Moringa-*gari* (1%)	3.45[a]	2.90[a]	2.80[a]	3.25[a]

Mean values with the same letter along the column are not significantly different at (P≤0.05)

Higher setback value is synonymous to reduced dough digestibility while lower setback during the cooling of the paste indicates lower tendency for retrogradation. This means that soy-*gari* will exhibit higher resistance to retrogradation. The peak time varied at (p≤0.05) between 5.76 and 6.96 min as shown in Table 2. Peak time is an indication of the time taken for the starch granules to gelatinize completely and form a stir mass. The pasting temperature ranged from 72.35 and 92.0^{o}C between soy-*gari* and moringa-*gari* respectively. This indicates the temperature at which starch granules in the products formed a stiff paste. Pasting temperature is related to the moisture content of product and decreases with increased moisture content. There were no appreciable differences in the peak time and pasting temperatures of both enriched and control samples. This shows that enrichment resulted in reduced peak viscosity, trough viscosity and the breakdown viscosity, while it also resulted in increased final and setback viscosities.

3.3. Functional Properties of Enriched *gari*

The result of the functional properties (swelling index and water holding capacity) of *gari* products is shown in Table 3. Swelling capacity of the *gari* products ranged from 2.22 and 4.82% with 100% *gari* having the highest value and melon-*gari* gave the lowest value. This may be due to higher amylose starch fraction in melon-*gari*. The lower swelling power value obtained in melon-*gari* than those of other *gari* products also suggests a more highly ordered arrangement in its granules that is the lower the swelling index, the more orderly the arrangement of the starch granule. Sanni *et al*. (2005) reported that the swelling index of granules reflect the extent of associative forces within the granules, therefore the higher the swelling index, the lower the associative forces between the granules. The WHC of *gari* product varied at (P≤0.05). The result of WHC of *gari* products ranged from 19.22 and 24.34%. 100% cassava roots had the highest value of 24.34% and soy-*gari* had the least value of 19.22%. The decrease in WHC may probably be due to lose of association of amylose and amylopectin in the native granules of starch and weaker associative forces maintaining the granules structure due to the fortifying materials. The increase in the protein content of the enriched *gari* products may have accounted for the slight increase in WHC. This seems plausible since proteins have been reported to contribute to WHC of food materials (Karim *et* al., 2014, Jimoh *et al*., 2009).

3.4. Sensory Evaluation of Enriched *Gari* Products

The ratings for taste colour, odour and overall acceptability showed that the incorporation of soybean, melon, okra and moringa to *gari* had effects (Table 5). Okra-*gari* was rated the least in terms of colour due to the appearance of dark particles from the okra seed flour. While *gari* obtained from 100% cassava roots was rated the best in terms of taste, followed by melon-*gari*, soy-*gari*, moringa-*gari* and okra-*gari* rated the least. Similar trend was observed for the odour. Despite the ratings for colour, aroma and taste, melon-*gari* was rated the best in overall acceptability while the *gari* obtained from 100% cassava roots was rated second. The trend of this result explains the influence of enrichment on the nutritional quality of *gari*.

4. Conclusions

The study revealed a general increase in the physicochemical composition of enriched *gari* samples compared to the 100% *gari*. The overall acceptability indicated melon-*gari* as the best. Therefore 5% melon *gari* is recommended as the best enriched *gari* product based on the physicochemical and overall acceptability and could therefore be employed to address the nutritional inadequacy of the community. However, studies are required on the influence of these materials on storability of *gari* and other cassava products.

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