International Journal of
Food Sciences
(IJF)

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International Journal of Food Sciences
ISSN 2789-7680 (online)
Vol. 8, Issue 1, No. 1, pp 1 – 22, 2025

www.iprjb.org

Physico-Chemical Properties of Selected Cassava Varieties Suitable for Fufu Processing in South-East Abia Nigeria, Nigeria

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Article History

Received 3rd July 2025

Received in Revised Form 9th August 2025

Accepted 2nd September 2025

How to cite in APA format:

Ugo, C. (2025). Physico-Chemical Properties of Selected Cassava Varieties Suitable for Fufu Processing in South-East Abia Nigeria, Nigeria. *International Journal of Food Sciences*, *8*(1), 1–22. https://doi.org/10.47604/ijf.3485

Abstract

Purpose: The physicochemical properties of cassava varieties have a major influence on the adoption and utilization for *fufu* processing and consumption across different locations in Nigeria especially the South-East region. This study evaluated the chemical composition, functional, and pasting properties of thirteen cassava (*Manihot esculenta* Crantz) varieties, including improved and farmer-preferred local varieties, to determine their suitability for fufu production in Abia State, Nigeria.

Methodology: These physicochemical properties were determined using standard analytical procedures. The data collected were analysised using R- statistical package.

Findings: The result obtained showed that the dry matter content of all the varieties ranged between 30% (NR8082) to 48.37% (the local clone). Starch content varied significantly, ranging from 47.46% to 61.20%, while total sugar ranged from 2.85% to 4.72%. Amylose and amylopectin contents indicated that most varieties could be classified as regular starch types, with desirable amylose-to-amylopectin ratios for *fufu* processing. The result of functional properties such as swelling power (9.12–14.99 g/g), solubility, and water absorption capacity also indicate these varieties are suitable for *fufu* processing. Pasting characteristics, including peak, final, and setback viscosities, revealed varietal suitability for specific textural and sensory attributes of fufu.

Unique Contribution to Theory, Practice and Policy: Overall, several improved cassava varieties exhibited comparable or superior quality traits relative to the local variety, suggesting their potential for adoption by processors and consumers seeking desirable fufu qualities.

Keywords: *Cassava, Fufu, Physico-chemical Properties, Adoption, Processing*

JEL Codes: *Q1, Q16*

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a staple root crop of major economic and food security importance in sub-Saharan Africa (Manyong *et al*., 2000; Immanuel *et al*., 2024) . In Nigeria, cassava is widely consumed in various traditional forms, with fufu; a fermented, dough-like food being among the most popular (Immanuel *et al*., 2024). The suitability of cassava for fufu production is influenced by a range of physicochemical and functional properties of its roots (Obasi *et al.,* 2018). These include dry matter content, starch composition, free sugars, cyanogenic potential, and rheological characteristics, all of which contribute to the sensory and textural quality of fufu (Obasi *et al.,* 2018). Despite the introduction of improved cassava varieties, adoption by processors remains low (Mwebaze *et al*., 2024), possibly due to discrepancies in root quality traits compared to traditional landraces. Dry matter content, for example, affects yield, energy requirements, and consumer-preferred textural attributes, while starch characteristics influence cooking quality and gelatinization behavior. Furthermore, functional properties such as water absorption and swelling power determine the efficiency and consistency of fufu preparation. Therefore information regarding the physicochemical and functional properties of cassava root is needed to maintain consistent quality and desired final products. Hence, this study seeks to characterize the chemical, functional, and pasting properties of selected cassava genotypes, with a focus on evaluating their suitability for producing fufu with desired quality traits preferred by processors in Abia State, southeastern Nigeria. The goal is to identify improved cassava varieties with attributes that yields high quality fufu , thereby enhancing consumer acceptability, adoption and processing efficiency.

MATERIALS AND METHODS

Sample Preparation

Ten newly bred (10) improved cassava varieties (IITA TMS1071313, NR05/0362, NR05/0107, TMS 1070337, TMS01/0034, NR05/0166, IITA TMS1070134, NR05/0046, NRCOB-7-25, IITATMS102045), two farmer preferred improved cassava varieties (TMS30572 and NR8082) and a processor prefered local variety were harvested from NRCRI Farmer managed field at Ihite Uboma L.G.A Imo State and used for this study.

Physico-chemical Analysis

The chemical, pasting and functional analyses were carried out on roots of the different cassava varieties. These physicochemical analyses were carried out in three replicates using standard analytical procedures.

Starch and Sugar Analysis

The calorimetric method (Phenol Sulphuric acid method) for determination of sugars and related substances was employed. One millimetre (1 ml) of 95 % ethanol, 2 ml of distilled water and 10 ml of hot ethanol was added to 0.02 g sample, vortexed and centrifuged for 10 min at 2000 rpm. The supernatant was decanted and 9 ml of distilled water was added. Quantities of distilled water (0.8 ml), 0.5 ml phenol and 25 ml H_2SO_4 were added to the extract. Absorbance was read at 420 nm for sugar determination. For the determination of starch, $HCLO_4$ was added to sediment. The sample was allowed to stand for one hour, and vortexed. An aliquot (0.95 ml) of distilled water, 0.5 ml phenol and 2.5 ml H2SO4 were added to 0.05 ml of extract and absorbance of sample read at 420 nm.

Calculation: The sugar and starch contents were calculated on percentage curve = 0.0055 basis.

$$\% \, Sugar = \frac{(a - i) \times d.f \times v \times 100}{b \times w \times 10^6}$$

$$\% \, Starch = \frac{(a - i) \times d.f \times v \times 0.9 \times 100}{b \times w \times 10^6}$$

Where: A = Absorbance of sample I = Intercept of standard curve D. F = Dilution factor based on aliquot taken for assay, 5 ml = sugar, 20 ml = starch. V = Total extract vol

20 ml = sugar, 25 ml = starch.

B = Slope of the standard curve = .0055 W = Weight of sample.

Dry Matter Content

The moisture content of the cassava flour prepared from the fresh cassava roots was determined by the gravimetric method by AOAC (2000). Two (2) grams of the flour was weighed into a clean dried pre-weighed moisture can. It was allowed to dry in the oven for 6 hour at 100 °C until a constant weight was obtained. The moisture content was calculated as follows:

% Moisture = (W3-W2) /W1 x 100

Where W1=weight of sample used

W2=weight of can + sample before drying

W3=weight of can + sample after drying

Determination of Amylose

The rapid calorimetric procedure for estimating the amylose content of starch and flour as described by Juliano (1971) was employed. 0.1 g or 100 mg of the sample was weighed into a 100 ml volumetric flask. 1 ml of 95 % (v/v) ethanol and 9 ml of 1 N-sodium hydroxide (NaOH) was carefully added and the mouth of the flask was covered and the content was mixed well. The samples were heated for 10 minutes in a boiling water bath to gelatinize the starch (the timing started when boiling began). The samples were then removed from the water bath and allowed to cool very well. It was then Made up to 10 ml with 9.2 ml of distilled water and shaken well.

Some 5 ml of the mixture was then pipetted into another 100 ml volumetric flask. Acetic acid (1 N, 1.0 ml) and 2 ml of iodine solution were added, and top to mark with distilled water. Absorbance (A) was then read using spectrophotometer at 620 nm wavelength. The blank contained 1 ml of ethanol, 9 ml of sodium hydroxide, and then boiled and top up to the mark with distilled water. 5 ml was then pipetted into a 100 ml volumetric flask. Approximately, 1 ml of 1 N acetic acid and 2 ml of iodine solution were added and then filled up to the mark, this was used to standardize the spectrophotometer at 620 nm.

% amylose = absorbance x 3.06 x 20

% amylopectin = 100 - % amylose

Total Cyanide

Total cyanide analysis was carried out using the auto-analyser. The sample is segmented by air and mixed with phosphate buffer pH (7.0) in a 5-turn coil. Linamarase, which activity had been determined was added to the sample and allowed to hydrolyse the bound cyanide (cyanogenic glycosides) while being mixed with the sample in a long heating bath coil maintained at 4 ^{o}C. Cyanohydrin was determined by subsituting the enzymes with buffer pH4.5 and the free cyanide (HCN) determined by substituting the enzyme, 0.01 N NaoH and 0.2 N NaoH with buffer pH 4.5. The cyanogens chloride formed react with the colour is detected in a 15 x 2 mm flow cell with 600 mm interference filters and recorded on a precalibrated chart.

Calculations.

$$MgHCN/100g = \frac{250}{wt} \times \%chart \times slope \times 0.04151$$

Pasting Properties

The pasting properties of the cassava varieties were evaluated as reported by Siah *et al.*, (2005). The Rapid visco- analyzer (RVA Newport scientific super 3D+, Australia) was used to determine the changes in viscosity/pasting properties (peak viscosity, trough, final viscosity, break- down viscosity, set- back viscosity, peak temperature and peak time) of the sun-dried, flash dried *fufu* flours and wet cake *fufu*. The weight of sample used for RVA analysis was calculated by correcting it to dry weight basis by the formula:

Corrected sample weight for RVA (S) = (A x 100) / Sample DM

Volume of water used = (W) =25 - (S-A)

Where A = Sample weight (depending on the type of sample, this is taken from the general guide

Determination of Swelling Power and Solubility

Swelling power and solubility was determined as described by Leach *et al.* (1959). One gram (1.0 g) of sample was weighed into a 100 ml conical flask. Fifteen (15) ml of distilled water was added and stirred for 15 min on a shaker (Gallenkamp flask shaker, Burrell Coperation, Pittsburgh PA, USA) at low speed. The mixture was transferred into a water bath (Precision Sc. Co model 83) for 40 minutes at 80-85 °C with constant stirring and centrifuged for 20 min at 3,000 rpm. The supernatant was decanted into a pre-weighed can and dried to constant weight. Sample was placed in a dessciator to cool and weight of the precipitate for the determination of solubility. The sediment in the centrifuge tube was also weighed for the determination of swelling power. The swelling power and solubility were given as follows:

$$\text{Swelling Power} = \frac{\text{Weight of sediment}}{\text{Sample weight- Weight of soluble solids}}$$

$$\text{\%Solubility index} = \frac{\text{Weight of soluble solids x100}}{\text{Weight of soluble solids}}$$

Determination of Dispersibility

Dispersibility was determined using the method of Kulkarni *et al. (1991*)**.** A quantity of ten gram (10 g) of sample was weighed into 100 ml measuring cylinder and distilled water to reach water added to reach volume of 100 ml. The set up was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 1. The difference was reported as percentage (%) dispersibility.

% Dispersibility = 100- Reading

Determination of Water Absorption Capacity

Water Absorption Capacity determined using the methodas described by Solsulski (1962). Fifteen (15) ml distilled water was added to 1 g of sample in a pre-weighed centrifuge tube.

The tube and mixture was agitated on Stural Sc. (U.K Merlin 503) centrifuge. The clear supernatant was discarded and the centrifuge was weighed with the sediment. The amount of water bound by flour was determined by difference and expressed as weight of water bound by 100 g dry flour.

WAC = (Sediment – sample weight) x 100

Bulk Density of Flours/ Meals/ Blends

Bulk density determined using the methodas described by Narayana andNarasinga Rao, 1984.

A calibrated centrifuge tube was weighed and the tube filled with samples to 5 ml. It was tapped constantly until there isno further change in volume. The contents were weighed as well as the tube. Weight of samples was determined by difference.

Calculation: Bulk density g / ml = $\frac{\text{weight of sample}}{\text{Volume occupied}}$

RESULTS AND DISCUSSION

Chemical Properties of the Varieties

The results in Table 4 show results of chemical properties of cassava roots of the selected varieties (moisture content, starch content, total sugar, amylose, amylopectin, ash, and hydrogen cyanide content) determined on a fresh and dry weight basis. The result obtained showed differences in the dry matter content of the cassava varieties, however, values obtained were not statistically different ($p > 0.05$). The non-significant difference in dry matter content among the cassava varieties may be attributed to the fact that they were at the same age at the time of harvesting (Chisenga, 2021). The results also showed that all the new cassava varieties had a dry matter content above 30%, which is high (Teye *etal*., 2011). The values obtained (Table 3) ranged from 30.57 % (NR8087) to 48.37 % (Local). Previous studies have shown that the dry matter content of different cassava ranges between 30 to 40 % (fresh weight basis) (Fakair *et al.*, 2012; Baafi and Safo-Kantanka, 2008). The farmer-preferred variety (Local) had higher dry matter content (48.37 %) compared to NR8087 (30.52 %) and TMS 30572 (40.92%) (2 improved varieties currently used by processors).

According to Adejumo (2012), high dry matter content is an indication of the suitability of the roots for long-term storage. The dry matter content of fresh cassava roots is positively linked to sensory quality attributes of *fufu* and *gari* and as such is an important trait criterion for the selection of cassava varieties for processing in Nigeria (Bischoff *et al.*, 2017). Several studies have also reported a positive correlation between high dry matter and good cooking ability of cassava-based products (Safo-Kantanka and Owusu-Nipa, 1992; Safo-Kantanka and Asare, 1993). The dry matter content of cassava roots is also of great importance in food processing as it affects drying time and labor requirements per tonne of cassava. In the case of artificial drying, fuel cost is also reduced by the utilization of materials that have high dry matter content. The dry matter content of cassava roots (Oguntimein, 1988) is affected by several factors such as the variety, harvesting age, and agronomic conditions. The high dry matter content exhibited by the varieties under study suggests that these newly improved cassava varieties will have good processing and sensory properties that will meet the needs of *fufu* processors and consumers.

The result obtained (Table 4) also revealed varietal differences in the starch content of cassava roots evaluated, values obtained ranged from 47.46 to 61.20 %. The roots of variety IITA

TMS/102045 had the lowest value while NR8082 had the highest starch content. The starch content of both the improved and preferred local cassava varieties was higher than the ranges reported previously in literature (25 to 34 % by Aryee (2006), 3.32 to 23.24 % by Mégnanou *et al.*, 2009 and 15.34 to 31.07 % by Afoakwa *et al*., 2011). Two improved varieties NR05/0362 and NR8082 had higher starch content than the local variety though the values were not statistically different. The starch content of variety NR05/0362 was also not significantly different from IITATMS/102045. Statistical analysis conducted on the data showed significant differences ($p < 0.05$) in the starch content of the cassava varieties. Mejı´a-Agu¨ero *et al.* (2012) also observed significant differences in starch contents among twenty-five cassava cultivars planted and harvested simultaneously in a single plantation. The differences in starch content may be related to the difference in dry matter content of the cassava varieties (Nuwamanya *et al.*, 2008). The high starch content of these varieties suggests that they may be suitable for industrial applications such as ethanol production.

Starch content is also an important criterion for selecting varieties by food processors (Rahman *et al*., 2003). It plays an important role in developing food products, either as a raw material or as a food additive such as a thickener, gelling agent, stabilizer, or texture enhancer (Rahman *et al*., 2003). Previous studies have also highlighted the importance of starch content on the sensory properties of cassava-based food products. Starch content and composition (amylose/amylopectin) influence the texture rather than the taste and other sensory attributes (Bechoff *et al*., 2018). The result of root starch content may serve as an indicator of the suitability of these cassava varieties for the processing of indigenous food products such as *fufu*. The starch content of cassava root was identified as an important trait that drives the selection, adoption, and utilization of cassava varieties by *fufu* processors in Abia State (Table 3). These improved cassava varieties may therefore be easily adopted by *fufu* processors in Abia State as replacements for the local varieties since they meet essential root quality traits required by processors within Abia State. Significant differences were also observedin the sugar contents of the fresh cassava, values obtained ranged from 2.85 (NR/0166) to 4.72 % (TMS01/0034). The values obtained for total sugar were within the range (1.57 to 7.50 %) as reported in the literature by Aryee *et al*. (2006).

In contrast, Afoakwa *et al*., (2011) reported higher total sugar contents ranging between 13.14 % and 18.47 % in some improved cassava varieties studied. Apart from two varieties (TMS 30572 and TMS 01/0034), the local variety had higher sugar content compared to the other new cassava varieties. High free sugar content improves the retting ability of cassava and organoleptic properties such as aroma and taste fermentation of *fufu* (BRAUMAN *et al*., 1996). These important sensory attributes have been identified as major determinants that drive consumer acceptance of cooked *fufu*. The result obtained suggests that the variety TMS 01/003 has good retting properties for processing *fufu* with intense aroma and sour taste, traits preferred by male *fufu* consumers in Abia State. Sugar content is also an important criterion for determining the suitability of cassava varieties as a raw material for industrial production of ethanol, organic acids, and lactic acid (Afoakwa *et al*., 2011). Nuwamanya *et al*. (2009) reported that reducing sugar in cassava roots has a significant effect on the functional properties of starch (such as swelling power) in food systems.

The amylose content obtained from the fresh cassava roots varied significantly ($p < 0.05$) with values ranging from 24.86 (Local) to 29.15 % (TMS 01/0034). The major determinant of the amylose content of starch is the activity of GBSS within the granule (Seung, 2020) Amylose content reported by earlier workers ranged between 17.9 to 23.6 % (Defloor *et al*., 1998); 17

to 25 % (Fernandez *et al*., 1996); 18 to 25 % (Moorthy, 2004); and 13.6 to 23.8 % (Rickard *et al*., 1991). Similarly, Dakubu and Bruce-Smith (1979) had earlier established that starches from fully matured cassava varieties had normal amylose content which varied from 13.6 to 19.1 %. In contrast to these previous findings, values obtained in this study were slightly higher. Eleven (11) varieties had amylose content ranging between 25.48 and 29.19 %, while two (NR 05/0362 and TMS 30572) had values below 25.48 %. Sabaté Agnès *et al*. (2012) classified cassava starches as low amylose (0-2 %), normal or regular (16–35 %), and high-amylose (30-31 %), respectively. The cassava varieties under investigation may therefore fall within the normal to high class. Varieties with high amylose are considered most suitable in food systems where starch granules can withstand high mechanical stress and temperature without breakdown of the starch as required during *fufu* processing due to the linear nature of amylose molecules (McPherson and Jane, 1999; Peroni *et al*., 2006). Cassava varieties with low amylose content are considered most suitable for paper and textile industries and are also preferred for use as thickeners in food industries (Dakuba and Bruce-Smith, 1979). The high amylose content of the cassava varieties will lead to a reduction in gelatinization temperature, stability of the formed paste viscosity and minimize retrogradation of cooked *fufu* during storage (Sasaki *et al*, 2000; Gerard *et al.*, 2001; Afoakwa *et al*., 2011). This study therefore suggests that most of the cassava varieties evaluated have quality attributes desirable to *fufu* processors and consumers within Abia State, South-East Nigeria.

The results obtained showed that the amylopectin content of the fresh cassava root varied significantly ($p < 0.05$) among the varieties. The values obtained ranged from 71.65 % (NR05/0107) to 75.15% (NR/0166). The amylopectin values obtained in this work were higher than those previously reported by Afoakwa *et al*., (2011) in six (6) improved Ghanaian cassava varieties (59.70 to 69.43%) but similar to those observed by Sanni in 2005 (8.39 and 76. 22 %) in two cassava varieties in Nigeria. The amylopectin content of the local farmer's preferred variety was comparable to the amylopectin of the new cassava varieties being evaluated. According to Nigel *et al*., (2004), amylopectin makes up 70- 80 % of the cassava starch content. Phenotypic variation in the amylopectin content of plant starch is reported to be influenced by the content and activities of "soluble starch synthase" during starch synthesis. On the other hand, the granule-bound starch synthase determines the amylose content. Gerrano *et al.* (2014) stated that the relative proportion of amylose and amylopectin vary considerably within plant species and plant organ and depends on organ development and growth conditions. Cassava starch/ flour containing approximately 80 % amylopectin is referred to as" high amylopectin" or waxy starch. (http://www.Cassava.org/), while those with normal levels of amylopectin (70-76 %) are called Non-waxy starch. The cassava evaluated can therefore be classified as non-waxy cassava varieties. The normal amylopectin content of these variety will produce desirable *fufu* quality attributes unlike high amylopectin starches waxy starches that limit exudation of amylose, decreased solubility, have high peak viscosity, bland taste, and sticky textured dough. (Jobling, 2004; Santelia & Zeeman, 2010; Chisenga 2021).

The ratio of amylose to amylopectin in this study varied from 24.86: 75.15(NR05/0362) to 28.35:71.65 (NR05/0107). The study shows that the preferred local variety had an amylose-to-amylopectin ratio of 25.48: 74.53.The ratio of amylose to amylopectin of the new varieties was comparable to that of the local variety. Generally, the proportion of amylose to amylopectin in cassava is 17 to 83 (http://www.foodinfo.net/uk/carbs/starch.htm). Gel strength, basic texture, the nature of texture gelatinization, viscosity, solubility, gel stability, and tackinessof starchy foods are influenced by the ratio of amylose to amylopectin **(**Glavas, 2011**).**High amylopectin starches provide correct viscosity but are unacceptable"stringy" and "slimy". Textural properties while high amylose give good gelling strength but create excessive firmness in puddings (Hengenbart 1996).This result of the local variety may therefore stand as a guide and reference for selecting a ratio of amylose to amylopectin cassava variety suitable for *fufu* processing.

The ash contents of the fresh root of the different cassava varieties ranged from 0.65 (NR8082) to 5.62 % (TMS 30572). The values obtained were higher than 1–2% previously reported by Chisenga (2021). Previous studies had reported lower ash content in different cassava varieties (0.12- 0. 28 % and 0.10-0. 20 %, Ladeira *et al.*, 2013; Nuwamanya *et al.*, 2009). The also data showed that the local variety had higher ash content, this was however not statistically different from that of the new cassava varieties under study. Ash content of food serves as an indicator or measurement of the mineral content in the sample and it contributes to the nutritional quality of food products (Wilson, 1987; Elazu and Elazu, 2012). Mineral matter such as phosphorus influences a number of starch characteristics such as gelatinization, paste viscosity, setback, swelling power, and solubility. High phosphorus in these varieties improves swelling power, peak, and breakdown viscosity but increases the retrogradation tendencies of products during storage (Karima et al 2007). Pavlovich-Abril et al. (2005) reported a positive relation between ash content and fiber content varieties this according to Chisenga (2021) enhances the loss of minerals during dewatering and drying operations of cassava root. The result obtained therefore suggests that *fufu* processed from new varieties may lower retrogradation properties, and better nutritional and culinary qualities compared *to fufu* from local varieties due to their lower ash contents.

The hydrogen cyanide content ranged from 13.29 mg/100g (NRCOB-7-25) to 2.66 mg/100g (NR05/0107). The values obtained were higher than those observed in past studies. Ezeigbo (2015) reported values between 5.955 to 6.257 mg/100g in the roots of six (6) different cassava varieties. Statistical analysis of the data revealed significant differences ($p < 0.05$) in the mean values obtained. The cyanide content of NR05/0107 was significantly lower than that of the preferred local variety, while NRCOB had significantly higher cyanide than the local clone. The differences in cyanide levels among varieties may be attributed to genotype, protein, fiber content, and environmental factors such as location and season. This study shows that all the cassava varieties tested had cyanide above the recommended level (< 50 ppm) in fresh roots and above the recommended level in processed foods for human consumption (10 mg HCN/kg dry matter basis). All the varieties will therefore require further processing such as fermentation to reduce cyanide content to the recommended level before consumption.

International Journal of Food Sciences
ISSN 2789-7680 (online)
Vol. 8, Issue 1, No. 1, pp 1 – 22, 2025
www.iprjb.org

Table 4: Selected Chemical Properties of 13 Improved Cassava Varieties

VARIETY	DM (%fw)	STARCH (%)	SUGAR (%)	AMYLOSE (%)	AMYLOPECTIN (%)	ASH (%)	HCN(mg/kg) Fw
IITATMS102045	41.13 ^{NS}	47.56^{h}	3.33^{h}	26.45^{e}	73.55^{e}	.78 ^{NS}	15.20^{e}
IITA TMS1071313	37.70 ^{NS}	56.99^{d}	3.58^{f}	26.67^{e}	73.33^{e}	1.54 ^{NS}	21.39^{a}
IITA TMS1070134	38.25 ^{NS}	51.99^{f}	4.38^{c}	26.10^{f}	73.91^{d}	.97 ^{NS}	14.93^{e}
LOCAL	48.37 ^{NS}	60.24^{b}	4.48^{b}	25.48^{h}	74.53^{b}	5.53 ^{NS}	16.84^{d}
NR05/0046	37.83 ^{NS}	52.13^{f}	3.93^{d}	25.83^{g}	74.18^{c}	.99 ^{NS}	18.75^{bc}
NR05/0107	39.00 ^{NS}	53.59^{e}	3.44^{g}	28.35^{b}	71.65^{h}	.88 ^{NS}	21.66^{a}
NR/0166	39.00 ^{NS}	52.50^{f}	2.85^{j}	27.29^{d}	72.71^{f}	.94 ^{NS}	17.66^{cd}
NR05/0362	40.31 ^{NS}	60.43^{ab}	3.90^{d}	24.86^{i}	75.15^{a}	1.24 ^{NS}	18.21^{cd}
NR8082	30.57 ^{NS}	61.20^{a}	3.70^{e}	25.78^{g}	74.22^{c}	.65 ^{NS}	19.85^{ab}
NRCOB-7-25	42.17 ^{NS}	57.19^{d}	4.46^{bc}	27.21^{d}	72.80^{f}	2.80 ^{NS}	13.29^{f}
TMS1070337	40.73 ^{NS}	49.95^{g}	3.16^{i}	27.61^{c}	72.40^{g}	1.51 ^{NS}	18.21^{cd}
TMS30572	43.90 ^{NS}	58.97^{c}	4.64^{a}	24.99^{i}	75.02^{a}	5.62 ^{NS}	13.84^{ef}
TMS01/0034	34.26^{NS}	56.64^{d}	4.72^{a}	29.15^{a}	70.85^{i}	5.49^{NS}	21.12^{ab}

NS, Not significant; Means with different superscripts on the column are significantly different $p < 0.05$

Functional Properties of the Varieties

Table 5 shows the results of the functional properties of the fresh cassava roots of the selected varieties. The parameters evaluated include swelling power (SP), solubility index, water absorption capacity (WAC), bulk density (BD), and dispersibility.

The result obtained from the study showed that the swelling power of the 13 cassava varieties differed significantly ($p < 0.05$). The values obtained ranged from 9.12 g/g (IITATMS102045) to 14.99 g/g for IITATMS/ 1071313 (Table 5). Values obtained were similar to those reported by Kusumayanti *et al.* (2015) (13.80 g/g) but higher than 0.4 to 1.4 g/g previously reported by Nuwamanya *et al.* (2009) in fresh cassava roots.

Moorthy (2002) reported that the swelling power of cassava starch varied from 42 to 71 g/g. The variation in swelling power of the 13 newly bred cassava varieties could be attributed to differences in starch content of the fresh cassava roots (Rampersad *et al.*, 2003), differences in strength and character of the micellar network association within the starch granules (Akintunde and Akintunde 2013), and variation in amylose and amylopectin content ratio(Moorthy, 2002; Chan *et al.*, 2009; Sanchez *et al.*, 2010; Kusumayanti *et al.*, 2015). Swelling power has been identified as a major root quality attribute that influences the utilization of cassava variety for *fufu* processing in Nigeria (Teekan *et al.*, 2018). The moderately high swelling ability of the fresh cassava roots makes them suitable for processing Indigenous foods such as *fufu* rather than for industrial application which requires high swelling ability (Nuwamanya *et al.*, 2009).

Table 5 shows no significant difference ($p > 0.05$) in the solubility and bulk density of flour from roots of the 13 cassava varieties. This contradicts the findings of Nuwamanya *et al.*, (2009) who reported significant differences in solubility of fresh roots of some Ugandan cassava varieties. The solubility of fresh cassava roots ranged from 1.23 (local) to 13.11 %

(IITA TMS/1070134) and was higher than the range (1.33- 7.67g100g-1) previously reported by Nuwamanya*et al.* (2009).The local variety had low solubility indices (1.2%) compared to most of the other varieties under study. Differences in the solubility of starches are due to differences in their granular and molecular structure (Bello-Pérez *etal*., 2000; Tian and Rickard, 1991).Singh *et al.* (2003) reported that the disintegration of the granule and subsequent release of soluble matters including amylose at a critical point during the swelling of the granules leads to solubility of starch. The high solubility index obtained in this study suggests that dried *fufu* flour from the various cassava varieties will disperse easily in waterhence forming dough with a homogenous and smooth appearance that is desirable to consumers(Abiodun and Akinoso,2014). The high solubility indices of the varieties also suggest that varieties would be appropriate for industrial application, especially in the pharmaceutical industry where starch is used in solution (Benesi, 2005; Murkejea *et al*., 2007). Furthermore, the high solubility index of these varieties implies that they will be suitable as substitutes for corn starch for dietary uses (Nuwamanya *et al.*, 2009). Furthermore, Raphael *et al.* (2011) stated that high starch solubility allows easy hydrolysis of starch molecules leading to the release of glucose for microbial activities. This suggests that the roots of the cassava varieties studied will require less time to soften during *fufu* processing. Length of fermentation was also identified as a major factor that influences the selection of cassava varieties by *fufu* processors in Abia State (Table 2).

Table 5 also shows that the roots of the cassava varieties did not differ significantly with respect to bulk density. Values obtained for bulk density of flour from roots of the various cassava varieties ranged from 0.59 (Local) – 0.75 g/ml (NR8082), this is similar to values (0.49 to 0.85 g/cm^3) reported previously for dried chipped cassava (Oghenechavwuko *et al.*, 2013). Hasmadi *et al.* (2020) reported bulk density values of 0.57 g/cm^3 and 0.79 g/cm^3 for samples Tawau and Semporna, respectively.The bulk density of the product is influenced by the starch content and initial moisture content of the material (Awuchi *et al.*, 2019). The high dry matter content of the varieties may therefore be responsible for the relatively high bulk of the flour this will improve the transportation and storability of *fufu* flour (Chisenga, 2021). Further, the high but non-significant variation in bulk density observed among the cassava variety especially NR8082 suggests that the varieties studied will have good dispersibility and thickening ability (Padmashree *et al.*, 1987; Udensi and Eke, 2000; Suresh and Samsher, 2013; Awuchi *et al.*, 2019) these are important quality attribute required for processing food products such as *fufu*.

The result for water absorption capacity shows that variety TMS10/71313 had the lowest water absorption capacity (121.89 %) while variety NR05/0362 (183.94 %) had the highest water absorption capacity (DWB). This is similar to the value (163 g/100g) reported by Bankole *et al.*, (2013) in unfortified cassava flour. Significant variations were observed in the water absorption capacity of the different cassava varieties ($p < 0.05$). This result suggests that the optimum amount of water required to prepare products such as *fufu* will vary among the varieties (Awuchi *et al.*, 2019), greater quantity of water will be required to prepare cooked *fufu* from fermented *fufu* mash (wet or dry) of NR05/0362 compared to the other varieties. The high water absorption capacity of NR05/0362 may be related to its high amylopectin content (Houssou and Ayernoor 2002). This result also suggests that *fufu* processed from NR05/0362 will have desirable attributes such as high swelling power and appropriate cohesive non-sticky textural properties that willmeet the needs of processors and consumers (Kouadia Kouadio *et al.*, 2011).

The values obtained for the dispersibility of the root were high ranging from 73.0% (NR05/0107) to 8.2 % (Local). Slight statistical variation was observed among the varieties (p

< 0.05); seven (7) varieties had dispersibility values of about 80% while the rest had values between 70% and 79%. These high values indicate that flour from these varieties can disperse and reconstitute easily in aqueous systems during the preparation of products such as *fufu* using either the mash or flour from the cassava varieties (Awoyale *et al*., 2020).

Table 5: Functional Properties of 13 Newly Bred Cassava Varieties

Varieties	Swelling power (g/g)	Solubility (%)	WAC (%)	Bulk density (g/ml)	Dispersibility (%)
IITA TMS1071313	14.99^{a}	6.42ns	121.89^{e}	0.61ns	73.4^{c}
NR05/0362	12.93^{ab}	8.05ns	183.94^{a}	0.74ns	76.0^{b}
NR8082	12.57^{abc}	9.21ns	151.16^{bc}	0.75ns	79.6^{a}
LOCAL	12.42^{abc}	1.23ns	13.25^{de}	0.59ns	80.2^{a}
NR05/0107	11.98^{bc}	6.60ns	151.95^{b}	0.66ns	73.0^{c}
TMS 1070337	11.61^{bcd}	6.98ns	148.82^{bc}	0.69ns	76.0^{b}
TMS01/0034	11.29^{bcd}	6.43ns	137.81^{cd}	0.75ns	80.0^{a}
NR05/0166	11.01^{bcd}	8.11ns	147.23^{bc}	0.63ns	80.0^{a}
IITA TMS1070134	1.57^{bcd}	13.11ns	152.60^{b}	0.70ns	73.4^{c}
TMS30572	1.54^{bcd}	5.84ns	135.23^{cde}	0.68ns	80.0^{a}
NR05/0046	9.90^{cd}	7.89ns	152.90^{b}	0.60ns	80.0^{a}
NRCOB-7-25	9.19^{d}	9.67ns	131.61^{de}	0.68ns	80.0^{a}
IITATMS102045	9.12^{d}	1.86ns	142.04^{bcd}	0.75ns	80.0^{a}
P values					

NS, Not significant; Means with different superscripts in the same column are significantly different (p < 0.05)

Pasting Properties of the Varieties

The results of the pasting profile of the flour from the roots of the 13 cassava varieties are presented in Table 6.

Table 5 also showed significant differences (p < 0.05) in the peak viscosity of the cassava varieties, values obtained ranged from 319.21 RVU (IITATMS/1070134) to 525.415 RVU (preferred local variety). The values obtained in this study were higher (292.72 RVU and 315 RVU, respectively) than those reported previously by Murayama *et al*. (2014). Very high pasting viscosity values (above 500 RVU) were observed in five new varieties comparable to the preferred Local variety; two other varieties had peak viscosity above 400RVU while three varieties had values above 300RVU (comparable to NR8082 another preferred improved variety). The variations may be attributed to differences in the molecular structure of amylopectin, amylose to amylopectin ratio, and the size of the starch granule of the cassava varieties (Hegenbart, 1996). The high peak viscosity exhibited by these varieties suggests that they will have good thickening power (Swinkels, 1992), paste strength (Eke *et al*., 2007) water binding capacity (Ritika*et al*., 2010), high swelling potential, low solubility and gelatinization temperature (easy to cook) (Hegenbart, 1996; Arisaka and Yoshi, 1999; Shittu *et al*., 2001).Research by Ojo et al. (2017) showed that cassava starch-mushroom flour blends with higher swelling capacities exhibited higher peak viscosities. Furthermore Omenai et al. (2024)

found that high peak viscosity enhances water absorption capacity of cassava flour. These are food quality attributes desirable to fufu processors.

The study also showed significant differences ($p < 0.05$) in the trough viscosity of flour from the different cassava varieties (Table 5). This shows that starch granules of the different cassava varieties will vary with respect to the degree of disintegration at high temperatures and shear stress during food processing. The Local variety had the highest (252.50 RVU) while IITA TMS1070134 had the lowest (14.50 RVU) through viscosity. The values obtained in this study were higher than the range (135.67 to 192.35 RVU) reported by Akintunde and Akintunde (2013). The high values of trough viscosity indicate low breakdown of starch granules in processing foods such as fufu which requires high temperature and mechanical stress (Maziya-Dixon *et al.*, 2005). The variation in trough values is related to the strength or weakness of the amylopectin structure and the ease with which amylose leaches into the aqueous phase which influences the textural properties of the final product (Singh *et al.*, 2006; Nuwamanya *et al.*, 2011). The result suggests that the varieties with higher trough viscosities are suitable for fufu Processing as they are expected to produce cohesive stable *fufu* dough (Akintunde and Akintunde, 2013) that meets the needs of *fufu* processors in South-East Nigeria.

The breakdown viscosity obtained in the study ranged between 272.92 RVU (local) to 397.46 RVU (NR05/0107) (Table 5). The varieties differed significantly ($p < 0.05$) in the breakdown viscosity. The values obtained were higher than previously reported by Maziya-Dixon *et al.*, (2005). Seven of the new varieties (IITA1071313, NR05/0362, TMS01/0034, NR05/0107, TMS1070337, NRCOB-7-25, and IITATMS1070134) had low breakdown values which were comparable to that of the preferred local variety. The low breakdown viscosity of the seven varieties (IITA1071313, NR05/0362, TMS01/0034, NR05/0107, TMS1070337, NRCOB-7-25, and IITATMS1070134) is an indication of their ability to withstand shear stress and high temperature (Olatunde *etal*., 2017) during processing of food products such as *fufu*.

According to Adebowale *et al.* (2005), samples with high breakdown viscosity possess a low ability to withstand heating and shear stress during cooking. Oduro *et al.* (2000) reported that starches with low paste stability or breakdown have very weak cross-linking within the granules and produce weak gels; such gels are most likely to disintegrate under shear and heat (Singh *et al.*, 2006). Starches and flour from the varieties NR05/0046, NR05/0166, IITA102045, NR8082, and TMS30572 characterized by high breakdown values could therefore be applied in the food industry, especially where low thickening power (Oduro *et al.*, 2000) is required such as in pastries and infant formula.

The final viscosity of the cassava varieties was significantly different ($p < 0.05$), and the values obtained ranged from 25.0 RVU (IITATMS1070134) to 317.79 RVU (TMS01/0034). The variety TMS01/0034 which had the highest final viscosity did not differ significantly from the local variety ($p < 0.05$), however significant differences ($p > 0.05$) were observed between TMS01/0034 and two farmer-preferred already released improved varieties (TMS30572 and NR8082). The values for the final viscosity of the newly improved cassava varieties were higher than that (95.9 RVU to 24.0 RVU) of some pro-vitamins (Maziya-Dixon *et al.*, 2005). The final viscosity is the pasting parameter commonly used to determine the quality of a starch-based sample as it indicates the ability of the material to form a stable gel easily after cooking (Sanni *et al.*, 2006) This suggests that paste formation may be easier for fermented *fufu* mash or flour produced from TMS01/0034 and the farmer preferred Local varieties due to their high final viscosities compared to that from IITATMS1070134, IITA102045, NR8082, NRCOB-7-25 and NR05/0046 with low final viscosities. The result also suggests that ready–to–eat *fufu*

International Journal of Food Sciences
ISSN 2789-7680 (online)
Vol. 8, Issue 1, No. 1, pp 1 – 22, 2025

prepared from IITATMS1070134, IITA102045, NR8082, NRCOB-7-25, and NR05/0046 may not have good moldability an attribute that drives acceptance among consumer acceptance (Chika *et al.*, 2013)

The result also shows that the cassava varieties differed statistically in terms of their setback viscosity, IITATMS1070134 had the lowest setback viscosity (1.50 RVU) while TMS01/0034 had the highest value (84.85 RVU). Alamu *et al.* (2017) reported values of setback viscosity 2.60 RVU (for 30572) to 65.41 RVU (for 01/1115) and 14.04 RVU (for 01/1404) to 73.07 RVU (for 00/0028) relatively close that obtained in the current Four of the varieties evaluated (NR 05/0046, NR 05/0166, IITA TMS102045 and NRCOB-7-25) had setback value that did not differ statistically with NR8082 (a farmer preferred improved variety). The setback viscosity of the varieties IITA TMS 1071313 NR 05/0362 and NR05/0107 were however statistically comparable to the setback viscosity of the local variety. Awoyale *et al.*, (2020) in their research work reported that low setback viscosity in cassava *fufu* or *gari* processed from some cassava varieties is an indicator of the higher resistance to retrogradation. Consequently, the result obtained implies that *fufu* or *gari* produced from IITATMS1070134 will not retrograde or harden easily during cooling and storage. Cassava varieties with low setback values will therefore be suitable for processing *fufu* with preferred consumer sensory attributes such as moderate soft texture and long shelf-life. This result therefore suggests that *fufu* produced from TMS01/0034 with higher setback viscosity may develop a hard texture upon cooling and will also have a shorter shelf life compared to *fufu* processed from varieties with lower setback values storage (Oduro *et al.*, 2000; Otegbayo *et al.*, 2006). Furthermore, starch extracted from the variety TMS01/0034 may also have higher tendencies to lose water (Mweta *et al.*, 2015) and hence will have limited application in baked food products.

Table 5 also shows statistical differences ($p < 0.05$) in the peak time of flour processed from the different cassava varieties. The values for peak time obtained in this study range from 3.73 minutes for IITATMS 1071013 to 4.80 minutes for NR05/0362. Adegun *et al.* (2010) reported similar values (3.60 min to 4.06 min) as`peak time for sour cassava starch. However, the values obtained were higher than those reported by Maziya-Dixon *et al.* (2005) (3.51 to 3.87min)for cassava varieties harvested from two different planting season*s* and (3.23 to 3.91 min) reported by Akintunde and Akintunde (2013) for starch produced from four different cassava varieties (TME 1, TMS 30572, TMS 01/1235 and TMS 01/1181) using two drying methods (sun and oven drying at 40^{o}C). The variation in peak time recorded in this study indicates that flour and other value-added products from these varieties will differ with respect to the time of processing or paste formation during processing. It also implies that the varieties with lower peak time will cook faster and will require lower energy for processing compared to the cassava varieties with higher peak time.

The pasting temperature of flourdiffered significantly ($p < 0.05$) among varieties, the values obtained ranged from 73.58 ºC (Local) to 78.40 ºC (NR-COB-7-24). The values obtained were higher compared to those (64.78 to 68.95 ºC) previously reported by Afoakwa *et al.* (2012) for six high yielding cassava mosaic disease resistant varieties. According to Afoakwa *et al.* (2012), the close range of the pasting temperature displayed by the CMD-resistant cassava varieties is an indication of similarities in their gelatinization temperature Differences in pasting temperature can be attributed to the amylose and phosphorus content of the material (Peronni *et al.*, 2006). Bemiller *et al.* (2011) also reported that the linear and strongly associated nature of amylose leads to high resistance in starch swelling, mechanical agitation, and increased leaching of amylose, these ultimately elevate the pasting temperature of starch molecules leading to the production of a firm gel during cooling. The difference in pasting temperature observed among the varieties investigated may therefore be attributed to the relatively high amylose content of the fresh cassava roots. Pasting temperature according to BeMiller *et al.* (2011) is an indicator of the temperature required to cook the flour beyond its gelatinization point and also serves as an indicator of energy cost for processing (Awoyale, 2020).This suggests that the time and energy required to prepare ready-to-eat fufu with roots from the local variety will be less compared to that used for NR-COB-7-24 and the other varieties (Arinola *et al.*, 2017). This suggests that the local cassava variety with low pasting temperature will require a shorter time to paste and less amount of energy to form stiff dough during the cooking of the ready-to-eat *fufu* compared to NR-COB-7-24 and the other varieties that have higher pasting temperatures (Arinola *et al.*, 2017). Low pasting temperature has also been associated with low water absorption capacityin cassava flour blends (Ojo *etal.*, 2017)

Table 6: Pasting Properties of 12 Newly Bred Cassava and Locally Preferred Varieties

Variety	Peak	Trough	Breakdown	Final Viscosity	Set back	Peak time	Pasting temp
LOCAL	525.415^{a}	252.500^{a}	272.92^{e}	315.790^{ab}	63.290^{bc}	4.70^{ab}	73.58^{g}
TMS30572	524.250^{a}	212.040^{c}	321.21^{cd}	26.085^{d}	48.045^{d}	4.27^{d}	74.45^{f}
IITA-TMS-IBA1071313	518.040^{a}	232.375^{b}	285.67^{de}	293.835^{bc}	61.455^{c}	4.51^{c}	74.73^{ef}
NR05/0362	516.040^{a}	231.540^{b}	284.50^{de}	292.665^{c}	61.125^{c}	4.80^{a}	76.70^{bc}
TMS 01/0034	515.875^{a}	232.915^{b}	282.96^{de}	317.795^{a}	84.85^{a}	4.64^{abc}	75.53^{de}
NR05/0107	508.540^{ab}	224.875^{bc}	283.67^{de}	296.625^{abc}	71.750^{b}	4.57^{bc}	77.20^{b}
TMS 1070337	506.250^{ab}	226.250^{bc}	28.00^{de}	277.540^{cd}	51.290^{d}	4.54^{bc}	74.00^{fg}
NR05/0046	458.835^{bc}	61.375^{e}	397.46^{a}	9.375^{ef}	29.000^{e}	3.87^{fg}	74.75^{ef}
NR05/0166	448.835^{c}	82.415^{d}	366.42^{ab}	108.920^{e}	26.500^{ef}	4.00^{f}	74.75^{ef}
NR8082	373.250^{d}	52.045^{e}	321.21^{cd}	77.040^{f}	25.000^{ef}	4.04^{ef}	76.35^{bcd}
IITA-TMS-IBA102045	362.790^{d}	21.540^{f}	341.25^{bc}	39.545^{g}	18.000^{fg}	3.90^{f}	76.73^{bc}
NR COB-7-25	344.585^{d}	55.080^{e}	289.50^{de}	79.125^{f}	24.040^{ef}	4.20^{de}	78.40^{a}
IITA TMS1070134	319.210^{d}	14.500^{f}	304.71^{cde}	25.000^{g}	1.500^{g}	3.73^{g}	75.90^{cd}

NS, Not significant.;

Means with different superscripts in the same column are significantly different $p < 0.05$

CONCLUSION AND RECOMMENDATIONS

The findings of this study reveal significant varietal differences in the chemical, functional, and pasting properties of cassava roots that are critical to fufu production. High dry matter and starch contents, moderate sugar levels, and favorable amylose-to-amylopectin ratios were observed in several improved cassava varieties, aligning with consumer-preferred traits for fufu. Functional parameters such as swelling power, solubility, and water absorption capacity, along with pasting characteristics—especially peak and setback viscosities—further highlighted the potential of specific varieties to produce fufu with optimal texture, moldability, and shelf-stability. Notably, some improved varieties, including NR05/0362 and TMS01/0034, demonstrated equal or superior quality traits relative to the traditionally favored local clone, suggesting they could serve as viable replacements in fufu value chains. Additionally, varieties with low hydrogen cyanide content enhance the safety profile of raw cassava material. These findings underscore the importance of integrating end-user quality traits into breeding programs and will therefore serve as a vital tool in promoting evidence-based selection of cassava varieties that meet the dual demands of fufu processors and consumers in Nigeria's market.

Further research is required to evaluate the specific interaction between these physicochemical parameters and desired fufu sensory and textural quality traits. Again, determining the effect of environment on these physicochemical parameters as well as sensory profile and consumer acceptability test of fufu samples produced from these improved cassava varieties may provide a valuable guide for breeders and enhance selection process.

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