Nigerian Food Journal
Official Journal of Nigerian Institute of Food Science and Technology
www.nifst.org
NIFOJ Vol. 36 No. 1, pages 135 – 140, 2018
FULL LENGTH ARTICLE

Physicochemical Properties of Flours from Five Nigerian Rice Cultivars

Chinma, C.E.,[1] Azeez, S.O.,[1] Olaitan, O. H.,[1] Danbaba, N.,[2] Anuonye, J.C.[1] and Oloyede, O.O. [1,3]

ABSTRACT

Physicochemical properties of five Nigerian rice cultivars (*Bisalachi, Ebagichi, Lamiyatu, Majalisa* and *Walue*) were investigated. Length, width, ratio of grain length to width and one thousand grain weight of the grains were determined. The colour attributes, proximate composition, amino acid profile, minerals, B-vitamins and phytic acid content of the flours were evaluated. The rice cultivars were long (*Ebagichi, Lamiyatu, Majalisa* and *Walue*) and medium (*Bisalachi*) grains. The 1000-kernel weight varied between 15.98 g (*Bisalachi*) and 22.37 g (*Lamiyatu*). Protein, carbohydrate, amylose and total amino acid content of rice flours ranged from 5.82 to 11.48 %, 74.57 to 80.90 %, 21.56 to 23.84 %, and 7.29 to 8.06 g/100 g, respectively. Aspartic and glutamic acid had the highest concentrations in the rice samples. The flours are rich in minerals and some B-vitamins. The increased consumption of the rice cultivars is recommended and applications in food systems need to be exploited.

Keywords: Rice cultivars, flour, physicochemical properties.

1.0 Introduction

Rice is the principal staple food for about half of the world's population (Gani *et al.*, 2017). Rice is rich in starch, minerals, B-vitamins but low in protein. Rice is mainly consumed as cooked rice but during the last decade, the consumption of rice flour has increased. Rice flour is widely used as an ingredient in many food products, including beverages, meat products, puddings, salad dressings and gluten-free diets (Falade and Christopher, 2015). There is an increasing demand for rice varieties with excellent quality characteristics throughout the world (Bhat and Riar, 2017).

Many hybrid and traditional rice varieties are cultivated in Nigeria (Odejobi *et al.*, 2015). In the recent years, over sixty new Nigerian rice varieties have been developed and released for commercial production, but some indigenous farmers' varieties are also being cultivated side by side the improved varieties (Odenigbo *et al.*, 2014). The physicochemical properties of some Nigerian rice cultivars have been documented in literature. However, data on the physicochemical properties of flours from many Nigerian rice cultivars are insufficient or lack in literature.

Physicochemical properties of rice flour are the main determinants of its technological functionality (Cornejo and Rosell, 2015). Physicochemical properties of rice flour also could indicate market value, utilization and consumer preferences of rice cultivars (Falade and Christopher, 2014). The objective of the study was to determine the physicochemical properties of flours from five Nigerian rice cultivars in order to provide baseline

[1] Department of Food Science and Technology, Federal University of Technology, Minna, Nigeria.
[2] Food Technology and Value Addition Research Program, National Cereals Research Institute, Badeggi, Bida, Niger State, Nigeria.
[3] Department of Food and Nutritional Sciences, University of Reading, Whiteknights, Reading, Berkshire RG6 6AH, UK.
Corresponding author: chinmachiemela@futminna.edu.ng

information that will enhance their application in food systems. Also, the study could be a way to present some other varieties different from those usually marketed.

2.0 Materials and Methods

2.1 *Materials*

Five Nigerian rice cultivars (*Bisalachi, Ebagichi, Lamiyatu, Majalisa* and *Walue*) were procured from the rice breeding Laboratory of National Cereal Research Institute, Badeggi, Bida, Niger State, Nigeria during 2014 and 2015 harvest season. The rice cultivars were cultivated under lowland ecology with recommended agronomic practices for rice production in Nigeria.

2.2 *Sample preparation*

Substantial quantities of paddy of each rice cultivar (about 11.00% moisture content) samples were dehusked in a Satake rice husker (THU-35B, Satake Corporation, Japan). The brown rice obtained was polished in Satake grain testing mill (model No. 553504, Satake Engineering Co., Japan) to obtain 8% degree of milling. Milled rice samples from each cultivar were separated from broken rice. Some portions of the milled rice grains (as shown in Figure 1) were separately stored in labelled plastic containers prior to determination of physical properties of the grains. The remaining portions of rice grains of the five cultivars were separately ground into fine flour using hammer mill (Globe P 44, Diamond Tools Co. Ltd. Henan, China). The samples were sieved through 100 µm sieve size and stored in airtight plastic containers covered with lids.

2.3 *Determination of physical properties of rice grains and flours*

The length and width of 20 whole rice grains from each cultivar were measured using a vernier caliper (12 inches digital caliper, Carrera Precision, China). The ratio of grain length to width was calculated. A 1000 grain weight and classification of grain type was as reported by Falade and Christopher (2015). Colour properties of flour samples were determined using a using a Chroma-Meter (CR-410, Konica-Minolta, Japan). The colour parameters measured were lightness (L), redness (+a), greenness (-a), yellowness (+b) and blueness (-b). A white tile with L, a and b values of 88.80, 2.10 and 0.34, respectively, was used as standard.

2.4 *Proximate analysis*

The moisture, protein, fat, ash and crude fiber content was determined according to AOAC (2005) methods 934.01, 920.87, 942.05 and 920.87 respectively, while total carbohydrate was estimated by subtracting the total percentage of the other components from one hundred.

2.5 *Amino acid analysis*

Amino acid composition was determined using the PICO-TAG method described by Bidlingmeyer *et al.* (1984). The results were expressed as g/100g sample on dry basis.

2.6 *Determination of amylose content*

The amylose content was determined using an atomic absorption spectrophotometer (Perkin-Elmer model 2380, USA) at 620 nm accord to the iodine method of Juliano *et al.* (1981).

2.7 *Mineral analysis*

Mineral (calcium, magnesium, potassium, sodium, iron and zinc) composition was determined using atomic absorption spectrophotometer (Perkin-Elmer model 2380, USA) according to AOAC 985.35 method (AOAC 2005). Phosphorus was determined using the vanadomolybdate method as described by AOAC 995.11 method (AOAC 2005).

2.8 *Determination of thiamin and riboflavin*

Thiamine and riboflavin content was determined using a fluorescent UV spectrophotometer (Cecil A20 Model) at a wavelength of 285 nm and 460 nm, respectively, according to AOAC 953.17 method (2005).

2.9 *Determination of phytic acid*

Phytic acid content of samples was determined according to the method of Vaintraub and Lapteva (1988).

3.0 Results and Discussion

3.1 *Physical properties of rice grains and flours*

The physical properties of rice grains and flours are presented in Table 1. The length of rice grains ranged from 5.60 mm (*Bisalachi*) to 9.63 mm (*Lamiyatu*) while the width varied between 1.90 mm (*Ebagichi*) and 2.20 mm (*Lamiyatu*). The length to width ratio ranged from 2.77 (*Bisalachi*) to 3.23 (*Majalisa*). Based on the length to width ratio result, rice grains were classified into long grain (*Ebagichi*, *Lamiyatu*, *Majalisa* and *Walue* with length to width ratio ≥ 3) and medium grain (*Bisalachi*, length to width ratio < 3) (Falade and Christopher, 2015). In terms of shape classification, the milled rice samples were classified as slender (*Ebagichi*, *Lamiyatu*, *Majalisa* and *Walue*, with length to width ratio ≥ 3) and intermediate shape (*Bisalachi*, length to width ratio < 3) (Falade and Christopher, 2015). The 1000-kernel weight varied between 15.98 g (*Bisalachi*) and 22.37 g (*Lamiyatu*).

Colour is an important quality parameter in the food processing industry and it attracts the consumers' choice and preference (Pathare *et al.*, 2013). The *L* value of rice flours ranged from 88.20 (*Lamiyatu*) to 91.70 (*Ebagichi*). Higher *L* values of the rice flours could indicate that the flours could find applications in food systems where high whiteness index value is required. The *a* and *b* values ranged from -0.13 (*Lamiyatu*) to -1.53 (*Majalisa*), and 5.30 to 7.30 (*Lamiyatu*), respectively. The differences in rice flour colours may be attributed to variations in phenolic constituents.

Table 1: Physical properties and colour attributes of rice flour processed from various rice varieties

Cultivar	Length (mm)	Width (mm)	Length/width ratio	1000-grain weight (g)	Grain type	L	a	b
Bisalachi	5.63±0.02c	2.03±0.04b	2.77±0.10b	15.98±0.33c	Medium	89.20±0.16c	-1.30±0.01a	5.96±0.13d
Ebagichi	6.10±0.01b	1.90±0.12c	3.22±0.14a	20.32±0.45c	Long	91.70±0.19a	-0.80±0.01a	6.10±0.10c
Lamiyatu	9.63±0.00a	2.20±0.05a	3.15±0.20a	22.37±0.39a	Long	84.90±0.31c	-0.13±0.00a	7.30±0.23a
Majalisa	6.60±0.01b	2.00±0.03b	3.23±0.10a	19.41±0.15d	Long	88.20±0.25d	-1.53±0.01a	6.76±0.06b
Walnea	6.63±0.01b	2.00±0.10b	3.21±0.22a	22.13±0.17b	Long	89.70±0.17b	-1.20±0.03a	5.30±0.14c

*Mean and standard deviation of triplicates.
Mean value with different superscript in a column are significantly ($p \leq 0.05$) different from each other.
L= lightness, a= redness and b= yellowness

3.2. *Proximate composition*

The proximate composition and amylose content of rice flours is presented in Table 2. Moisture content of rice flours ranged significantly from 7.09% (*Ebagichi*) to 9.15% (*Lamiyatu*). Moisture content is one of the important factors that govern the physical properties of grain (Goswami *et al.*, 2015). The low moisture content of the rice flours suggests great shelf stability of the grains during storage. The protein content ranged significantly from 5.82% (*Walue*) to 11.48% (*Majalisa*). The protein values of the flours suggest a high market value and useful application in food formulation due to their appreciable protein value (especially *Majalisa* with 11.48% protein value) and hypoallergenic nature of rice flour. Fat content of rice flours ranged from 1.10% (*Majalisa*) to 3.42% (*Walue*). Ash content varied between 1.13% (*Lamiyatu*) and 1.31% (*Majalisa*). Crude fiber content varied between 1.06 % (*Walue*) and 3.52% (*Majalisa*). Carbohydrate content of rice flours ranged from 74.57% (*Majalisa*) to 80.90% (*Walue*). The moisture, protein, ash, fat, crude fiber and carbohydrate results are in agreement with Kraithong *et al.* (2018) who reported moisture content at 5.47 to 9.87% , ash at 0.47 to 1.57%, crude protein at 6.51 to 7.27%, crude fat at 1.13 to 3.60 % and carbohydrate at 77.06 to 85.58 %.

Table 2: Chemical composition (% dry weight basis) of Nigerian rice flours

Cultivar	Moisture	Protein	Fat	Ash	Crude fiber	Carbohydrate	Amylose
Bisalachi	8.14 ± 0.14^{b}	6.32 ± 0.16^{e}	2.17 ± 0.10^{a}	1.25 ± 0.03^{a}	1.31 ± 0.01^{a}	80.81 ± 0.75^{a}	23.41 ± 0.57^{b}
Ebagichi	7.09 ± 0.06^{c}	8.20 ± 0.54^{c}	2.32 ± 0.21^{a}	1.21 ± 0.01^{a}	1.19 ± 0.01^{b}	79.97 ± 0.49^{b}	22.78 ± 0.63^{c}
Lamiyatu	9.15 ± 0.29^{a}	7.56 ± 0.19^{d}	1.16 ± 0.06^{c}	1.19 ± 0.02^{a}	1.26 ± 0.02^{b}	79.68 ± 0.63^{b}	21.93 ± 0.49^{d}
Majalisa	7.92 ± 0.10^{b}	11.48 ± 0.33^{a}	1.10 ± 0.15^{c}	1.31 ± 0.00^{a}	3.52 ± 0.00^{a}	74.57 ± 0.52^{c}	20.56 ± 0.35^{e}
Waluea	7.60 ± 0.22^{b}	5.82 ± 0.14^{f}	3.42 ± 0.09^{b}	1.13 ± 0.01^{a}	1.06 ± 0.01^{b}	80.90 ± 0.79^{a}	23.84 ± 0.23^{a}

*Mean and standard deviation of triplicates.
Mean value with different superscript in a column are significantly ($p\leq 0.05$) different from each other.

The amylose content of rice flours ranged from 20.56% (*Majalisa*) to 23.84% (*Walue*). The amylose values are consistent with Kraithong *et al.* (2018) who reported amylose content of 18.30 to 33.80% for Thai organic rice flours. It was observed in this study that high carbohydrate content contributed to high amylose value of the rice flours. According to the amylose result, the rice samples were classified into intermediate (20 to 25%) (Falade and Christopher, 2015). Intermediate amylose rice is preferred in most countries of the world due to their fluffy and hard texture upon cooking (Bhat and Riar, 2017). This implies that the rice flours could be applied in food systems that require hard texture such as noodles and extruded products. This attribute of cooked rice is valued in Nigeria.

3.3 Amino acid composition

The amino acid profile of rice flours are presented in Table 3. The total essential amino acid of rice flours from *Bisalachi*, *Ebagichi*, *Lamiyatu*, *Majalisa*

Table 3: Amino acid composition (g / 100 g) of Nigerian rice flours

Parameter	*Bisalachi*	*Ebagichi*	*Lamiyatu*	*Majalisa*	*Walue*
Histidine	0.14 ± 0.01^{a}	0.13 ± 0.01^{a}	0.14 ± 0.00^{a}	0.16 ± 0.01^{a}	0.12 ± 0.01^{a}
Isoleucine	0.32 ± 0.00^{a}	0.36 ± 0.01^{a}	0.34 ± 0.01^{a}	0.37 ± 0.01^{a}	0.29 ± 0.00^{a}
Leucine	0.65 ± 0.01^{a}	0.68 ± 0.04^{a}	0.68 ± 0.05^{a}	0.69 ± 0.03^{a}	0.61 ± 0.01^{a}
Lysine	0.30 ± 0.01^{a}	0.31 ± 0.02^{a}	0.31 ± 0.03^{a}	0.33 ± 0.04^{a}	0.30 ± 0.02^{a}
Methionine	0.21 ± 0.03^{a}	0.23 ± 0.02^{a}	0.24 ± 0.02^{a}	0.22 ± 0.03^{a}	0.22 ± 0.01^{a}
Phenyalanine	0.40 ± 0.00^{a}	0.45 ± 0.01^{a}	0.38 ± 0.01^{a}	0.47 ± 0.00^{a}	0.39 ± 0.01^{a}
Threonine	0.34 ± 0.01^{a}	0.31 ± 0.01^{a}	0.32 ± 0.01^{a}	0.26 ± 0.01^{a}	0.36 ± 0.01^{a}
Valine	0.40 ± 0.03^{a}	0.46 ± 0.02^{a}	0.40 ± 0.02^{a}	0.49 ± 0.02^{a}	0.41 ± 0.01^{a}
Tryptophan	0.10 ± 0.00^{a}	0.12 ± 0.01^{a}	0.12 ± 0.01^{a}	0.14 ± 0.01^{a}	0.08 ± 0.00^{a}
Alanine	0.35 ± 0.02^{a}	0.36 ± 0.02^{a}	0.30 ± 0.01^{a}	0.36 ± 0.02^{a}	0.34 ± 0.02^{a}
Arginine	0.67 ± 0.01^{b}	0.70 ± 0.02^{b}	0.68 ± 0.04^{b}	0.79 ± 0.03^{a}	0.66 ± 0.02^{b}
Aspartic acid	1.09 ± 0.03^{a}	1.06 ± 0.03^{a}	1.10 ± 0.06^{a}	1.05 ± 0.00^{a}	1.10 ± 0.04^{a}
Cysteine	0.12 ± 0.00^{a}	0.10 ± 0.01^{a}	0.12 ± 0.01^{a}	0.12 ± 0.00^{a}	0.11 ± 0.01^{a}
Glutamic acid	1.15 ± 0.07^{a}	1.17 ± 0.03^{a}	1.16 ± 0.05^{a}	1.18 ± 0.03^{a}	1.13 ± 0.01^{a}
Glycine	0.27 ± 0.03^{a}	0.26 ± 0.00^{a}	0.26 ± 0.01^{a}	0.28 ± 0.01^{a}	0.24 ± 0.00^{a}
Proline	0.45 ± 0.01^{a}	0.49 ± 0.02^{a}	0.48 ± 0.03^{a}	0.51 ± 0.03^{a}	0.40 ± 0.02^{a}
Serine	0.23 ± 0.00^{a}	0.25 ± 0.00^{a}	0.25 ± 0.00^{a}	0.24 ± 0.02^{a}	0.22 ± 0.01^{a}
Tryosine	0.34 ± 0.01^{a}	0.37 ± 0.01^{a}	0.36 ± 0.01^{a}	0.40 ± 0.01^{a}	0.31 ± 0.01^{a}
Total amino acid	7.53	7.81	7.64	8.06	7.29

*Mean and standard deviation of triplicates.
Mean value with the same superscript in a row are not significantly ($p\geq 0.05$) different from each other.

and *Walue* were 7.53, 7.81, 7.64, 8.06 and 7.29, respectively. Rice flour with high protein value had higher amino acid value than the lower protein rice samples. Cysteine, methionine and threonine values were lower in rice samples that contained higher protein content compared to others. Aspartic and glutamic acid had the highest concentrations in the rice samples while cysteine and tryptophan were the lowest. The high contents of aspartic and glutamic acid were in agreement with Xi *et al.* (2016) for white-belly and white-core rice grains. Lysine and methionine are limiting essential amino acid in cereals. In this study, lysine and methionine content ranged from 0.30 to 0.33 g/100g, and 0.21 to 0.24 g/ 100g, respectively.

3.4 Mineral, phytic, thiamine and riboflavin content

There was significant difference in calcium, magnesium, phosphorus and potassium content among rice cultivars (Table 4). Calcium, an important mineral that contributes to the health of bone and teeth, and regulation of blood pressure, ranged from 25.97mg/100g (*Walue*) to 30.04mg/100g (*Majalisa*). Iron which plays an important role on oxygen transportation through the human body and prevention of anaemia, ranged from 2.63mg/100g (*Walue*) to 3.48mg/100g (*Majalisa*). Zinc, an important mineral that promotes basic cellular and antioxidant function, ranged from 1.25mg/100g (*Ebagachi*) to 1.46mg/100g (*Walue*). Magnesium which plays an important role in maintaining normal muscle and nerve functions, ranged from 219.44mg/100g (*Walue*) to 272.10mg/100g (*Majalisa*). Phosphorus content ranged from 190.49mg/100g (*Ebagichi*) to 266.50mg/100g (*Majalisa*). Potassium content varied between 244.57mg/100g (*Walue*) to 280.15mg/100g (*Majalisa*). Sodium content ranged from 2.23mg/100g (*Majalisa*) to 3.15 mg/100g (*Walue*). The low sodium content of the rice flours could be of health benefit to hypertension patients that require low sodium consumption. Calcium, iron, magnesium, phosphorus and potassium contents obtained in this work are higher than values of 3.07 to 7.46mg/100g calcium, 0.37 to 1.21mg/100g iron, 0.80 to 2.31mg/100g zinc, 42.00 to 87.00 mg/100g magnesium, 144.00mg/100g phosphorus, and 105.00 to 171.00mg/100g potassium for some India rice varieties (Prasad *et al.*, 2018). Thiamine and riboflavin which are important in energy metabolism and many body functions, varied between 0.16mg/100g (*Lamiyatu*) and 0.24mg/100g (*Majalisa*). There was no significant difference in the riboflavin content (0.02 to 0.03mg/100g) among rice flours. The appreciable amounts of mineral, thiamine and riboflavin values of the rice flours could indicate their potential as sources of micronutrients.

Table 4: Mineral, phytic acid, thiamin and riboflavin content of Nigerian rice flours

Parameter	*Bisalachi*	*Ebagichi*	*Lamiyatu*	*Majalisa*	*Walue*
Calcium (mg/100g)	28.23±0.17^{c}	29.68±0.36^{b}	27.10±0.48^{d}	30.04±0.53^{a}	25.97±0.65^{e}
Iron (mg/100g)	3.30±0.23^{a}	3.22±0.19^{b}	2.87±0.35^{c}	3.48±0.60^{a}	2.63±0.12^{c}
Zinc (mg/100g)	1.30±0.11^{a}	1.25±0.08^{a}	1.38±0.05^{a}	1.46±0.01^{a}	1.40±0.03^{a}
Magnesium (mg/100g)	263.80±0.42^{b}	255.67±0.90^{c}	239.32±0.75^{d}	272.10±0.64^{a}	219.44±0.56^{e}
Phosphorus (mg/100g)	212.72±0.66^{c}	190.49±0.24^{d}	223.05±0.50^{b}	266.50±0.31^{a}	185.98±0.70^{e}
Potassium (mg/100g)	245.35±0.50^{d}	262.10±0.81^{b}	258.23±0.39^{c}	280.15±0.63^{a}	244.57±0.82^{e}
Sodium (mg/100g)	2.40±0.50^{c}	2.27±0.81^{d}	3.15±0.39^{a}	2.23±0.63^{d}	3.01±0.82^{b}
Phytic acid (μg/g)	95.11±0.61^{d}	103.60±0.95^{c}	117.82±0.88^{b}	80.36±0.72^{e}	120.66±0.91^{a}
Thiamine (mg/100g)	0.23±0.01^{a}	0.22±0.00^{a}	0.16±0.01^{b}	0.24±0.00^{a}	0.20±0.01^{a}
Riboflavin (mg/100g)	0.03±0.00^{a}	0.02±0.01^{a}	0.02±0.01^{a}	0.03±0.01^{a}	0.02±0.01^{a}

*Mean and standard deviation of triplicates.

Mean value with different superscript in a row are significantly ($p \leq 0.05$) different from each other.

Phytic acid content of flour ranged from 80.36 µg/g (*Majalisa*) to 120.66 µg/g (*Walue*) (Table 4). Phytic acid inhibits the absorption of minerals (such as calcium, iron and zinc), protein and starch in the body. Contrary to the antinutritive effect of phytic acid, there are scientific evidence demonstrating a wide range of benefits to health and well-being such as decreasing plasma cholesterol and triglycerides, decreasing heavy toxic metals and possessing antioxidant and anti-carcinogenic effects (Kumar *et al.*, 2010). Utilization of the rice flours in food formulations will impact health benefits associated with phytic acid.

4.0 Conclusion

This study established that some of the rice cultivars (*Ebagichi, Lamiyatu, Majalisa* and *Walue*) are long grains while *bisalachi* is a medium grain. *Majalisa* rice flour contained higher protein, total amino acid, minerals (such as calcium, iron, zinc, magnesium and phosphorus) and some B-vitamins with low carbohydrate and phytic acid content. The rice flours contained intermediate amylose value. The physicochemical properties of the flours are promising for application in food systems. The results demonstrated a wide range of physicochemical properties of the rice cultivars studied, which provided baseline information for their applications in food systems.

References

AOAC. (2005). Association of Official Analytical Chemists. In: official methods of analysis, 18th edn. (edited by W. Horwitz and G.W. Latimer Jr.). Gaithersburg, MD, USA: AOAC International.

Bhat, F.M. and Riar, C.S. (2017). Physicochemical, cooking, and textural characteristics of grains of different rice (*Oryza sativa* L.) cultivars of temperate region of India and their interrelationships. *Journal of Texture Studies* 48 (2): 160-170.

Bidlingmeyer, B.A., Cohen, S.A., Tarvin, T.L. (1984) Rapid analysis of amino acids using pre-column derivatization. *Journal of Chromatography B: Biomedical Sciences and Applications* 336: 93-104.

Cornejo, F. and Rosell, C.M. (2015). Physicochemical properties of long rice grain varieties in relation to gluten free bread quality. *LWT-Food Science and Technology* 62(2): 1203-1210.

Falade, K.O., Semon, M., Fadairo, O.S., Oladunjoye, A.O. and Orou, K.K. (2014). Functional and physicochemical properties of flours and starches of African rice cultivars. *Food Hydrocolloids* 39: 41-50.

Falade, K.O. and Christopher, A.S. (2015). Physical, functional, pasting and thermal properties of flours and starches of six Nigerian rice cultivars. *Food Hydrocolloids* 44: 478-490.

Gani, A., Ashwar, B.A., Akhter, G., Shah, A., Wani, I.A. and Masoodi, F.A. (2017). Physicochemical, structural, pasting and thermal properties of starches of fourteen Himalayan rice cultivars. *International Journal of Biological Macromolecules* 95: 1101-1107.

Goswami, D., Manikantan, M.R., Gupta, R.K. and Vishwakarma, R.K. (2015). Moisture dependent selected post-harvest engineering properties of *ragi* (*Eleusine coracana*) grown in northern hills of India. *Journal of Postharvest Technology* 3(3), 82-88.

Juliano, B., Perez, C., Blakeney, A., Castillo, T., Kongseree, N. and Laignelet, B. (1981). International cooperative testing on the amylose content of milled rice. *Starch-Stärke* 33(5): 157-162.

Kraithong, S., Lee, S. and Rawdkuen, S. (2018). Physicochemical and functional properties of Thai organic rice flour. *J Cereal Sci* 79: 259-266.

Kumar, V., Sinha, A.K., Makkar, H.P. and Becker, K. (2010). Dietary roles of phytate and phytase in human nutrition: a review. *Food Chemistry* 120 (4): 945-959.

Odenigbo, A.M., Danbaba, N. & Ngadi, M. (2014). Nutrient composition and predicted glycemic index of rice varieties from Nigeria. *British Journal of Applied Science & Technology* 4(2): 302.

Odejobi, O.J, Ige, M.M. and Adeniyi, K.A (2015) Physicochemical properties of the flour and starch from three Nigeria rice (*Oryza sativa* L.) varieties. *Journal of Food Measurement and Characterization* 9 (1): 61-67.

Pathare, P.B., Opara, U.L. and A-Said, F.A. (2013). Color measurement and analysis in fresh and processed foods: a review. *Food Bioprocess Technology* 6: 36-60.

Prasad, V.S.S, Hymavathy, P., Babu, V.R. and Longvah, T. (2018). Nutritional composition in relation to glycemic potential of popular Indian rice varieties. *Food Chemistry* 238, 29-34.

Vaintraub, I.A. and Lapteva, N.A. (1988). Colorimetric determination of phytate in unpurified extracts of seeds and the products of their processing. *Analytical Biochemistry* 175(1): 227-230.

Xi, M., Zhao, Y., Lin, Z., Zhang, X., Ding, C., Tang, S. and Ding, Y. (2016). Comparison of physicochemical characteristics between white-belly and white-core rice grains. *Journal of Cereal Science* 69: 392-397.