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Functional and Pasting Properties of Different Rice Varieties from Ebonyi State Nigeria

Onyekachukwu Obumneme Enyi[1]*, Chukwunwike Uchenna Enyi[2] and Theophilus Chikodi Odom[3]

[1]Department of Biotechnology, Ebonyi State University Abakaliki, P.M.B 501 Ebonyi State, Nigeria

[2]Department of Food Science and Technology, University of Agriculture and Environmental Science Umuagwo, P.M.B 1038 Imo State Nigeria

[3]Department of Food Science and Technology, Abia State Polytechnic, Aba, Nigeria

ABSTRACT

This study was targeted at carrying out a critical comparison of selected varieties of rice obtained from Ebonyi State Nigeria with a view to determining their functional and pasting properties and as well advises both farmers and consumers accordingly. The aim of the research was to determine the functional and pasting properties of selected rice varieties. The paddy rice was processed before determining both functional and pasting properties. Findings from this work indicate that Peak viscosity ranged from 128.50 to 245.50 RVU, with IWA 3 exhibiting the highest value. Breakdown viscosity (22.08-106.75 RVU), trough viscosity (85.08-159.25 RVU), and final viscosity (145.25-294.33 RVU) varied significantly ($p<0.05$) among varieties. Pasting temperature (82.35-85.65°C) and peak time (5.45-5.96 min) showed minimal variation. Bulk density (4.30-4.60 g/cm^3), water absorption capacity (8.20-8.90 g/ml), and gelatinization temperature (70.30-70.90°C) were statistically similar ($p>0.05$) among varieties. Particle size ranged from 0.72 to 0.87 g/g, with no significant differences. These findings suggest varying processing suitability among the rice varieties. IWA 3 stands out as a top-performing variety, exhibiting highest peak viscosity, highest breakdown viscosity, highest final viscosity and high trough viscosity.

***Corresponding author**

Onyekachukwu Obumneme Enyi, Department of Biotechnology, Ebonyi State University Abakaliki, PMB 501 Ebonyi State, Nigeria.

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Introduction

Rice is known to be amongst the staple grains planted and as well eaten by majority of the people in the world, mostly within Africa/Asia continents. Rice serves as a source of carbohydrate to majority of the people in the world [1]. It is regarded to be a valuable product not because it is amongst the food crops being planted, but it as well being consumed by majority of the people in the world [2]. Currently, there are many identified rice varieties in existence. These varieties vary both in their functional and physicochemical properties Rice is an aquatic crop which is mostly cultivated under submergence conditions [3]. Variations in environmental factors and soil nutrient often affect rice growth, yield and quality [4]. Their morphological behaviour differs in various soil nutrient, water levels, climatic conditions, size of seed, panicle length of seed, number of spikelet etc. Climate change has a major impact on rice production, which include reduction in crop yield and as well as the quality of the grain [5]. Degree of milling and type of rice affect the proximate composition of rice because the method removes different layers of rice thereby altering the nutritional value of the rice [6]. Rice grain can be classified among the major source of carbohydrates for billions of people worldwide, most importantly to the developing countries. Generally, small quantity of fat can be found in rice grain, about 70–80% carbohydrate, 12% moisture, 7% digestible protein which is known for its good biological value when compared to other forms of protein found in plant source and dietary fibre [7].

Study on the rice physical attributes is very important for the construction of desired machine that will be used for the processing of rice and also for the creation of standardized operational procedures that will be beneficial in reducing the rate of losses that take place during milling operation. An idea of different density parameters could be beneficial in choosing appropriate size for storage compartments without having any effect on the heat transfer phenomena of moisture in drying and aeration processes [8]. Starch is a major component present in rice, it is responsible for over 80% of the entire composition. Rice starch can serve different purposes such as control of syneresis, as texturiser to enhance the viscosity of the food product and as well as the shelf-life properties [9]. Rice starch is commonly employed in rice cakes, flour and as well as in different snack products due to its ability to form fine particle grain, exhibit quality flavour, light colour and better pro cessing properties [10]. Different varieties of rice are being produced in Nigeria. One of the most commonly cultivated varieties of rice in Nigeria is the Faro varieties [11]. These varieties differ from one another with regard to their different characteristics. This implies that a specific rice variety grown in one region may have different characteristics than the same variety grown in another region [11]. Therefore, the study was aimed at carrying a critical comparison of selected varieties of rice from different Ebonyi State Nigeria with a view to determining their functional and pasting properties and as well advises farmers and consumers accordingly.

Materials and Method

Raw Material Source

Ten rice paddy varieties IWA 1, IWA 2, IWA 3, IWA 6, IWA 7, IWA 8, FARO 44, FARO 52, Agreement and Argwula were purchased from Biotechnology Research and Development Centre (BRDC) Ebonyi state University Abakaliki.

Preparation of Samples

After harvesting, the grains were sun dried to a moisture content of 13 – 14% and then cleaned thoroughly to remove unwanted materials like husks, broken stalks, chaffs, and immature grains in order to obtain whole grain samples for the experiment following the methods of Enyi et al. and Compaore et al. [11-12].

Parboiling of Paddy

The samples were parboiled using the method of Enyi et al. [11]. Paddy hydration was achieved by soaking grain in water at room temperature (28oC) for 14 hrs in other to reach the desired moisture content of 27%. After that, the samples were separated from the soaking water and were properly washed in a clean tap water and subsequently allowed to drain off. The samples were then steamed using a steamer with a periodic turning of the paddy for even distribution of heat at a temperature of 120oC. The temperature was controlled and maintained using a digital temperature controller (model: XTC5400 India). Steaming was halted after 45 minutes of steam being produced in the paddy. After parboiling, the samples were sun-dried to 12–14% moisture content, then dehusked using a JGMJ 8096 dehusking machine and polished using an LTJM 2090 polisher. The milled rice samples were packaged in airtight containers and stored at room temperature (28°C) pending analysis.

Functional Properties Determination

Bulk Density (BD)

The method of Dhritiman et al. was employed to check for the bulk density (BD) of the samples. The rice samples were filled in a measuring cylinder and leveled. The bulk density was calculated as unit mass per volume occupied by rice grains [13].

Water Absorption Capacity

Water absorption was determined according to the method by Ziad et al. [14]. Two (2 g) of rice grains were cooked with 20 ml of water in a 100 ml beaker placed on a heating mantle. Samples were removed at cooking time, weighed and were calculated using the formula below:

$$\text{Water absorption} = \frac{\text{Weight of cooked rice}}{\text{Weight of raw rice}}$$

Gelatinization Temperature

The method of AOAC was employed to check for the gelatinization temperature of the samples. A 3% (w/v) suspension of the sample was prepared by mixing 3 g of the sample in 3 mL of distilled water [15]. The suspension was heated on a hot plate with a thermometer suspended over it with its bulk immersed in the mixture. It was heated and stirred continuously until it started to gel. The temperature of this point was recorded as the gelatinization temperature.

Particle Size

The method of AOAC was employed to check for the gelatinization temperature of the samples. Hundred (100 g) of the sample was placed on the top of Edicolt sieve shaker and it was vibrated for 10 min. 20, 40 and >40µm was collected separately and used for the analysis [15]. Particle size analysis was calculated as follows:

$$\%\text{Retained} = \frac{\text{Weight of aggregate in the sieve}}{\text{Total weight of aggregate}} \text{X} \frac{100}{1}$$

Pasting Properties Determination

The pasting properties of the different varieties of rice were determined using a Rapid Visco Analyzer (RVA Techmaster, Newport Scientific, Australia) specifically, a Newport Scientific RVA-SUPER 3 with Thermocline for Windows software (Brabender® OHG, Duisburg, Germany). Rheological properties of 8% rice flour slurries (having an approximately 40 g, adjusted to 14% moisture, in 240 mL deionised water) were measured. The slurry was subjected to a temperature from 50°C to 95°C at 1.5°C/min rate and was held at 95°C for 15 min, cooling was done at temperature of 50°C at 1.5°C/min rate while holding it at 50°C for 15 min. RVA parameters determined include peak time, peak and final viscosity, trough, setback, pasting temperature and breakdown.

Data Analysis

All experiments were conducted in triplicate, with results reported as mean values ± standard deviation (SD). Statistical significance between groups was evaluated using a one way analysis of variance (ANOVA), followed by Duncan's Multiple range test. Differences were considered statistically significant at p-values ≤ 0.05. These analyses were performed using statistical software (SPSS version 22).

Results and Discussion

Pasting Properties

The pasting properties of the rice varieties are presented in Table 1.

Peak Viscosity

The peak contents of the selected rice varieties ranged between 128.50 – 245.50 RVU. The lowest value (12.50 RVU) was recorded by IWA 2 while the highest value (245.50 RVU) was recorded by IWA 3. There were significant effect ($p<0.05$) within some of the selected varieties. The peak viscosity for the grain volume from all the rice varieties varies from the values 310.38 and 223.50 RVU reported by Phimon et al. for Hom Mali and RD43 rice varieties [16]. Peak viscosity indicates the ability of starch granule to swell. Ye et al. reported that the peak viscosity reflects the binding power of water and starch granule swelling which influence the final product texture due to swollen and collapsed granules [17]. Xiangli et al. reported peak viscosities of 200–364 RVU in rice starches, which also vary when compared to the values from the present study [18].

Breakdown Viscosity

The breakdown contents of the selected rice varieties ranged between 22.08 – 106.75 RVU. The lowest value (22.08 RVU) was recorded by IWA 2 while the highest value (106.75 RVU) was recorded by IWA 3. Significant effect ($p<0.05$) existed within some of the samples. The breakdown viscosity for the different varieties vary from 137.04 and 67.33 RVU found by Phimon et al. for Hom Mali and RD43 rice varieties. Breakdown viscosity shows how flour disintegrate, becomes resistant against heat, and shearing after cooking [16, 19]. An increase in the breakdown in viscosity may imply to a decrease in the power of the rice starch to be able to carrying both heating and shear stress during cooking.

Trough Viscosity

The trough contents of the selected rice varieties ranged between 85.08 – 159.25 RVU. The lowest value (85.08 RVU) was recorded by IWA 7 while the highest value (159.25 RVU) was recorded by IWA 3. Significant effect ($p<0.05$) existed within the samples. Trough viscosity is the ability of the viscous to reach minimum level after cooling [20]. The trough viscosity for the different varieties of rice also varies from the values 173.33 and 156.17 RVU found by Phimon et al. for Hom Mali and RD43 rice varieties but very much lower when compared to the values 919 RVU as stated by David et al. [16, 21].

Pasting Temperature

The pasting temperatures of the selected rice varieties ranged between 82.35 – 85.65oC. The lowest value (82.35oC) was recorded by faro 44 while the highest value (85.65oC) was recorded by argwula. No significant effect ($p>0.05$) existed within majority of the selected varieties. This is the temperature whereby starches begin to gelatinise, absorbing water and swelling. Xiangli et al. reported pasting temperature within the range 68.4 - 82.8°C which is lower when compared to the values of this work [18]. The variations can be described according to the work reported by Jamal et al. that amylose-lipid complexes can restrict swelling, raising pasting temperature and lowering peak viscosity. Pasting temperature impacts the final product's texture, appearance and sensory properties [22].

Final Viscosity

The final viscosity contents of the selected rice varieties ranged between 145.25 – 294.33 RUV. The lowest value (145.25 RVU) was recorded by IWA 7 while the highest value (294.33 RVU) was recorded by IWA 3. There were significant ($p<0.05$) differences within the samples except for IWA 8 and agreement. This is used to determine the potentials of the starch to be able to form a viscous paste [19]. The final viscosity for the different varieties of rice were lower than the values 302.71 and 342.08 RVU found by Phimon et al. for Hom Mali and RD43 rice varieties and 775 RVU found by David et al. [16, 21]. The variations in the final viscosity within the different varieties of rice from this present study could be as a result of the variations in the amylose content and various chemical constituents, like protein type and amount.

Setback Content

The setback contents of the selected rice varieties ranged between 60.17 – 135.08 RUV. The lowest value (60.17 RVU) was recorded by IWA 7 while the highest value (135.08 RVU) was recorded by IWA 3. There were significant ($p<0.05$) differences within the samples except for IWA 2 and argwula. Setback is used to determine the re-crystallisation of gelatinised starch during cooling [23]. The setback for the different varieties of rice vary from 129.38 and 185.92 RVU found by Phimon et al. for Hom Mali rice varieties. Setback explains the power of starch pastes to stiffen, which is used to measure the rate of starch re-trogradation [16, 23]. An increase in the values of breakdown viscosity and decrease in the values of setback viscosity result to a better cooking quality, as cooked rice resists retrogradation and stays soft upon cooling [24]. The difference in setback of the starches from the different varieties of rice may be as a result of the quantity of amylose released from the granules.

Peak Time

The peak time contents of the selected rice varieties ranged between 5.45 – 5.96 min. The lowest value (5.45 min) was recorded by IWA 6 while the highest value (5.96 min) was recorded by IWA 3. No significant effect ($p>0.05$) existed within the samples. The peak time for the different varieties of rice was similar to the values 5.43 and 5.70 min reported by Phimon et al. for Hom Mali and RD43 rice varieties. Ye et al. explained that high amylose content in rice flour can increase final viscosity, the pasting temperature and as well as setback as a result of the lower swelling power and molecular re-arrangement of the flour. Amylose-lipid complexes may also have an effect on the pasting properties of the rice by elevating the ability of the starch granules to resist water, leading to a decreased swelling of the granule and decreased release of amylose [16, 17]. This interaction leads to a decrease in peak viscosity and breakdown viscosity, while raising setback and final viscosity [25]. The differences in the pasting properties of the different varieties of rice when compared with the findings of other researchers could be as a result of the differences in the soil nutrients and weather conditions of the planting location, variety types and management practices as stated by Enyi et al. and Liu et al. [11, 26].

Table 1: Pasting Properties of the Selected Rice Varieties

Variety	Peak viscosity (RVU)	Break down viscosity (RVU)	Trough viscosity (RVU)	Pasting temperature	Final viscosity (RVU)	Setback (RVU)	Peak time (min)
IWA 1	213.8^{d}±1.06	106.8^{a}±0.97	109.1^{g}±1.07	83.65^{ab}±0.94	196.7^{h}±1.20	89.58^{f}±1.20	5.83^{a}±1.10
IWA 2	128.5^{g}±4.40	22.1^{h}±1.12	106.42^{g}±0.95	84.45^{a}±1.00	229.3^{g}±1.03	122.92^{b}±1.10	5.77^{a}±0.91
IWA 3	245.5^{a}±0.60	86.25^{b}±0.92	159.3^{a}±1.39	83.85^{ab}±1.005	294.3^{a}±1.41	135.08^{a}±0.77	5.96^{a}±0.74
IWA 6	163.17^{e}±0.12	28.17^{g}±1.12	135.0^{e}±0.16	82.55^{b}±1.00	242.6^{d}±1.00	108.58^{c}±1.03	5.45^{a}±0.77
IWA 7	133.5^{f}±0.84	48.42^{e}±0.77	85.1^{h}±0.77	84.75^{a}±1.00	145.3^{i}±0.91	60.17^{h}±0.97	5.60^{a}±0.70
IWA 8	210.7^{d}±1.19	66.33^{d}±1.20	144.3^{c}±0.96	82.35^{b}±0.94	231.4^{f}±1.22	87.08^{f}±1.00	5.80^{a}±1.00
Faro 44	234.9^{b}±1.00	79.92^{c}±1.00	150.0^{b}±1.00	82.36^{b}±1.00	256.1^{b}±1.00	101.17^{d}±1.00	5.58^{a}±1.00
Faro 52	221.4^{c}±1.00	64.42^{d}±1.00	157.0^{a}±1.00	84.75^{a}±1.00	237.08^{e}±1.00	80.08^{g}±1.00	5.92^{a}±1.00
Agreement	222.1^{c}±1.00	81.67^{c}±1.00	140.42^{d}±1.00	84.25^{ab}±1.00	233.0^{f}±1.00	92.58^{e}±1.00	5.66^{a}±1.00
Argwula	161.2^{e}±1.00	37.92^{f}±1.00	125.25^{f}±1.00	85.65^{a}±1.00	247.3^{c}±1.00	124.08^{b}±1.00	5.72^{a}±1.00

Data represent means of triplicate analyses ± standard deviation. Values with different superscripts in the same column differ significantly ($p<0.05$).

Functional Properties

The functional properties of the rice varieties are presented in Table 2.

Bulk Density

The bulk density of the selected rice varieties ranged between 4.30 – 4.60 g/cm3. The lowest values (4.30 g/cm3) were recorded by IWA 1 and IWA 6 while the highest value (4.60 g/cm3) was recorded by IWA 7. There were no significant (p>0.05) differences among the selected rice varieties. The result of bulk density of the varieties of rice varies from 0.71 – 0.83 g/cm3 reported by Nmesomachi et al. for different rice varieties from Ebonyi and Anambra States. The variation in bulk density could be because of the variation in starch content among the rice varieties. Iwe and Onadipe reported that starch content increases bulk density [27, 28]. Bulk density is also dependent on factors such as method of measurement, geometry, size, solid density and surface properties of the materials and could be improved when the particles are small, compatible, properly tapped and with a suitable packaging material. Bulk density reflects the relative volume of packaging material required. The higher the bulk density, the denser the packaging material required. It indicates the porosity of a product which influences the package design and could be used in determining the type of packaging material required [28].

Water Absorption Capacity

The water absorption capacity of the selected rice varieties ranged between 8.20 – 8.90 g/ml. The lowest values (8.20 g/ml) were recorded by IWA 2 and IWA 3 while the highest value (8.90 g/ml) was recorded by agreement. There were no significant (p>0.05) differences among the selected rice varieties. The result of the water absorption capacity of the rice varieties was higher than the values 2.60 – 4.00 g/ml reported by Nmesomachi et al. for different rice varieties from Ebonyi and Anambra States. The water absorption capacity is an essential functional property of cereals which may be defined as the amount of water retained by a known weight of flour under specific conditions. The water absorption capacity depends on capillary, pore size and charges of the protein molecules [27]. This is due to strong correlation of extent of protein hydration with polar constituents along with the hydrophilic interaction through hydrogen bonding. The rice samples evaluated generally had a moderate water absorption capacity which may be attributed to the protein content. Higher protein content of flour is responsible for high hydrogen bonding and high electrostatic repulsion [29].

Gelatinization Temperature

The gelatinization temperature of the selected rice varieties ranged between 70.30 – 70.90oC. The lowest values (70.30 oC) were recorded by faro 52 and argwula while the highest values (70.90 oC) were recorded by IWA 2 and IWA 2. There were no significant (p>0.05) differences among the selected rice varieties. The results of the gelatinization temperature of the rice varieties were lower than the values 78.00 – 90.00oC reported by Nmesomachi et al. for different rice varieties from Ebonyi and Anambra States but within the values 70 – 74oC reported by Enyi et al. for milling, "cooking and thermal properties on selected varieties of rice in Ebonyi State, Nigeria [27, 30]. Variation in the gelation characteristics of the rice varieties could be attributed to the relative ratio of protein, carbohydrates and lipids that make up the flours and the interaction between such components" [31]. This property of starch granules to form a gel when subjected to heat is important in the formulation of baked goods. The flours samples could be employed in baking.

Particle Size

The particle size of the selected rice varieties ranged between 0.72 – 0.87 g/g. The lowest value (0.72 g/g) was recorded by agreement while the highest values (0.87 g/g) were recorded by IWA 7 and faro 44. There were no significant (p>0.05) differences among the selected rice varieties. The results of the particle size of the rice varieties were lower than the values 7.01 – 8.74 g/g reported by Jih-jou et al. for relationships between grain physicochemical characteristics and flour particle size distribution for Taiwan rice cultivars as described by other authors in their studies, particle size affects the expansion of extrudates [32, 33].

Table 2: Functional Properties of the Selected Rice Varieties

Variety	Bulk density (g/cm)	Water absorption capacity (g/ml)	Gelatinization temperature (oC)	Particle size (g/g)
IWA 1	4.30^{a}±0.08	8.82^{a}±0.01	70.90^{a}±0.02	0.79^{a}±0.01
IWA 2	4.40^{a}±0.03	8.20^{b}±0.02	70.90^{a}±0.01	0.77^{a}±0.01
IWA 3	4.40^{a}±0.01	8.21^{b}±0.04	70.40^{b}±0.01	0.77^{a}±0.02
IWA 6	4.30^{a}±0.05	8.62^{a}±0.04	70.70^{a}±0.02	0.86^{a}±0.04
IWA 7	4.60^{a}±0.01	8.6^{a}±0.03	70.60^{a}±0.04	0.87^{a}±0.02
IWA 8	4.40^{a}±0.03	8.61^{a}±0.01	70.80^{a}±0.03	0.86^{a}±0.01
Faro 44	4.50^{a}±0.02	8.42^{b}±0.02	70.60^{a}±0.03	0.87^{a}±0.02
Faro 52	4.40^{a}±0.02	8.80^{a}±0.02	70.30^{b}±0.00	0.82^{a}±0.01
Agreement	4.50^{a}±0.02	8.91^{a}±0.03	70.60^{a}±0.01	0.72^{a}±0.02
Argwula	4.40^{a}±0.01	8.80^{a}±0.01	70.30^{b}±0.02	0.80^{a}±0.03

Data represent means of triplicate analyses ± standard deviation. Values with different superscripts in the same column differ significantly (p<0.05).

Conclusion

The selected rice varieties exhibited diverse pasting properties, with IWA 3 showing exceptionally high peak viscosity, breakdown viscosity, and final viscosity, indicating potential suitability for products requiring high gel strength. The relatively consistent pasting temperature and peak time across varieties suggest similar cooking characteristics. Functional characteristics, such as bulk density and water absorption capacity, were statistically similar, implying comparable handling and processing properties. The particle size distribution indicates minimal variation in milling quality. These results can inform breeding programs, processing optimization, and product development, ultimately enhancing rice utilization and value addition in Nigeria.

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