Physicochemical and Cooking Properties of Some of the Popular Milled Rice (Oryza sativa L.) Cultivars in Six Regions of Nigeria

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Abstract- The study investigated some physicochemical and cooking properties of rice cultivars grown in different agroecological zones of Nigeria. The popular cultivars were identified and sourced from the mills and from the open markets in the following State capitals. These were: Zabamari and Dikwa from Borno northeast(NEB), Supi and Sudi, Kano northwest(NWK), Okai and Ikwo southeast, Abia(SEA), Igbemo and Ofada, southwest, Ekiti and Ogun respectively(SWE, SWO), and Mars and Sipi, southsouth, Cross River(SSC). The kernel lengths(5.82-7.22mm), breadths(2.16-2.70) and length(L) breadth(B) ratios(L/B, 2.37-2.97) of rice kernels were significantly different($p<0.05$), only Sudi and Mars had medium slender kernels, others were either short or long bolds. Thousand kernel weights(18.70-24.50g) of Bali and Sudi were greater and Mairuwa the least; Ofada, Dikwa, Mars and Sipi had higher true densities(1.28-1.73g/ml) and bulk densities(0.672-0.914g/ml). Mars and Ikwo water uptake ratios(1.50-2.03) were greater than others ; generally gruel solids(0.31-0.91%) were low; Supi, Sudi, Igbemo and Ofada had greater kernel lengths after cooking(KLAC) (6.05-8.23mm) and linear elongation ratios(1.07-1.42). Moisture, ash, crude fat, crude protein (N×5.95) and carbohydrate(by difference) contents varied significantly($p<0.05$) from 10.26-12.14%, 0.34-1.14%, 1.23-1.99%, 5.02-9.08% and 76.66-82.45% respectively. The dominant mineral elements were potassium(30.17-125.11mg/100g) and phosphorus (29.15-54.15mg/100g), others present in varying amounts were calcium(6.22-10.04mg/100g), zinc(0.80-1.11mg/100g) and iron(0.29-0.69mg/100g). The colour, taste, aroma, and texture of the cooked sudi, okai, ofada and igbemo were poorer than others perhaps due to poor handling and storage conditions prior to purchase. Six cultivars(Sudi, Supi, Dikwa, Zabamari, Sipi and Mars) were identified as having excellent physicochemical and cooking properties, therefore should be adopted as national rice and given extensive cultivation. Further studies that will take into consideration the type and extent of milling operations of these rice cultivars undergo is advocated.

Index Terms- Cooking properties, kernel dimension, mineral elements Nigeria rice, proximate composition.

I. INTRODUCTION

Rice is a monocot of the genus, *Oryza* with two known species; a lesser known Africa rice (*Oryza glaberrima)* and the more dominant Asian rice (*Oryza sativa)* with many cultivated varieties dictated by climatic, economic and socio-cultural considerations. Rice is grown in two main agro-ecological zones (Forest and Savannah) in Nigeria on five identifiable production systems: upland and lowland rain-fed, irrigation, deep water and mangrove swamps (Otenga and SantAnna, 1999; Nkama, 2011). Although improved varieties such as NERICA (a hybrid of African and Asian rice) and FARO (improved Oryza sativas) are available and steadily displacing the local varieties, however the latter possess unique cooking and eating qualities which have long been cherished and engrained into the culinary culture of the local community, still resistance to encroachment from the improved varieties is steadily weakening because they have better agronomic and cooking qualities. Dibba et al.(2012) reported that the rate of diffusion of NERICA varieties in Gambia hard not exceeded 40%, less than projected. Prior to 1960s rice food was an occasional or ceremonial foodstuff, but with the rising income of the working class occasioned by crude oil boom in the 1990s, attention then shifted dramatically to the consumption of better processed imported rice. In Nigeria currently, white rice is a frequently consumed staple; cooked whole and eaten with sauce/stew or cooked as the popular *joloof* rice. Surprisingly, rice-based food products are uncommon in Nigeria unlike wheat with many commercialized value-added products competing for space. Rice and wheat are the main drivers of urbanization in many developing countries displacing local foods; the highest rice consumption occurs among the urban dwellers exceeding 32Kg per head per year in Nigeria (Ayinde et al.,2016). Previously, Nigeria produced on average 2.7 million metric tons against 5 million needed for domestic consumption (Ajala and Gana, 2015; FSCluster,2017; Nextzon, 2017). Currently, the consumption level has gone up to 7.9million metric tons as well as the production level and now has become the largest rice in Africa displacing Madagascar and Egypt (FSCluster,2017;) The overriding factors that determine the acceptance of a given variety in Nigeria are wholesomeness, rice length and stickiness when cooked but little consideration is given to rice nutritional value. It is reported that rice quality is influenced by variety, geographic location, degree of processing and storage conditions among others (Juliano, 1985; Zhout et al., 2001). Although Nigeria is leading producer of rice in Africa, however low quality rice occasioned by village-level processing, handling and storage techniques have ignited the crave for imported rice, the largest in Africa a trend which has negatively affected the country's foreign exchange reserve since the 1990s exceeding one billion US dolar annually(Nextzon, 2017). Nigeria is one of the leading importers of rice in the world, mainly from Asia, where 92% of world rice is produced chiefly on irrigated production systems (Abbas et al., 2011). With reduced inflow of hard currency the government of Nigeria initiated a policy called agricultural transformation agenda which is directed at boosting production, handling and storage systems of key food crops of which rice is one. The impact of this policy is yet to be substantially felt as milled rice available in Nigerian markets are characterized by high level of broken rice, impurity and chalky grain. Rice is the source of dietary energy for more than half of the world's population (Zhout et al., 2002; Ghadge and Prasad, 2012), constituting about 75% of calorie intake of some Asian countries (Roy et al., 2011). Paddy contains on average 77-87% carbohydrate, 7-16% protein, 1.5-9% fat (Kent, 1983), and after milling the carbohydrate content increased to 85-90%, other nutrients decreased; fat 1.5-1.79%, protein 6.5-8.5%, as well as minerals and beneficial phytochemicals. Further decreases occur if the kernels are polished, because the protein, fat, vitamins and minerals are concentrated in the germ and outer layers which constitute about 10% of brown rice are removed during milling (Roy et al.,2011). Although cooking quality of rice is directly related to the physical and chemical characteristics of the starch such as amylose amylopectin ratio, gelatinization temperature and gel consistency (Juliano,1985; Tan et al.,1999) however, varietal differences, processing (e.g. parboiling, polishing) and storage conditions influence rice quality greatly (Zhout et al., 2001; Zhout et al., 2003). Rice adaptation to all agro-climatic conditions has lead to the evolution of thousands of varieties with varying cooking, eating and product-making properties (Ravi et al.,2012). Many varieties do exist in Nigeria identifiable by their local names, and the high demand for some is responsible for their popularity in the region where they are mainly cultivated. Previous studies focused on the varieties found within an agricultural zone and these include those of Adeyemi et al.,1986; Ebuehi and Oyewole, 2008; Otegbayo et al.,2001; Hussein et al.,2009; Danbaba et al.,2011; Oko and Ugwu, 2011; Alaka et al.,2011; Oko et al.,2012; but comprehensive study of the plethora rice of varieties across Nigeria is yet to be undertaken; even at that newer hybrids are steadily being introduced. Therefore, the aim of this study was to evaluate the cooking and physicochemical characteristics of some popular rice varieties available in six geopolitical regions of Nigeria.

II. Materials and Methods

2.1 Collection of samples of the rice varieties.

Two most popular samples of rice were obtained from each of the six geopolitical regions of Nigeria either from the millers or sellers who identified the most popular varieties by their local names and physical features. We were conscious of the fact that the same rice variety could bear different or variant names in different places spread by inter-state trade. Personal visits, students on vacation and inter-state taxi drivers were the agents through which samples of rice were procured from each zone. Production date, processing (whether parboiled or not, degree of milling) and storage conditions or length of storage of each variety collected were not known. A total of twelve locally grown and processed varieties, the most popular local rice, two from each of six geopolitical zones of Nigeria were identified and purchased. Table 1 presents the varietal name, region/place of collection and the code assigned to each variety. The collected samples were individually sorted, winnowed and bagged separately in a low density polyethene bag and left at room temperature for two weeks prior to use.

Table 1: Names, regions and states/places from where rice varieties were collected.

Name of Variety	Region of Nigeria	Place of Collection	Sample Code
Bali	Northcentral	Benue	NCB-Bali
Mairuwa	Northcentral	Benue	NCB-Mairuwa
Dikwa	Northeast	Borno	NEB-Dikwa
Zabamari	Northeast	Borno	NEB-Zanchabari
Supi	Northwest	Kano	NWK-Supi
Sudi	Northwest	Kano	NWK-Sudi
Okai	Southeast	Abia	SEA-Okai
Ikwo	Southeast	Abia	SEA-Ikwo
Ofada	Southwest	Ogun	SWE-Ofada
Igbemo	Southwest	Ekiti	SWE-Igbemo
Mars	Southsouth	Cross river	SSC-Mars
Sipi	South south	Cross river	SSC-Sipi

NCB-Bali and NCB-Mairuwa: Bali and Mairuwa were sourced from Benue State, North Central Nigeria, NEB-

Zanchabari and NEB-Dikwa: Zabamari and Dikwa from Borno State, North Eastern Nigeria, NWK-Supi and NWK-Sudi=Supi and Sudi from Kano State, North Western, SEA-Okai and SEA-Ikwo: Okai and Ikwo from Abia State, South Eastern, SWO-Ofada and SWE-Igbemo: Ofada and Igbemo from Ogun and Ekiti States respectively, South Western, SSC-Mars and SSC-Sipi: Mars and Sipi are from Cross River State, South Southern Nigeria.

2.2 Physical analysis of the rice varieties

The length and width of randomly selected ten rice kernels were measured using a digital Venier Caliper. The values obtained were used to calculate length-to-breadth ratio (L/B). Thousand kernel weight (TKW) was determined applying the method of Varnamkhastic et al.(2008) by weighing 1000 randomly selected head rice. Bulk density was determined by the method described by Fraser et al.(1978); the volume occupied by a weighed quantity of head rice kernels using a measuring cylinder. True density was determined using toluene displacement method of Mohsenin et al.(1986), measuring the volume displaced by a weighed quantity (10g) of rice kernels. Values of bulk or true density were obtained from the ratio: mass/volume.

2.3 Cooking properties determination

i. **Water uptake ratio (WUR):** The method described by Faruq et al.(2015) was used to determine WUR. Weighed (W_1) randomly selected 20 head rice kernels were cooked for 30 min in a 250ml measuring cylinder containing 20ml of tap water submerged in a boiling water bath. The cooked kernels were placed in a petridish lined with filter paper in order to remove adhering surface water and later re-weighed (W_2).The WUR was obtained from the retio: W_2-W_1/W_1.

ii. **Residual solid loss (Solids in cooking water):** Ten millimeter (10ml) of cooking water was placed in a tarred evaporating dish, evaporated in the oven set at 110◦C till constant weight was obtained. The weight difference after cooling in a dessicator expressed as the percentage of the weight of the sample cooked was expressed as the solids in gruel (%) (Ekka et al., 2016).

iii. **Cooked lengths of rice kernels (10):** The lengths of cooked rice kernels were measured using a graph paper and taken as kernel length after cooking (KLAC or L_2), the difference between length (L_2) of the cooked rice kernel and the length of the uncooked (L_1) was taken as the actual grain elongation. The grain elongation ratio was obtained from the ratio: L_2/L_1.

2.4 Proximate composition of the milled rice cultivars

The moisture, crude fat, crude protein (N×5.95) and total ash were determined according to the approved methods of AOAC (2000) using methods No: 925.09, 4.5.01, 979.09 and 923.03 respectively; carbohydrate contents were obtained by "difference": 100(%protein+%fat+%ash+%moisture)

2.5 Mineral determination of the milled rice cultivars

The rice samples were prepared for ash determination according to the method of AOAC (2000). Weighed samples were dry-ashed, the ash was dissolved in 20ml of dilute HCl, the mixture was filtered, and the filtrate was made up to volume in 100ml volumetric flask with deionised water. Iron (Fe), Zinc (Zn), Calcium (Ca), Potassium (K) and Phosphorous (P) contents were determined in 10ml aliquot of the filtrate using atomic absorption spectrophotometer (SMART Spectro 2000, LaMotte) with pre-calibrated reagent system provided by the manufacturer.

2.6 Sensory evaluation of cooked samples.

Weighed quantity (100g) of each rice variety was cooked in 500ml of water, 1g common salt and 5ml of vegetable oil were added. Cooked cooled rice were presented to 15 panelists, (8 females and 7 females) drawn from staff and students of the department (Food Science and Technology, University of Maiduguri, Nigeria) on coded disposable plates. The sensory attributes evaluated were color/appearance, taste, aroma, texture and overall acceptability on the basis of 9-point Hedonic scale where 9 represents liked extremely, 5 represents neither liked nor disliked and 1 represents disliked extremely.

2.7 Statistical Analysis

Mean of the parameters were calculated and the data were subjected to one-way analysis of variance. Means was separated using Duncan's multiple range test and significance was accepted at 5% level of probability (P<0.05). The statistical analysis was carried out using SPSS version 16.

III. Results and Discussion

3.1 Physical dimensions of the twelve cultivars

The mean lengths (L), breadths (B) and length: breadth ratios of the twelve cultivars varied significantly (p<0.05) from 5.82-7.22mm, 2.16-2.70mm and 2.16-2.77 respectively.(Table 2a) The cultivar with the longest kernel (7.22mm) was SSC-Mars and the shortest (5.82mm) NCB-Mairuwa. Six cultivars had kernel lengths greater 6.0mm (NWK-Supi and Sudi, NEB-Dikwa and Zabamari, NCB-Bali, SSC-Sipi) and five others with lengths less than 6.0mm (NCB-Mairuwa, SEA-Ikwo, SEA-Okai, SWO-Ofada, SWO-Igbemo). SWO-Ofada had the largest breadth and NEB-Dikwa, NEB-Zabamari and SSC-Sipi smallest. NEB-Dikwa and SSC-Mars had the highest L/B ratio respectively 2.87 and 2.97 respectively.None had L/B ratio greater than 3 therefore the cultivars consisted mainly of short-bold (33%) and long-bold(50%) rice cultivars except SSC-Mars and NWK-Sudi.(extra long,>7mm). According to the classification of Shilpa and Krishnan (2010) and Dhivyapriya and Kalaiyarasi (2015) these two belonged to medium slender rice. Ofada and Igbemo from Southwest, Bali and Mairuwa North Central Nigeria belonged to short bold class of rice cultivars. The values of L, B and L/B obtained here were similar to L: 5.95-7.53; L/B: 2.17-2.87 reported by Alaka et al.(2015) for rice varieties obtained from Ebonyi State of Nigeria. It can be concluded that that majority of Nigerian grown rice belong to medium (>5.2mm, L/B < 3mm) and long grain (> 6mm, L/B > 3mm) category according to Gariboldi (1973) classification, this class usually has intermediate amylose content(20-25) and the tendency to remain separate and fluffy when cooked is high. Mir et al.(2013) reported 4.73-8.32mm for length, and breadth, 2.02-3.03mm for brown rice cultivars grown in India. High yielding hybrids studied by Dhivyapyrisa and Kalaiyarasi (2015) had L, B, and L/B 4.60-7.40, 1.60-2.30mm and 2.00-4.11mm respectively further indicating cultivars under study consisted mainly of short and long bolds. Knowledge of rice kernel dimension enables the optimization of milling and storage operations thereby reducing postharvest loses (Ghadge and Prasad, 2012)

Table 2a:Physical dimensions of rice varieties from six regions of Nigeria

Variety	L (mm)	W(mm)	L/B	Shape
NCB-Bali	6.05±0.33[e]	2.55±0.18[b]	2.39±0.18[e]	Short bold
NCB-Mairuwa	5.82±0.34[g]	2.48±0.20[e]	2.37±0.25[e]	Short bold
NEB-Zanchabari	6.26±0.28[c]	2.21±0.13[f]	2.81±0.14[ab]	Long bold
NEB-Dikwa	6.17±0.60[d]	2.16±0.15[f]	2.87±0.12[ab]	Long bold
NWK-Supi	6.05±0.55[e]	2.35±0.17[e]	2.60±0.21[bc]	Long bold
NWK-Sudi	6.83±0.018[b]	2.34±0.19[e]	2.92±0.15[a]	Medium slender
SEA-Okai	5.94±0.42[f]	2.36±0.21[e]	2.55±0.24[c]	Long bold
SEA-Ikwo	5.95±0.44[f]	2.48±0.16[c]	2.52±0.20[c]	Long bold
SWO-Ofada	5.84±0.43[g]	2.70±0.11[a]	2.16±0.27[f]	Short bold
SWE-Igbemo	5.93±0.39[f]	2.43±0.19[d]	2.46±0.27[d]	Short bold
SSC-Mars	7.22±0.71[a]	2.16±0.13[f]	2.97±0.12[a]	Medium slender
SSC-Sipi	6.07±0.52[e]	2.21±0.07[f]	2.76±0.16[b]	Long bold

L: Length, B: Breadth, L/B

Values are Mean±SE (n=3). Means within each column not having the same letters are significantly different (p<0.05). NCB-Bali and NCB-Mairuwa: Bali and Mairuwa were sourced from Benue State, North Central Nigeria, NEB-Zanchabari and NEB-Dikwa: Zabamari and Dikwa from Borno State, North Eastern Nigeria, NWK-Supi and NWK-Sudi=Supi and Sudi from Kano State, North Western, SEA-Okai and SEA-Ikwo: Okai and Ikwo from Abia State, South Eastern, SWO-Ofada and SWE-Igbemo: Ofada and Igbemo from Ogun and Ekiti States respectively, South Western, SSC-Mars and SSC-Sipi: Mars and Sipi are from Cross River State, South Southern Nigeria.

3.2 Weight and density of milled rice cultivars from six regions of Nigeria

Thousand kernel weight (TKW), True density (TD) and Bulk density of the twelve milled rice cultivars varied significantly (P<0.05) from 18.70-25.10(g), 1.27-1.73g/ml and 0.678-0.918 (g/ml) as-is-moisture basis respectively.(Table 2b) These parameters give idea of the quantity of matter otherwise the nutrient density of the rice kernels, the values are said to be influenced by such factors as the level of maturity, moisture content and of chalkiness of the rice grains. The higher TKW were observed in NWK-Sudi (24.0g), NCB-Bali (24.50g) and SSC-Mars (25.10g) while NEB-Dikwa (18.70g) had the least TKW. According to FAO (1973), none belonged to the extra-heavy class (>28g) instead they were of heavy category (22-28g) except NEB-Dikwa. Cultivars with very higher TD were SWO-Ofada (1.50g/ml), SSC-Mars (1.55g/ml), NEB-Dikwa (1.55g/ml), SSC-Sipi (1.66g/ml) and NWK-Sudi (1.73g/ml). Seven cultivars had TD less than 1.50g/ml, those with the smallest TD were NCB-Mairuwa (1.27g/ml), SEA-Ikwo (1.28g/ml) and SEA-Okai (1.29g/ml). Bulk densities of SSC-Mars (0.823g/ml), NEB-Dikwa (0.837g/ml), SSC-Sipi (0.879g/ml) and NWK-Sudi (0.914g/ml) were the higher than those of NCB-Mairuwa (0.672g/ml), SEA-Ikwo (0.678g/ml) and SEA-Okai (0.684g/ml) with the least BD. The results are in agreement with the findings of Mir et al. (2012) for brown rice (TKW: 18.18-22.92g; TD: 1270.81-1484.42kg/m^3) as well as the TKW of 18.60-31.60g reported by Kokot and Phoung (1999). Relatively smaller values of TKW (15.30-19.70g) was reported by Ghadge and Prasad (2012) for rice cultivars grown in India, however TD (1.517-1.528g/ml) and BD (0.795-0.870g/ml) reported by the same authors are in agreement with values obtained in the present study. Consider that the cultivars under investigation were grown on different production ecologies, exposed to different agro-climatic conditions and received different processing and storage conditions, however variation of the parameters were not as wide as anticipated.

Table 2b:Weight and density of some milled rice cultivars from six regions of Nigeria

Variety	TKW(g)	TD(g/ml)	BD(g/ml)
NCB-Bali	24.5±0.11^a	1.34±0.03d	0.709±0.011^e
NCB-Mairuwa	22.70±0.11^b	1.27±0.04^e	0.672±0.020^d
NEB-Zanchabari	21.10±0.12^d	1.31±0.03^d	0.694±0.015^d
NEB-Dikwa	18.70±0.1^e	1.58±0.02^b	0.837±0.016^{ab}
NWK-Supi	22.00±0.12^c	1.46±0.03^c	0.777±0.014^b
NWK-Sudi	24.00±0.13^{ab}	1.73±0.01^a	0.914±0.013^a
SEA-Okai	20.70±0.13^d	1.29±0.04^e	0.684±0.022^d
SEA-Ikwo	22.70±0.11^b	1.28±0.04^e	0.678±0.028^d
SWO-Ofada	22.30±0.15^c	1.50±0.02^b	0.795±0.015^b
SWE-Igbemo	22.90±0.11^b	1.39±0.03^{cd}	0.732±0.015^b
SSC-Mars	25.10±0.13^a	1.55±0.02^b	0.823±0.014^{ab}
SSC-Sipi	22.60±0.13^{bc}	1.66±0.01^{ab}	0.879±0.017^a

TKW: Thousand Kernel Weight, TD: True Density, BD: Bulk Density Values are Mean±SE (n=3). Means within each column not having the same letters are significantly different ($p<0.05$). NCB-Bali and NCB-Mairuwa: Bali and Mairuwa were sourced from Benue State, North Central Nigeria, NEB-Zanchabari and NEB-Dikwa: Zabamari and Dikwa from Borno State, North Eastern Nigeria, NWK-Supi and NWK-Sudi=Supi and Sudi from Kano State, North Western, SEA-Okai and SEA-Ikwo: Okai and Ikwo from Abia State, South Eastern, SWO-Ofada and SWE-Igbemo: Ofada and Igbemo from Ogun and Ekiti States respectively, South Western, SSC-Mars and SSC-Sipi: Mars and Sipi are from Cross River State, South Southern Nigeria.

3.3 Cooking properties of milled rice cultivars from six regions of Nigeria

Water Uptake ratios(WUR), Gruel solids(GR %), Kernel lengths after cooking (KLAC) and Linear elongation ratios(LER) of the twelve milled rice cultivars varied significantly ($p<0.05$) from 1.55-2.03, 0.31-0.91 (%), 6.05-8.25mm and 1.07-1.42 respectively.(Table 3) SEA-Ikwo (2.03), SSC-Mars (2.02) and SSC-Sipi (1.88) had water uptake ratio significantly higher than others. None of the cultivars had WUR less than 1.50. Higher water uptake ratio is a desirable quality indicator because it gives rise to high volume expansion however excess water absorption during cooking leads to high level of gruel solids or pasty gruel that will in turn lead to the development of burnt flavor and sticky rice kernels; a characteristic of low amylose or chalky rice kernels, an undesirable quality indicator (Tan et al.,2000). Shilpa and Krishnan (2010) reported WUR of 250-350% for rice varieties of Goa India, higher than 2.37-4.00 reported by Moulick et al.(2016) for rice varieties from West Bengal but 1.51-1.82 reported by Hussain et al.(2009) is in agreement with WUR of 1.55-2.03 obtained in this study. Level of gruel solids were generally low considering that Ravi et al.(2012) reported 5.7% for a variety called *Salem Samba* greater than the mean gruel solids of 0.71% obtained here, indicating either the rice kernels were hard or were parboiled before milling or were of intermediate to high amylose rice grain. NEB-Dikwa (0.91%) and NEB-Zabamari had the highest percentage gruel solids and NWK-Supi (0.31%) the least. Mean KLAC of 7.66m for the twelve cultivars is comparable to 8.4mm for *Salem Samba* reported by Ravi et al.(2012) but KLAC of 6.05-8.25mm obtained here is greater than 2.31-5.88mm for aromatic Indian rice varieties reported by Shilpa and Krishnan (2010) but comparable to 7.10-8.20mm for rice hybrids studied by Dhivyapyriya and Kalaivyarasi (2015). KLAC of SSC-Sipi (8.25mm), SWE-Igbemo (8.23), NWK-Supi (8.22mm), NWK-Sudi and SWO-Ofada (7.97mm) were higher as well as those of SSC-Mars and SEA-Ikwo, a desirable cooking quality. The least lengthwise extension after cooking was observed in NCB-Mairuwa and NCB-Bali both from North Central Nigeria. Linear extension ratios (LER) (1.32-1.42) of the twelve varieties were comparable to 1.24-1.57 for rice hybrids reported by Dhivyapriya and Kalaivarasi (2015) and less than a mean of 1.54 reported by Ravi et al. (2012). Higher LER are desirable cooking quality.

Table 3: Cooking characteristics of milled rice cultivars from six regions of Nigeria

Variety	Water uptake ratio	Gruel solids (%)	K LA C (mm)	LER
NCB-Bali	1.51±1.67[d]	0.74±0.26[b]	6.19±0.07[c]	1.16±0.02[cd]
NCB-Mairuwa	1.60±1.63[c]	0.73±0.20[b]	6.05±0.18[cd]	1.07±0.04[e]
NEB-Zanchabari	1.58±1.51[c]	0.90±0.27[a]	6.62±0.08[cd]	1.12±0.06[c]
N EB-Dikwa	1.87±1.20[b]	0.91±0.27[a]	6.52±0.11[d]	1.11±0.07[c]
NWK-Supi	1.50±1.10[d]	0.31±0.07[d]	8.22±0.04[a]	1.38±0.03[ab]
NWK-Sudi	1.55±1.70[f]	0.85±0.20[ab]	8.11±0.06[ab]	1.23±0.06[c]
SEO-Okai	1.59±1.69[c]	0.65±0.18[bc]	7.49±0.09[bc]	1.30±0.04[b]
SEA-Ikwo	2.03±0.95[a]	0.71±0.19[b]	7.63±0.05[b]	1.31±0.05[ab]
SWO-Ofada	1.50±1.69[e]	0.71±0.22[b]	7.97±0.07[b]	1.39±0.05[a]
SWE-Igbemo	1.57±1.51[c]	0.68±0.13[bc]	8.23±0.03[a]	1.42±0.03[a]
SSC-Mars	2.02±0.99[a]	0.61±0.17[c]	7.63±0.08[b]	1.13±0.06[c]
SSC-Sipi	1.88±1.05[b]	0.69±0.19[bc]	8.25±0.04[a]	1.36±0.02[ab]

LER: Linear Elongation Ratio. KLAC: Kernel Length after Cooking

Values are Mean±SE (n=3). Means within each column not having the same letters are significantly different ($p<0.05$). NCB-Bali and NCB-Mairuwa: Bali and Mairuwa were sourced from Benue State, North Central Nigeria, NEB-Zanchabari and NEB-Dikwa: Zabamari and Dikwa from Borno State, North Eastern Nigeria, NWK-Supi and NWK-Sudi=Supi and Sudi from Kano State, North Western, SEA-Okai and SEA-Ikwo: Okai and Ikwo from Abia State, South Eastern, SWO-Ofada and SWE-Igbemo: Ofada and Igbemo from Ogun and Ekiti States respectively, South Western, SSC-Mars and SSC-Sipi: Mars and Sipi are from Cross River State, South Southern Nigeria.

3.4 Proximate composition of milled rice cultivars from six regions of Nigeria

The moisture, ash, fat, protein (N×5.95) and carbohydrate (by difference) contents of the milled rice cultivars varied significantly from 10.26 -12.35%, 0.34-1.40%, 0.89-2.00%, 5.02-9.08% and 76.66-82.45% respectively.(Table 4) The differences in moisture contents can only be attributed to varietal difference and level of milling each cultivar received involving the removal of the outer protective layers since the samples were left at room temperature for two weeks to attain equilibrium moisture content prior to physicochemical analysis. This might be responsible for the narrow range of moisture contents obtained here. Devi et al.(2015) reported moisture contents of 7.11-11.29%(5% polishing) and 7.01-11.28%(10% polishing) respectively for ninety Indian rice varieties. Moisture content of 11.4-12.2% for selected rice cultivars of Bangladesh reported by Zubair et al.(2015) is comparable to 10.26-12.35% obtained in this study. SSC-Mars had the highest protein content (9.08%), others with protein contents greater than 7.0% were NWK-Supi (7.18%), SEA-Okai (7.79%), and SSC-Supi (7.81). The varieties with lower protein contents were NCB-Mairuwa (5.02%), SWE-Igbemo (5.15%), SWO-Ofada (5.32%), and NEB-Dikwa (5.73%). The varieties under investigation cannot be regarded as high protein cultivars according to the classification of Resurrecion et al.(1979). Oko and Ugwu(2011) reported crude protein of 1.58-6.22% for rice varieties obtained from Abakaliki, South East, indicating that Nigeria grown rice varieties are relatively of lower protein content; in that report *Sipi* was found to contain the least level of protein(1.58%) but contrary to that finding *Sipi* sourced from Cross River State, South South Nigeria had a mean protein level of 7.81%. Rice is one of the main sources of dietary energy for Nigerians and has not been regarded as a major source of protein but being a sought after staple its role in the provision of dietary protein to Nigerians cannot be overstressed. Geographic location, climatic, agronomic practices as well as level of processing have serious bearing on the proximate composition and mineral contents of rice varieties. Zubair et al.(2015) reported crude protein of 6.51-7.04% for some rice varieties while Wire-Manu and Amamoo (2017) reported 5.69-8.40 for local and improved varieties in Ghana. Devi et al.(2015) noted that the level of polishing have affects the proximate composition since the outer layers being removed contain higher level of fat, fiber, and ash. In their study they reported a crude protein of 5.20-10.80% and 5.22-10.29% for 5% and 10% levels of polishing respectively.

Generally, rice grains are not known to contain high level of fat, the range 0.89-2.00 obtained in this study is comparable to 0.46-2.57% reported by Wireko-Manu and Amamoo (2017) but greater than the mean of 0.97% and 0.73% for brown and polished Pakistani rice varieties respectively reported by Anjum et al.(2007). The fat contents of SSC-Supi, SEA-Ikwo, SEA-Okai and NWK-Sudi were not significantly different ($P>0.05$) and were the higher, the least were observed in SWE-Igbemo (0.89%) and SSC-Mars (1.06%). Those with higher fat contents will likely have better taste when cooked although rice is prepared as *joloof* or plain rice eaten with stew or sauce in Nigeria. The level of polishing determines the amount of fat available, since fat in rice kernels are concentrated in the outer layers which are usually removed during milling which also affect the ash and fiber contents as well. The ash contents of 0.34-1.40% observed in this study indicates those with higher ash contents such as SEA-Ikwo, SWE-Igbemo, and SSC-Mars received lower level of polishing than those with lower levels of ash such as NEB-Dikwa (0.34%) and NCB-Mairuwa (0.65%). Comparable results of 1.00-2.00% was reported by Oko and Ugwu (2011) and 0.53-0.80% reported by Ebuehi and Oyewole(2007) for *arosa* and *ofada* rice varieties from South-West Nigeria. The range of carbohydrate contents (76.66-82.45%) observed in this study is similar to 79.65-81.06% reported by Zubair et al (2015); 76.92-86.03% (Oko and Ugwu, 2011) and 74.2-79.4% (Wireko-Manu and Amamoo (2017)). Devi et al.(2015) observed the carbohydrate content of rice increases with increased refinement, and reported carbohydrate contents of ninety-two Indian rice varieties: 76.71-84.05% and 78.42-85.18% for 5% and 10% levels of polishing.

Table 4: Proximate composition (%) of milled rice cultivars from six regions of Nigeria

Variety	Moisture	Ash	Fat	Protein	Carbohydrates
NCB-Bali	11.38^{f}	0.74^{c}	1.82^{b}	6.53^{d}	79.54^{ab}
NCB-Mairuwa	10.86^{d}	0.65^{d}	1.69^{c}	5.02^{h}	81.73^{a}
NEB-Zanchabari	12.14^{ab}	0.85^{b}	1.67^{c}	6.24^{de}	79.10^{ab}
NEB-Dikwa	11.20^{c}	0.34^{e}	1.23^{d}	5.73^{f}	81.53^{a}
NWK-Supi	11.81^{b}	0.79^{c}	1.83^{b}	7.18^{c}	78.59^{b}
NWK-Sudi	10.60^{de}	0.84^{b}	1.97^{a}	6.48^{d}	80.01^{ab}
SEA-Okai	10.42^{f}	0.88^{b}	1.99^{a}	7.79^{b}	78.98^{b}
SEA--Ikwo	12.00^{cab}	1.14^{ab}	1.97^{c}	6.08^{e}	78.81^{b}
SWO-Ofada	11.16^{c}	0.89^{b}	1.82^{b}	5.32^{g}	80.71^{ab}
SWE-Igbemo	10.37^{f}	1.40^{a}	0.89^{b}	5.15^{h}	82.45^{a}
SSC-Mars	12.35^{a}	1.10^{ab}	1.06^{e}	9.08^{a}	76.66^{c}
SSC-Sipi	10.26^{g}	0.82^{de}	2.00^{a}	7.81^{b}	79.19^{ab}

Values are Mean (n=3). Means within each column not having the same letters are significantly different ($p<0.05$). NCB-Bali and NCB-Mairuwa: Bali and Mairuwa were sourced from Benue State, North Central Nigeria, NEB-Zanchabari and NEB-Dikwa: Zabamari and Dikwa from Borno State, North Eastern Nigeria, NWK-Supi and NWK-Sudi=Supi and Sudi from Kano State, North Western, SEA-Okai and SEA-Ikwo: Okai and Ikwo from Abia State, South Eastern, SWO-Ofada and SWE-Igbemo: Ofada and Igbemo from Ogun and Ekiti States respectively, South Western, SSC-Mars and SSC-Sipi: Mars and Sipi are from Cross River State, South Southern Nigeria.

3.5 Mineral contents of the milled rice cultivars from six regions of Nigeria.

Significant variations existed in the mineral contents of the milled rice varieties. The range of values (mg/100g) for Calcium (Ca), Potassium (K), Phosphorous (P), Iron (Fe), and Zinc (Zn) were 6.22-10.24, 30.17-125.16, 29.64-54.15, 0.38-0.69 and 0.42-1.04 respectively.(Table 5) The mean values (mg/100) were 7.72±1.05, 60.63±33.03, 38.46±7.84, 0.53±0.10 and 0.80±0.20 Ca, K, P, Fe and Zn respectively. The increasing order of the concentration of the elements present in the rice cultivars was K>P>Ca>Zn>Fe and the order reported by Zang et al (2009) is P>K>S>Mg>Ca>Zn>Na>Al>Mn>Fe etc. different from K>Mg>Zn>Ca>Mn>Fe>Na>Cu reported by Govarethinam et al.(2014). The gap between values of Calcium, Iron and Zinc were narrow as indicated by their standard deviations. Bali and Mairuwa from North Central and SWE-Igbemo and SSC-Mars had significant higher calcium levels than others. The levels of Calcium in rice varieties reported by Juliano (1985) was 10-30mg/100g; Oko and Ugwu et al. (2011) 0.07-0.11%; Govarethinam et al.(2014), 0.47-0.95mg/100g; Heinemann et al.(2005) reported a mean of 6.7mg/100g. It all points out that rice is not a good source of Calcium, an element that is linked to prevalence of cardiovascular diseases such as hypertension when its intake is inadequate (Wang et al., 2008). The concentrations of Potassium were higher in SSC-Mars (125.11mg/100g) and SWO-Ofada (109.14mg/100g) and lower concentrations were obtained in six varieties: NCB-Bali (30.17mg/100g), SEA-Ikwo(30.77mg/100g),SWE-Igbemo(31.19mg/100g),NCB-Mairuwa(33.42mg/100g),NEB-Dikwa(35.80mg/100g) and NWK-Supi (40.10mg/100g), lower than values reported by Zohoun et al.(2018) 2290mg/kg, Oko and Ugwu. (2011) 150-200mg/100g, Govarethinam et al.(2014) 33.3-212.8mg/g. Average potassium values of 91mg/100g, 66mg/100g, and 87mg/100g were reported by Anthoine et al.(2012), Heinemann et al.(2005) and Jang et al.(2012) respectively. The adequacy of mineral intake such as Potassium in rice-based foods depends essentially on the degree of milling among other prevailing factors such as variety and geographic location. Potassium in conjunction with Sodium is responsible for the maintenance of electrolyte osmotic and acid-base balance that is necessary for nerve conduction, muscle contractions and vascular volume (Recenziga Prikaz, 2001). The highest level of phosphorous (54.15mg/100g) was obtained in SWO-Ofada and the least were in NCB-Bali (29.64 mg/100g), SEA-Ikwo (29.47mg/100g) and NEB-Dikwa (29.31mg/100g). Oko et al. (2012) reported 0.50-0.55%. Phosphorous higher than 0.166% and 150mg/100g reported by Zohoun et al.(2018) and Abbas et al. (2011) respectively. A range of 80-150mg/100mg Phosphorus reported by Juliano (1985) is higher than 29.64-54.15mg/100g obtained in this study. Phosphorous and Calcium cooperatively influence lipid metabolism positively. Calcium to Phosphorous ratio of 1 or greater intake have positive influence on blood pressure (So-young Bu, 2012).

The highest levels of Iron (mg/100g) were observed in SEA-Okai (0.69), SWO-Ofada (0.65) and NEB-Zabamari (0.63) lower amounts were observed in SSC-Sipi (0.29) and SSC-Mars (0.40). The Zinc contents(mg/100g) followed a similar trend higher in five varieties: NEB-Zabamaari (1.11), SEA-Okai (1.04), SEA-Ikwo (0.95), NWK-Supi (0.94) and NWK-Sudi (0.91); the least was observed in SSC-Sipi (0.42). Ajum (2007) reported 1.57-1.94mg/100g and 1.44-2.97mg/100g for Iron and Zinc respectively in four Pakistani milled rice varieties. Values of Zinc and Iron obtained in this study were comparable to 0.2 -2.8mg/100g for iron and 0.6-2.2mg/100g for Zinc reported by Juliano (1985) and 0.29-0.78mg/100g for Iron and 0.88-2.6mg/100g Zinc reported by Alaka et al. (2011). Apart from the degree of milling, other factors such as geographic location, varietal differences and cultural differences are the factors that determine the amount of nutrients available in milled rice (Welch, 2002; Abbas et al.,2011). White rice is not an excellent source of Iron and Zinc, two vital micronutrients, their deficiency are a global health problem affecting population of all age groups and sex, endemic in rice consuming countries of Asia (Kumar et al.,2017). Most locally processed rice available in Nigerian markets are not polished but semi-milled, straight- milled in most cases, adhering bran pieces and high level of broken kernels are common features.

Table 5:Mineral contents (mg/100g) of popular milled rice cultivars from six regions of Nigeria

Variety	Zinc	Calcium	Potassium	Phosphorous	Iron
NCB-Bali	0.80[b]	10.04[a]	30.17[ef]	29.64[d]	0.49[c]
NCB-Mairuwa	0.82[b]	8.11[b]	33.42[e]	34.79[cd]	0.44[d]
NEB-Zanchabari	1.11[a]	6.28[de]	77.81[bc]	42.67[bc]	0.63[a]
NEB-Dikwa	0.94[ab]	7.68[c]	35.80[e]	9.31[d]	0.59[b]
NWK-Supi	0.91[ab]	6.22[de]	40.10[d]	46.46[b]	0.52[bc]
NWK-Sudi	1.04[a]	7.38[c]	87.22[b]	45.78[ab]	0.69[a]
SEA-Okai	0.95[ab]	7.94[c]	60.85[c]	40.06[bc]	0.56[bc]
SEA-Ikwo	0.89[b]	7.34[e]	30.77[ef]	29.47[d]	0.65[a]
SWO-Ofada	0.71[c]	6.94[d]	109.14[ab]	54.15[a]	0.48[c]
SWE- Igbemo	0.60[d]	8.64[b]	31.19[e]	32.55c[d]	0.49[c]
SSC-Mars	0.53[e]	8.40[b]	125.11[a]	37.81[c]	0.40[d]
SSC-Sipi	0.42_f	7.68[c]	66.13[c]	38.86[c]	0.29[e]
Overall Mean	0.80±0.20	7.72± 1.05	60.63±30.13	38.33± 7.84	0.53±0.10

Values are Means within each column not having the same letters are significantly different ($p<0.05$). NCB-Bali and NCB-Mairuwa: Bali and Mairuwa were sourced from Benue State, North Central Nigeria, NEB-Zanchabari and NEB-Dikwa: Zabamari and Dikwa from Borno State, North Eastern Nigeria, NWK-Supi and NWK-Sudi=Supi and Sudi from Kano State, North Western, SEA-Okai and SEA-Ikwo: Okai and Ikwo from Abia State, South Eastern, SWO-Ofada and SWE-Igbemo: Ofada and Igbemo from Ogun and Ekiti States respectively, South Western, SSC-Mars and SSC-Sipi: Mars and Sipi are from Cross River State, South Southern Nigeria.

3.6 Sensory properties of the cooked milled rice varieties from six regions of Nigeria

The cultivars with the best cream/white color when cooked were SSC-Mars (7.30), NEB-Dikwa (7.30), NEB-Zabamari (7.30), NCB-Bali (7.10). The color of SWE-Igbemo (3.90), SWO-Ofada (3.30), and SEA-Okhai (4.90) were disliked by the test panelists.(Table 6) On a 9-point hedonic scale the color of NWK-Sudi (5.40) and SEA-Ikwo (5.50) were neither liked nor disliked. Color of cooked rice is a criterion of quality, color of cooked milled rice ranges from white to grey depending on the leveling of milling, less than white indicates high protein content or long storage duration. As for the taste scores, NEB-Dikwa (7.30) and NEB-Zabamari (7.20) had the best, the taste of NWK-Sudi (4.80), SWO-Ofada (4.70), SWE-Igbemo (4.60) were disliked by the panelists, equally the aroma of SWE-Igbemo (3.90), SWO-Ofada (3.30) were poorly accepted as well SEA-Okwai (4.80), the varieties that scored 7 and above for aroma were SSC-Sipi (7.20), NEB-Zabamari (7.20), NEB-Dikwa (7.10), others had aroma scores of between 5 and 6 on a scale of nine. Special preparation method must be adopted for those varieties with poor sensory attributes otherwise acceptance outside the region of production will not be achieved. Poor handling and storage practices may create foreign and unacceptable taste or aroma. The texture(soft and fluffy) of cooked SSC-Mars (7.20), SSC-Sipi (7.00), NEB-Zabamari (7.10) were higher indicative perhaps of high amylose varieties while those of SWO-Ofada (4.10), SWE-Igbemo (4.20) and NWK-Sudi (4.80) were disliked perhaps their poor taste and aroma negatively influenced the panelists in assessing their texture. Cooked rice hardens on cooling, the extent of hardening depends on the extent of cooking, water uptake, amylose amylopectin ratio among other factors. The overall acceptability scores of SWE-Igbemo and SWO-Ofada were the least, while SSC-Mars (7.60) had the highest overall acceptability score, NEB-Dikwa (7.50) followed closely. Others were NEB-Zabamari (7.10) and NCB-Bali (7.00). Although, Nigerian consumers attach premium quality on slender-shaped long rice kernels, it is to be noted here that taste and aroma of cooked are among the determinant factors that influence acceptability.

Table 6: Sensory scores of cooked rice cultivars from six regions of Nigeria and a foreign variety

Variety	Colour	Taste	Aroma	Texture	Overall Score
Foreign	7.20[a]	7.70[ab]	7.20[a]	6.60[ab]	7.50[a]
NCB-Bali	7.10[a]	6.50[bc]	6.40[ab]	6.40[ab]	7.00[ab]
NCB-Mairuwa	6.30[ab]	6.20[cd]	6.40[ab]	6.40[ab]	6.60[ab]
NEB-Zanchabari	7.20[a]	7.20[abc]	7.20[a]	7.10[a]	7.10[ab]
NEB-Dikwa	7.30[a]	7.50[ab]	7.10[a]	6.70[a]	7.50[a]
NWK-Supi	6.50[ab]	6.60[abc]	5.30[bd]	6.20[ab]	6.90[ab]
NWK-Sudi	5.40[bc]	4.80[ef]	4.60[def]	4.80[cd]	5.10[cd]
SEA-Okai	4.90[cd]	5.10[def]	4.80[cde]	5.70[bc]	6.00[bc]
SEA--Ikwo	5.50[bc]	6.00[de]	6.10[abc]	6.10[ab]	6.70[ab]
SWO-Ofada	3.30[e]	4.70[f]	3.30[f]	4.10[d]	4.30[d]
SWE-Igbemo	3.90[de]	4.60[f]	3.90[ef]	4.20[d]	4.30[d]
SSC-Mars	7.30[a]	6.60[abc]	6.90[a]	7.20[a]	7.60[a]
SSC-Sipi	6.60[ab]	7.80[a]	7.20[a]	7.00[a]	7.30[a]

Values are Mean (n=3). Means within each column not having the same letters are significantly different ($p<0.05$). NCB-Bali and NCB-Mairuwa: Bali and Mairuwa were sourced from Benue State, North Central Nigeria, NEB-Zanchabari and NEB-Dikwa: Zabamari and Dikwa from Borno State, North Eastern Nigeria, NWK-Supi and NWK-Sudi=Supi and Sudi from Kano State, North Western, SEA-Okai and SEA-Ikwo: Okai and Ikwo from Abia State, South Eastern, SWO-Ofada and SWE-Igbemo: Ofada and Igbemo from Ogun and Ekiti States respectively, South Western, SSC-Mars and SSC-Sipi: Mars and Sipi are from Cross River State, South Southern Nigeria.

IV. CONCLUSION

The rice cultivars under study consisted mainly of short and long bold semi-milled kernels. The length of storage or extent of parboiling if any could not be ascertained and it known that these factors bear heavily on rice grain properties. Proximate composition of the cultivars did not deviate from results reported in the literature. Supi, Sudi, Dikwa, Zabamari, Sipi and Mars increasing order had excellent physicochemical and cooking properties that have positioned them in the elite class of rice cultivars, however short grained Ikwo, Okai, Igbemo, and Mairuwa although had poorer cooked sensory scores and which demanded special method of cooking, however they had better kernel length after cooking(KLAC). Nigerians attach premium quality to extra long pr long rice kernels without knowing their cooking behavior. It is suggested that cultivars these cultivars qualities should be popularized through cultivation in other agricultural belts to determine observed qualities indicators would be maintained. Mars in particulars should be declared a national rice cultivars provided its yield potential is high. With better processing handling and storage conditions, it could be averred that some Nigerian grown rice cultivars compare favourably with other known cultivars elsewhere.

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