Potentials of rice as a suitable alternative for the production of *ogi* (a cereal-based starchy fermented gruel)

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Abstract: In the present study, the physicochemical and sensory properties of *ogi* (a cereal-based starchy fermented gruel) produced from two local rice varieties, *Abakaliki* and *Tapa*, were determined. *Ogi* from white maize served as the control. There was a gradual increase in temperature from approximately 28 to 30 °C during fermentation. White maize exhibited the highest acidity level throughout the fermentation period. *Tapa* and *Abakaliki* rice *ogi* samples (i.e., TRO and ARO, respectively) were higher in yields and amylose contents than white maize *ogi* (WMO). WMO had significantly ($P < 0.05$) lower moisture content (54.14%) than ARO (62.18%) and TRO (68.02%). The highest and lowest sedimentation rates recorded for WMO and TRO, respectively, were attributed to difference in moisture contents and granule bulk densities. WMO showed higher solubility indices (3.54 to 4.66%) at all the temperatures (60 to 100 °C) tested. TRO and ARO had higher final and setback viscosities, as well as pasting temperatures than WMO, but were lower in breakdown viscosity. *Ogi* samples from rice recorded significantly ($P < 0.05$) higher L^* values and distinct color characteristics with reference to a sample from maize, and this was suspected to have partially influenced their higher preference by the panelists during sensory evaluation. Rice is not just suitable for *ogi* production but looks promising to enjoy even more consumer acceptability than maize in this respect. However, there are notable peculiarities, such as major roles attributable to amylose contents.

Keywords: acceptability, fermentation, *ogi*, physicochemical, rice

Practical Applications: The study confirms the potential of rice as a promising alternative to white maize in the production of *ogi* while comparing the quality attributes of products from the two cereal types. Results from the study represent useful scientific insights into the distinct variations in some properties of rice and maize during fermentation. Production of *ogi* from rice, such as *Abakaliki* and *Tapa* varieties, may present an effective strategy to support government's political will aimed at promoting local rice in Nigeria and in Africa at large.

1. INTRODUCTION

Literature abounds with information on the production of *ogi* from maize (Bolaji, Adenuga-Ogunji, & Abegunde, 2017a; Okara & Lokoyi, 2012), millet (Inyang & Idoko, 2006; Olawale, Oyeleke, Akinro, & Olakunle, 2012), sorghum (Adelekan & Oyewole, 2010; Apotiola, 2013), or the combination of two or more of these cereals (Eke-Ejiofor, 2018; Odewole et al., 2017). However, despite being one of the most important cereal crops in the world, as well as the most economically important crop in developing countries (Ajala & Gana, 2015), there is dearth of information on the suitability of rice for *ogi* production. Meanwhile, *ogi* is described as a cereal-based food (Inyang & Idoko, 2006), but whether or not this hypothesis includes rice is a question yet to be satisfactorily answered.

Ogi, as being referred to in Western Nigeria, is also known as *akamu* and *furali* in southeastern and northern parts of the country, respectively (Okara & Lokoyi, 2012). The English name given to the product in Nigeria is "pap," owing to its nonrequirement for chewing, and suitability for people having intestinal disorders. It is a major staple food, consumed by children, adults, and convalescents, and traditionally the first native food that infants are introduced to, either for supplementation of breast milk (Okara & Lokoyi, 2012) or as a weaning diet when they are 3 to 6 months old. The traditional production of *ogi* involves 1 to 3 days of steeping, followed by wet-milling, of the cereal grain of interest, then sieving of the resulting slurry and fermentation of obtained filtrate. The resulting sour wet slurry is normally prepared into a ready-to-consume gruel by stirring in hot water, then optionally sweetened with sugar or honey, depending on individual's choice. The color of the product varies with the type and variety of cereal used; while the color of *ogi* made from white maize is creamy, yellow, or white; when made from sorghum or millet, the product is typically reddish brown and dirty gray in color, respectively (Okara & Lokoyi, 2012).

At present, there is limited product versatility from Nigerian local rice varieties. This means local demand for these grains is yet very low. Meanwhile, if the government policies and efforts over

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the years aimed at promoting local rice production in the country (National Bureau of Statistics, 2018) are to be sustainably attained, the need for increase in local demand cannot be overemphasized. Identification of more uses for a crop is an effective way to improve its market demand and boost its cultivation (Wijesinghe & Sarananda, 2010). This strategy, particularly for local rice in Nigeria, would prove more effective when the new product in question commands wide consumers' base. An example of such products is *ogi*, a staple food for over 70% of Nigerians (Okara & Lokoyi, 2012).

Bolaji, Peluola-Adeyemi, Ojo, and Akande (2017b) investigated the feasibility of *ogi* production from rice and found out that the product recorded consumers' acceptability that was comparable to *ogi* produced from maize. But detailed data from this study were not provided. Furthermore, important variables such as changes in some key physicochemical properties during fermentation, as well as the yield (recovery) and pasting characteristics of the products, were not reported. Also, there is no evidence that the optimum length of fermentation/souring with the best sensory results was established—this is important as fermentation requirement is a function of the type of substrate used.

Therefore, a 2-day fermentation/soaring period was adopted in the production of *ogi* from two varieties of *Oryza glaberrima* (*Abakaliki* and *Tapa*). Changes in some selected physicochemical indices during fermentation, as well as quality attributes including yield, pasting, and sensory properties of the products, in comparison with a sample from maize were investigated. Since maize has been reported to be the most popular cereal in the production of *ogi* in Nigeria (Bolaji et al., 2017a), it served as a reference sample in this study.

2. MATERIALS AND METHODS

Two local rice varieties (*Tapa* and *Abakaliki*) and white maize were obtained from Ipata market in Ilorin, Nigeria. The grains were packaged in tightly closed containers to prevent attack by insects and rodents, and then stored in a moisture-free environment for subsequent use.

2.1 Production of *ogi*

Method described by Omemu and Bankole (2015) was used with little modifications. The two local rice varieties were sorted to remove stones, dirt, and other extraneous materials, and then washed with clean potable water. The washed grains were steeped in clean water in ratio 2:3 (w/v) (Adelekan & Oyewole, 2010) at ambient temperature (28 ± 2 °C) for 2 days. Thereafter, the steep water was decanted and the grains were wet-milled (Mini-Processor Model A90LD, Thorn Emi Ken-wood Small Appliance Ltd., Hampshire, UK). Clean water was added to the resulting slurries (1:5 w/v) that were then wet-sieved with a muslin cloth of about 300 μm pore size. The filtrates obtained from the two rice varieties were each divided into three equal portions and were separately allowed to undergo sedimentation and natural fermentation for 1, 2, and 3 days, respectively (being the range commonly used for *ogi* production from maize, millet, or sorghum (Omemu & Bankole, 2015)) at ambient temperature (28 ± 2°C) (Adelekan & Oyewole, 2010). Following decantation of the filtrate, soured wet sediments (*ogi*) obtained were then prepared into a ready-to-consume gruel (as described in Section 2.9). These were then evaluated for overall acceptability by a 50-semitrained member panel.

Fermentation time (2 days) giving the highest mean overall acceptability score was then used in the main study to produce fresh *ogi* samples separately from the two local rice varieties and white variety maize grains following the same procedure described above. The samples were then packaged in polypropylene bags and stored in a cool dry place for subsequent analyses.

2.2 Determination of changes in temperature, pH, total titratable acidity, and total sugar during fermentation

These analyses were carried out at day 0, 1, and 2 of fermentation period. Temperature and pH were measured using a thermometer (Model 2751-K, Digitron instrumentation Ltd., Preston, UK) and pH meter (Corning Scholar 425, UL Laboratories, Shenzhen, China), respectively. Total titratable acidity was carried out according to previously described methods of Association of official Analytical Chemists (A.O.A.C., 2005) while total sugar was determined using Lane and Eynon method as described by Shahnawz, Sheikh, and Khaskheli (2012).

2.3 Determination of *ogi* recovery

This was determined according to the method of Akingbala, Rooney, and Faubion (1981). The *ogi* samples were oven-dried at 60 °C until constant weight was attained. Subsamples were then oven-dried at 130 °C for 2 hr. The residual moisture contents of these were then calculated and the *ogi* recoveries were calculated by dividing the weights of the dried *ogi* by the weights of the grain used on dry basis.

2.4 Moisture determination

The moisture contents of the *ogi* samples were determined using A.O.A.C. (2005) method. Briefly, 3 g of the *ogi* sample was oven-dried at 135 °C for 2 hr. The sample was cooled in a desiccator afterwards, and moisture content was calculated as the percentage weight loss.

2.5 Amylose determination

Procedure described by Akintayo et al. (2019) was used. Suspension containing 20 mg of the sample and 10 mL of 0.5 M KOH solution was transferred into 100 mL flask that was then filled to the mark with distilled water. Thereafter, to an aliquot (10 mL) of the suspension, 5 mL of 0.1 M HCl and 5 mL of iodine reagent (0.0025 M I_2/0.0065 M KI) were added in that order. This was diluted to 50 mL, and absorbance was taken at 625 nm using a spectrophotometer (model Jenway 7305, Bibby Scientific, London, UK). Amylose content was then measured using a standard curve that had been prepared from different concentrations (0–50%) of reference amylose from potato starch (BDH Chemical Ltd, England).

2.6 Solubility index

This was carried out following a documented procedure as described by Bolaji, Oyewo, and Adepoju (2014) with little modification. *Ogi* samples were each weighed (0.5 g, dry basis) into 10 mL distilled water in a separate test tube, heated in water bath at 60, 80, and 100 °C. After 30 min of heating at each temperature, the samples were cooled, and then centrifuged (Centra GP8R, International Equipment Company, USA) at 2000 × g for 30 min. The decanted filtrates (5 mL) after centrifugation were then transferred into an air oven and dried at 105 °C to constant weights. The solubility indices were then calculated as percentage weights of dissolved solids per heated *ogi* samples.

2.7 Determination of pasting properties

The pasting properties of the various *ogi* samples were determined using a Rapid Visco-Analyzer (RVA) (Newport Scientific Instruments, Australia) according to RVA corn-starch method (Ribotta, Colombo, & Rosell, 2012). The *ogi* samples were each prepared into a suspension (28.0 g) by addition of amount of sample equivalent to 3.0 g dry starch (Jude-Ojei, Lola, Ajayi, & Seun, 2017). This was stirred initially at 960 rpm for 10 s and subsequently at 160 rpm for the remainder of the test period. The analysis was carried out as follows: the sample was equilibrated at 50 °C for 1 min. Thereafter, the temperature was raised to 95 °C over a period of 4 min 42 s. The sample was held at 95 °C for 3 min, after which it was cooled to 50 °C within 3 min 42 s. It was then held at 50 °C for 2 min. Parameters determined include peak viscosity (Rapid Visco Unit, RVU), trough viscosity (RVU), breakdown viscosity (RVU), final viscosity (RVU), setback (RVU), peak time (min) and peak temperature (°C).

2.8 Hunter color determination

The CIE tristimulus L^*, a^*, and b^* parameters of the *ogi* samples were measured using a chroma meter (ColourFlex-Diffuse, A60-1014-593, Hunter Associates Laboratory, Reston, VA, USA) (45°/0° geometry, illuminant D65). The chroma meter operates on the International Commission on Illumination (CIE) L^*, a^* and b^* color schemes, where L^* means "lightness" (axis: 0 is black, 100 is white), a^* means "red-green" (axis: positive values are red, negative values are green, and 0 is neutral), b^* means "yellow-blue" (axis: positive values are yellow, negative values are blue, and 0 is neutral). Prior to the analyses, the instrument was standardized. Measurements were taken in triplicates.

Total color difference (ΔE) was calculated as follows:

$$\Delta E = \sqrt{\Delta a^2 + \Delta b^2 + \Delta L^2}$$

where: $\Delta a = a_1 - a_0$

$$\Delta b = b_1 - b_0$$

$$\Delta L = L_1 - L_0$$

a_0, b_0, and L_0 are corresponding values for the control sample.

2.9 Sensory evaluation

The Department of Home Economics and Food Science, University of Ilorin, Nigeria reviewed and approved the study before sensory evaluation was conducted. The consent of each panelist was also obtained to indicate their willingness to participate in the sensory evaluation.

First, the *ogi* slurries were separately prepared into ready-to-consume gruels as follows: each was prepared into a suspension by pre-dissolving five teaspoons in 25 mL of potable water. This was then mixed with 350 mL of boiled water and continuously stirred for 5 min to prevent formation of lumps. The resulting gruels were allowed to cool to about 40 °C, then alphanumerically coded and presented to 50 panelists, comprising of students and staff from the Department of Home Economics and Food Science, University of Ilorin, Nigeria, who are familiar with *ogi*. The panelists were screened and selected based on their ability to recognize sensory attributes of *ogi*.

Prior to selection of the sensory panelists, screening was done based on the ability of the prospective panelists to discern important quality attributes of *ogi* and their interest to participate in the sensory evaluation. The panelists were asked to assess the samples based on appearance, aroma, taste, mouthfeel, and overall acceptability, using a 9-point hedonic scale where 1 and 9 represent "dislike extremely" and "like extremely," respectively.

2.10 Statistical analysis

Data obtained from various analyses above were subjected to analysis of variance and means generated were separated by multiple range of comparison test (Duncan) using the statistical package for social sciences (SPSS, Version 20.0).

3. RESULTS AND DISCUSSIONS

3.1 Changes in some selected physicochemical properties during fermentation

Temperatures of the fermenting rice and maize slurries were in the ranges of 28.3 to 28.9 °C and 28.2 to 29.8 °C, respectively (Figure 1A) over the 2-day fermentation period. There was a steady increase in all the three samples, however this was more rapid in maize than rice. This may be connected with higher rate of anaerobic respiration in maize than rice as deducible from a correspondingly higher acidity in maize (Figure 1B and 1C). However, generally, the pattern of temperature increase was similar with both cereal types, as both witnessed higher temperature rise within the last one day than the first day. Temperature values recorded in the present study are in agreement with previous results (approximately 28 to 30 °C) (Okowa, Kigigha, & Izah, 2016; Omemu, 2011).

There was a consistent decrease in pH of maize and rice during fermentation (Figure 1B). At the start of the fermentation, pH of maize slurry was 5.25, while that of rice was 6.04 (*Abakaliki*) and 6.02 (*Tapa*). After the first day (24 h), these pH values had fallen to 4.91, 5.56, and 5.43, respectively. However, similar pH values (approximately 4) were attained at the end of the 2-day fermentation process. It turned out that the fall in pH was generally more pronounced at the last day of fermentation than the first for all the samples. This trend is similar to earlier observation by Nwokoro and Chukwu (2012). The authors reported that the pH of maize dropped approximately from 6.6 to 4.3 during a 2-day fermentation, with higher fall being recorded in the last day. Slightly lower values (5.84–3.74) were however reported by Omemu, Okafor, Obadina, Bankole, and Adeyeye (2018).

Total titratable acidity (TTA) steadily increased with increasing fermentation time (Figure 1C). Maize had higher values (0.63 to 0.83%) than both local rice varieties (0.30 to 0.51%). The increasing pattern was similar in maize and *Tapa* rice while *Abakiliki* showed a higher increasing rate at the last day. TTA values obtained are higher than some ranges (approximately 0.3 to 0.7%) in the literature (Nwokoro & Chukwu, 2012; Omemu et al., 2018). However, Adeyemi and Beckley (1986) had earlier described that the TTA of *ogi* made from maize may vary between 0.12% and 1.2%, depending on factors such as moisture contents and methods of analysis.

Higher acidity accumulation in maize during fermentation as indicated by lower pH and higher TTA is presumably due to easier starch hydrolysis as a result of lower amylose content (Figure 2). This may also be associated with higher total sugar content at the start of fermentation (Figure 1D). This probably meant more availability of fermentable substrates in maize than rice. pH represents the amount of free hydrogen ions while TTA measures both free and bound hydrogen ions, and both as an indication of acidity have implications on flavor and shelf stability of food

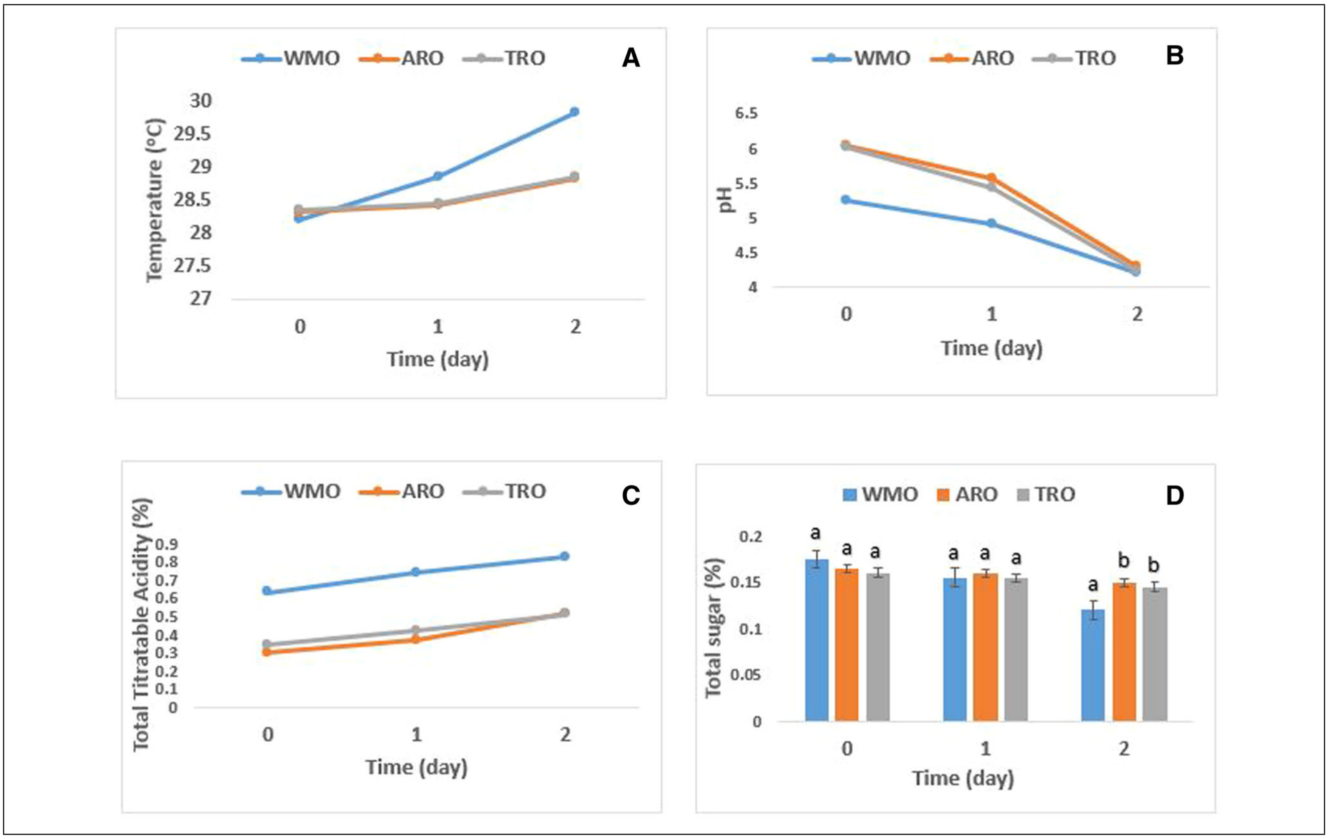

Figure 1–Changes in temperature (A), pH (B), total titratable acidity (TTA) (C), and total sugar (D) of *Abakaliki* rice, *Tapa* rice, and white maize during fermentation for *ogi* production. WMO, White maize *ogi;* ARO, *Abakaliki* rice *ogi;* TRO, *Tapa* rice *ogi*. Values are means ($n = 3$) ± standard deviations; means within the same column having any different superscript(s) differ significantly ($P < 0.05$).
Note: *Y* axes on Figure 1A and 1B start from 27 and 4, respectively, to show differences in values more clearly

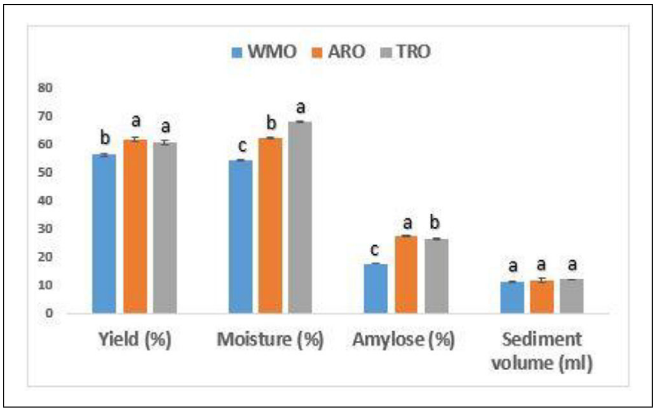

Figure 2–Yields, moisture, amylose contents and sediment volumes of *ogi* from selected local rice varieties and white maize. WMO, White maize *ogi;* ARO, *Abakaliki* rice *ogi;* TRO, *Tapa* rice *ogi*. Error bars represent standard deviations of triplicate determinations. Bars for the same parameter not followed by the same letter are significantly ($P < 0.05$) different.

products. Acidity development during *ogi* production has been majorly linked to the activity of lactobacilli (Nwokoro & Chukwu, 2012). These bacteria predominantly produce lactic acid, with a resultant antimicrobial effect and sour taste. Therefore, it is plausible that *ogi* from rice would be less sour and more prone to microbial attack during storage than a sample from maize.

Total sugar contents steadily reduced (Figure 1D) as fermentation progressed irrespective of cereal type. However, maize recorded highest reduction (from approximately 0.18% at day 0 to 0.15% at day 2) while *Tapa* rice recorded the lowest (from approximately 0.16 at day 0 to 0.15% at day 2). The higher reduction rate of total sugar content in maize coincided with a correspondingly higher acidity accumulation, suggesting that the sugar was being converted into lactic acid by fermenting microorganisms. Though, total sugar was higher in maize than rice at the beginning of fermentation, rice showed significantly ($P < 0.05$) higher values at the end. Previously, 0.23% and 0.0033 to 2.4% were reported for *ogi* made from maize (Eke-Ejiofor & Beleya, 2017) and different sorghum varieties (Ajani, 2010; Akingbala et al., 1981), respectively. It is therefore suggestive that sugar contents of *ogi* depend on cereal type and variety.

3.2 Yield of *ogi*

The yield of *ogi* made from rice was approximately 8 to 9% higher than yield from maize (Figure 2). This observed difference can be accounted for by the nature of the grains. The maize grains used in this study, just as practiced traditionally, were not dehusked, hence were not like the rice grains that had little to no bran. The loss of this fibrous part during the sieving operation of the maize *ogi* slurry eventually resulted in a lower yield. This may partly explain why high amount of bran in maize is found undesirable by *ogi* producers from an economic point of view (Omueti, Iken, Kling, & Okoruwa, 2006). This suggests that *ogi* producers might well prefer rice for *ogi* production in this respect. *Ogi* yields in the ranges of 51.2 to 60.0% (Adeyemi, 2018) and

42 to 62% (Omueti et al., 2006) have been previously reported for different varieties of maize studied. Aside cereal types and varieties, differences in *ogi* yields can be attributed to differences in aperture size of sieve (Omueti et al., 2006) and processing methods (Nago, Hounhouigan, Akissoe, Zanou, & Mestres, 1998).

3.3 Moisture content

Maize *ogi* was significantly lower in moisture (with value of 54.14%) than samples from the two rice varieties (62.18 to 68.02%) (Figure 2). The brans of maize probably caused restriction in its water intake during soaking unlike in rice grains where water absorption was relatively higher. However, the difference between the moisture contents of *ogi* samples from the local rice varieties can be associated with their amylose contents, suggesting that *Tapa* rice absorbed more water during soaking due to its less amylose content (Figure 2) as compared to *Abakaliki* rice. Similar relationship between amylose and water absorption has been documented (Ayadi, Rosentrater, Muthukumarappan, & Kannadhason, 2016). Bolaji et al. (2011a) previously reported about 50.4% as the moisture content of maize *ogi*. The higher moisture contents obtained for *ogi* samples from *Abakaliki* and *Tapa* rice is a peculiarity, implying that less amount of water will be required during their preparation into a ready-to-consume gruel. *Ogi* slurry is usually made into a suspension before addition of hot water, and the viscosity of this suspension determines the proper development of the final gruel. The difference in moisture contents might also imply differences in shelf stability. However, the preservation of *ogi* derives majorly from its acidity and the traditional practice of regular decantation and replacement of its surface water, to prevent mold growth.

3.4 Amylose contents

Ogi samples from rice were significantly higher in amylose contents (26.34–27.45%) than a sample from maize (17.71%) (Figure 2). This wide variation suggests consequential variation in some physicochemical properties of the samples during reconstitution in hot water. For example, amylose content (%) has been reported to influence the solubility (%) (Kibar, Gönenç, & Us, 2010) and swelling power (%) (Eke-Ejiofor, 2018) of starchy food materials. The amylose content of *ogi* from maize in this study falls within the range of 17.66–18.92% previously reported with 1–5 days fermentation (Adegunwa, Alamu, Bakare, & Godwin, 2011). Variation in amylose contents has a remarkable implication on the susceptibility of starchy foods to hydrolysis. For instance, high amylose content is associated with a low glycemic response and recommended for diabetic patients for a controlled blood glucose level (Denardin, Boufleur, Reckziege, da Silva, & Walter, 2012). This implies some probable health benefit of *ogi* samples made from rice. However, higher amylose contents might also indicate less suitability of these samples as a weaning food, due to possibly lower digestibility when compared to maize *ogi*, but it has been observed that prediction of starch digestibility from the standpoint of amylose content alone can be inaccurate (Gayin, 2015).

3.5 Sedimentation property

After the first 30 min of settling, maize *ogi* exhibited the highest sedimentation rate of 1.10 mL/min, while *Tapa* rice *ogi* had the lowest (0.9 mL/min) (Figure 3). The variation observed may be associated with differences in bulk densities of starch granules. This probably complemented the effect of gravitational force on the starch granules of maize *ogi* slurry, leading to enhanced settling. Higher bulk densities have been recorded for the starch granules of maize than those of rice (Ali, Wani, Wani, & Masoodi, 2016). Inverse relationship between moisture contents and sedimentation property is also suggested. This is plausible, as the higher the moisture content, the lower the bulk density, thus the lower the sedimentation tendency. Sedimentation property can be used as an index to assess the extent of damage to starch gelatinization, swelling power, and cooking quality (Bolaji et al., 2014). Specifically, sedimentation is a very vital parameter since it is one of the key unit operations involved in *ogi* production. Slower sedimentation rate may prolong production process, or result in lower yield if not allowed to fully complete as much solids fraction dispersed in fermenting water may be lost during decantation.

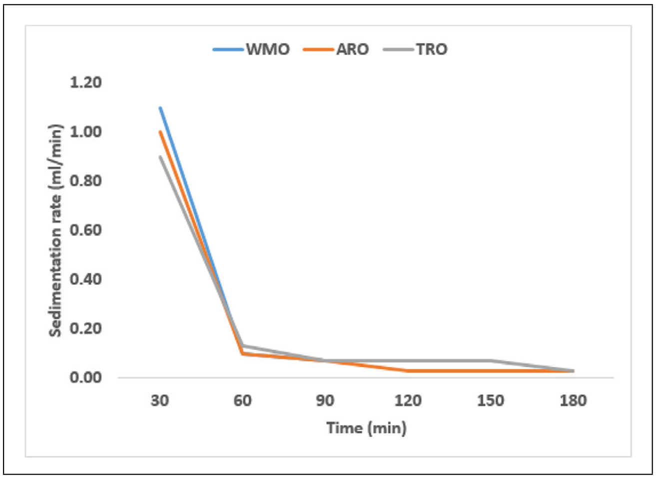

Figure 3–Sedimentation rate (mL/min) of *ogi* slurry from selected rice varieties and white maize.
WMO, White maize *ogi;* ARO, *Abakaliki* rice *ogi;* TRO, *Tapa* rice *ogi*.

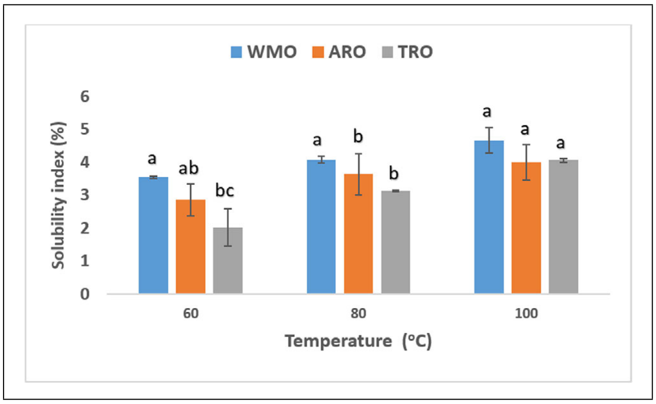

Figure 4–Solubility indices of *ogi* from selected local rice varieties and white maize. WMO, White maize *ogi;* ARO, *Abakaliki* rice *ogi;* TRO, *Tapa* rice *ogi*. Values are means ($n = 3$) ± standard deviations. Bars for the same parameter not followed by the same letter are significantly ($P < 0.05$) different

3.6 Solubility indices

The *ogi* samples showed significant ($P < 0.05$) variations in solubility indices, with the sample from maize exhibiting higher values (3.54, 4.07, and 4.66% at 60, 80, and 100°C, respectively) than those from rice (Figure 4). The main factor responsible for this difference could not be ascertained, but a similar observation has been earlier reported by Ali et al. (2016). The authors found the solubility indices of maize starches to be higher than those of rice. Solubility indices in the range of 0.37–0.01 g/g (37 to 1%) were reported for *ogi* using different soaking times (12 to

Table 1–Pasting properties of *ogi* from selected local rice varieties and white maize.

Parameter	Peak viscosity (RVU)	Trough (RVU)	Break down (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (min)	Pasting temperature (°C)
WMO	$1701.5^{a} \pm 44.6$	$1310.0^{b} \pm 42.4$	$391.5^{a} \pm 2.1$	$2004.0^{b} \pm 70.7$	$694.0^{b} \pm 28.3$	$6.8^{b} \pm 0.03$	$78.3^{c} \pm 0.0$
ARO	$1638.0^{b} \pm 7.1$	$1401.5^{ab} \pm 31.8$	$236.5^{b} \pm 24.7$	$2415.5^{a} \pm 34.7$	$1014.0^{a} \pm 66.5$	$6.5^{a} \pm 0.09$	$86.4^{b} \pm 0.0$
TRO	$1781.5^{a} \pm 0.7$	$1487.0^{a} \pm 31.1$	$294.5^{b} \pm 31.8$	$2283.5^{a} \pm 19.1$	$796.5^{b} \pm 50.2$	$6.5^{a} \pm 0.09$	$89.6^{a} \pm 0.0$

WMO, White maize *ogi;* ARO, *Abakaliki* rice *ogi;* TRO, *Tapa* rice *ogi*. Values are means ($n = 3$) ± standard deviations; means in the same column having any different superscript (s) differ significantly ($P < 0.05$)

36 hr) and drying temperatures (40 to 60 °C) when tests were carried out between 60 °C and 90 °C heating (Bolaji et al., 2014). Olorode, Idowu, and Ilori (2013) reported solubility index of 5.77% at 30 °C for yellow maize *ogi*, while Mathew, Adebowale, and Oladayo (2018) found varying values within 1.21 to 3.36% at 50 to 90 °C for *ogi* produced from sorghum. These widely differing results suggest the roles of factors such as a soaking period, drying temperature, cereal type, and variety, as well as test heating temperature on the solubility powers of fermented cereal products.

While the lower amylose (higher amylopectin) content of maize *ogi* might be suspected for its higher solubility (Kibar et al., 2010), same hypothesis cannot explain the difference between *ogi* samples from the rice grains. However, some significant negative correlation has been previously reported between moisture content and water solubility index (Yousf, Nazir, Salim, Ahsan, & Sirwal, 2017). Furthermore, aside amylose content, factors influencing solubility index of rice starches include viscosity patterns and the presence of negatively charged phosphate groups within the granules (Ali et al., 2016). Solubility of *ogi* is important particularly since the product is usually reconstituted in water when being prepared into a ready-to-consume gruel. The higher the solubility, the better the reconstitution of *ogi* in water (Bolaji et al., 2014).

The solubility indices of all the *ogi* samples, irrespective of cereal type, increased with increase in temperatures between 60 °C and 100 °C, with samples from rice showing higher percentage increase when compared to the sample from maize. The general increase in solubility with increasing temperature is at variance with the report of Bolaji et al. (2014) but consistent with the findings of Olorode et al. (2013) and Mathew et al. (2018).

3.7 Pasting properties

Ogi made from *Tapa* rice recorded the highest peak viscosity (1781.0 RVU) but this difference was not significant when compared with a sample from maize (Table 1). The significantly lower peak viscosity of *ogi* from *Abakaliki* rice than a sample from *Tapa* rice may be connected with its higher amylose content (Figure 2). Amylose is believed to inhibit swelling of starch, and high swelling power is required for high peak viscosity. Since peak viscosity indicates the maximum viscosity attained during or after heating, it may be presumed that *Abakaliki* rice may not be preferred by consumers who desire that maximum thickness of *ogi* be developed during or immediately after preparation, rather than later. However, it is interesting to note that *ogi* made from maize, which had the least amylose content (Figure 2), was not the highest in peak viscosity, suggesting that amylose was not the sole determining factor in this study. This is plausible as other factors such as starch granule size and composition, as well as the presence of nonstarch components, also affect peak viscosity (Akintayo et al., 2019).

Lowest trough was obtained for *ogi* from maize (Table 1), indicating that at a constant temperature, immediately after peak viscosity had been attained, the sample became least viscous, having lost about 23% of its original (peak) viscosity, while samples from the local rice varieties recorded between 14.44% and 16.53% reductions. Trough is an important pasting parameter for starchy foods that normally undergo prolonged holding at a constant temperature after attaining maximum viscosity. Though, preparation of *ogi* into a ready-to-consume gruel does not traditionally involve prolonged holding at a constant temperature, occasionally, this is required when the right consistency is not obtained after hot water has been added to *ogi* slurry off heat source, hence cooking on a heat source for some time may be adopted as a corrective measure. It therefore implies that in case a prolonged cooking on a heat source is required, *ogi* from either of the two local rice varieties will give a relatively higher viscosity than a sample from maize. Trough denotes the capacity of starch paste to hold water at a constant temperature, so sometimes referred to as a holding viscosity. The results recorded in this study are therefore consistent with earlier study that rice had a higher water absorption capacity than maize (Olayemi, Oyi, & Allagh, 2008). The authors reported that rice and corn starches exhibited capacities to absorb three and two times of their own weights, respectively.

Breakdown viscosity ranged from 236.0 to 391.5 RVU for *ogi* samples from *Abakaliki* rice and maize, respectively. The significantly lower breakdown values of *ogi* from rice (Table 1) suggest less tendency to rupture during heating and shear, and is a vital requirement for the stability of a cooked paste (Ayo-Omogie & Ogunsakin, 2013). This may in turn be attributed to higher amylose content (Figure 2). Chinnaswamy and Bhattacharya (1984) had earlier observed increasing shear strength of starch extrudate with increasing amylose content. Possible difference in a starch granule size might have also influenced the extent of breakdown, as Ali et al. (2016) reported a larger (103–119%) granule size for maize than rice cultivars studied and Zakpaa, Al-Hassan, and Adubofour (2010) had previously explained that a larger granule size makes starch more sensitive to shear.

Ogi from rice were approximately 14 to 21% higher in the final viscosity than a sample from maize (Table 1). Similar results have been reported by Ali et al. (2016) while comparing the pasting properties of starches from some rice and maize cultivars. Since higher final viscosity of *ogi* limits its suitability for infants (Ayo-Omogie & Ogunsakin, 2013), it may be necessary to modify the processing operations when producing *ogi* from rice, for reduced paste viscosity. One way to achieve this is prior germination of the grains (Adelekan & Oyewole, 2010). Furthermore, Apotiola (2013) reported a substantial reduction in the final viscosity of *ogi* made from sorghum when the steeping time was increased from 24 to 72 hr. This is extending the hypothesis that though *ogi* might be described as a cereal-based gruel, the use of the local rice varieties in this study might require some modification of the traditional processing process, if the products are to have a similar potential as a weaning food when compared to maize *ogi*.

Generally, higher setback viscosity values were obtained for *ogi* from *Abakaliki and Tapa* rice than a sample from maize (Table 1).

Table 2–Color of cooked reconstituted *ogi* from selected local rice varieties and white maize.

Sample	L^*	a^*	b^*	ΔE
WMO	$58.41^{b} \pm 0.64$	$-7.24^{a} \pm 1.00$	$3.41^{a} \pm 0.83$	
ARO	$62.87^{a} \pm 0.78$	$-6.67^{a} \pm 0.21$	$0.27^{b} \pm 0.15$	15.6 ± 3.34
TRO	$61.40^{a} \pm 0.40$	$-12.19^{a} \pm 8.87$	$0.83^{ab} \pm 0.35$	16.6 ± 0.33

WMO, White maize *ogi;* ARO, *Abakaliki* rice *ogi;* TRO, *Tapa* rice *ogi*. Values are means ($n = 3$) ± standard deviations; means in the same column having any different superscript(s) differ significantly ($P < 0.05$).

Table 3–Sensory properties of *ogi* from selected local rice varieties and white maize.

Parameters	Appearance	Aroma	Sourness	Consistency	Overall acceptability
WMO	$6.28^{c} \pm 1.36$	$6.20^{c} \pm 1.04$	$7.70^{a} \pm 1.18$	$7.04^{b} \pm 1.21$	$6.58^{b} \pm 1.24$
ARO	$7.40^{b} \pm 0.92$	$6.73^{b} \pm 1.09$	$6.70^{b} \pm 1.29$	$7.48^{a} \pm 1.06$	$7.28^{a} \pm 1.01$
TRO	$8.15^{a} \pm 0.77$	$7.83^{a} \pm 0.90$	$6.73^{b} \pm 0.85$	$7.65^{a} \pm 1.15$	$7.73^{a} \pm 0.75$

WMO, White maize *ogi;* ARO, *Abakaliki* rice *ogi;* TRO, *Tapa* rice *ogi*. Values are means ($n = 3$) ± standard deviations; means in the same column having any different superscript(s) differ significantly ($P < 0.05$).

The higher the setback viscosity, the lower the stability of a cooked paste against retrogradation during storage (Jude-Ojei et al., 2017). It therefore implies that there will be faster rates of alteration in the consistency of *ogi* from *Abakaliki* and *Tapa* rice, in that order, while *ogi* from maize will be the most shelf-stable in viscosity. Syneresis is one of the common changes that takes place during storage of cooked *ogi*, and is characterized with moisture release. While the released moisture settles on the surface, the gruel beneath becomes thicker with a reduced flow property. Therefore *ogi* with lower setback viscosity will have lower tendency to undergo syneresis during storage. Though this phenomenon is described to be a result of interaction between leached amylose and amylopectin molecules resulting in the development of functional zones, syneresis resulting from amylose molecules aggregation and crystallization reaches completion within the first few hours of storage while amylopectin molecules are responsible for what happens at later hours (Ali et al., 2016).

Peak time and pasting temperatures of the *ogi* samples were in the ranges of 6.5 to 6.8 min and 78.3 to 89.6 °C, respectively (Table 1). This implies that all the *ogi* samples will attain their maximum viscosity approximately within 6 to 7 min. These values are a little higher than the range (approx. 5 to 6 min) previously reported for *ogi* made from maize in the literature (Bolaji, Awonorin, Olalusi, & Adepoju, 2011b; Ojo & Enujiugha, 2016). This may be associated with differences in cereal type and variety, as well as processing methods. The significantly lower peak time of *ogi* from rice than maize suggests they will require a shorter time to reach their peak viscosity.

The higher pasting temperatures obtained for *ogi* made from rice in this study are similar to the findings of Ali et al. (2016). The authors reported that rice starches, owing to their resistance to swelling, had higher pasting temperatures than starches from maize. Since pasting temperature denotes the onset of gelatinization or increase in viscosity (Fasoyiro & Arowora, 2013), *ogi* made from rice will require higher temperature than a sample from maize for initial increase in viscosity. However, the results generally suggest that all the *ogi* samples can be well cooked into a ready-to-consume gruel, below the boiling temperature.

3.8 Color of cooked reconstituted *ogi*

There were significant ($P < 0.05$) differences in the L^* and b^* values of the various *ogi* samples but a^* values were similar (Table 2). *Ogi* made from *Abakaliki* and *Tapa* rice were significantly ($P < 0.05$) whiter in color than the sample from maize. This suggests different effects of cereal variety on the inherent whiteness of their starches. It can also be inferred that the various starches attained different levels of purity despite being taken through the same processing operations. Implication of this is that *ogi* samples from rice might have some sensory advantage over the sample from maize. This is plausible as consumers look out for whiteness in *ogi*, as well as its derived products (Nago et al., 1998). L^* values (58.41 to 62.87) obtained in the present study are lower than values (80–84) reported in the literature for *ogi* made from white maize (Nago et al., 1998). The difference may be accounted for by the stages at which the color characteristics were assessed. While Nago et al. (1998) examined the color of the samples in their uncooked form, cooked reconstituted samples were assessed in the present study. (This was on the basis that, since *ogi* is usually taken after reconstitution in hot water, which would inevitably lead to some change in color, assessing the color characteristics of the final product may be more desirable from consumers' point of view.) Therefore caramelization of residual reducing sugar in the starches during reconstitution of the *ogi* slurry in hot water may account for the decrease in L^* values. This is consistent with the report of Mathew et al. (2018) that boiling might cause some nonenzymatic browning reaction resulting in reduced lightness of *ogi*.

The total color difference was 15.6 and 16.6 for *ogi* produced from *Abakaliki* and *Tapa* rice, respectively, with the sample from maize as the reference (Table 2). This indicates a substantial color difference between *ogi* samples from rice and maize, and can be attributed to the significant differences in L^* and b^* values. Implication of this is that consumers will well notice the difference in color characteristics of *ogi* made from rice and maize in this study.

3.9 Sensory attributes of cooked reconstituted *ogi*

Ogi samples made from *Tapa* and *Abakaliki* rice both recorded significantly ($P < 0.05$) higher ratings than the sample from maize in all sensory attributes evaluated, except sourness (Table 3). This kind of observation is rare as consumers are not known to readily prefer a newly introduced food substitute to an already established one, due to familiarity with quality attributes of the latter (Akintayo et al., 2019). While the reason for this remains unclear, two factors can be suspected to have influenced the panelists' judgment. First is the whiter (Table 2) and creamier appearance of *ogi* made from rice when compared to that from maize. Color of *ogi* has an influence on consumers' choice with whiteness being expected when made from white maize. This probably made samples from rice more appealing to the panelists. The second factor that might have played a role is the higher viscosity of the samples from rice (Table 1). This can be linked with their consistency ratings (Table 3), suggesting viscosity as one of the desired parameters by the *ogi* consumers. It should however be noted that the sensory study had fewer panelists than standard methods recommend, so the results should be interpreted with caution.

4. CONCLUSION

Ogi produced from *Abakaliki* and *Tapa* rice in this study were approximately 8 to 9% higher in yield than *ogi* from maize. They were also higher in moisture contents but lower in solubility, compared to *ogi* made from maize. Changes in acidity and total sugar were more rapid in maize than rice during fermentation. Higher amylose contents of rice were suspected for the higher retrogradation tendency and higher pasting temperatures exhibited by the *ogi* produced from them. Rice *ogi* were whiter with substantially distinct color, and had more appealing sensory qualities, except in sourness, when compared with *ogi* from maize. They were also more generally accepted by the panelists than maize *ogi*. Success in the application of the result of this research will go a long way in increasing utilization of local rice in Nigeria and in Africa at large.

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AUTHOR CONTRIBUTIONS

Olaide Akintayo conceived the idea of the study and took part in study design and execution, as well as report writing. Yunus Hashim conducted the production and experimental work and took part in report writing. Adesewa Adereti was involved in material sourcing and production work. Mutiat Balogun conducted the design and review of the study. Islamiyat Bolarinwa provided needed literature. Olufunmilola Abiodun was involved in the final review of the study. Adegbola Dauda was involved in the final review of the study. Anuoluwapo Solaja was involved in the literature review. Oluwatoyin Alabi was involved in some experimental work and discussion.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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