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Influence of Fertilizer on the Yield and Quality Parameters of *Garri* from Two Improved Cassava Cultivars (TME 419 and TMS 01/1412)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Food insecurity is a major problem in developing countries, to overcome this problem, fertilizers are used to increase yield of agricultural produce. However, fertilizer may affect the quality of processed products. This study aimed to investigate the influence of fertilizer treatments levels on yield and quality properties of garri from two improved cassava varieties (TME 419 and TMS 01/1412).
Methodology: Cassava roots were planted with varying fertilizer levels [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)]. Garri yield, chemical, physicochemical, pasting properties, and sensory attributes of garri were evaluated.
Results: Results showed 30% and 22% increase in garri yield from 100% fertilized TME and TMS cassava root, respectively. The chemical contents of the garri samples increased with increasing

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fertilizer level. Cyanide contents of the garri samples decrease with increasing fertilizer level. Garri from 100% fertilizer treatment had higher water absorption capacity (3.51 g/ml and 3.32 g/ml), reconstitution index (72.75% and 77.20%) and gelation index (7.0% and 8.0%), but lower swelling capacity (3.43 g/ml and 3.02 g/ml) and bulk density (0.55 g/cm^3 and 0.51 g/cm^3) in TME and TMS cultivar, respectively.

Conclusion: High level of fertilizer application improved the chemical components, reduced the cyanide contents and pasting properties of garri samples from the two cassava cultivars.

Keywords: Chemical composition; fertilizer treatment; garri yield; pasting properties; physicochemical properties; sensory attributes.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is the 5th main essential crop in tropical zones [1]. Cassava is a main source of energy in the diet of several million people worldwide [2-3]. It is one of the staples that have been bio-fortified with pro-vitamin A because of its large consumption by millions of people in the Sub-Saharan Africa [4].

Vitamin A plays a very significant role in reproduction, vision, bone growth, mucus membrane and healthy skin maintenance [5]. Vitamin A deficiency is one of the major micronutrient problems in many low-income countries, and is the main cause of loss of sight in children less than 5 years of age [6]. The prevalence of vitamin A in Nigeria is reported to be 28.1% and 4.7% in pre-school children and nursing mothers, respectively [7]. Inadequate consumption of vitamin A has been linked to morbidity and partial or total blindness in many children. Bio-fortification of staple crops such as cassava with pro-vitamin A carotenoids is a currently formed policy to address vitamin A status of people suffering from vitamin A deficiency [8].

Bio-fortification of cassava roots with micronutrient(s) is an important means of improving the nutrients intake of the populace in developing Africa countries [9]. This is because of high consumption of cassava in Africa. Two new cassava varieties which have low cyanide content, drought resistance, high yielding, early maturing and increased vitamin A content were introduced to Nigerian farmers in the recent past [10]. However, cassava roots need enough nutrients for optimum development and yield [11]. In Nigeria, high quantities of cassava (>70%) are converted to *garri* [12]. Garri is the major product from cassava roots [14]. It is a free-flowing particulate product comprising of roasted coarse particles and an important local food in Nigeria [13].

Fertilizer application supplies major soil nutrient such as nitrogen, potassium and phosphorus needed for growth of the plant. Addition of these soil nutrients will translate to synthesis of the starch, which is responsible for variation in starch and flour quality. High yield of crop could also be achieved with balanced NPK fertilizer and organic matter application [15]. According to Okwu and Awurum [16], application of fertilizer on cassava increased root yield but might affect the chemical composition of the root and its product such as *garri*. The aim of the study was to determine the yield and quality of *garri* from two fertilized improved cassava cultivar.

2. MATERIALS AND METHODS

2.1 Materials

Freshly harvested mature cassava roots, TME 419 and TMS 01/1412 (a bio-fortified variety) used for this study were obtained from the Teaching and Research Farm of Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria.

2.2 Methods

2.2.1 Planting of cassava roots

Stem cuttings from the two (2) cassava cultivars, TME 419 and TMS 01/1412 were planted by the Department of Crop Production and Soil Science, 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 varying concentrations 0% (no fertilizer), 50% (45, 20 and 35 kg/hectare of NPK-12-12-17, MOP and Urea, respectively) and 100% (90, 40 and 70 kg/hectare of NPK-12-12-17, MOP and Urea, respectively) to assess the fresh root yield before processing to *garri*. Factorial design 2×3 (2 varieties at 3 fertilizer application levels) was used for the study.

2.2.2 Determination of garri yield

The percentage yield of *garri* samples obtained from fresh cassava roots from each cultivar was determined using the following expression [11].

$$\%Garri\ Yield = \frac{weight\ of\ garri}{weight\ of\ fresh\ cassava\ root}\ x\ 100$$

2.2.3 Sample preparation

The method of Komolafe and Arawande [17] was adopted for the processing of the *garri* samples. Briefly, assava root (15 kg) of each cultivar was peeled manually using a stainless-steel kitchen knife. The peeled roots were washed thoroughly to remove dirt and grated in a locally fabricated 5 hp (horse power) diesel powered grater. The grated pulp was packaged into hessian bag and the sacks were allowed to ferment for 72 h. The fermented pulp was placed between wooden platforms using a hydraulic press (locally fabricated) to express out the water. The pressed cake was crushed manually and sieved with traditional woven splinters made of cane. The sieved pulp was *garri*-fried (80-85 °C) inside a wide shallow cast iron trough and stirred constantly with a wooden paddle over a wooden fire for 30 min to dextrinize and dry the grits until well dried. The *garri* was cooled, packaged in an amber colored container to prevent exposure to light, labeled and sealed prior to analyses.

2.3 Chemical Analyses

2.3.1 Proximate analysis

The cassava roots and *garri* products were analysed for moisture, ash, crude fibre, crude protein, crude fat contents [18]. Carbohydrate was determined by difference [i.e. 100% - (%moisture + %ash + %crude fibre + %crude protein + %crude fat)].

2.3.2 Determination of pH value

The pH of the *garri* samples were determined by dissolving the *garri* sample (10 g) in water (100 mL). The suspension was measured by using a pH meter with a direct digital readout after calibrating the pH meter [18].

2.3.3 Determination of total titratable acidity

The *garri* sample (5 g) was placed in a conical flask and 200 ml of carbon dioxide-free distilled water was added. The flask was allowed to stand in a water bath at 40 °C for 1 h, after which the flask and its contents was swirled occasionally to ensure complete mixing before filtration. The filtrate was titrated against 0.1 M NaOH solution [18]. The total titratable acidity of the samples was estimated as % lactic acid as follows;

$$\%Lactic\ Acid = \frac{Titre\ value\ x\ Normality\ of\ alkaline}{weight\ of\ sample}\ x\ 100$$

2.3.4 Determination of cyanide content

The cyanide content was determined following the procedure of Nwabueze and Anoruoh [19]. Distilled water (50 ml) was added to g*arri* sample (5 g) in a conical flask and the mixture was allowed stand overnight at ambient temperature. Alkaline picrate solution (4 ml) was added to the supernatant (5 ml) and the solution was placed water bath (5 min) for the colour to change to change to dark brown prior to taking the absorbance at 490 nm spectrophotometer. Distilled water (1 mL) was used as blank. Cyanide concentration was estimated as follows:

$$Cyanide\ content\ (mg/100g) = \frac{X\ (mg)}{weight\ of\ sample}\ x\ 100$$

where, X (mg) = Concentration of cyanide from the graph

2.3.5 Starch and beta-carotene content determination

Starch was determined by the procedure described by Benesi et al. [20] with slight modifications, briefly, fresh cassava roots were washed, peeled, and chopped into approximately 1 cm cubes and pulverized using a hammer mill. The pulp was suspended in 10 times its volume of water, stirred for 5 min and filtered using muslin cloth. The filtrate was allowed to stand for 2 h for the starch to sediment and the top liquid was decanted and discarded. The sediment was broken, water was added as in the first step, and the mixture was stirred for 5 min and filtered using muslin cloth. The filtrate was allowed to stand for 2 h for the starch to sediment and thetp liquid was decanted and discarded. The sediment was washed and dried at 65 °C for 12 h.

Beta-carotene contents of the *garri* sample was determined following the method of Singh et al. [21] and Bolarinwa et al [22]. Briefly, The *garri* sample (5 g) was ground and placed in 10 ml acetone. Few crystals of anhydrous sodium sulphate were added and the mixture was allowed to settle. The supernatant was then decanted into a beaker and transferred to a separator funnel. Petroleum ether (10 ml) was added to the supernatant, mixed thoroughly and allowed to separate into two layers. The lower layer was discarded and the upper layer was collected in a 100 ml volumetric flask, and the volume was made up to 100 ml with petroleum ether. The optical density (OD) of the solution was then determined at 452 nm, using petroleum ether as blank.

Calculation:

$$B - carotene = OD\ x \frac{13.9x10000x100}{weight\ of\ sample\ x\ 560\ x\ 1000}$$

Where, OD = Optical density of the solution at 452 nm

2.4 Physicochemical Properties of the Garri Samples

2.4.1 Bulk density, Water absorption capacity (WAC) and Swelling power determination

The bulk density of the *garri* samples were determined by the method described by Bolarinwa and Muhammad [23]. The WAC and the swelling power of the *garri* samples were determined according to the procedure described by Onwuamanam [24].

2.4.2 Reconstitution index determination and least gelation concentration

Reconstitution index was determined by placing the *garri* sample (10 g) in 100ml measuring cylinder and distilled water was added to make up to 100 mL. The mixture was thoroughly mixed, left to stand for 3 h for the particles to settle. Reconstitution index was estimated by subtracting settled particle volume from 100. The least gelation concentration of the samples was estimated following the procedure described by Adebowale et al. [25].

2.5 Pasting Properties

Pasting characteristics were determined with a Rapid Visco Analyzer (RVA) (Model RVA 3D$^+$, Newport Scientific Australia) according to the method of Newport Scientific [26].

2.6 Determination of Mineral Content

The *garri* samples were first ash by weighing about 2 g of the *garri* samples into clean dried crucibles, ash for 2h in muffle furnace (550 ^oC). The crucibles were cooled for a few minutes and HCL (3 mL) was added, and the mixture was filtered and transferred into 50 mL volumetric flask. The solutions were further diluted to 100 mL with distilled water. Calcium, zinc, iron, copper and magnesium were measured using atomic absorption spectrophotometer.

2.7 Sensory Evaluation

The *garri* samples were subjected to sensory evaluation to determine consumer preferences and acceptability. Thirty semi- trained panelists were used for the sensory evaluation. The samples were coded, served in clean disposable plates and assessed in dried form. The panelists were given enough water to rinse their mouths between each sample. The panelists were to rate the samples based on the following quality attributes; taste, flavour/aroma, texture, color, appearance and overall acceptability using 9 - point hedonic scale, where 9 and 1, represent like extremely and dislike extremely, respectively.

2.8 Statistical Analyses

All treatments were replicated for reproducibility and analysis was done in triplicate. Statistical analysis was done using Statistical Analysis Systems (SAS 2006) version 15.0 of SAS Institute, Inc. Significant differences ($p<0.05$) were determined using analysis of variance (ANOVA) and means were separated using Duncan Multiple Range test.

3. RESULTS AND DISCUSSION

3.1 Yield of *Garri* Samples from the Cassava Cultivars

The results of the *garri* yield as affected by the fertilizer treatments levels is presented in Fig. 1. Higher fertilizer treatment level resulted in higher yield of the *garri* from TME 419 cassava cultivar, however, there was no significant difference in the yield of TMS 01/1412 cassava roots treated with high level of fertilizer. TME 419 cassava roots treated with 100% fertilizer level had higher

(27%) *garri* yield than that of the similarly treated TMS 01/1412 which recorded 17% *garri* yield. Thus, the use of fertilizer for cassava cultivation significantly increased the yields of *garri* from the two cassava cultivars. These findings were in agreement with the report of Howeler [27] and Buasong et al. [28], who reported that fertilizer application resulted in significant increase in the yield and starch content of stored cassava roots from indigenous cassava cultivars.

3.2 Proximate Composition of the *Garri* Samples

The proximate composition results of the *garri* samples are presented in Table 1. An increasing trend was observed in the moisture content (MC) in the *garri* samples with increasing fertilizer treatment, irrespective of the cultivar. The MC of the *garri* produced from TMS 01/1412 (7.66 - 9.27%) were lower than those obtained from TME 419 *garri* samples (10.08 - 12.54%) (Table 1). Generally, the protein contents of cassava root cultivars are low. Thus, conversion of the roots to *garri* notably reduced the protein content in the *garri* samples from both cultivars (1.83 – 2.29%) (Table 1). Proximate results showed that the range of MC obtained for almost all the *garri* samples agrees with several other reports in the literature [29-30].

In general, the protein contents of the *garri* samples are very low. This may be due to heat denaturation of the protein during *garri* preparation [13]. The range of protein content reported for *garri* samples (1.96 - 2.65 %) by Asegbeloyin and Onyimonyi [31] agrees with those obtained in this study (1.83 – 2.27%). However, protein content of *garri* (1.0%) reported by Aryee et al. [32] was lower than those obtained in this study. This could be due to differences in the cassava cultivar used for the *garri* production.

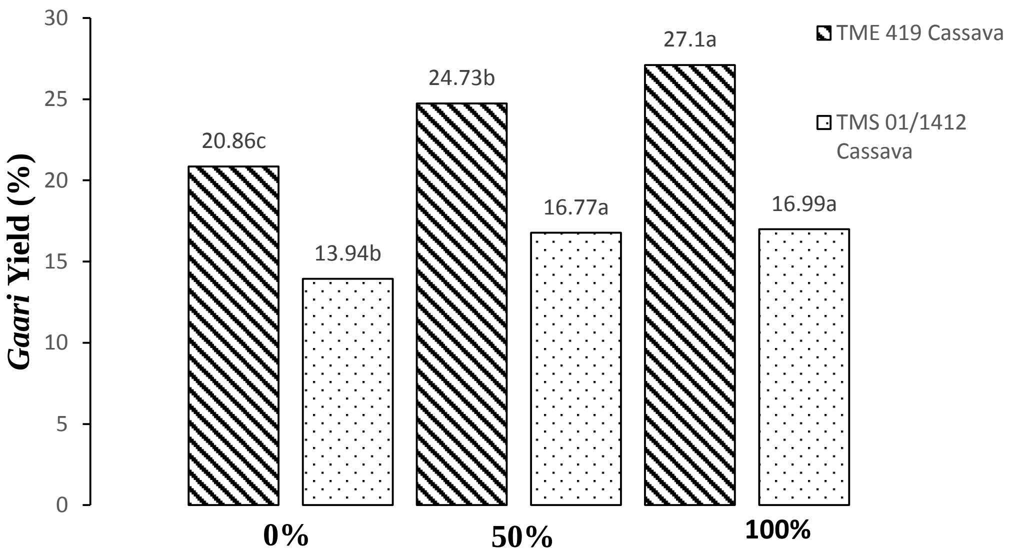

Fig. 1. Effect of fertilizer treatment on *garri* yield from TME 419 and TMS 01/1412 cassava cultivars

Table 1. Proximate composition of the *garri* samples

Cassava Cultivar	Fertilizer Treatment (%)	Moisture (%)	Protein (%)	Crude Fat (%)	Ash (%)	Crude Fibre (%)	Carbohydrate (%)
TME 419	0	10.08^{c}	1.83^{b}	0.97^{c}	1.23^{f}	3.94^{a}	81.94^{d}
	5	11.56^{b}	1.84^{b}	0.99^{c}	1.37^{e}	3.71^{b}	80.53^{e}
	100	12.54^{a}	1.86^{b}	1.01^{b}	1.45^{d}	3.52^{c}	79.62^{f}
TMS 01/1412	0	07.60^{f}	2.23^{a}	1.39^{a}	1.63^{c}	3.47^{d}	83.68^{a}
	50	08.68^{e}	2.25^{a}	1.40^{a}	1.70^{b}	3.29^{e}	81.37^{c}
	100	09.27^{d}	2.29^{a}	1.43^{a}	1.79^{a}	2.87^{f}	82.37^{b}

Mean value with different superscript along the same column are significantly different (p = .05).

As presented in Table 1, the fat content of TMS 01/1412 *garri* samples (1.39 – 1.43%) were significantly (P<0.05) higher than those of TME 419 *garri* samples (0.97 – 1.01%). Ash content is a measure of the amount of minerals present in a product. An increasing trend was observed in the ash content of the *garri* samples from both cultivars with increasing fertilizer treatment levels. The ash content was generally higher in *garri* in TMS 01/1412 compared with TME 419, irrespective of the fertilizer treatment levels. Higher fat contents recorded for *garri* samples from fertilized and unfertilized TMS 01/1412 cassava compared with samples from TMS 419 cassava could be due to varietal differences [33]. The value of fat reported for *garri* (0.2%) by Aryee et al*.* [31] was however lower than those obtained in this study. This could probably be due to differences in the cassava cultivar used for the *garri* production.

The range of ash content of *garri* reported in this study (Table 1) was lower than that reported by Otutu et al. [34]. On the other hand, the ash content of the 100% fertilizer treated TME 419 *garri* (1.45%) and the fertilized TMS 01/1412 *garri* samples (1.70 – 1.79%) were close to regulatory standard of 1.5% ash content [35]. The differences in the ash contents of the *garri* samples may be attributed to the amount of minerals supplied to the harvested roots by the fertilized soil, and can also be due to contamination with metals from the garification medium [34, 36].

The crude fibre content of TME 419 cassava root was significantly higher (1.05 – 1.09%) than that of the TMS 01/1412 cassava root (0.49 – 0.62%)(results not shown). Similarly, *garri* samples produced from TME 419 had higher crude fibre content (3.52 – 3.94%) compared to those from TMS 01/1412 cassava root (2.87 – 3.47%). This indicate that higher fertilizer treatment level resulted in lower the crude fibre content of *garri* samples from TMS 01/1412 cassava. This indicates that fertilizer treatment had significant effect on the fibrous texture of the *garri*. The fibre contents (3.52 – 3.71%) of the fertilized TME 419 *garri* samples are lower than that of the unfertilized TME 419 *garri* (3.94%). The crude fibre content (2.87 – 3.71%) of the *garri* samples produced from the two fertilized cassava cultivars are within the fibre content (0.38-7.08%) of *garri* reported in past study [34]. However, the range of crude fibre reported for *garri* by Nwokoro et al*.* [37] was lower than those obtained in this study. The differences may be attributed to degree of maturity, location, soil, varietal differences and other agronomical practices employed during or after planting [34, 29].

Notable differences were observed in the carbohydrate values of *garri* samples from the two cassava cultivars (Table 1). TME 419 *garri* samples from the highest fertilizer treatment level (100%) had the lowest carbohydrate value (79.62%) while those from unfertilized cassava roots had the highest value (81.94%). Similar results were obtained for TMS 01/1412 *garri* samples. Fertilized cassava *garri* had lower carbohydrate contents compared with unfertilized *garri* samples, irrespective of the cassava cultivar. The carbohydrate contents (79.62 – 83.68%) of the *garri* samples reported in this study are within the range of 82.52% - 87.10% reported for *garri* from cassava and sweet potato tuber mixes [38].

3.3 Chemical Composition of the *Garri* Samples

The chemical composition of the garri samples is presented in Table 2. The cyanide content of the *garri* produced from TME 419 (2.05- 4.48 mg/kg) was lower than those obtained from TMS 01/1412 (4.28- 6.30 mg/kg). This could be due to series of processing methods

Table 2. Chemical composition of the *garri* samples

Cassava Cultivar	Fertilizer Treatment (%)	HCN (mg/Kg)	Starch (%)	Beta-Carotene (µg/g)	TTA (%)	pH
TME 419	0	4.48^{c}	66.87^{b}	0.25^{b}	0.96^{a}	4.30^{a}
	50	4.19^{c}	67.43^{b}	0.26^{b}	0.94^{a}	4.10^{b}
	100	2.05^{d}	68.34^{a}	0.24^{b}	0.93^{a}	4.10^{b}
TMS 01/1412	0	6.30^{a}	64.40^{d}	1.69^{a}	1.00^{a}	4.30^{a}
	50	5.53^{b}	65.60^{c}	1.71^{a}	0.97^{a}	4.10^{b}
	100	4.28^{c}	66.50^{b}	1.70^{a}	0.95^{a}	4.00^{b}

Mean value with different superscript along the same column are significantly different (p =.05). HCN – Cyanide. TTA – Titratable Acidity.

(grating, fermentation, frying etc) employed in the conversion of the cassava roots to *garri* sample. In general, the cyanide contents of the *garri* samples from unfertilized and fertilized cassava roots from the two cassava cultivars are lower than the recommended cyanide concentration (10 mg/kg) for cassava flour [39].

The starch contents in the fresh roots (19.50 - 31.58%) (results not shown) were generally lower than the values recorded in the *garri* samples (64.40 - 68.34%). The starch content of the *garri* samples from the fertilized cassava roots increased with increasing level of fertilizer treatment. This indicates that fertilizer improves the starch contents of cassava root from TME 419 better than that of the TMS 01/1412 cassava cultivar. Processing methods are also responsible for granules breakdown, cellulose softening and increased starch availability [40].

The beta-carotene content of the *garri* from unfertilized and fertilized TME 419 cassava roots were not significantly different (Table 2). Similar trend was observed in terms of the beta-carotene contents of *garri* from TMS 01/1412 cassava roots. However, beta-carotene content (1.69 – 1.71 µg/g) of TMS 01/1412 *garri* samples were significantly higher than that of TME 419 (0.24 – 0.26 µg/g). This indicates that fertilizer application does not seem to have any effect on the beta-carotene contents of the *garri* samples. Higher beta-carotene in TMS 01/1412 *garri* samples could be because TMS 01/1412 cultivar is a pro-vitamin A bio-fortified cassava. In general, the beta-carotene contents of the *garri* samples were lower than those of the cassava roots (result not shown) due to loss of the pro-vitamin A (beta-carotene) during the conversion of the roots to *garri* [41]. According to Chaávez et al. [42], only 20% of the original carotenoids present in yellow cassava roots can be recovered during production of *garri.*

The titratable acidity (TTA) values of garri samples from fertilized TME 419 cassava roots were between 0. 93% and 0.94% for 100% and 50% fertilizer treatment respectively, while *garri* produced from unfertilized cassava contain 0.96% TTA. TTA values of *garri* samples from TMS 01/1412 fertilized cassava was 0.95% and 0.97% for 100% and 50% fertilizer treatment, respectively. *Garri* from TMS 01/1412 unfertilized cassava had the highest TTA value of 1.00%. Thus, the TTA values of the *garri* samples were not significantly affected by fertilizer application in both cassava cultivars. Lower TTA values were recorded for the samples from fertilized cassava root. This indicates that the *garri* samples from fertilized cassava roots are slightly acidic. The TTA values (0.93 – 1.0) reported for the *garri* samples in this study is within the recommended TTA values (0.6-1.2%) for *garri* [43].

The pH values (4.0 – 4.1) of the *garri* samples from the fertilized cassava cultivars were not significantly different ($p<0.05$) irrespective of the cultivar and treatment level (Table 2). pH values of the samples (4.3) from unfertilized cassava roots were significantly different ($p>0.05$) from that of the *garri* samples (4.0 – 4.1) from fertilized cassava tubers. Thus, *garri* samples from 50% and 100% fertilizer treatment levels had lower pH (4.0 – 4.1) compared to the samples from unfertilized cassava root (4.3). This observation is the same for both TME 419 and TMS 01/1412 cultivars. The pH values of the *garri* samples (4.0 – 4.3) are within the range of pH (4.3 - 4.5) of *garri* commercially available in South-West Nigeria [14].

3.4 Physicochemical Properties of the Garri Samples

Table 3 shows the results of the effect of fertilizer on the physicochemical properties of the *garri* samples. A general decrease in the swelling capacity (3.80 – 3.43 g/ml) and the bulk density (0.62 – 0.55 g/cm^3) of the *garri* samples were recorded, however, the water absorption capacity (3.23 – 3.51 g/ml), reconstitution index (69.20 – 72.75%) and least gelation index (4.0 – 7.0%) of the samples increased with increasing fertilizer treatment levels (Table 3) in TME 419 cassava cultivar. Similar trends were recorded for TMS 01/1412 *garri* samples.

The reduction observed in the swelling capacity of the *garri* samples in this study could be due to binding of protein with starch granules. According to Debet and Gidley [44], granular bound proteins reduce the swelling power of starchy granules. Lower swelling capacity (3.02 – 3.60 mg/mL) in the fertilized cassava root *garri* samples compared to the unfertilized samples (3.31 – 3.80 mg/mL) could be due to the negative effect of fertilizer on the swelling power of flour [45], as a result of high protein contents in the fertilized sample. The range of bulk density of TME 419 (0.55 - 0.62 g/cm^3) samples were higher than those of TMS 01/1412 (0.51 - 0.57 g/cm^3) *garri* samples. The bulk density of all the *garri* samples reported in this study are within the range (0.5 - 0.91g/cm^3) reported by Adindu and Aprioku [46].

Table 3. Physicochemical properties of the *garri* samples

Cassava Cultivar	Fertilizer treatment (%)	Swelling capacity (g/ml)	Bulk density (g/cm^3)	WAC (g/ml)	Rec. Index (%)	Gelation Index (%)
TME 419	0	3.80^{a}	0.62^{a}	3.23^{c}	69.20^{f}	4.00^{e}
	50	3.60^{b}	0.58^{b}	3.39^{b}	71.50^{e}	6.00^{c}
	100	3.43^{c}	0.55^{bc}	3.51^{a}	72.75^{d}	7.00^{b}
TMS 01/1412	0	3.31^{d}	0.57^{c}	2.25^{e}	74.19^{c}	5.00^{d}
	50	3.14^{e}	0.52^{d}	2.87^{d}	75.90^{b}	7.00^{b}
	100	3.02^{f}	0.51^{d}	3.32^{c}	77.20^{a}	8.00^{a}

Mean value with different superscript(s) along the same column are significantly different (p = .05). Rec. Index – Reconstitution Index

The WAC of TME 419 (3.23-3.51 g/ml) *garri* samples were higher than the WAC of TMS 01/1412 (2.25 -3.32 g/ml) *garri* samples. This difference may be as a result of low protein content in TME 419 *garri* samples, as high protein content of TMS 01/1412 *garri* will reduce its swelling capacity and hence, its WAC [36]. The range of WAC of *garri* reported in this study is however, lower than those (7.70 -8.16 g/g) reported for *garri* by Kure et al. [47]. This difference may be due to cultivar differences and cultivation practices.

The ability of the *garri* sample to reconstitute also increases as the level of fertilizer treatment increases. The reconstitution index of the *garri* samples was found to be higher in samples from TMS 01/1412 (74.19 - 77.20%) than the samples from TME 419 (69.20 - 72.75%). The lower values recorded for *garri* samples from TME 419 might not be unconnected with the relatively high starch content of the cultivar and carbohydrate levels of the sample. This is essential in the reconstitution of '*Eba'* dough, the most common form of consuming *garri* in Nigeria.

An increasing trend was observed in the ability of the *garri* to form gel (least gelation) as the level of fertilizer treatment increases in both cultivars. The least gelation was generally higher (5 - 8%) in *garri* samples from TMS 01/1412 than those samples from TME 419 (4 - 7%) irrespective of fertilizer treatment levels. The implication of high gelation of *garri* sample is that they may not form thick gels or have a gelatinous nature on reconstitution as expected of *garri* with lower gelation. High gelation value of TMS 01/1412 could be due to competition for water between protein content moiety from the samples and its starch content to form protein-polysaccharides complex [48].

3.5 Pasting Properties of the *Garri* Samples

The results of the pasting properties of the *garri* samples are presented in Table 4. Regardless of the fertilizer treatment, the peak viscosity of *garri* produced from TME 419 (2025.00 - 2210.01 RVU) was higher than those of the samples obtained from TMS 01/1412 (1506.94RVU-1865.06 RVU). The trough values of the *garri* samples increased in both cultivar with increasing fertilizer treatment levels. The holding strength was generally higher in *garri* from TME 419 (1542.66-1652.93 RVU) than those samples from TMS 01/1412 (1377.00 - 1432.60 RVU) irrespective of the fertilizer treatment levels.

Table 4. Pasting properties of *garri* samples

Cassava Cultivar	Fertilizer treatment (%)	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak Temp (ºC)	Peak Time (min)
TME 419	0	2025.00^{c}	1542.66^{c}	482.01^{b}	2674.77^{a}	1131.61^{a}	78.19^{b}	5.11^{b}
	50	2135.92^{b}	1581.92^{b}	554.96^{a}	2595.60^{b}	1012.93c	79.09^{a}	5.13^{b}
	100	2210.01^{a}	1652.93^{a}	557.04^{a}	2435.01^{c}	782.05^{e}	79.93^{a}	5.44^{a}
TMS 01/1412	0	1506.94^{f}	1377.00^{e}	129.95^{e}	2455.01^{c}	1078.01^{b}	73.72^{e}	5.05^{c}
	50	1633.98^{e}	1398.55^{e}	235.12^{d}	2382.58^{d}	983.74^{d}	75.39^{d}	5.16^{b}
	100	1865.06^{d}	1432.60^{d}	432.26^{c}	2211.63^{e}	779.32^{f}	77.39^{c}	5.42^{a}

Mean value with different superscript along the same column are significantly different (p = .05).

An increasing trend was observed in the peak viscosity of the *garri* samples with increasing fertilizer treatment irrespective of the cultivar. Highest peak viscosity recorded in the samples from 100% fertilizer treatment shows a positive correlation with high starch content of the sample. This observation is in agreement with the findings of Odedeji and Adeleke [49] and Mensah [11], who reported that high peak viscosity is a reflection of high starch content in the product. The range of peak viscosity obtained from this study agrees with those reported by Olatunde and Ade-Omowaye [29].

Trough is a measure of the ability of the paste to endure shear during gelatinization processing at high temperature [50]. The trough values obtained in this study is similar to the values reported by Mensah [11] for cassava flour.

The breakdown viscosity of the *garri* samples increased with increasing fertilizer treatment irrespective of the cultivar. This indicates that *garri* samples from unfertilized cassava roots will show greater resistance to shear during heating compared to samples from fertilized roots because of their lower viscosity. The breakdown viscosity of *garri* sample from TME 419 (482.01 - 557.04 RVU) was higher than that of TMS 01/1412 (129.75 - 432.26 RVU), while samples from unfertilized cassava roots had the lowest breakdown viscosity (Table 4).

The two cassava cultivars differed significantly ($p<0.05$) in their final viscosity, with samples from TME 419 (2435.01-2674.77 RVU) having higher final viscosity than samples from TMS 01/1412 (2211.63-2455.01RVU). Setback viscosity was lowest in *garri* from 100% fertilized TMS 01/1412 (779.32 RVU) than the sample from 100% fertilized TME 419 (782.05 RVU). The range of breakdown viscosity obtained in this study is close to those reported by Ikegwu et al. [51] for starch produced from improved cassava varieties. A general decrease was observed in final viscosity of the *garri* samples from both cassava cultivars with increasing fertilizer treatment levels. However, *garri* samples from unfertilized cassava had the highest final viscosities (Table 4) with the potential of forming better paste or gel stabilities. This observation is in conformity with the findings of Iwe and Agiriga [52], who reported a more stable gel in cassava flour cultivars with high final viscosity value.

A decreasing trend was observed in the setback viscosity of the *garri* samples from both cultivars with increasing fertilizer treatment levels. On the other hand, *garri* samples from unfertilized cassava roots had the highest setback viscosity (Table 4). This indicates that garri samples from fertilized cassava roots will show decrease retrogradation properties. The observation is in conformity with the findings of Gunaratne et al. [45], who reported that fertilizer affect the chain length of amylopectin which results in decreases in retrogradation. A higher setback value is useful if the starch is to be used for domestic products such as *fufu and eba* which requires a high viscosity and paste stability with low temperature [43].

Peak temperature was found to be higher in samples from TME 419 (78.19 -79.93 ^{o}C) than those samples from TMS 01/1412 (73.72 - 77.39 ^{o}C) while lower peak temperature was recorded for *garri* samples from unfertilized cassava roots. Significant increasing trend observed in the peak temperature of the *garri* samples from TMS 01/1412 cassava cultivar with increasing fertilizer treatment could be due to low stability of the starch granules of the *garri* samples which makes it easier to lose the molecular structure of the samples during heating [11]. Low pasting temperature indicates faster swelling and less energy consumption during cooking [53]. The range of pasting temperature (79.20 - 80.65 ^{o}C) reported for *garri* by Oluwamukomi and Jolayemi [54] is similar to those obtained in this study (Table 04).

The pasting time of the *garri* samples was found to increase with increasing fertilizer treatment irrespective of the variety. However, the pasting times were not significantly ($p>0.05$) higher in *garri* samples from TME 419 (5.11 - 5.44 min) and TMS 01/1412 (5.05 -5.42 min) samples (Table 04). Pasting time is a measure of the actual cooking time for flour-based food products [55]. This indicates that *garri* samples produced from 100% fertilized treatment level will take longer time to cook compared with sample from 50% fertilized and unfertilized cassava.

3.6 Mineral Composition of the *Garri* Samples

The results of the mineral composition of the *garri* samples are presented in Table 5. TME 419 *garri* sample produced from 100% fertilizer treatment had the highest level of copper (4.00 ppm), iron (34.50 ppm) and zinc (12.02 ppm) compared to the copper (3.79 ppm), iron (33.40 ppm) and zinc (12.00 ppm) contents of TME 419 *garri* sample produced from 50% fertilizer

Table 5. Mineral composition of the *garri* samples

Cassava Cultivar	Fertilizer treatment (%)	Cu (ppm)	Fe (ppm)	Mg (ppm)	Ca (ppm)	Zn (ppm)
TME 419	0	2.01^{c}	31.20^{c}	500^{a}	300^{b}	11.01^{b}
	50	3.79^{b}	33.40^{b}	400^{b}	400^{a}	12.00^{a}
	100	4.00^{a}	34.50^{a}	400^{b}	300^{b}	12.02^{a}
TMS 01/1412	0	1.00^{d}	29.01^{a}	400^{b}	400^{a}	8.31^{d}
	50	1.01^{d}	30.52^{d}	400^{b}	400^{a}	10.00^{c}
	100	2.26^{c}	31.50^{c}	300^{c}	300^{b}	10.06^{c}

Mean value with different superscript along the same column are significantly different (p = .05).

Table 6. Sensory scores of the *garri* samples

Cassava Cultivar	Fertilizer treatment (%)	Taste	Colour	Texture	Flavour	Appearance	Overall Acceptance
TME 419	0	5.7^{a}	5.6^{c}	6.1^{a}	5.6^{c}	5.6^{b}	5.7^{b}
	50	5.8^{a}	6.0^{a}	6.1^{a}	6.0^{a}	6.0^{a}	5.9^{a}
	100	5.4^{b}	5.6^{c}	5.2^{c}	5.0^{d}	5.6^{b}	5.3^{d}
TMS 01/1412	0	5.6^{a}	5.9^{a}	5.5^{b}	5.8^{b}	5.5^{b}	5.6^{c}
	50	5.6^{a}	5.8^{b}	5.4^{b}	5.5^{c}	5.4^{c}	5.5^{c}
	100	5.7^{a}	5.6^{c}	5.5^{b}	5.5^{c}	6.0^{a}	5.7^{b}

Mean value with different superscript along the same column are significantly different (p = .05).

treatment, and the copper (2.26 ppm), iron (31.50 ppm) and zinc (10.06 ppm) content of *garri* from 100% fertilized TMS 01/1412 cassava root.

Garri samples produced from fertilized cassava roots had higher copper, iron and zinc contents compared to those from unfertilized cassava root. However, there was reduction in the magnesium and calcium contents of the *garri* samples with increased fertilizer treatment level. This indicates that 100% fertilizer treatment level favours higher copper, zinc and iron contents of cassava root and products. On the other hand, fertilizer treatment levels (50 and 100%) does not have significant effect on the magnesium and calcium contents of *garri* samples from the two cassava cultivars.

3.7 Sensory Quality of the *Garri* Samples

The results of the effect of fertilizer treatment on the sensory qualities of *garri* are presented in Table 6. TME 419 *garri* samples from 50% and 100% fertilized cassava roots were not significantly different (p>0.05) from unfertilized TME 419 *garri* (control sample) in terms of most of the sensory attributes except for flavour and overall acceptability. However, TME 419 *garri* samples from 50% fertilized cassava roots was highly rated by the panelists in terms of all quality attributes while the sample from 100% fertilized cassava roots was least rated.

In the case of *garri* from TMS 01/1412, g*arri* sample from unfertilized TMS 01/1412 cassava root (control sample) was similarly rated with the sample from the fertilized cassava roots in terms of taste and texture. On the other hand, *garri* from 100% fertilized TMS 01/1412 cassava roots had higher sensory scores than 50% fertilized TMS 01/1412 sample in terms of taste, texture, appearance and overall acceptance.

Higher sensory attributes scores recorded for TME 419 *garri* samples from 50% fertilized cassava roots indicates that 50% fertilizer treatment level improve the sensory quality of *garri* from TME 419 cassava cultivar. On the other hand, higher level of fertilizer treatment (100%) improved the taste, appearance and overall acceptance of TMS 01/1412 *garri* sample. This indicates that 100% fertilizer treatment level improve the sensory quality of *garri* from TMS 01/1412 cassava cultivar.

4. CONCLUSIONS

This study showed that fertilizer treatment had significant effects on the quality of *garri* from TME 419 and TMS 01/1412 cassava cultivars. G*arri* yield increased as the level of fertilizer treatment on cassava roots increased. High level of fertilizer application (100%) improved the protein, fat, ash, and starch contents of *garri* from the two cassava cultivars. *Garri* samples from cassava cultivars treated with 100% fertilizer had lowest cyanide content, swelling capacity and bulk density, but higher water absorption capacity, reconstitution and gelation index. Fertilizer treatment did not significantly improve the beta-carotene of the *garri* and had negative effect on the pasting properties of *garri*. In terms of sensory attributes, TME 419 *garri* samples from 50% fertilizer treatment was highly rated in all the sensory attributes while TMS 01/1412 *garri* from 100% fertilizer treatment had highest sensory scores in most of the sensory attributes. Since sensory analysis is an important quality attributes for *garri* acceptability by consumers, 50% fertilizer treatment is recommended for *garri* production from TME 419 cultivar while 100% fertilizer treatment is recommended for TMS 01/1412 cultivar. However, *garri* that is meant for *eba* production should not be produce from 100% fertilized treatment level due to the negative effect of fertilizer on the pasting properties of the *garri.*

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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