American Journal of Multidisciplinary Research in Africa
Vol. 2(1), pp. 1-10, January, 2022
AJMRA-21-008

ISSN: 2769-0504
https://www.mprijournals.com/

Full Length Research

Evaluating the Processing Parameter of Milling, Cooking and Thermal Properties on Selected Varieties of Rice in Ebonyi State, Nigeria

[1]**Enyi** Chukwunwike Uchenna, [2]**Ota** Henry Obiahu*, [1]**Apuye** Enricka Agbo, [1]**Ekwu** Francis and [3]**Okorie** Chinasa

[1]Department of Food Science and Technology, Faculty of Agriculture, Ebonyi State University Abakaliki, P.M.B 501 Ebonyi State ,Nigeria

[2]Institute of Surface-Earth System Science, School of Earth System Science, Tianjin University, Tianjin 300072, China

[3]Department of Food Science and Technology, College of Applied Food Sciences and Tourism, Michael Okpara University of Agriculture Umudike P.M.B 7267 Umuahia, Abia State, Nigeria

*Corresponding author's email: ota.henry@aau.edu.et

Accepted 7th January, 2022

Abstract: Nigeria farmers are rice producers growing many varieties and prone to accepting any new varieties with seemingly better grain yield and qualities. This study analyzed the quality aspects of milling, cooking and thermal properties of selected rice varieties. Ten paddy rice varieties were processed to raw rice and analyzed for their milling, cooking and thermal properties. The results shows that IWA 7 had the highest head rice yield and least broken grain while IWA 8 had the least head rice yield and highest broken grain. Agreement and Argwula had the highest total milling yield while IWA 1 had the least. IWA 2 had the highest brown rice while Argwula had no brown rice. There were no unmilled grains and stones were found only in Argwula and IWA 3 varieties. Faro 52 had the highest immature and no chalky grain. The gelatinization temperatures were intermediate. Agreement had the highest percentage of amylose content while Faro 44 had the lowest. The volume expansion ranged from 1.5 to 7. The thermal conductivity values ranged from 0.332 to 0.354 Wm- ºC, the specific heat capacity values ranged from 3.44-3.89 kJ/kg ºC and thermal diffusivity ranged from 0.75 to 0.80m^2/s. Varieties with higher amylose content required a shorter cooking time. This makes IWA 6 and Agreement the varieties with the best cooking quality. Thermal properties were good for all the varieties and the rice grains exhibit the ability to retain heat better than other existing varieties.

Keywords: Rice Varieties: Amylose: Parboiling: Specific Heat Capacity: Rice Grain Quality

Cite this Article As: Enyi, C. U., Ota, H. O., Apuye, E. A., Ekwu, F. & Okorie, C. (2022). Evaluating the Processing Parameter of Milling, Cooking and Thermal Properties on Selected Varieties of Rice in Ebonyi State, Nigeria. American Journal of Research in Business and Social Sciences, 2(1): 1-10.

1.0 Introduction of the Study

One of the important cereal crops that is put under vast cultivation worldwide and serves as a primary source of food for more than two-thirds of the world's population is rice (Ndjiondjop *et al.,* 2010). Oryza sativa (Asian rice) and Oryza glaberrima (African rice) are the two main types of domesticated rice that are massively cultivated by farmers globally, but African rice, which is indigenous to the West African sub region, has seen less development (Sarla & Swamy, 2005). One of the main advantages attributed to African rice in comparison to Asian rice is its resistance to a number of biotic stresses such as diseases, insects and nematodes, and abiotic stresses such as drought, flooding and salinity. Other advantages cited by producers include its suitability for weaning foods, high protein content and good keeping quality of cooked grains (Sarla & Swamy, 2005). Nonetheless, it is characterized by low yield and high tendency to shatter, a situation that translates to high postharvest losses. Conventional milling also leads to high levels of broken rice because it breaks easily (Sarla & Swamy, 2005). In spite of these challenges, however, some African farmers still crop African rice because of its adaptability, ceremonial and cultural importance (Falade *et al.,* 2014).

Milling of rice grain is the process of applying load to the kernels in other to remove the bran layers and germ (Shitanda & Nishiyama, 2002). Milling quality parameters like head rice yield (HRY) and degree of milling (DOM) could be affected by the physical properties of rough rice. Kernels are exposed to different compressive, bending, shear and frictional forces during rice milling, and breakages can occur (Zhang *et al.,* 2005). This breakage causes head rice yield (HRY) reduction and economic losses. The relationship of head rice yield to mechanical properties has been used by various researchers to show the susceptibility of rice varieties to breakage during processing. Mechanical properties of sound and fissured rice kernels and their implications for rice breakage has been reported by Zhang *et al*. (2005). Their results showed that fissuring caused a rice kernel to stand less and absorb less deformation energy prior to breakage.

Rice quality is defined by standard parameters like milling recovery, head rice yield, degree of milling (DOM) and whiteness. Visual quality is quantified using industrial measurement of whiteness and degree of milling (Singh *et al.,* 2000), which translate to the amount of bran removed and visual appearance of rice kernels. Milling yield is the weight of unbroken milled rice in ratio to the weight of milled rice. Whole kernel milled rice in the ratio to the weight of rough rice processed is been measured by head rice yield (IRRI, 2009). Millers use both milling yield and head rice yield to determine the overall quality of rice kernel. United State Standard for Brown Rice for processing (USDA) defines a broken grain as a grain of rice that is less than three-fourth of a grain for yield determination (USDA, 2009). The amount of the bran layer and germ removed by milling or processing is measured by the degree of milling (DOM) (Hua *et al.,* 2006). The quality of the milled rice is been measured by the amount of bran removed from the shelled rice. To obtain well milled rice, the Standard Committee of the American Association of Cereal Chemist suggests a goal of a twelve percent weight reduction in the difference between shelled rice and milled rice weights during the process of milling. Whiteness and transparency are measures of the physical appearance of the rice grain (Bautista & Siebenmorgen, 2002).

Cooking, eating and end-use quality characteristics of rice are majorly determined by the properties of the starch that makes up 90 percent of milled rice (Danbaba *et al.,* 2012). The cooking properties can be determined in terms of volume expansion, grain elongation during cooking, gelatinization temperature and cooking time. Rice varieties with amylase content of more than 25 percent absorb more water and have a fluffy texture after cooking (Frei & Becker, 2003). Various processes within an individual rice particle occur during cooking. The heating, water intake and swelling of the rice particle all involve diffusive processes. When water is available at sufficiently high temperatures, the starch undergoes a gelatinization reaction. Many rice studies have focused on the soaking of rice grains at fixed temperatures or the parboiling process. The objective of this present study is to analyze the various quality aspects of milling, cooking and thermal properties of selected local and improved rice varieties.

It was observed from the above literature review that the interactive effects of milling, thermal properties, and cooking time on rice quality like rice yield, broken grain, total milling yield, and unmilled grain have not been exploited. No predictive models are combining these process variables, which are mostly used as a quality determinant in food industries. Predictive models show how the quality parameters relate well with the process variables, which is a highly beneficial tool to processing industries, as an outcome of the adjustment in the processing conditions can be easily predicted before it is adopted. Also, previous research work has only utilized the two-step milling system for their study, using a one-step milling machine will increase the knowledge-base for rice processing industries. In addition, the selected African rice varieties were also evaluated in terms of physical, chemical and thermal properties of grains and yield. Information generated from this study would contribute to the selection of material for the development of suitable cultivars to meet diverse consumer preferences in Africa and elsewhere.

2.0 Materials and Methods

2.1 Description of Study Area

The study area is located in Ebonyi State, Southeastern Nigeria, geographically, the area lies between 7°6′1″E to 8°0′0″E longitudes and 5°5′5″ N and 6°0′0″N latitudes (Ota *et al.,* 2021). It is characterized by undulating sandstone ridges and shale low lands, trending in a NE-SW direction (Ukaegbu & Akpabio, 2009). The mean annual rainfall ranges between 2040-2190mm (Ota et al., 2020). Continentally, the study area is located in West Africa (Fig. 1), The population data of Ebonyi State population was only 1.0 million in 1991 and 2.1 million in 2006 (Census, 2006) and has reached over 2.8 million in 2018. The digital elevation model (DEM) of the study area from previous study showed that the elevation figure ranged from -10 to 282m above sea level with the north areas having the highest elevation coverage (Ota *et al.,* 2021).

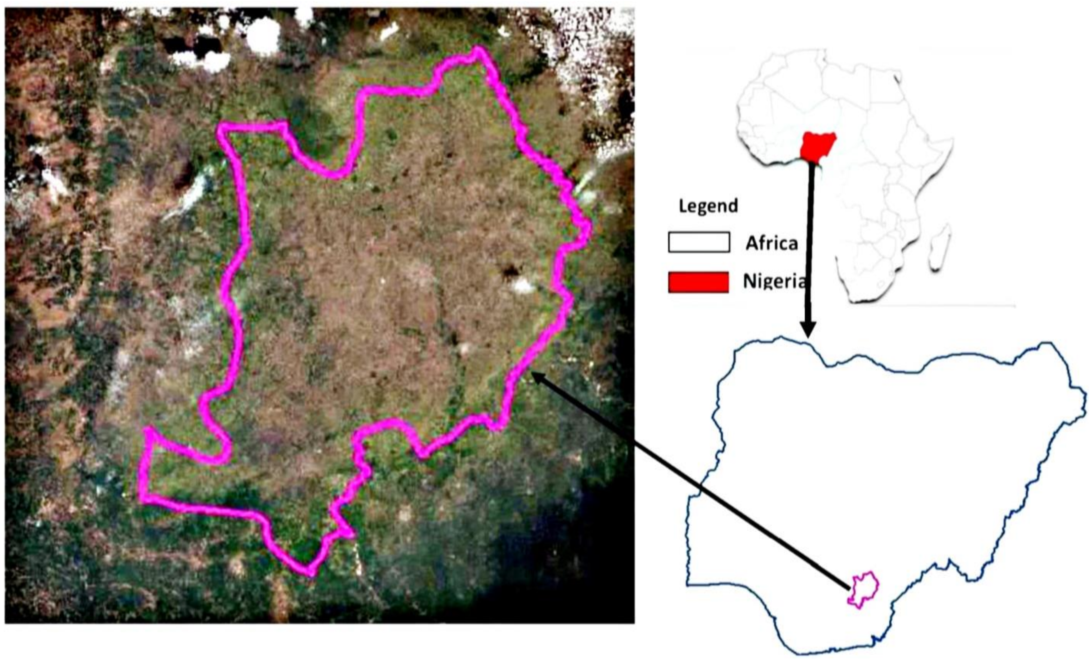

Fig. 1. Map of Study Area

Source: Ota et al. (2021)

2.2 Sample Collection and Preparation

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.

2.3 Parboiling and Milling Process

The rice varieties were first cleaned before introducing it into the soaking drum. Cold water which was three times the weight of the paddy (1 kg of paddy rice to 3 liters of water) was added and the electric drum heated until the steeping water temperature rose to 80%. The paddy rice was allowed to steep for 14 hours at ambient temperature (29%). The paddy was then removed from the water, washed with clean water and drained in a basket. The paddy was then steamed in the steaming drum. Steaming was halted at temperature of 80% after 30 minutes. The paddy was then dried in the sun until a moisture content of 12–14% was obtained. The dried paddy was dehusked using a dehusking machine (laboratory machine), model JGMJ 8096 and polished using a polisher (laboratory machine), model LTJM 2090 at rice mill in Ikwo local government area of Ebonyi state. The samples collected after milling were subjected to milling cooking and thermal analysis.

2.4 Determination of Milling, Cooking and Thermal Properties

The methods described by Bahattacharya & Murthy (1987) were used to determine the percentage head rice yield, percentage broken grain, percentage total milling yield, percentage immature grain, percentage unmilled grain, percentage stone in the milled rice, percentage brown rice and percentage chalkiness. The method described by Kabir (2002) was used to determine the gelatinization time, gelatinization temperature and volume expansion of the rice. The method described by Nuwamanya *et al.* (2011) was used to determine the amylose and amylopectin of the rice. The method described of Dipti *et al.* (2002) was used to determine the cooking time of the rice. The method described by Opoku *et al.* (2006) was used to determine the thermal conductivity of the raw rice grains. The method described by Jindal & Murakami (1984) was used to determine the specific heat capacity. The thermal diffusivity (α) of raw rice grains were calculated using the measured values of thermal conductivity, specific heat and bulk density using the following equation 1.

$$\frac{K}{\ell Cp} \qquad \text{Eq. 1}$$

Where
K = Thermal conductivity (W/M^{0}C)
α is the thermal diffusivity (M^2/S),
ℓ = Density of rice grain (kg/m3)
Cp = Specific heat (kJ/kg^{0}C)

2.5 Data Analysis

Analysis of variance was used for the determination of significant differences (p<0.05) among treatment means and separation of means was carried out using the SPSS version 20.0. Separation of means was carried out by Duncan Multiple range test and values were reported as means and standard deviation (Steel & Torrie, 1980).

3.0 Results and Discussion

3.1 Milling Properties Variation under Different Varieties of Rice

Milling properties of the rice varieties are shown in Table 1. The head rice yield ranged from 59.55 % to 98.95 % with IWA 7 variety having the highest value of 98.95 % and IWA 8 had the lowest. There were significant (p<0.05) difference among the samples. The differences in head rice yield for the varieties were because of the differences in the tensile strength of the kernels. According to Parnasakhorn & Noomhorm (2008), increase in head rice yield of parboiling rice was because of increased tensile strength of the kernel caused by gelatinization of the starch granules, so that the kernel tolerate milling and suffer reduced grain breakage. According to Dipti *et al.* (2003), good quality rice should have a head rice yield of at least 70 %. All the rice varieties tested were of good quality in terms of head rice yield except IWA 8. The high yield of head rice observed in the sample is an indication of profitability to the miller since intact whole grain attracts more price than the broken grain (Jung *et al.,* 2001).

The percentage broken grain ranged from 0.85 % to 37.40 %. The highest broken milled rice was obtained for IWA 8 and the lowest was for IWA 7. The rice varieties were found to differ (p<0.05) significantly in the values of their broken grains. The highest percentage of broken grains observed with IWA 8 variety was expected. This is because IWA 8 had higher length compared to other varieties. According to Wiset *et al.* (2001) long grain rice varieties are more susceptible to cracking and breakage during post harvest operations. Preference for rice grain characteristics vary with consumer groups but rice grain shape has been reported to play a major role in consumer preferences in different countries and populations (Kesavan *et al.,* 2013).

The percentage total milling yield ranged from 94.81 % to 99.95 %. Agreement and Argwula varieties had more total milling yield of 99.95 % each and IWA 1 had the least total milling yield of 94.80%. Agreement and Argwula vary significantly (p<0.05) from other rice varieties. According to Knowledge bank on Rice Quality (2005) the percentage total milled rice contains whole grain or head rice and broken grain. There was no unmilled grain recorded for the varieties tested. This may be due to that the paddies were properly sun dried. According to Bhattacharya (1980) parboiling toughens the grain and reduces the amount of breakage in milling but prolonged parboiled rice tends to absorb more water and if not properly sun dried retains shell during milling. The percentage brown rice obtained ranged from 0 to 4.1 %. IWA 2 had the highest brown rice of 4.1 % and argwula had the least brown rice of 0%. Low yield of brown rice recorded for all the tested varieties was as a result of the milling duration and the variety of the rice. According to Takai & Barredo (1981) milling duration is very important as prolonged continuous milling increases the degree of polishing and breakage. The percentage stone ranged from 0 % to 0.05 %. Argwula variety had the highest stone in milled rice with 0.05 % and IWA 1, IWA 2, IWA 6, IWA 7, IWA 8, Faro 44, Faro 52 and Agreement had no stone in them. Argwula vary significantly (p<0.05) from other rice varieties. The absence of stone in the samples tested was as a result of good handling during processing. According to Marina (1991) crops dry much faster on cement floors and the finished product is free of impurities or stones which are commonly found in rice dried on mud floors. The presence of stone no matter how small downgrades the quality of rice.

The percentage immature grain ranged between 0.15 % and 1.5 %. The highest immature grain was obtained for Faro 52 at 1.5 % and the lowest was for Argwula variety at 0.15 %. The presence of immature grains were as a result of some paddies being harvested prematurely, making them to lack strength and break easily. According to different workers, immature rice kernels lack strength and as a consequence break easily during dehulling and milling operations (Siebenmorgen *et al.,* 2006). The percentage chalkiness ranged from 0 % to 4.3 %. IWA 1 had the highest chalky grains of 4.3% and Faro 52 and Agreemet varieties had no chalky grain. IWA 1 differ significantly (p<0.05) from other rice varieties. The presence of chalky grains tends to suggest inadequate soaking time. According to Bhattacharya & Subba Rao (1996) insufficient soaking time as well as temperature leads to development of white core at the center of the rice grains. IWA 1 may probably require a longer soaking time to make their grains more translucent than opaque. Chalkiness however totally disappear during cooking and as a result may have no direct effect on cooking and eating qualities, high levels of chalkiness however downgrades the physical qualities and reduce milling recovery of rice (Islam *et al.,* 2001)

Table 1: Milling properties of the rice varieties

Variety (%)	HRY	BG	TMY	UG	BR	Stone	IG	C
IWA 1	82.05^{h}	12.85^{c}	94.80^{i}	0.00	1.00^{c}	0.00^{b}	0.35^{c}	4.30^{a}
IWA 2	79.55^{i}	16.70^{b}	96.15^{h}	0.00	4.10^{a}	0.00^{b}	0.75^{b}	0.10^{cd}
IWA 3	96.80^{c}	1.35^{i}	98.05^{f}	0.00	1.05^{bc}	0.03^{ab}	0.85^{b}	0.10^{cd}
IWA 6	92.95^{f}	5.95^{e}	98.85^{d}	0.00	1.15^{b}	0.00^{b}	0.40^{c}	0.10^{cd}
IWA 7	98.95^{a}	0.85^{j}	99.80^{b}	0.00	0.70^{d}	0.00^{b}	0.80^{b}	0.45^{b}
IWA 8	59.55^{j}	37.40^{a}	97.10^{g}	0.00	0.20^{f}	0.00^{b}	1.35^{a}	0.30^{bc}
Faro 44	92.70^{g}	6.20^{d}	98.90^{c}	0.00	0.65^{de}	0.00^{b}	0.80^{b}	0.20^{cd}
Faro 52	95.85^{d}	2.60^{g}	98.15^{e}	0.00	0.55^{e}	0.00^{b}	1.50^{a}	0.00^{d}
Agreement	94.40^{e}	5.55^{f}	99.95^{a}	0.00	0.05^{g}	0.00^{b}	0.35^{c}	0.00^{d}
Argwula	97.65^{b}	2.05^{h}	99.95^{a}	0.00	0.00^{g}	0.05^{a}	0.15^{c}	0.10^{cd}

Values show the mean of duplicate analysis and ± standard deviation. Figures with different superscript down the column are significantly different (p<0.05). HRY= Head rice yield, BG= Broken grain, TMY= Total milling yield, UG= Unmilled grain, BR= Brown rice, IG= Immature grain, C= Chalkiness

3.2 Cooking Properties of the Rice Varieties

Cooking properties of the rice varieties are shown in Fig 3. The gelatinization temperature ranged from 70% - 74%. IWA 8 and faro 52 had the highest gelatinization temperatures while IWA 6, IWA 7 and Agreement had the lowest gelatinization temperatures of 70% each. The gelatinization time ranged 5-9mins. IWA 1 and IWA 3 had the highest gelatinization time while FARO 44 had the least gelatinization time. According to Cruz and Khush (2000) gelatinization temperature of rice was classified as low (55-69%), intermediate (70-75%) and high (> 75%). The values are within the values (70 – 75%), reported by Alaka and Orji (2012) for rice grains which falls under intermediate in terms of gelatinization behaviour. IWA 1 vary significantly (p<0.05) from other varieties. The time required for cooking is determined by the gelatinization temperature (GT). Gelatinization temperature is regarded as the temperature at which the phase transition of starch granules from an ordered state to a disordered state occurs (Ubwa *et al.,* 2012). Environmental conditions such as temperature during ripening influences the gelatinization. A high ambient temperature during development results in starch with a higher gelatinization. Rice with high gelatinization temperature often cooks to a stronger texture and retrogrades more than rice with low gelatinization temperatures (IRRI 2006). Also, rice with a high gelatinization temperature tends to require more water and time to cook than those with low or intermediate gelatinization temperature (IRRI, 2008). From the results, the rice varieties fall under intermediate, and they had short cooking times.

The cooking time of the rice grains ranged from 10 to 14mins. Faro 44 had the highest cooking time and IWA 6 and Agreement had the least cooking times. The values are lower than 19 – 26 mins reported by Oko *et al.* (2012) for rice grains. The report is also contrary to the report of Otegbayo *et al.* (2001) who reported cooking time of 52 - 56mins and Danbaba *et al.* (2011) who reported a cooking time of 17 – 24 mins for Ofada rice. Cooking time for rice is the time when 90 % of the starch in the grains no longer show opaque center when pressed between two glass plates. The lower the cooking time, the lower the fuel and energy consumption during cooking. From the results, it was observed that the varieties had short cooking times, which implies that there will be less fuel and

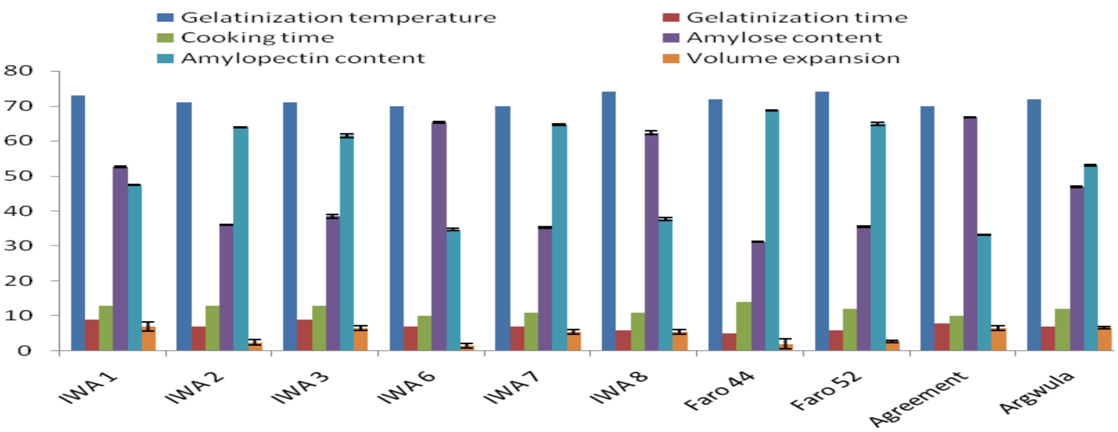

Fig. 2. Cooking properties of the rice varieties

energy consumption.

The amylose content of the varieties ranged from 31.2 and 66.8 %. Agreement had the highest percentage of amylose while Faro 44 recorded the least value for percentage amylose. The values are higher than 19.81 - 25.51 % reported by Oko *et al.* (2012), 19.77 - 24.13 % by Danbaba *et al.* (2012), for rice grains. The amylose:amylopectin ratio of rice is the central property of rice starch and it is an important parameter to determine the eating and cooking characteristics (Samina, 2012). Rice with high amylose content tends to have high volume expansion and a high degree of flakiness on cooking. Yu *et al.* (2009), observed that cooked rice that has high amylose concentration easily hardens, whereas cooked rice with lower amylose content hardens at a much slower rate.

This was observed in IWA 1, Argwula but IWA 3, Faro 44 and Faro 52 did not exhibit this behaviour. High amylose grains also cook dry, are less tender and become harder upon cooling (IRRI, 2008). When rice cools to room temperature or beyond, the chains of amylose crystallize. Rice is grouped based on their amylose content into waxy (0-2 %), very low (3-9 %), intermediate (20-25 %) and high (> 25 %), according to Cruz and Khush (2000). Based on the results shown in Fig 3, all the rice varieties are classified as high amylose. Agreement (66.8 %), IWA 6 (65.3 %) and IWA 8 (62.4 %) will be ideal for diabetic patients, since starchy foods with high amylose level are associated with lower blood glucose level and slower emptying of the human gastrointestinal tract compared to those with low levels of this macromolecule (Frei & Becker, 2003). Also, feeding with cooked rice high in amylose instead of cooked rice low in amylose may be effective to control serum, blood glucose and lipids (Magdy *et al.,* 2010). More so, Cristiane *et al.* (2007) reported that serium triglyceride and cholesterol levels significantly decreased after consumption of a diet rich in high amylose compared to a diet rich in amylopectin (low amylose). The volume expansion values ranged from 1.5 to 7. IWA 1 had the highest volume expansion while IWA 6 had the least volume expansion value.

3.3 Thermal Properties of the Rice Varieties

Thermal properties of the rice varieties are shown in Fig 3. The thermal conductivity values range from 0.327 to 0.354 Wm-^{0}K. IWA 2 and Agreement had the highest thermal conductivity values while IWA 3 had the least value. IWA 3 vary significantly ($p<0.05$) from other sample. The values are within the range 0.012 - 0.543 Wm- ^{0}K reported by Ramesh (2000) for thermal conductivity of rice. Recent research studies have reported similar values 0.35 ± 2 Wm-^{1} ^{o}K. They however differ with those 0.080 – 0.138 Wm-^{1}K^{-1} in the temperature range of 3-69 ^{O}C and moisture content range of 9.2-17.0 % reported by Yang *et al.* (2003) for thermal conductivity of rice. Thermal conductivity is how much heat flux would pass through a certain material depending on the temperature gradient over that material. Heat transfer occurs at a higher rate across materials of high thermal conductivity than across materials of low thermal conductivity. From Table 3, the heat transfer during any heating process of the rice grains will occur at a normal rate since the values are neither higher nor lower than the standard for thermal conductivity of rice grains.

The specific heat capacity of the rice grains ranged from 3.44 - 3.89 KJ/kg Oc. IWA 3 had the highest specific heat value while IWA 6 had the lowest value. There were no significant ($p>0.05$) differences among IWA 2, IWA 7, agreement and argwula. The values are higher than those reported by Majid *et al.* (2012) for specific heat of rough rice. Specific heat deals with the amount of energy (in Joules/gram degree Celsius) that must be put into one gram of a substance in order to raise the temperature of the substance to one degree. A high specific heat capacity resists heating and cooling, which would indicate that it takes a lot of energy to raise the temperature of the substance whereas a low specific heat capacity would mean it only takes a little bit of energy to raise the temperature of the substance. From Table 3, it was shown that the rice grains have a high specific heat capacity which will result to use of higher energy in order to increase the temperature.

The thermal diffusivity values ranged from 0.75 to 0.80 m^2/s. IWA 1 and Faro 52 had the highest thermal diffusivity values while IWA 6, 7 and 8 had the least values. The values are higher than 1.00 $\times 10^{-7}$ m^2/s reported by Jones *et al.* (1992) for thermal diffusivity of rice. Argwula vary significantly ($p<0.05$) from other varieties. Thermal diffusivity measures the ability of a material to conduct thermal energy relative to its ability to store thermal energy. Rice grains with high thermal diffusivity as observed in Figure 2, would indicate that it undergoes rapid movement of heat because the rice grains will conduct heat quickly relative to its volumetric heat capacity.

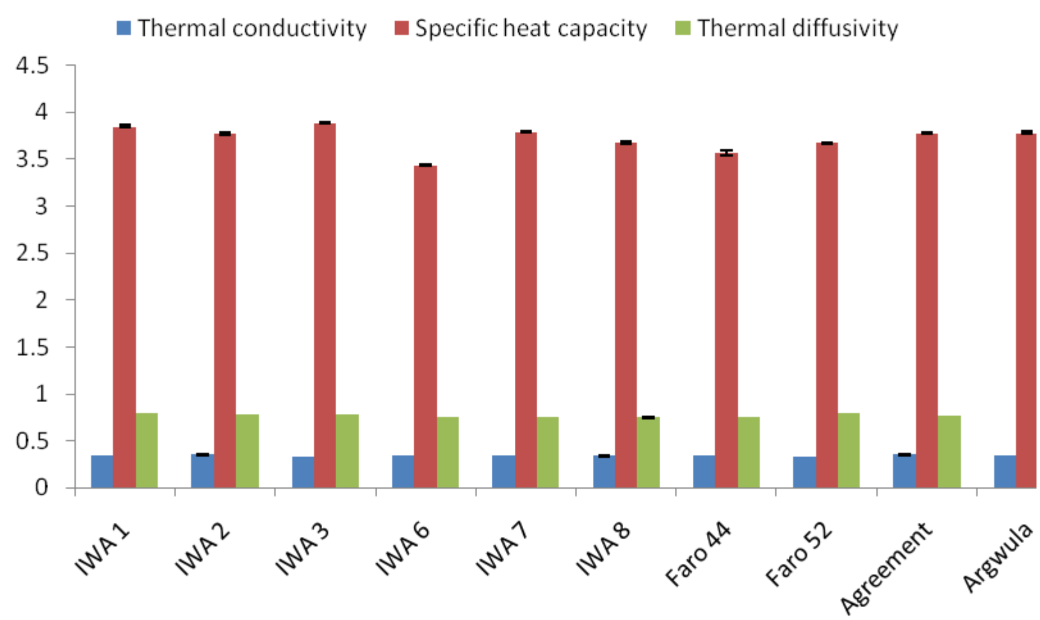

Fig. 3. Thermal properties of the rice varieties

4.0 Conclusion of the Study

The rice varieties had very high head rice yield except for IWA 8 which had high broken grains. There were very low brown rice for the varieties. This was as a result of the efficiency of the dehulling and polishing machines used. The high percentage of chalkiness in IWA 1 indicates that some varieties may require longer soaking time than others. Presences of stones were only seen in IWA 3 and Argwula varieties at a very small quantity. These new varieties have shorter cooking time which is a good attribute for consumer preference in terms of saving energy. The gelatinization temperatures were within the range of other existing rice varieties. The amylose content, although higher than reported in literature, is suitable for diabetic patients. Some varieties had higher volume expansion than the others. The thermal conductivity values were within the range specified for thermal conductivity of rice. The specific heat capacity, were higher than other existing varieties which would indicate high resistance to heating and cooling. The thermal diffusivity values from the results indicate that the rice grains have the ability to store heat over a longer period than other existing varieties. The investigation into the thermal properties gives information that will be useful in designing many equipments relating to rice processing.

Declaration of Competing Interest: The authors declare that there are no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments: My honest appreciation goes to the Director of Biotechnology Research and Development Center (BRDC) Ebonyi State university Abakaliki, Prof Osalebe Happiness for providing us with these improved and local rice varieties for use.

5.0 References of the Study

Alaka, I. C. & Orji, C. D. (2012). Milling and Cooking Characteristics of Six Local Rice Varieties Milled at Abakaliki Rice Mill. *J. of the Sci, Agri, Food Tech. and the Enviro.* 12:18-22.

Bautista, R. & Siebenmorgen, T. (2002). Evaluation of Laboratory Mills for Milling Small Samples of Rice. *Applied Engineering in Agriculture,* 18: 577-583.

Bhattacharya, K. R. & Subba Rao, P. V. (1996). Effect of Processing Condition on the Quality of Parboiled Rice. *J. of Agric. Food Chem.* 14: 426-476.

Bhattacharya, K. R. & Murthy, S. N. (1987). *Rice Quality Curing Products. Regional Extension Service Centre*. Rice Milling Scientific Services No 6 Central Food Res Inst Mysore India, 11-12.

Bhattacharya, K. R. (1980). Breakage of Rice during Milling: *A Review Trop. Sci*. 22: 255-276.

Cristiane, C. D., Mellisa, W., Leila, P. S., Gabrielle, D. S. & Carlos, A. F. (2007). Effect of Amylose Content of Rice Varieties on Glycemic Metabolism and Biological Responses in Rats. *Food Chemistry*, 105: 1474-1479.

Cruz, N. D. & Khush, G. S. (2000). *Rice Grain Quality Evaluation Procedures*. Ln: R. K Singh and G. S. Khush (Eds). Aromatic Rice, Pp 15-28. Oxford and IBH Publishing Co, Ltd, New Delhi.

Danbaba, N., Anounye, J. C., Gana, A. S., Abo, M. E. & Ukwungwu, M. N. (2011). Grain Quality Characteristics of Ofada Rice (Oryza Sativa L.). *Cooking and Eating Quality. J.* 18:619-624.

Dipti, S. S., Bari, M. N. & Kabir, K. A. (2003). Grain Quality Characteristics of some Beruim Rice Varieties Of Bangladesh. *Pakistan J. of Nut. 2(4): 242-245.*

Dipti, S. S., Hossain, S. T., Bari, M. N. & Kabir, N. (2002). Physicochemical and Cooking Properties of some Fine Rice Varieties. *Pakistan J. of Nutrition, 1(4): 188.*

Falade, K. O., Semon, M., Fadairo, O. S., Oladunjoye, A. O., & Orou, K. K. (2014). Functional and Physico-Chemical Properties of Flours and Starches of African Rice Cultivars. *Food Hydrocolloids,* 39, 41e50.

Frei, M. & Becker, K. (2003). Studies on the in Vitro Starch Digestibility and Glycemic Index of Six Different Indigenous Rice Cultivars from the Phillipines. *J. of Food Chem.* 83: 395-400.

Hua, N., Bengtson, R., Schramm, R., Patel, T., Walker, T. & Lima, M. (2006). Optimization of Yield and Quality Parameters, for the Cocodrie Rice Variety as a Function of Harvest Time. *Applied Engineering in Agriculture*. 22: 95-99.

IRRI (2006). Breeding for Grain Quality. International Rice Research Institute. Republic of the Phillipines.

IRRI (2008). The Rice Plant and how it Grows. International Rice Research Institute. Republic of the Phillipines.

IRRI (2009). Rice Quality Training Manual. International Rice Research Institute. Republic of the Phillipines.

Islam, M. R., Roy, P., Shimizu, N. & Kimura, T. (2001). Quality Evaluation of Parboiled Rice with Physical Properties. *Food Science and Technology Research*, 7(1): 57-63.

Jindal, V. K. & Murakami, E. G. (1984). Thermal Properties of Shredded Coconut in Engineering and Food. Vol 1(Ed B.M Mckennan). London : Elsevier Applied Science Publishers.

Jones, J. C., Wotton, M. & Green, S. (1992). Measured Thermal Diffusivities of Cereal Products. *Food Aust*. 44:501-503.

Jung, K. P., Sangsook, K. & Kwang, O. K. (2001). Effect of Milling Ratio on Sensory Properties of Cooked Rice and on Physiochemical Properties of Milled and Cooked Rice. *Cereal Chemistry*, 78(2): 151-156.

Kabir, K. A. (2002). *Cooking Qualities of Rice and Chemical Method*. Entomology Division Bangladesh Rice Research Institution, Gazipur, 1701 Bangladesh.

Kesavan, M., Song, J. T., & Seo, H. S. (2013). Seed Size: A Priority Trait in Cereal Crops. *Physiologia Plantarum,* 147, 113e120.

Knowledge Bank on Rice Quality Inc. (2005). Physiochemical Properties of Parboiled Rice. International Rice Institute. Republic of the Phillipines.

Magdy, A. S., Hossam, S. E., Mona, A. M., Amera, T. M. & Sohir, N. A. (2010). Effect of Amylose Content and Pre-Germinated Brown Rice on Serum Blood Glucose and Lipids in Experimental Animals. *Australian J. of Basic and Applied Sci.* 4(2): 114-121.

Majid, K., Shahin, R. & Ali, J. (2012). Moisture Dependent Physical Properties of Rough Rice. *Elixir Mech. Eng*. 52: 11609-11613.

Marina, C. B. (1991). Post Harvest and Processing Technologies of African Staple Foods: A Technical Compendium.

Ndjiondjop, M. N., Manneh, B., Cissoko, M., Drame, N. K., Kakai, R. G. & Bocco, R. (2010). Drought Resistance in an Interspecific Backcross Population of Rice (Oryza Spp.) Derived from the Cross WAB56-104 (O. Sativa) CG14 (O. Glaberrima). Plant Science, 179, 364e373.

Nuwamanya, E., Baguna, Y., Wembabazy, E. & Rubaihayo, P. (2011). A Comparative Study of the Physicochemical Properties of Starch from Root, Tuber and Cereal Crops. *African J. of Biotech*. 10: 12018-12030.

Oko, A. O., Ubi, B. E. & Danbaba, N. (2012). Rice Cooking Quality and Physicochemical Characteristics: A Comparative Analysis of Selected Local and newly Introduced Rice Varieties in Ebonyi State, Nigeria. *Food and Health*, 2 (1): 43-49.

Opoku, A., Tabic, L. G., Crerar, B. & Shaw, M. D. (2006). Thermal Conductivity and Thermal Diffusivity of Timothy Hay. *Canadian Biosystem Engineering*, 48(3): 1-3.7.

Ota, H.O., Zhifeng, Y. & Udume B. U. (2021). Spatiotemporal Analysis of Land Use Land Cover Changes and Built-Up Expansion Projection in Predominantly Dystric Nitosol of Ebonyi State, Nigeria. *J. of Environ Challenge*, 5(21): 54-65.

Ota, H. O. & Eyasu, E. (2020). Effect of Land Use Land Cover Changes on the Rate of Soil Erosion in the Upper Eyiohia River Catchment of Afikpo North Area, Nigeria. *Journal of Environmental Challenge*, 9(14): 12-23.

Otegbayo, B. O., Samuel, F. & Fashakin, J. D. (2001). Effect of Parboiling on Physicochemical Quality of two Local Rice Varieties. *J. of Food Tech. in Africa, 6(4): 130-132.*

Parnasakhorn, S. & Noomhorm, A. (2008). Changes in Physicochemical Properties of Parboiled Brown Rice during Heat Treatment. *International J. Agricultural Engineering*. 10: 8-9.

Ramesh, M. N. (2000). Effect of Cooking and Drying on the Thermal Conductivity of Rice. *Int. J. of Food Prop. (*3): 77-92.

Samina, A., Faqir, M. A., Rai, M. A. & Muhammad, A. K. (20120. Cooking and Eating Characteristics of Rice (*Oryza Sativa. L.)*. *Park. J. Food Science*, 22(3): 161-166.

Sarla, N. & Swamy, B. P. M. (2005). Oryza Glaberrima: A Source for the Improvement of Oryza Sativa. *Current Science*, 89, 955e963.

Shitanda, D. Y. & Nishiyama, K. S. (2002). Compressive Strength of Rough Rice Considering Variation of Contact Area. *J. Of Food Engineering*. 53: 53-58.

Siebenmorgen, T. J., Bautista, R. C. & Meullenet, J.F. (2006). Predicting Rice Physiochemical Properties Using Thickness Fraction Properties. *Cereal Chemistry*, 83(3): 275-283.

Singh, R., Singh, U. & Khush, G. (2000). *Aromatic Rice*. New Delhi: Oxford and IBH Pub.

Steel, G. D. & Torrie, J. H. (1980). *Procedures of Statistics. A Biometrical Approach*. 2nd Ed. Mcgraw Hill, Book Company, New York, P. 63.

Takai, H. & Barredo, I. R. (1981). Milling Characteristics of a Friction Laboratory Rice Mill. Agric. *Engineering Research*, 26(5): 441-448.

Takeuchi, S., Madea, M., Gomi, Y. & Fukuoka, W. H. (1997). The Change of Moisture Distribution in a Rice Grain during Boiling as Observed by NMR Imaging. *J. of Food Sci.* 33: 281-297.

Ubwa, S. T., Abah, J., Asemave, K. & Shambe, T. (2012). Studies on the Gelatinization Temperature of some Cereal Starches. *Int. J. Of Chem.* 4(6): 76-85.

Ukaegbu, V. U. & Akpabio, I. O. (2009). Geology and Stratigraphy Northeast of Afikpo Basin, Lower Benue Trough, Nigeria”. *Pac. J. Sci. Technol.* 10: 518–527.

USDA (2009). Brown Rice Standards. [Online] [Cited: December 2009] Http://Archive.Gipsa.Usda.Gov/Reference-Library/Standards/Ricestandards-Brown_Rice.Pdf

Wiset, L., Srzednicki, G., Driscoll, R. H., Nimmuntavin, C. & Siwapornrak, P. (2001). Effect of High Temperature Drying on Rice Quality. *The CIGRJ. Sci. Res. Develop;* 3: 17-23.

Yang, W. T. J., Siebenmorgen, T. P. H. & Crossen, A. G. (2003). Effect of Glass Transition on Thermal Conductivity of Rough Rice. *Bio-System Engineering*, 84, 193-200.

Yu, S., Ma, Y., & Sun, D. (2009). Impact of Amylose Content on Starch Retrogradation and Texture of Cooked Milled Rice during Storage. *Journal of Cereal Science*, 50, 139e144.

Zhang, Q., Yang, W. & Sun, Z. (2005). Mechanical Properties of Sound and Fissured Rice Kernels and their Implications for Rice Breakage. *J. of Food Engineering*, 68: 65-70.