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Characterization of a popular cassava product obtained from fertilizer treated new and conventional cassava varieties towards achieving zero hunger

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Abstract

As part of the effort to achieve zero hunger, the effect of fertilizer application on cassava roots was investigated on the quality attributes of a popular consumer product (*gari*) in Nigeria and other West African countries. A 2×3 full factorial design was used for the study. The study assessed the impact of varying fertilizer treatment levels (FTL) (0% (control), 50% (45, 20 and 35 kg/hectare of NPK-12-12-17, Muriate of Potash and Urea, respectively) and 100% (90, 40 and 70 kg/hectare of NPK-12-12-17, Muriate of Potash and Urea, respectively) of two cassava varieties (TMS 98/0505 and *Oko-'yawo*) on the yield, chemical, physico-chemical and sensory parameters of *gari*. The data were subjected to Analysis of Variance, while means were separated using Duncan Multiple Range Test at p<0.05. There was a significant increase in yield, crude fat, crude protein, ash, and starch contents with an increase in FTL, while there was a significant reduction in cyanide with an increase in FTL from both cassava varieties. The bulk density and swelling capacity significantly decreased with an increase in FTL while water absorption capacity, reconstitution index, least gelation and pasting characteristics except for final viscosity, increased with an increase in FTL in *gari* from both cassava varieties. The sensory evaluation showed about 90% and 75% preference for *gari* from *oko-'yawo* and TMS 98/0505 without fertilizer treatment respectively. Fertilizer application had positive impacts on many objective parameters evaluated on the *gari* produced from both varieties and the one from TMS 98/0505 showed better characteristics than *oko-'yawo* at the same FTL. The subjective parameters were however not improved with fertilizer application.

1. Introduction

The need to increase food production is always a priority in developing countries such as Nigeria. To feed the ever-increasing world population, the food supply from every farm holder has to increase by at least 63% in 10 years (Adekunle *et al.,* 2007). Farmers plant a wide range of crops to meet the food demand of people such as yam, cassava, beans and others. This could be replaced with several efforts toward achieving zero hunger (SDG 2).

Cassava (*Manihot esculenta* Crantz*)* is a security food crop with great potential to reduce hunger in developing nations (Dixon *et al.,* 2005) because of its ability to grow under a wide range of conditions that are quite unsuitable for other crops. It is a major staple food crop of the people in most parts of Africa and it plays an important role in terms of food security, employment and income generation for farm families where it is being grown. It derives its importance from the fact that it produces more calories per unit area from its starchy root which is a valuable source of cheap calories, especially in developing countries (Som, 2007). In addition, cassava has become a preferred root crop because of its low labour input, capital and time required in cultivation (Topouzis, 2003). Optimum utilization of cassava and cassava products can be a catalyst for rural industrial development by raising the income levels of farmers, processors and traders as well as ensuring the nutrition and food security status of the country (Plucknett *et al.,* 1998; Balagopalan, 2002).

The dry weight of cassava root contains 80 to 90% carbohydrate, of which 80% is starch and the rest constitutes sugars (Tewe and Lutaladio, 2004). Apart from its use as food, it is also an important industrial raw material for the production of starch, alcohol, pharmaceuticals, gums, confectioneries and livestock

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feed (Nnodu *et al.,* 2006). In many parts of Africa, the leaves and tender shoots are also consumed as vegetables (Eke-Okoro and Dixon, 2000).

Cassava has earned the reputation of being well adapted to soils of low fertility. This stems from its ability to produce some yield, however low, in subsistence agricultural systems on soils of low fertility status and this has contributed greatly to its success over other staple food crops. For this reason, peasant farmers do not fertilize cassava as they are contented with the minimal yield obtained from using limited inputs from their poor soils. The cassava plant is well adapted to low levels of available phosphorous (on account of its mycorrhizal association which makes phosphorous available to it) but requires fairly high levels of nitrogen and potassium, especially when grown for many years on the same plot or continuously cultivated plots (Howeler *et al.,* 2000; Ayoola and Makinde, 2007). Apart from increasing yield, high levels of potassium application have been shown to improve dry matter, starch content and reduce the hydrocyanic acid (HCN) content of cassava roots (El-Sharkawy and Cadavid, 2000; Okpara *et al.,* 2010).

Organo-mineral fertilizer which combines both organic and inorganic components has been recommended and its application gives the benefit of applying organic fertilizer and a little dose of inorganic fertilizer. Pressure on land for other purposes and population increase has resulted in shortened fallow periods – a natural method of replenishing soil nutrients (Eneji *et al.,* 1996). Therefore, additional nutrients in form of organic, inorganic (especially NPK) or organo-mineral fertilizer must be applied to boost soil nutrient content for the production of high cassava yield (Makinde, 2007). The inorganic component releases nutrients quickly for the establishment of the crop while the organic component ensures the steady release of nutrients throughout the growth cycle of the crop (Eneji *et al.,* 1996).

The increased demand for cassava and its products for local consumption has prompted an increase in its production. Researchers opined that developing new and improved varieties is one way of boosting the steady supply of cassava roots for value chain development and industry (IITA, 2013). Research efforts by the National Root Crops Research Institute (NRCRI) Umudike and International Institute of Tropical Agriculture (IITA) Ibadan; have brought about the development and release of high-yielding and disease-resistant cultivars such as TMS30572, TMS92/0326, TMS98/0505 and others (NRCRI, 2005).

However, fresh cassava has limited storage life because of its high moisture content, its processing into relatively shelf-stable intermediate and final products for various food applications is, therefore, necessary (Quaye *et al.,* 2009). Cassava can be transformed into various products such as *gari*, *fufu*, *lafun* and many other West African traditional dishes (Obilie *et al.,* 2004; Afoakwa *et al.,* 2010). Cassava, when dried to a powdery or pearly extract, is called tapioca, the fermented, flaky version is named *gari*. *Gari,* a roasted fermented cassava meal, is the most popular cassava product consumed in West Africa and the most important food product in the diet of millions of Nigerians (Afoakwa *et al.,* 2010). It is a staple food that used to be within the purchasing power of all categories of people in a society irrespective of their income (Sanni *et al.,* 2007).

The establishment of the relationship between fertilizer application on a new improved cassava variety along with a well-known local variety and yield, and selected quality parameters of their resultant end product (*gari*) will promote the adoption of the new breeds which was the focus of this study.

2. Materials and methods

2.1 Materials

Cassava stems, TMS 98/0505 (a new improved variety) and *oko-'yawo* (a local variety) were obtained from LAUTECH Teaching and Research farm, Ogbomoso, Nigeria. All the reagents used were of analytical grade.

2.2 Experimental design

Stem cuttings from the two cassava cultivars, TMS98/0505 and *oko-'yawo* were planted by the Department of Crop Production and Soil Science in LAUTECH in a Randomized Complete Block Design (RCBD) in three (3) replicates. Fertilizers (N.P.K. 12-12-17, Muriate of Potash (MOP) and Urea) were applied to the plants at different fertilizer treatment levels (FTLs): 0% (No fertilizer, served as a control), 50% (45, 20 and 35 kg/hectare of NPK-12-12-17, Muriate of Potash and Urea, respectively) and 100% (90, 40 and 70 kg/hectare of NPK-12-12-17, Muriate of Potash and Urea, respectively). A factorial design (2×3, 2 varieties at 3 FTLs) was used for the study. The yield, chemical, physico-chemical and sensory properties of the product (*gari*) were determined by using standard methods.

2.3 Methods

Gari samples were produced as described by Komolafe and Arawande (2010). The cassava roots (15 kg) of each cultivar were peeled manually. The peeled roots were washed to remove dirt and grated in a 5 hp diesel powered grater. The grated meal was packed in a hessian bag and allowed to ferment for 72 hrs. The fermented pulp was dewatered using a hydraulic press. The pressed cake was pulverized and sieved with a wire mesh screen. The sieved pulp was gratified in a wide shallow cast-iron trough over a wooden fire at an average temperature of 80±5 °C and stirred constantly with a wooden paddle for 30 mins to dextrins and dry the grits. The *gari* was cooled, packaged in an amber coloured container, and stored until needed for analyses.

2.3.1 Yield of gari

The percentage yield of *gari* samples was determined using the method described by Ukenye *et al.* (2013) and expressed as:

$$\%\ Gari\ \text{yield} = \frac{\text{Weight of } gari}{\text{Weight of fresh cassava root}} \times 100$$

2.3.2 Chemical analyses

The analyses carried out on the *gari* samples were moisture, crude fat, crude protein, ash, crude fibre and carbohydrate (by difference) contents, total titratable acidity (TTA), and pH according to the methods of AOAC (2000), hydrogen cyanide by Onwuka and Olopade (2005), total carotenoids by Rodringuez-Amaya and Kimaya (2004), and starch content by Benesi *et al.* (2004).

2.3.3 Physico-chemical properties

The bulk density was determined using the method described by Milani *et al.* (2007). The swelling and water absorption capacities of the samples were determined according to the method described by Onwuamanam (2011). The reconstitution index was determined using the method described by Malomo *et al.* (2012). The least gelation of the samples was determined as described by Adebowale *et al.* (2005). The pasting characteristics were determined with a Rapid Visco Analyzer (RVA), Model RVA 3D^{+} (Newport Scientific, Australia).

2.3.4 Sensory evaluation

Sensory evaluation was conducted to determine consumer preferences and acceptability of the samples, using a 7-point hedonic scale for the degree of likeness. On the scale, 7 represents “like extremely”, midpoint, 4 represents “neither like nor dislike” and runs down to 1 which represents “dislike extremely”. The quality parameters assessed were colour, texture, taste, aroma, appearance and overall acceptability. A total of fifty panellists who are regular *gari* consumers were selected randomly and used for the sensory evaluation. Samples were coded and randomly presented in ceramic plates at the same time and were assessed in both dried and reconstituted forms (Olatunde *et al.,* 2013).

2.3.5 Statistical analysis

The data generated were subjected to statistical analysis using the Statistical Analysis System (SAS) package (version 8.2 of SAS Institute Inc, 1999) for analysis of variance (ANOVA) and means separation was carried out using the Duncan Multiple Range test and a significant difference was accepted at $p<0.05$ (SAS, 2004).

3. Results and discussion

3.1 The yield of the gari samples

The yield of *gari* is presented in Table 1. Fertilizer treatment level (FTL) significantly increased the *gari* yield (20.43 – 25.16%) in both varieties. The yield from the new variety was higher than the local variety at all the FTLs. The increase in *gari* yield could be due to an increase in the dry matter of the cassava roots which could have resulted from greater uptake of nutrients by the cassava plants made available by the fertilizer (Agbaje and Akinlosotu, 2004; Issaka *et al.,* 2007). This supports an earlier report that the application of fertilizer especially potassium-based ones, not only enhance cassava tuber yield but also improves tuber quality (Imas and John, 2013). However, the *gari* yields recorded for both varieties were lower than the *gari* yield (31.2%) reported by Karim *et al.* (2009) from fresh cassava roots but within the range (17.72-32.77%) reported by Oghenechavwuko *et al.* (2013) for *gari* yield calculated based on the weight of whole cassava root and similar to the range (19.86-23.23.68%) reported by Sobowale *et al.* (2016) for *gari* yield of TMS30572 cassava cultivar.

Table 1. Yield (%) of *gari* obtained from two varieties of cassava roots planted with different fertilizer levels

Fertilizer level (%)	Variety	
	TMS 98/0505	*Oko-'yawo*
0	21.94^{a}	19.35^{a}
50	22.58^{b}	20.43^{b}
100	25.16^{c}	23.23^{c}

Values with different superscript within the same column are significantly different ($p<0.05$).

3.2 Proximate composition of the gari samples

As summarized in Table 2, the crude fat, crude protein, and ash contents of the *gari* samples ranged from 8.81 to 11.41%, 0.03 to 0.71%, 1.44 to 3.77%, and 1.01 to 2.13%, respectively, with *gari* produced from *oko - 'yawo* with 0% FTL having the lowest value and the one from TMS98/0505 with 100% FTL having the highest value. A reverse observation was recorded for moisture content (8.81 to 11.41%), in which *gari*

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Table 2. Proximate composition (%) of *gari* samples obtained from fertilizer treated cassava roots

Variety	Fertilizer level (%)	Moisture	Crude fat	Crude protein	Ash	Crude fibre	Carbohydrate
TMS98/0505	0	8.81[a]	0.56[c]	3.41[d]	1.85[d]	3.96[f]	81.41[cd]
	50	9.51[b]	0.63[d]	3.61[e]	1.92[d]	3.91[e]	80.42[a]
	100	10.21[c]	0.71[e]	3.77[f]	2.13[e]	3.86[d]	79.32[ab]
Oko-'yawo	0	10.87[d]	0.03[a]	1.44[a]	1.01[a]	3.01[c]	83.64[e]
	50	11.02[e]	0.04[a]	1.92[b]	1.31[b]	2.87[b]	82.84[d]
	100	11.41[f]	0.06[b]	2.48[c]	1.60[c]	2.67[a]	81.78[bc]

Values with different superscript within the same column are significantly different (p<0.05).

produced from TMS98/0505 with 0% FTL had the lowest value while *gari* from *oko-'yawo* with 100% FTL had the highest value. All the parameters increased significantly (p<0.05) with an increase in FTL. At the same FTL, the *gari* samples produced from TMS98/0505 had a higher value than *gari* produced from *oko-'yawo* for crude fat, crude protein and ash, while the *gari* samples from *oko-'yawo* had a higher value than the one from TMS 98/0505 for moisture.

The moisture contents of all the samples are within the ranges (8.5– 0.6%) reported by Ikujenlola and Opawale (2007) and (9.54 -11.57%) reported by Apea–Bah *et al.* (2009) in *gari* samples from four elite cassava varieties. However, in both samples, the moisture content was below 12% which is the recommended allowable maximum moisture content for *gari* (Codex Standard 151-1989). The moisture content of gari samples depends largely on the method and extent of drying and also the humidity of the surrounding atmosphere (Lawal, 2004). Moisture content is a major quality determinant in most crops and foods including *gari* (Akinoso and Kasali, 2012). This indicates that the *gari* samples could have a high level of storage stability which facilitates effective product distribution. The crude fat values were comparable to 0.057% obtained for cassava residue flour (Ohuoba *et al.,* 2019) and 0.33-1.51% obtained for *gari* produced from peeled and unpeeled cassava roots (Ibegbulem and Chikezie, 2018). The range of protein contents of *gari* fell within 2.3–5.7% as reported by NRCRI (2005) and comparable to 1.76 - 2.11% reported for cassava *gari* by Ogueke *et al.* (2013) and 1.88 – 2.23% reported for cassava *gari* by Arinola (2016). The protein contents in *gari* obtained from TMS 98/0505 were significantly (p<0.05) higher than those in *gari* from *oko-'yawo* at the same FTL. This is contrary to the report that *gari* produced from a local cassava variety exhibited the highest values of protein content over an improved cassava variety (Alphonse *et al.,* 2018). This observation might be attributed to fertilizer treatment of the cassava roots used for producing the *gari* samples. This finding indicates the possible nutritional advantage of fertilizer treatment and the preference of TMS98/0505 over *oko-'yawo* (Agbaje and Akinlosotu, 2004; Issaka *et al.,* 2007). The ash contents were generally higher than 1.18% recorded for cassava *gari* by Oluwamukomi and Adeyemi (2013). Similarly, the ash content of *gari* from TMS 98/0505 was also higher than the ones reported for *fufu* produced from cassava roots (Ohuoba, 2019) and the one reported for *gari* by Ajifolokun and Adeniran (2018) but below the general standard (2.7%) stipulated for *gari* (Adebayo *et al*., 2012). The independent variables in this study might have played a significant role.

The crude fibre and carbohydrate contents ranged from 2.67 to 3.96% and 79.32 to 83.64%, respectively. For crude fibre, the *gari* produced from TMS 98/0505 with 0% FTL had the highest value while the one produced from *oko-'yawo* with 100% FTL had the lowest value. For carbohydrates, however, the *gari* sample from TMS 98/0505 with 100% FTL had the lowest value while the one produced from *oko-'yawo* with 0% FTL had the highest value. The crude fibre contents obtained were comparable to the value (4%) reported by Gil and Buitrago (2002) for cassava products and higher than the stipulated standard (2%) for *gari* (Codex Standard 151-1989, Sanni *et al.,* 2005). It seems fertilizer treatment of cassava roots might have minimal reducing effects on the fibre content of the *gari* samples. However, the relatively high fibre of the *gari* could be utilized when bulkiness is desired in the diet. Diet rich in dietary fibre is usually encouraged because of its implication in the prevention of certain diseases indicating the possible nutritional advantage of the TMS98/0505 *gari* with relatively high fibre content. Samples obtained from cassava roots with 0% FTL had higher fibre content in both varieties. The carbohydrate contents are within the range (81.00 - 83.13%) obtained for *gari* produced from peeled and unpeeled cassava roots (Ibegbulem and Chikezie, 2018) and (66.88 - 82.39%) for *gari* analogue from co-fermented breadfruit and cassava (Ajifolokun and Adeniran, 2018). The high carbohydrate content makes *gari* a good source of energy with *oko-'yawo* having the potential of yielding more energy on consumption.

Fertilizer treatment, which adds more nutrients to the soil (Osagie, 1992) for plant utilization and cassava varietal differences significantly affected the proximate composition of the *gari* samples (Alphonse *et al.,* 2018).

3.3 Chemical composition of the gari samples

The cyanide (HCN) and starch contents (Table 3) of the *gari* samples ranged from 3.61 to 8.00 mg/kg and 65.13 to 68.71%, respectively, with *gari* produced from TMS98/0505 with 100% FTL having the lowest value and *gari* produced from *oko-'yawo* with 0% FTL having the highest value of cyanide. The HCN content was reduced with an increase in FTL in both varieties. Samples from *oko-'yawo* roots were however higher than those from TMS98/0505 at the same FTL. The range of cyanide content obtained in this study was lower than the range (1.44-3.95 mg HCN/100 g) reported by Chikezie and Ojiako (2013) for *gari* obtained from matured cassava roots and also lower than the value (11.4 mg HCN/kg) reported by Hongbete *et al.* (2009) for another fermented cassava product (*lafun*) but in agreement with the report of Okigbo (2001). The reduction in HCN of the *gari* samples from fertilizer treated cassava roots could stem from potassium in the fertilizer as El-Sharkawy and Cadavid (2000) reported a significant reduction in HCN of cassava roots from different cassava cultivars fertilized with potassium-based fertilizer. Reduction of hydrogen cyanide in the cassava roots could be by blocking its synthesis in leaves and petioles or by reducing the flux of reduced nitrogen in form of cyanogenic glucosides to the roots (Jørgensen *et al.*, 2005) which could have been partly or wholly spearheaded by potassium in the soil. This underscores the significance of utilizing potassium-based fertilizers in controlling HCN in cassava roots and their derivable products such as *gari* for minimizing HCN induced health hazards. However, degradation of cyanide during cassava mash fermentation, dewatering, roasting and hydrolytic action of microorganisms in cassava mash on linamarin and lotaustralin could also play a significant role in the reduction of residual HCN in the *gari* samples (Alphonse *et al.,* 2018). The cyanide contents were generally lower than the recommended safe level of 10 mg HCN/kg prescribed by the Food and Agricultural Organization (FAO) (Adindu *et al.,* 2003).

The highest starch content was recorded in *gari* from TMS98/0505 with 100% FTL while the lowest was recorded in the one from *oko-'yawo* with 0% FTL. The starch content of the *gari* samples obtained from both cassava varieties increased with an increase in FTL. The range of starch content in the *gari* samples from this study is lower than the range (72.09-72.96%) reported by Nwokoso *et al.* (2005) for *gari* samples with different particle sizes from Southern Nigeria. The increase in starch content of the *gari* samples from both cassava varieties could result from an increase in the dry matter and starch content of cassava roots on treatment with fertilizer (Okpara, 2000) as fertilizer application is very key to effective translocation of photosynthates in form of starch and other dry matter components from the green parts of a cassava plant to its storage roots (Imas and John, 2013). The *gari* samples produced from the cassava roots, being high in carbohydrates should be consumed in combination with sources of other nutrients especially protein, to improve nutrition since it is one of the staple foods consumed in Africa, especially in Nigeria (Ajifolokun and Adeniran, 2018).

The total carotenoids in the *gari* samples produced from TMS98/0505 significantly varied between 0.11 µg/100 g in *gari* sample from TMS 98/0505 with 50% FTL and 0.16 µg/100 g in *gari* sample from TMS98/0505 with 0% FTL. The low carotenoid content of the *gari* samples could be attributed to degradation during processing and exposure to sunlight and oxygen during postharvest handling (Chavasit *et al.,* 2002; Chavez *et al.,* 2007; Oliveira *et al.,* 2010). Taleon *et al.* (2018) reported a significant total carotenoid loss in processed bio-fortified cassava during storage. It is interesting to note that only the *gari* samples obtained from the improved cassava variety had carotenoid content though at low levels.

The pH and total titratable acidity (TTA) of the *gari* samples ranged from 4.03% to 4.27% and 0.99% to 1.02%, respectively. The pH of the *gari* produced from *oko-'yawo* with 0% FTL was the lowest while that of *gari* produced from TMS98/0505 with 100% FTL was the highest. There was an increase in the pH with an increase in FTL for *gari* produced from the two varieties of cassava. The pH of *gari* from TMS 98/0505 was higher than that of *gari* from *oko-'yawo* at the same FTL. The low pH values which might be due to the formation of organic acids mostly acetic and lactic acids during fermentation conform with the pH (4.21) reported for

Table 3. Chemical composition of the *gari* samples obtained from fertilizer treated cassava roots

Variety	Fertilizer level (%)	HCN (mg/kg)	Carotenoids (µg/100 g)	Starch (%)	pH	Total titratable acidity (%)
TMS98/0505	0	5.27^{c}	0.16^{c}	66.87^{c}	4.10^{b}	1.02^{c}
	50	4.25^{b}	0.11^{a}	67.84^{e}	4.20^{c}	1.01^{bc}
	100	3.61^{a}	0.14^{b}	68.71^{f}	4.30^{d}	0.99^{a}
Oko-'yawo	0	8.00^{f}	ND	65.13^{a}	4.03^{a}	1.01^{bc}
	50	7.21^{e}	ND	66.35^{b}	4.10^{b}	1.01^{bc}
	100	6.41^{d}	ND	67.01^{d}	4.20^{c}	0.99^{a}

Values with different superscript within the same column are significantly different ($p<0.05$). ND, Not detectable.

cassava *gari* by Komolafe and Arawande (2010) and the one reported for nine traditional Beninese *gari* (4.0-4.4) by Adinsi *et al.* (2019) and fell within the recommended standard pH range (3.5–4.5) for fermented acid food products (Bainbridge *et al.,* 1996). The organic acids would contribute to the desirable sourness which is preferred by some consumers (Arinola, 2016). The TTA decreased as the FTL increased but there was no significant difference (p>0.05) in the TTA values of the *gari* samples from both cassava varieties at the same FTL. The decrease in TTA may be due to a decrease in free sugars from which acids are produced during fermentation. The values obtained are in agreement with the TTA values of sweet potato–*gari* samples (0.94 – 1.11%) as reported by Sanni *et al.* (2007). The TTA of the *gari* samples is similar to those recommended by the Codex Alimentarius Commission (Codex Alimentarius Commission, 1989).

3.4 Functional properties of the gari samples

The functional properties of the *gari* samples are presented in Table 4. The bulk density (BD), swelling capacity (SC), water absorption capacity (WAC), reconstitution index (RI) and least gelation (LG) ranged from 0.60 to 0.71 g/cm^3, 3.07 to 3.83 g/mL, 3.08 to 3.85 g/mL, 60.50 to 76.20% and 7.00 to 14.00%, respectively.

For BD and SC, the *gari* sample produced from TMS 98/0505 with 0% FTL had the highest value while the one produced from *oko-'yawo* with 100% FTL had the lowest value. The parameters decreased with an increase in FTL and were higher for *gari* samples produced from TMS98/0505 than the ones from *oko-'yawo* at the same FTL. The decreasing trend in the properties could result from fertilizer treatment of the cassava roots used for producing the *gari* samples. The result also shows that different varieties of cassava could exhibit different degrees of these properties. The BD values of the *gari* samples were comparable to 0.53 g/cm^3 reported for toasted fermented cassava products (Awoyale *et al.,* 2017) but similar to the range reported by Komolafe and Arawande (2010) for *gari* samples from cassava. The high BD implies that the *gari* samples would have a high rate of dispersion (Udensi *et al.,* 2008) and a high tendency to soak properly in water and this may enhance consumers' acceptability (Otutu *et al.,* 2013). The SC values of both varieties compared well to the values (3.16 to 3.51 g/ml) reported by Makanjuola *et al.* (2012). The SC obtained in this study was generally high and could confer desirable qualities on the *gari* samples as it may swell 3 times its volume in addition to water (Apea-Bah *et al.,* 2009) and may also improve digestibility (Moorthy, 2002).

The WAC of the *gari* sample produced from TMS 98/0505 with 100% FTL was the highest while that of the one produced from *oko-'yawo* with 0% was the lowest. The parameter increased with an increase in FTL and the value for TMS98/0505 was higher than that of *oko-'yawo* at the same FTL. The WAC values are higher than the one (2.00 g/ml) reported for cassava *gari* by Ohuoba *et al.* (2019). In addition to fertilizer treatment and cassava varietal differences, fermentation and toasting with its accompanied partial starch gelatinization, may have played a pivotal role in enhancing WAC of the *gari* samples (Arinola, 2016; Awoyale *et al.,* 2017). The relatively high WAC of *gari* from TMS 98/0505 as compared with that of *gari* from *oko-'yawo* might be a result of differential protein contents in the cassava varieties as the ability of food materials to absorb water is sometimes attributed to their protein contents (Kinsella, 1976). The high WAC of the *gari* sample which also determines SC (Achinewu *et al.,* 1998) could be an indication of high affinity for water molecules (Niba *et al.,* 2001) due to the presence of free amylose and associative forces within the starch granules and moisture content (Achinewu *et al.,* 1998).

The RI and LG of the *gari* samples produced from *oko-'yawo* with 100% FTL were the highest while the ones for the *gari* produced from TMS 98/0505 with 0% FTL were the lowest. The parameters increased with an increase in FTL and the *gari* samples produced from *oko-'yawo* had higher values than the ones produced from TMS98/0505 at the same FTL. The variation in the RI and LG could be a result of alteration in starch structure on fertilizer treatment of the cassava roots. The results of RI are similar to the range (55.75–77.00%) reported by Olatunde *et al.* (2013) for cocoyam. The high RI

Table 4. Functional properties of *gari* samples obtained from fertilizer treated cassava roots

Variety	Fertilizer level (%)	Bulk density (g/cm^3)	Swelling capacity (g/ml)	Water absorption capacity (g/mL)	Reconstitution index (%)	Least gelation (%)
TMS98/0505	0	0.71^e	3.83^e	3.33^b	60.50^a	7.00^a
	50	0.65^d	3.47^d	3.45^d	61.40^b	8.00^b
	100	0.61^b	3.23^{bc}	3.85^f	62.30^c	9.00^c
Oko-'yawo	0	0.65^d	3.30^c	3.08^a	74.00^d	11.00^d
	50	0.63^c	3.17^b	3.40^c	75.00^e	13.00^e
	100	0.60^a	3.07^a	3.56^e	76.20^f	14.00^f

Values with different superscript within the same column are significantly different (p<0.05).

obtained in this study could make *gari* samples suitable for preparing good quality *eba* while *the* high LG of the *gari* samples from cassava with 100% FTL implies that they may not form thick gels on reconstitution easily as compared with the *gari* samples from cassava with 0% FTL which had low gelation endpoints. This is similar to the least gelation concentrations reported for high-quality cassava flour (HQCF) from fertilizer treated cassava roots (Rasaq *et al.,* 2020).

3.5 Pasting properties of the gari samples

The pasting properties (Table 5) of the *gari* samples are important in predicting their behaviour during and after cooking. The *gari* samples produced from TMS98/0505 with 100% FTL had the highest peak viscosity, trough, peak time and pasting temperature which were 1838.33 RVU, 1584.33 RVU, 7.00 min and 88.85 °C respectively, while the *gari* samples from *oko-'yawo* with 0% FTL had the lowest values which were 1014.33 RVU, 928.33 RVU, 5.27 min and 80.00 °C, respectively. There was a significant ($p<0.05$) increase in these values with an increase in FTL with *gari* samples from TMS 98/0505 having higher values than *oko-'yawo* at the same FTL. The highest (254.00 RVU) and the lowest (35.67 RVU) breakdown were recorded in *gari* samples from TMS 98/0505 with 100% FTL and from *oko-'yawo* with 0% FTL, respectively. The highest (2506.67 RVU) and the lowest (1668.33 RVU) final viscosities were recorded in *gari* samples from TMS98/0505 with 0% FTL and from *oko-'yawo* with 100% FTL, respectively. A significant ($p<0.05$) decrease in the final viscosity was observed in *gari* samples from both cassava varieties with the increase in FTL, and the *gari* sample from TMS98/0505 had a higher value than the one from *oko-'yawo* at the same FTL. The variation in the pasting characteristics could be a result of FTL and cassava varietal differences.

Peak viscosity determines the cooking characteristics of starch materials (Akinoso and Olatunde, 2014) and measures the maximum viscosity reached by a sample during the heating phase. Rasaq *et al.* (2020) reported that the peak viscosity of flour samples from TME419 increased following fertilizer applica-tion. The high peak viscosity shown by cassava products indicates a weak granular structure for its starch when compared to those products with a low peak viscosity (Aprianita *et al.,* 2009). This viscosity may be rapidly lowered on heating under shear, leading to a long and cohesive paste texture (Mufumbo *et al.,* 2011) which is desirable in the preparation of *eba*. The trough is the minimum viscosity value at a constant temperature phase and is an index of starch granule stability to heating (Shittu *et al.,* 2007). The high trough value shown by *gari* from cassava treated with fertilizer indicates the high stability of gel during the cooking of starch (Fadimu *et al.,* 2018). Falade and Okoafor (2013) added that low breakdown indicates a low peak viscosity. It could be observed from the results that the *gari* samples from both varieties with 0% FTL may show better or greater resistance to shear during heating compared to *gari* samples obtained from cassava roots with 50% and 100% FTL because of their low breakdown values (Corke *et al.,* 1997). The peak time is the set time when the paste reaches its peak viscosity and forms gels at a particular temperature (Etudaiye *et al.,* 2009). The time to attain peak viscosity is considerably lower than those reported for dried *fufu* (22-38 mins) by Sanni and Jaji (2003), and *pupuru* (37-43 mins) by Shittu *et al.* (2001). This could be due to partial gelatinization of *gari* during toasting. Pasting temperature is the temperature at which permanent swelling of starch granules takes place leading to peak viscosity (Adebowale *et al.,* 2005). The values were higher than the values reported for dried *fufu* (76–78°C) (Sanni and Jaji, 2003) and toasted tapioca (63.07–63.60°C) (Adebowale *et al.,* 2008). The low paste temperatures and paste sta-bility of the *gari* samples from *oko-'yawo* which could be desirable are suggestive of fewer associative forces and cross-links within the starch granules (Rasaq *et al.,* 2020). The final viscosity is the change in viscosity after hold-ing cooked starch at 50°C. It is one of the most common parameters used to define the quality of a starch-based food sample, as it indicates the ability of the flour to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear force during stirring (Adebowale *et al.,* 2008). The final viscosity values were lower than the values reported for pure cassava *gari* and cocoyam *gari*

Table 5. The pasting properties of *gari* samples obtained from fertilizer treated cassava roots

Variety	Fertilizer level (%)	Peak viscosity (RVU)	Trough (RVU)	Break down (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (min.)	Pasting temperature (°C)
TMS98/0505	0	1386.33^{c}	1350.67^{d}	35.67^{a}	2506.67^{c}	1156.00^{e}	5.47^{b}	84.00^{b}
	50	1563.33^{e}	1456.00^{e}	106.33^{c}	2130.67^{b}	674.67^{d}	5.67^{c}	86.35^{d}
	100	1838.33^{f}	1584.33^{f}	254.00^{f}	1794.00^{a}	209.67^{a}	7.00^{f}	88.85^{f}
Oko-'yawo	0	1014.33^{a}	928.33^{a}	85.67^{b}	2463.33^{c}	1535.00^{f}	5.27^{a}	80.00^{a}
	50	1313.33^{b}	1182.33^{b}	131.00^{d}	1831.33^{b}	649.00^{c}	5.87^{d}	84.40^{c}
	100	1485.33^{d}	1302.33^{c}	183.33^{e}	1668.33^{a}	366.00^{b}	6.50^{e}	87.15^{e}

Values with different superscript within the same column are significantly different ($p<0.05$).

(Olatunde *et al.,* 2013). The *gari* samples from *oko-'yawo* with 100% FTL may have a low tendency to retrograde (Ogunnike *et al.,* 2015; Nwancho *et al.,* 2014; Moorthy 2002). For the setback, *gari* from *oko-'yawo* with 100% FTL had the highest value while the one from TMS98/0505 with 100% FTL had the lowest value. There was a significant ($p<0.05$) decrease in the value with an increase in FTL. The *gari* samples from *oko-'yawo* with 0% FTL may retrograde faster after cooking due to their high setback values.

3.6 Sensory attributes of the gari samples

The result of the sensory evaluation (Table 6) showed that *gari* samples from *oko-'yawo* with 0% FTL had the highest scores in all the sensory characteristics followed by the *gari* sample from TMS98/0505 with 0% FTL. The preference for the *gari* samples from *oko-'yawo* and TMS98/0505 with 0% FTL was almost 90% and 75% respectively. Application of fertilizer however reduced the preference for the resultant product to between 67% and 72% in both varieties. The reduced sensory attributes indicate possible adverse effects fertilizer treatment could have on the production of acceptable *gari* from both varieties. This observation suggests that fertilizer application to cassava roots did not yield *gari* product with enhanced sensory attributes although the preference is still acceptable to a certain limit.

4. Conclusion

Fertilizer application and treatment levels positively influenced *gari* yield, major macro-nutrients, total ash, and functional properties with an appreciable reduction in cyanide level. The *gari* produced from TMS98/0505 was superior to the one from *oko-'yawo*, indicating a potential preference for utilizing TMS98/0505 in *gari* processing over *oko-'yawo*. Application of fertilizer, however, impacted negatively on the sensory attributes' scores of the resultant *gari* samples with *gari* from the local variety without fertilizer consistently had the best scores in all the evaluated sensory attributes. Fertilizer application and treatment levels in cassava roots did not concurrently enhance both the nutrient profile and sensory attributes of the *gari* from TMS98/0505 and *oko-'yawo* indicating the need for further studies to establish appropriate treatment levels for holistic positive impact.

Conflict of interest

The authors declare no conflict of interest.

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Table 6. Sensory scores of *gari* samples obtained from fertilizer treated cassava roots

Variety	Fertilizer level (%)	Taste	Colour	Texture	Flavour	Appearance	Overall acceptability
TMS98/0505	0	5.45^{c}	5.80^{d}	5.50^{e}	5.30^{d}	4.44^{e}	5.26^{d}
	50	4.90^{a}	5.60^{c}	5.10^{c}	4.60^{a}	3.70^{a}	4.78^{b}
	100	5.30^{b}	5.60^{c}	5.40^{d}	4.60^{a}	4.00^{d}	5.04^{c}
Oko-'yawo	0	6.80^{d}	6.60^{e}	6.10^{f}	6.10^{e}	5.70^{f}	6.26^{e}
	50	5.40^{bc}	5.00^{a}	4.50^{a}	4.90^{c}	3.80^{b}	4.72^{a}
	100	4.90^{a}	5.20^{b}	4.80^{b}	4.70^{b}	3.90^{c}	4.70^{a}

Values with different superscript within the same column are significantly different ($p<0.05$).

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