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Comparative study of the milling and cooking qualities of some Nigerian rice varieties cultivated in Ebonyi State, Nigeria

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ABSTRACT

Rice is a staple food consumed worldwide in all human races. Differences inherent in cooking and milling properties of rice grains are a major challenge in choice making. The milling and cooking qualities of 14 rice varieties were studied. Cooking qualities were determined using micro-cooking methods. Significant differences (P< 0.05) were recorded in all traits studied among all the varieties. 'Eleco 20' showed the highest lightness (dL) value (40.90±3.20), while the highest values of red/green, dA (4.47±0.96) and yellow/blue, dB (24.87±0.72) were found in FARO52. The highest (88.67 ±0.58%) and least (47.67±9.25%) whole grains were obtained in 'Ton 2' and '306' respectively. Water uptake ratio has the highest value in 'Aiwa 8' and least in 'Mass'. NERICA 7 has highest elongation ratio, GER (2.97±0.69) while 'Aiwa 8' has the least (1.18±0.11) value. 'Ton 2' is the variety of choice with highest percentage head rice and highest GER. Enormous variations in milling properties and cooking quality characteristics exist among the rice varieties studied and choice should be based on intended use. The result of this research will help in checking appearance of rice grains after cooking following their milling yield, solid in cooking water and cooking time.

Keywords: Milling, cooking, rice and Nigeria

Highlights

- 'Eleco 20'showed the highest lightness (dL) value of 33.50±3.20 while 'mass' had the least dL value of 23.47±1.27.
- 'Ton 2' has highest whole grains (88.67±0.58%) while '306' had least amount of whole grains (47.67±9.29%) after grading.
- 306' showed highest minimum and optimum cooking time (33.33±0.58 and 35.33±0.58 minutes) while 'Canada' had the least values of minimum and optimum cooking times (16.00±1.00 and 18.00±1.00 minutes).
- The highest grain elongation ratio was recorded in NERICA 7 (2.97±0.69) with least value in 'Aiwa 8' (1.18±0.11).

INTRODUCTION

Rice (*Oryza sativa L.*) is a staple food which is a major food crop worldwide sthat is capable of feeding almost half of the world's entire population [1]. Rice together with grasses belongs to monocotyledonous plants of the genus *Oryza sativa (*Asian rice) or *Oryza glaberrima* (African rice). Rice is a cereal and is the most widely eaten staple food for human beings [2]; [3]. Since maize is cultivated for many other reasons different from that of feeding by humans, rice remains the most crucial grain as it concerns human nutrition and the supply of energy because rice supplies a very great amount of the energy needed by humans [4]. Many varieties of rice exist and people's choice seems to change from one place to the other. Rice is usually cultivated as an annual plant, but survives as a perennial crop in areas with high rainfall and water retaining capacity and can produce a ratoon (surviving from remnants) crop for many decades and will as a result hardly go on extinction. The rice plant grows to height of 1-1.8m tall, but this in most cases is a direct function of the variety cultivated and the fertility of the soil. It has long and slender leaves. The nutritional and processing characteristics of rice are very crucial for overall good state of the consumers and also necessary for commercial purposes including economy of rice farmers. The property of rice is necessary for its acceptance and determines the market price, consumer acceptance and the end users of different rice varieties. The quality of rice is not easy to determine because it depends on too many factors which are connected to the consumer and the intended use of the rice grains. In the developed countries, only high and good quality varieties are requested and this helps rice farmers to increase their income from rice. Differences in ethnic groups also affect what is said to be quality characteristics.

MATERIALS AND METHODS

Plant materials: Fourteen rice varieties sourced from different parts of Nigeria: *Aiwa8*, *Awafum*, *B12*, *Canada*, *Cp*, *Dangot*, *Eleco20*, FARO52, *Maruwa*, *Mass*, NERICA7, *Short Caro*, *Ton2* and *306* were grown under the same normal agronomic practices in the Faculty of Sciences, Ebonyi State University, Abakaliki. All analyses were carried out at the National Cereal Research Institute, Badeggi, Niger State, Nigeria.

Sample preparation: The rice grains were harvested at maturity and threshed. The grains were parboiled and sun-dried. The paddy were dehusked using laboratory Dehusker, THU 35B (Satake Engineering Company Ltd, Tokyo) and then prepared for analyses.

Grain Quality Tests

Colour of Polished Grains: The colour reader, CR-10, Konical Minote Optics Inc, Japan, was used to read the lightness and colour values of whole kernel polished rice using the L*a*b* uniform colour space procedure. The value of L* shows the lightness value, a* and b* stand for red/green and yellow/blue coordinates of the L* a* b* colour space system [5].

Percentage Broken and Percentage Head Rice: The head rice yield was calculated by grading 150g of milled rice to separate the broken from the whole grains and expressing the head rice as a percentage of the 150g of milled rice according to the method of [6]. $\%\,\text{broken} = \dfrac{\text{Weight of broken (g)}}{150\text{g}} \text{X}\, 100$

% Whole grain = 100 - % broken grains

Water Uptake Ratio: Water absorption ratio of each sample was determined by weighing 2.0g of whole rice grains with Digital Electronic Pocket Scale, EHA-251, Camry Electronics, China. The 2.0g sample of rice was cooked in 20ml of distilled water to its cooking time and the water was drained from the cooked rice. The cooked rice grains were again weighed and the water uptake ratio was calculated as the ratio of final cooked weight to uncooked weight [7].

$$\text{water uptake ratio} = \frac{\text{Weight of cooked rice}}{\text{weight of uncooked rice}}$$

One Thousand Grain Weight: One thousand whole grains were counted and weighed with the Electronic pocket Scale, EHA-251, Camry Electronics, China. The grains were cooked to cooking time. The samples were again weighed after draining the superficial water following the procedure of [8].

Cooking Time: The cooking time of each variety was obtained by the procedure of [9]. 10g of rice grains was cooked in distilled water at boiling point. After 10 minutes of cooking, two rice grains were picked at 2 minutes intervals and tested until the end of the cooking. That is when no whitish spot was seen in any of the grains pressed between glass slides. Ten grains were picked and pressed between two glass slides.

Solid in Cooking Water: The mass of rice lost in to the cooking water (gruel) was obtained by cooking 2.0g milled rice grains in 20ml of water. The gruel was collected as filtrate in a Petri dish and dried in oven maintained at 105°c until its weight became constant. Total mass of solid lost during cooking was calculated by obtaining the difference in weights of dish with dried gruel and that with gruel. [8].

Grain Elongation Ratio: Ten whole milled kernels were measured lengthwise with Digital Calliper, ADS 765-100, A and D Co. Ltd, Japan. The kernels were cooked in 20ml distilled water for 20 minutes. Cooked grains of rice were transferred to a Petri dish. The cooked whole rice grains were picked and their lengths were measured with the same Digital Caliper. The elongation ratio was calculated as the ratio of the length of cooked rice to the length of uncooked rice grains [9].

Statistical Analysis: Data were analyzed by analysis of variance using statistical software version 9.1 of SAS institute, 1998. Differences obtained were declared significant at $P \leq 0.05$. The means were separated by least significant difference (LSD) at 5% probability level. Relationships among traits values were determined using Pearson correlation coefficient.

RESULTS

Result of Colour Values: The result shows significant variation in all the colour values among all the rice varieties (Table 1). FARO 52 is most deviated from white (dE=41.57±0.90) while mass is least deviated (30.93±1.27). 'Eleco 20'showed the highest lightness (dL) value of 33.50±3.20 while mass had the least dL value of 23.47±1.27. FARO 52 showed the highest colour values, red/green, dA (4.47±0.96) and yellow/blue, dB (24.87±0.72). 'Short caro' showed the least value of red/green, dA (-0.83±0.74) and yellow/blue, dB (19.63±1.84).

Table 1. Mean Colour Values of Polished Rice Grains

VARIETIES	De	dL	dA	dB
MARUWA	36.50±0.80[ab]	27.57±1.22[ab]	4.00±0. 10[a]	2 3. 57±0. 2[a]
AIWA 8	39.67±1.25[a]	31.47±1.40[a]	3.63±l,21[a]	23.13±0.71[ab]
AWAFUM	37.23±1.02[ab]	30.17±1.25[a]	2.47±1.22[ab]	21.63±0.55[b]
CANADA	38.00±2.07[a]	28. 83±2. 57 [a]	3.50±0.95[a]	24.43±0.45[a]
MASS	30.93±1. 27[b]	23.47±1. 27[ab]	0.27±0.25[b]	20.20±0.56[b]
TON 2	36.73±1. 29[ab]	29.33±1.56[3]	1.27±0.21[b]	22.00±0.35[ab]
306	33.93±1.50[b]	26.77±2.44[3b]	1.43±0.45[b]	20.87±1. 01[b]
CP	33.60±3.24[b]	26.17±4. 58[ab]	1.77±0.60[ab]	20.80±1. 06[b]
FARO 52	41.57±0.90[a]	33.00±1. 57[a]	4.47±0.96[a]	24.87±0.72[a]
DANGOT	36.93±4.04[ab]	29.93±4.21[a]	1.47±1.50[b]	21.57±1. 19[b]
N ERICA 7	35.87±0.76[ab]	29.40±0.96[a]	1.33±0.32[b]	20.47±1. 21[b]
SHORT	3 3. 67±4. 63 [b]	26.97±6.10[ab]	-0.83±2.74[bc]	19.63±1.84[bc]
CARO ELECO 20	40.90±2.42[a]	33.50±3.20[a]	3.37±1.08[a]	23.10±0.40[ab]
B12	37.77±1.25[ab]	30.00±1.71[a]	2.87±0. 2 l[a]	22.73±0.32[ab]
Grand **Average**	36.66±3.43	29.04±3.54	2.21±1.7	22.07±1.73

*Values are mean ± standard deviation
*means with the same letter down the column are not significantly different at $p \leq 0.05$
Key: dE = deviation from white, dL = lightness, dA = red/green, dB = yellow/blue

Result of Milling and Cooking Properties: Table 2 shows significant difference ($P < 0.05$) in whole grain recovery. 'Ton 2' has highest whole grains (88.67±0.58%) while '306' had least amount of whole grains (47.67±9.29%) after grading. 'Ton 2' had the highest weight (26.00±1.00g) while 'Eleco 20' had the least weight (14.67±1.15g) before cooking but NERICA 7 had highest value (84.00±2.00) after cooking while 'Eleco 20' had least initial and final values. '306' shows highest minimum and optimum cooking time (33.33±0.58 and 35.33±0.58 minutes) while 'Canada' had the least values of both cooking times (16.00±1.00 and 18.00±1.00 minutes) respectively. 'Aiwa 8' showed highest water uptake ratio (4.30±0.53) while mass was least with 2.80±0.26. 'Ton 2' and 'Mass' show highest mass in gruel (0.19±0.07g and 0.19±0.03) while '306' had least solid in cooking water of 0.02±0.01g. Table 3 shows correlation between pairs of milling and cooking quality parameters.

Table 2. Mean Values of Milling and Cooking Properties

VARIETY	PHR (%)	PBG (%)	1000GW(g)	1000GWA(g)	MCT(min)	OCT(min)	WUR	SCW(g)
MARUWA	86.33±2. 31^{a}	13.67±2.31^{b}	20.67±1.15^{a}	72.00±4.00^{bc}	25.33±1.53^{bc}	27.33±1.53^{bc}	3.50±0.26^{ab}	0.02+0 .01^{bc}
AIWA 8	70.33±4.73^{b}	29.67±4.73^{ab}	18.00±0. 00^{bc}	72.00±2. 00^{bc}	27.67±1.53^{b}	29.67±1.53^{b}	4.30±0.53^{a}	0.06+0.01^{b}
AWAFUM	88.00±4.36^{a}	12.00±4.36^{b}	24.33±0.58^{b}	82.00±2.00^{a}	28.33±2.52^{b}	30.33±2.52^{b}	3.37±0.12^{ab}	0.07+0.01^{b}
CANADA	64.67±4.16^{b}	35.33±4. 16^{ab}	18.00±0.00^{bc}	64.00±2.00^{e}	16.00±1. 00^{d}	18.00±1.00^{d}	3.57±0,15^{ab}	0.18±0.03^{a}
MASS	63.00±6.08^{b}	37.00±6.08^{ab}	23.33±0.58^{b}	76.00±2.00^{a}	22.33±0.57^{c}	24.33±0.58^{c}	2.80±0.26^{c}	0.19+0.03^{a}
TON 2	88.67±0.58^{a}	11.33±0.58^{b}	26.00±1.00^{a}	73.33±4. 62^{b}	25.00±2.00^{bc}	27.00±2.00^{bc}	4.10±0.00^{a}	0.19+0.07^{a}
306	47.67±9.29^{bc}	52.33±9. 29^{a}	19.00±0.00^{bc}	78.00±0.00^{ab}	33.33±0.58^{a}	35.33±0.58^{a}	3.633±0.21^{ab}	0.02+0.01^{c}
CP	55.33±4.51^{bc}	44.67±4.51^{a}	20.33±0.58^{b}	74.00±0.58^{b}	24.33±1.53^{bc}	26.33±1.53^{bc}	3.57±0.21^{ab}	0.07+0.03^{b}
FARO 52	87.00± 1.00^{a}	13.00±1.00^{b}	18.67±1.15^{bc}	67.33±1. 15^{C}	27.00±0.00^{b}	29.00±0.00^{b}	3.63±0.21^{ab}	0.06+0.02^{b}
DANGOT	67.33±1.53^{b}	32.67±l.53^{ab}	22.00±1.00^{ab}	80.00±2.00^{ab}	31.00±0.00^{a}	33.00±0.00^{a}	3.63±0.15^{ab}	0.08+0.02^{b}
NERICA7	68.67±8.50^{b}	31.33±8.50^{ab}	23.33±0.58^{b}	84.00±2.00^{a}	26.67±0.58^{b}	28.67±0.58^{b}	3.60±0.10^{ab}	0.06+0.02^{b}
SHORT CARO	63.3±14.15^{b}	36.67±14.15^{ab}	22.33±1.15^{ab}	72.00±2. 00^{bc}	27.00±2.00^{b}	29.00±2.00^{b}	3.20±0.20^{ab}	0.06+0.01^{b}
ELECO 20	53.67±3.79^{bc}	46.33±3. 79^{a}	14.67±1.15^{c}	58.00±0.00^{d}	24.33±1.53^{bc}	26.33+±.53^{bc}	4.03±0.80^{a}	0.06+0.05^{b}
B12	71.33±8. 50^{b}	28.67±8. 50^{3b}	18.67±0.58^{bc}	66.00±2.00^{c}	24.33±1.53^{bc}	26.33±1.53^{bc}	3. 57±0. 21^{a}	0.02+0.01^{bc}
Grand Average	69.67±14.11	30.33±14.11	20.67±3.06	72.76±7.28	25.90±4.11	27.90±4.11	3.61±0.44	0.09+0.06

*Values are mean ± standard deviation

*means with the same letter down the column are not significantly different at $p \leq 0.05$

Key: PHR = percentage head rice, PBG = percentage broken grain, 1000GW = 1000 grain weight before cooking, 1000GWA = 1000 grain weight after cooking, MCT = minimum cooking time, OCT = optimum cooking time, WUR = water uptake ratio, SCW =; solid in cooking water

Table 3: Correlation between Milling Property and some Cooking Properties

	PHR	PBG	1000GW	1000GWA	MCT	OCT	WUR	SCW
PHR	1							
PBG	-1.000**	1						
1000GW	0.413**	-0.423**	1					
1000GWA	0.116	-0.II6	0.693**	1				
MCT	-0.023	0.023	0.166	0.501**	1			
OCT	-0.023	0.023	0.166	0.501**	1.000**	1		
WUR	0.065	-0.0665	-.0.065	-.202	0.125	0.125	1	
SCW	-0.047	0.047	0.329	0.000	-0.353*	-0.353*	-0.083	1

** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)

Key: PHR = percentage head rice, PBG = percentage broken grain, 1000GW = one thousand grain weight before cooking, 1000GWA = one thousand grain weight after cooking, MCT = minimum cooking time, OCT = optimum cooking time, WUR = water uptake ratio, SCW = solid in cooking water.

Result of Dimensional Changes: The result of changes in all the dimensional values of the grains is presented in table 4. 'Aiwa 8' had the highest initial length (8.87±0.88mm) and width (3.04±0.38mm) but 'Ton 2' showed the highest length (10.72±0.60mm) after cooking. The highest width after cooking (3.47±0.33mm) was recorded in CP. 'Maruwa' had the highest elongation, L1/W1 (3.53±0.71) while 'Awafum' is least (2.59±0.18). 'Mass' had the highest ratio of length/width after cooking, L2/W2 (3.42±0.75) while 'CP' had the least value of L2/W2 (2.52±0.36). The highest grain elongation ratio was recorded in NERICA 7 (2.97±0.69) with least value in 'Aiwa 8' (1.18±0.11).

Table 4 Mean Dimensional Values and Ratios of Rice Grains

VARIETIES	L1(mm)	L2(mm)	W1(mm)	W2(mm)	L1/W1	L2/W2	GER(L2/L1)
MARUWA	6.36±1.01^{c}	9.63±l.30^{ab}	1. 84±0.3 l^{d}	3.09±0.28^{bc}	3.53±0.71^{a}	3.13±0.44^{a}	1.52±0.18^{ab}
AIWA 8	8.87±0. 8 8^{a}	10.36±0.43^{a}	3.04±0.38^{a}	3.29±0.37^{b}	3.15±0.39^{ab}	2.59±0.40^{ab}	1.18±0.11^{ab}
AWAFUM	6.52±03 8-^{c}	9.59±0.38^{ab}	2.51±0.09$^{b'}$	3.43±0.26^{b}	2.59±0.18^{b}	2.82±0.27^{ab}	1.48±0.11^{ab}
CANADA	6.5±0.82^{c}	9.12±0.67^{C}	2.04±0.28^{c}	2.83±0.33^{bc}	3.23±0.58^{a}	3.27±0.56^{a}	1.43±0.29^{ab}
MASS	6.68±0.20^{bc}	9.53±0.89^{ab}	2.45±0.18^{b}	2.96±0.35^{bc}	2.73±0.26^{b}	3. 42±0.7 5^{a}	1.43±0.14^{ab}
TON 2	7.34±0.74^{b}	10.72±0. 60^{a}	2.33±0.18^{b}	3.35±0.20^{b}	3.17±0.34^{ab}	3.21±0.18^{a}	1.47±0.19^{ab}
306	6,58±0.70^{c}	9.36±0.81^{ab}	2.21±0.16^{bc}	3.04±0.34^{bc}	2.99±0.34^{ab}	3.12±0.38^{a}	1.42±0.20^{ab}
CP	6.49±0.35^{c}	8.68±0.97^{c}	2.24±0.20^{bc}	3.47±0.33^{a}	2.91±0. 25^{ab}	2.52±0.36^{ab}	1.34±0.17^{ab}
FARO 52	6.43±0.70^{c}	8.87±0.60^{c}	2.28±0.26^{bc}	3.29±0.21^{b}	2.86±0.48^{ab}	2.69±0.14^{ab}	1.38±0.12^{ab}
DANGOT	6.49±0. 46^{c}	9.11±0.75^{c}	2.36±0.19^{b}	3.26±0.40^{b}	2.77±0.18^{b}	2.83±0.32^{ab}	1.36±0.15^{ab}
NERICA7	6.63±0.29^{c}	9.95±1.04^{ab}	2.35±0.16^{b}	3.34±0.56^{b}	2.85±0.22^{ab}	3.06±0.70^{a}	2.97±4.69^{a}
SHORT CARD	7.17±0.58^{b}	8.80±09 5^{c}	2.18±0.12^{bc}	3.32±0.22^{b}	3.30±0.36^{a}	2.66±0.33^{ab}	1.23±0.12^{ab}
ELECO 20	6.65±0.89^{c}	8.73±0.84^{c}	2.03±0.20^{c}	2.9±0.43^{bc}	3.40±0.58^{a}	3.04±0.72^{a}	2.15±2.15^{a}
B12	6.72±0.35^{bc}	9.23±1.17^{ab}	2.15±0.18^{bc}	3.04±0.32^{bc}	3.16±0.28^{ab}	3.10±0.66^{a}	1.38±0.15^{ab}
Grand Average	6.82±0.88	9.41±1.01	2.29±0.34	3.19±0.38	3.05±0.46	2.96±0.53	1.55±1.43

*Values are mean ± standard deviation
*means with the same letter down the column are not significantly different at $p \leq 0.05$

Table 5: Correlation between Dimensional values

	L1	L2	W1	W2	L1/w1	L2/w2	GER(L2/L1)
L1	1						
L2	0.339**	1					
W1	0.490**	297**	1				
W2	0.120	-0.020	0.182*	1			
L1/w1	0.407**	-0.001	-0.548**	-0.078	1		
L2/w2	-0.092	0.538**	-0.0132	-0.720**	0.021	1	
GER	-0.110	0.107	-0.078	0.061	-0.025	0.033	1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)
Key: L1 = length before cooking, L2 = length after cooking, W1 = width before cooking, W2 = width after cooking, GER = grain elongation ratio.

DISCUSSION

Colour Value: Grains of the varieties studied have lightness values (dL) ranging from 23.47 to 33.50 (table 1). 'Eleco 20' with dL value of 33.50 has the best appearance after polishing followed by FARO 52 with dL value of 33.00 while 'Mass' (23.47) followed by CP (26.17) have low lightness values. This result agrees with the report of [10] with highest lightness value of 35.40. FARO52 has the highest deviation from white (dE) value of 41.57 while 'Mass' has the least value (30.93). 'Short caro' has least values of dA and dB (-0.83 and 19.63 respectively). FARO52 has the highest values of red/green (dA) and yellow/blue (dB).Significant variation ($p<0.05$) exists between the varieties in all the colour values (dL, dB, dA and dE). The lightness value is one of the quality indicators of rice grains. The lightness value of paraboiled rice decreases while colour value increases with increasing soaking temperature [5]. This means that soaking at lower temperature will result in less coloured grains. Decrease in the lightness value of grains is a major side effect of parboiling since it reduces the market value and consumer acceptability [11]. [12], attributed discoloration to Maillard non enzymatic browning and that intensity of the colour is a function of processing conditions. [13], reported that diffusion of rice husk pigment into the endosperm during soaking contributes to colour intensity.

Milling Yield and Cooking Quality Parameters: Table 2 shows the result of milling yield. 'Ton2' has highest value of percentage head rice (88.67±0.58%) while 306 has the least percentage head rice (47.67±9.29%). 'Eleco20', 'CP', '306' and 'Mass' have low percentage head rice. Highest percentage broken grains was found in '306', followed by 'Eleco20'. This result is comparable to that reported by [10] where head rice and broken grain were in the range of 82.6-93.7% and 17.4-6.3% respectively. High percentage of broken grains indicates poor milling quality [10], but this is affected by mode of drying, grain type, growing conditions and variety [10]. Varieties like

'Ton2', 'Awafum', 'FARO52' and 'Maruwa' with high percentage head rice will have high market value as whole grains command consumer acceptability. '306', 'CP' and 'Eleco20' will have poor market value due to their high percentage broken grains. Broken grains will have more exposed for imbibitions and will affect the water uptake, cooking time, texture and integrity of the grains after cooking. There was significant difference ($P<0.05$) in weight of 1000 grains of different varieties. 'Ton2' had highest weight before cooking followed by 'Awafum' while 'Eleco20' had least weight before cooking. Table 3 shows NERICA7 with highest weight (84.00±2.00g) after cooking. This is followed by 'Awafum' (82.00±2.00g). 'Eleco20' maintained its least weight (58.00±0.00g) after cooking. This result is comparable to that reported by [4] on six rice varieties in which 1000 kernel weight ranged from 16.97±0.5g to 19.43±0.6g before cooking. Weight of the cooked grain is related to the water uptake and grain elongation. There was significant variation in the minimum and optimum cooking time of the rice varieties studied (Table 2). Highest cooking time was recorded for '306' followed by 'Dangot' while 'Canada' followed by 'Mass' has least cooking time. Optimum cooking time range from 18.00±1.00 to 35.33±0.58 minutes with average value of 27.90±4.11 minutes. [13], reported, optimum cooking time ranging from 19 to 26 minutes. In consideration of fuel economy 'Canada' and 'mass' requires higher time to cook and consequently more fuel (energy supply). [14], reported positive correlation between cooking time and water uptake. Rice grain texture after may be affected by how long it was cooked and by the amylose content of the grains. High amylose varieties remain separated after cooking while high amylopectin varieties stick together after cooking. Water uptake ratio is in the range of 4.3 to 2.8 and solid in cooking water ranges from 0.02g to 0.2g (table 2). [8], reported solid in cooking water in the range of 0.5% to 1.7% while [14], reported range of 0.01g to 0.95g. High water uptake ratio of about 200% is good cooking quality of rice [8]. All the varieties studied have over 200% water uptake and are therefore of good cooking quality considering their high water uptake which is related to volume expansion. 'Eleco20', 'Aiwa8' and 'Ton2' are the best varieties in water uptake and will be of choice to consumers who are interested in varieties with high volume expansion. [13], attributed variation in the amount of solid in cooking water to varietal differences inherent in the cultivars. Amount of solid in cooking water gives a measure of the grain integrity after cooking. Varieties with high amount of solid in cooking water will lose most of their nutrient to the gruel and will not ensure nutritional in case the cooked rice is filtered and the is discarded. The result also shows significant positive correlation between weight after cooking and cooking time (Table 3). Significant negative relationship existed between cooking time and solid in cooking water, and this may be a function of gelatinization process. There is also significant positive correlation ($r = 0.413$) between weight before cooking and milling yield (percentage whole grains). This may be related to grain type (long bold, long slender, short bold, short slender) and drying process. Negative correlation existed between water uptake ratio and weight of uncooked and cooked rice kernels. This may be attributed to the variation in weight as moisture content varies. This result is on par with the report of [4] in which no significant correlation existed between gruel solid loss and water uptake while negative correlation existed between cooking time and gruel solid loss. In this work, '306' with the highest cooking time recorded the least amount of solid in cooking water, and is a trait of high quality varieties since nutrient will not be easily lost to gruel.

Dimensional Changes: There is significant differences ($P<0.05$) in all the dimensional values and ratios (table 4). 'Aiwa8' has the highest length and width before cooking ($L1$ and $W1$) while 'Maruwa' has least length and width before cooking. Initial length ranged from 6.36mm to 8.87mm and width in the range of 1.84 to 3.04mm. These increased to 8.68mm-10.72mm and 2.83mm-3.47mm respectively. 'Ton2' showed highest elongation while 'CP' has highest width-wise expansion. Length-wise elongation is a desirable trait in rice compared with those with high width-wise expansion. [15], reported that higher elongation ratio of cooked rice was preferred by the consumers to those with lower elongation ratio. Consumers prefer varieties with high elongation values for preparation of fried rice. These varieties with high elongation values have been reported to have less solid in cooking water, and stick less than those with high width-wise expansion. NERICA7 and 'Eleco20' with the highest and second to highest grain elongation ratios respectively will be best for this purpose. Varieties with high width-wise expansion such as 'Awafum' and 'CP' are best for preparations other than consumption as whole grains. These varieties will be desired in places like Northern Nigeria where rice flour is prepared and swallowed like fermented cassava (Akpu in Igbo language) or garri. This preparation is called 'Tuwo Shinkafa' in Hausa language (Northern Nigeria). Elongation of rice can be influenced by both the length/width ratio and amylose content [4]. The result shows no significant relationship between grain elongation ratio and other dimensional values and ratios. Strong positive correlation existed between initial and final dimensional values.

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