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Comparative analysis of the proximate composition, vitamins contents, and metals profile of Nigerian rice (*Oryza glaberrima*) and imported rice (*Oryza sativa*)

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Abstract

The study was designed to determine and compare the proximate composition, metals, and vitamin levels in three Nigerian rice varieties of *Oryza glaberrima* (Brown, Mokwa, and Ofada rice) and one imported rice of *Oryza sativa*. The samples were processed and evaluated in triplicate using standard methods. Brown rice had the highest carbohydrate (76.03%) content; Mokwa had the highest moisture (12.04%); Ofada had the highest protein (10.60%), and energy value (413.75 kCal/100g); the imported rice had the highest fibre content (1.53%). In terms of minerals, Brown was highest in zinc (13.83%), Ofada was highest in iron (485 %). Ofada and Brown rice had relatively high levels of lead metal. Ofada led in thiamine (0.31 mg/100g), riboflavin (0.08 mg/100g) and niacin (3.03 mg 100 g^{-1}). The findings revealed that *O. glaberrima* Nigerian rice cultivars showed higher or at least comparable nutritive values than the *O. sativa* counterpart but the high level of metals like lead should incite further scrutiny.

Key words: Food energy, heavy metals, local rice, nutritional quality, rice varieties, storage

Introduction

Rice (*Oryza sativa* L.) is one of the essential and staple food crops for human consumption. It is cultivated in different parts of the world and its uniqueness is associated with the affinity for swamp environments (Huang *et al*., 2016). Rice grain is a major source of carbohydrates, protein, and other essential nutrients for billions of people globally, especially in developing countries (Saleh *et al*., 2019). Rice (*O.*

sativa) also constitutes a common diet for a class of people in most countries. Notably, it has been revealed that it provides 700 calories/day/person for about 3 billion people worldwide (Vlachos and Arvanitoyannis, 2008). Also, rice contains a small amount of fat and is a good source of thiamine, riboflavin, niacin, and other vitamin-B complexes (Fresco, 2005) and dietary fibre (Cherie and Dagnaw, 2019). Rice has not been considered a reasonable source of minerals, however, appreciable calcium (Ca), magnesium (Mg) and phosphorus (P) are present along with some traces of iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) (Zhang *et al*., 2014; Oko *et al*., 2012). High levels of bioactive compounds such as phenolic acids, flavonoids, *ã* -oryzanol, aminobutyric acid (GABA), *á*-tocopherol, and *ã* -tocotrienol have been reported in rice (Gong *et al*., 2017; Pang *et al*., 2018; Seo *et al*., 2013). The nutritional values and bioactive compounds of rice may depend on factors such as varieties, soil fertility, fertiliser application (Verma and Srivastav, 2017), geographic location, postharvest treatment, and processing conditions (Masuzaki *et al*., 2018). The proximate composition of rice is determined by the type of rice and degree of milling because the process eliminates different layers of rice. Consequently, changing the nutrition value among the rice samples from a cultivar. The difference can occur in terms of the number of carbohydrates, vitamins, and minerals present in rice (Rathna Priya *et al*., 2019). Although rice is cultivated in Nigeria, the country still depends on the foreign brands to meet the demand (Godwin, 2012). Consumers have preferences for foreign brands because of taste, fine grains, status linked with consuming foreign commodities, and most especially, doubt on the nutritional contents of local rice species (Nkwazema, 2016; Abdullahi *et al*., 2019). Ofada, Mokwa, and Brown rice are among the varieties of rice (*O. glaberrima*) produced in Nigeria. Mokwa and Ofada are included in local rice varieties produced in Nigeria (Adebamowo *et al*., 2017), Ofada rice is specific to the southwest, Nigeria. Ofada is an unpolished short-grain robust rice variety with common red kernels, named after a community (Ofada) in Obafemi-Owode Local Government Area of Ogun State, produced and milled in southwest Nigeria. Brown rice has been reported to possess higher levels of protein, fat, vitamins, and minerals than white rice. In addition, natural products such as phenolic acids, flavonoids, γ–oryzanol, aminobutyric acid (GABA), α-tocopherol, and γ-tocotrienol are reported in brown rice (Gong *et al*., 2017; Pang *et al*., 2018). These components are reported to be present in high amounts in the bran layer of rice grain (Sharif *et al*., 2014). The health opportunities of brown rice include antioxidant, antidiabetic, anticancer, neuroprotective, and the ability to lower cholesterol (Chompoopong *et al*., 2016; Masuzaki *et al*., 2018). Locally milled or processed rice in Nigeria is commonly brownish in colour and unpolished because of the partial milling activities. Locally produced rice is also associated with colour variation, having a mixture of different varieties in a pack and containing stones, as reported by (Osaretin *et al*., 2017). Mokwa rice is unpolished, produced, and milled in Nigeria as well, but neater than Ofada and brown rice varieties. There is sparse information on the nutritional values of these locally produced rice varieties at the moment in Nigeria. Hence, this study focused on the comparison of proximate, vitamin, and mineral compositions of three local rice varieties (Ofada, Mokwa, and Brown: *Oryza glaberrima*) produced in Nigeria, using imported rice species (*O. sativa*) as control, with the aim to establishing the nutritional advantage of rice produced and processed in Nigeria.

Methodology

Study site and sample collection

Rice varieties were obtained from Lafenwa Market in Abeokuta, which is a rice processing and distribution market, located 7° 10' 0'' North, 3° 3' 0'' East in Ogun State, Nigeria. The four rice samples purchased include; Brown, Mokwa, Ofada rice (Nigerian *Oryza glaberrima* rice), and an imported (*O. sativa*); as shown in Figure 1. The local rice varieties from Nigeria are between white and different types of brown, medium grain size, and unpolished, whereas imported rice varieties are polished, long grains, and white. Only whole rice grains without any physical damage or insect infestation were selected for analysis.

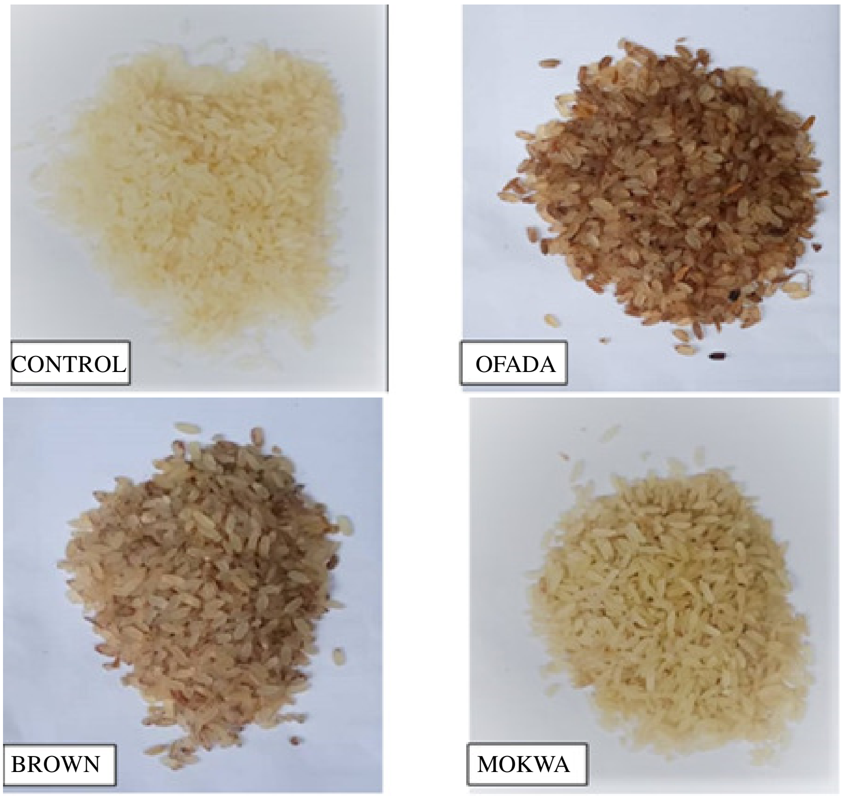

Figure 1. Rice cultivars under investigation.

Sample preparation

Two hundred grams (200 g) of each of the four samples were separately powdered by mortar and pestle in the laboratory, sieved to remove large grains, packed in an airtight polyethylene bag, and stored at room temperature until further analysis.

Determination of proximate composition

The proximate compositions of the samples were determined by a standard method used for moisture, fat - according to AACC (2000), protein, fibre as described by AOAC (1990), ash using AOAC (1997), and carbohydrate content based on the method of Umar *et al*. (2013).

Determination of food energy

Calorific value is an important property indicating the useful energy content of foods. The gross food energy was estimated according to Osborn and Voogt (1978), using the equation:

$$\text{Food energy (kCal/g)} = (CP \times 4) + (F \times 9) + (CHO \times 4)$$

where CP = crude protein (%); F = fat (%); and CHO = carbohydrate content (%).

Determination of mineral content

The mineral contents were determined using the methods prescribed in AOAC (2000) as reported by Verma and Srivastav (2017).

Determination of vitamins

Riboflavin, thiamin, and niacin contents of the samples were determined on 100 g samples according to the methods reported by Umar *et al.* (2013).

Statistical analysis

All measurements were carried out in triplicate for each of the samples and the results were expressed as the mean ± SEM using Graph pad Prism 5.0 Statistic software. One-way analysis of variance (ANOVA) was conducted, followed by Tukey–Kramer multiple comparisons, and a *p-value* less than 0.05 was considered significantly different.

Results

Proximate composition

There were significant differences in proximate compositions of moisture, crude protein, crude fibre, carbohydrate, and food energy among the three locally grown varieties in Nigeria and the imported rice variety (control) ($P<0.05$; Table 1). Mokwa had the highest moisture content but there were no discernible differences in moisture

Table 1. The percentage proximate composition of the four variety samples of rice

Composition (%)	Rice varieties			
	Brown	Mokwa	Ofada	Imported
Ash	1.37±0.03	1.13±0.03	1.20±0.00	1.23±0.05
Moisture	10.93±0.03	**12.04±0.03***	10.92±0.07	10.88±0.02
Crude Protein	9.73±0.05	9.39±0.01	**10.60±0.08***	9.67±0.05
Crude Fat	1.62±0.01	1.59±0.00	1.67±0.03	1.57±0.03
Crude Fibre	1.32±0.01	1.46±0.01*	1.23±0.03	**1.53±0.03***
Carbohydrate	**76.03±0.9***	74.46±0.04	74.38±0.18	75.08±.0.07
Dry Matter	89.07±0.03*	87.96±0.03	89.08±0.07*	**89.12±0.02***
Food energy (kCal/100 g)	357.62±0.96	349.71±0.05	**413.75±0.29**	409.29±0.15

Values are means of three replicates ± the respective standard errors of means. Comparison was made across the column. * indicate significantly different at P<0.05

content among Ofada, brown and the imported rice variety (range of 10.88-12.04%). Ofada with the highest values (10.6% CP), differed significantly in crude protein content from the rest of the study varieties, which had more or less similar values (range of 9.39-9.73%). With regard to crude fibre, the highest values were in the imported variety (1.53%), followed by Mokwa, then brown, and Ofada (at 1.23%) had the lowest crude fibre content. All varieties were >70% in carbohydrate content. Brown rice variety had the highest carbohydrate content at 76.03%, followed by the imported variety, which was not different from Ofada and Mokwa. The energy value among the 4 rice varieties studied ranged from 349.71±0.05 to 413.75±0.29 kCal per 100 g. Ofada had the highest amount of energy, followed by the imported control rice, whose values were higher than for Brown and Mokwa varieties (Table 1). Percentage ash ranged from 1.13 to 1.37%. The crude fat content of the studied varieties ranged from 1.57 to 1.67% (Table 1).

Mineral composition

Iron, copper, lead, zinc, and aluminum varied significantly among the studied rice varieties (P<0.05; Table 2). Iron had the highest values among the minerals in the rice samples, with a range of 211.77 to 485. Ofada had the highest levels of iron and Mokwa the lowest. Copper was highest in Brown and Imported rice varieties, while Ofada had the lowest copper levels (range of 0.27 to 0.75). Lead was highest in Brown, closely followed by Ofada, both of which are more or less doubled the lead content in Mokwa and the imported variety. Zinc followed the trend of Lead. Ofada had the highest aluminum content whilst Mokwa had the lowest (Table 2). In general, the locally grown Ofada and Brown rice had higher mineral contents notably zinc

Table 2. The percentage of Selected Metals in the four variety samples of the rice

Mineral (%)	Rice varieties			
	Brown	Mokwa	Ofada	Imported
Iron	303.00±0.47	211.77±0.35	485.00±1.70*	388.00±0.47
Copper	0.75±0.02*	0.33±0.01	0.27±0.03	0.73±0.03*
Cadmium	BDL	BDL	BDL	BDL
Lead	9.70±0.08*	4.34±0.04	8.22±0.05*	4.69±0.02
Zinc	13.83±0.05*	4.27±0.03	10.68±0.05*	6.39±0.02
Alminium	3.07±0.03	2.63±0.03	3.97±0.05*	3.60±0.12

Values are means of three replicates ± the respective standard errors of means. Comparison was made across the column. * indicate significant difference at P< 0.05, BDL - below detectable levels

and lead; additionally, Ofada led in iron and aluminum whereas Brown was the lead in copper. The imported control only registered high readings in copper, alongside Brown (Table 2). The cadmium content was below the detection limit in all the studied samples (local and imported).

Vitamin composition

Thiamine, riboflavin, and niacin were the vitamins measured in this study and their levels were not significantly influenced by variety (P<0.05; Table 3).

Table 3. The percentage of vitamin for the four samples of rice

Vitamins (mg 100 g^{-1})	Rice varieties			
	Brown	Mokwa	Ofada	Imported
Thiamine	0.26±0.01	0.20±0.01	0.31±0.01	0.24±0.01
Riboflavin	0.07±0.00	0.05±0.00	0.08±0.00	0.06±0.00
Niacin	2.88±0.02	2.95±0.01	3.03±0.01	2.89±0.01

Values are means of three replicates ± the respective standard errors of means. Comparison was made across the column. There was no significant difference at P<0.05

Discussion

Moisture content

The moisture content of a sample referred to as the total volume of water content present in that sample, dictates the texture, appearance, and the stability of the food, as well as the suitability of food for the growth of microorganisms (Thomas *et al.*, 2013; Umar *et al.*, 2013). The values in all the studied samples were lower than the safe moisture content (14%) for the safe storage of processed rice, although 12% is the recommended value for long-term storage to avoid insect infestation and growth of microorganisms. The range of 10.92-12.04% values obtained for the studied three local rice varieties are within the ranges for aromatic and non-aromatic Indian rice (Verma and Srivastav, 2017), those of rice varieties grown in Ethiopia (Cherie and Dagnaw, 2019; Tegegne *et al.*, 2020) and elsewhere (Saikia *et al.*, 2012; Longvah *et al.*, 2017), a range that shows that they can be stored safely for a given period of time.

Crude protein

Proteins in food materials are essential as they form the basic building blocks of cells and tissue repairs in the body system (Mbatchou and Dawda, 2013). Protein content dictates the nutritional value of any food (Sompong *et al.*, 2011). Rice protein fractions include albumin (water-soluble), globulin (salt-soluble), glutelin (alkali-soluble), and prolamin (alcohol-soluble) (Amagliani, *et al.*, 2017). The protein level in rice is believed to constitute up to 8% of the grain. This amount of protein though relatively low is nevertheless of commendable nutritional value (Longvah *et al.*, 2017; Verma and Srivastav, 2017; Rathna *et al.*, 2019). The protein levels in the investigated rice varieties were found to have >9% CP with Ofada exceeding 10% CP a factor that was reported by Sowunmi *et al.* (2014) studying farmers' perceptions in Nigeria.

Crude fat

Lipids or fats are one of the constituents of foods, which are soluble in organic solvents but insoluble in water (Awuchi *et al.*, 2019). Lipids include but are not limited to glycerol, free fatty acids, phospholipids, and sterols (Umar *et al.*, 2013). The values of fat obtained in the samples analysed in this study were within the results from varieties of rice in Ethiopia reported by Cherie and Dagnaw (2019), also, the results were close to the findings for brown rice by Devi *et al.* (2015). In this study, the observed levels of fat were close to the reported value (1.73 ±0.42) for wheat but less than those of maize (4.18±1.15), sorghum (3.65±0.70), and millet (4.58 ± 0.43) in a study by Robet *et al.* (2020)

Crude fibre

Dietary fibre is referred to as edible parts of plants or analogous carbohydrates resistant to digestion and absorption in the small intestine with fermentation (complete or partial) in the large intestine (Awuchi *et al*., 2019). Dietary fibre includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibre enhances beneficial physiological effects, such as laxation, attenuation of blood cholesterol, and glucose, it represents the sum of the non-digestible components of a foodstuff or food product, which are mainly polysaccharides in nature, with exception of amylopectin and amylose molecules in cooked starch that is digestible (Nielsen, 2009). Both the local and control samples exhibited higher values than the range (0.22-0.95) reported by Rathna *et al*. (2019). The quantity of crude fibre dictates the digestion rate of rice, and a high level reduces the digestion process (Verma and Srivastav, 2017).

Carbohydrate content

Carbohydrates are a class of organic compounds designated the "hydrates of carbon" because of their observed elemental composition. Carbohydrates are the main features of plants and are an almost inevitable and important element of daily life, constituting the bulk of daily food (Twinomuhwezi *et al*., 2020). Mbatchou and Dawda (2013) conveyed that the quantity of starch in grain determines the level of stickiness after cooking. The quantities of carbohydrates shown in this study were found to be similar to many of the values reported by Cherie and Dagnaw (2019) for varieties of rice in Ethiopia, also similar to some of the values reported in a review by Rathna *et al*. (2019) from varieties of rice in south India. However, the carbohydrate levels in this study were little below many of the values (mean percentage of 82.86%) recorded by Oko *et al*. (2012) in selected local and newly introduced rice varieties grown in the Ebonyi State of Nigeria. That said, the levels of >74% carbohydrates indicate that local rice can supply the required energy needed by the human body for normal growth and development.

Energy value

Food energy designates the level of energy present in the diet through cellular respiration (Thomas *et al*., 2013). The range of energy obtained from the samples studied was found to be above the values reported by Tegegne *et al*. (2020), also, the values of energy in Brown and Mokwa rice samples (local rice) were within the range reported for brown rice while those of Ofada and control rice were more than values in brown and white rice in the findings of Saleh *et al*. (2019).

Mineral and ash content

Ash represents the inorganic residue of material after the removal of the water and the organic matter by heating in the presence of oxidising agents, it determines the number of minerals in foods (Thomas *et al*., 2013). From the study, there was no significant difference in the percentage of ash among all the samples. The values obtained in the studied samples were within the same category as reported by Umar *et al*. (2013) for wild rice from Kaduna State, Central Nigeria; also in Ethiopia (Cherie and Dagnaw, 2019); as well as the level obtained by Devi *et al*. (2015) and the result of Sompong *et al*. (2011) from rice varieties in Asia.

Mineral elements are important in the anabolism and catabolism processes in living organisms, inadequacies of which could cause metabolic disorders. Rice is not one of the foodstuffs that contained a sufficient quantity of minerals, however, because it is a common food, it produces a base level of minerals for the consumers (Zhang *et al*., 2014; Huang *et al*., 2016). In this study, local samples had better contents of iron, zinc, aluminum, and copper. The values of zinc in this study were within the range of values reported in coloured rice varieties in south India while iron values in this study were higher than the values in the varieties from the region (Rathna *et al*. (2019). Also, good levels of copper and zinc were observed in this study but lower than the levels reported by Reddy *et al*. (2017) while the amount of iron in this study was higher than the amount reported in that study. Metals such as copper, zinc, and iron are crucial elements because they are required for proper biological activities, copper is necessary for normal catalytic activities of many enzymes while zinc as a metalloenzyme participates in catalytic functions, regulatory functions, and structural stability. Zinc is also involved in DNA and RNA synthesis, as well as cell proliferation (Briffa *et al*., 2020). Iron constitutes part of various vital enzymes such as the electron transport chain's cytochromes and is therefore essential for a wide range of biological processes (Rout and Sahoo, 2015).

The values of Lead in all the samples in this study were higher than the level observed by Olalekan *et al*. (2019), the levels were above the recommended limits for human consumption. Some of the toxicological effects of Lead include calcium homeostasis disruption, reduced cholinergic function by blocking an induced release of acetylcholine, and it affects the hematopoietic system in both humans and animals. On the other hand, aluminum has been identified as a poison to organs such as the lungs, bone, and central nervous system (Briffa *et al*., 2020). The high level of heavy metals such as Lead observed in some of the studied samples may have resulted from soil condition, type of fertiliser used, production environment, and postharvest treatments (Verma and Srivastav, 2017; Saleh *et al*., 2019).

Vitamin content

Thiamine (Vitamin B1) is involved in the pentose phosphate pathway as a coenzyme, a factor in the synthesis of steroid hormone, nucleic acids, and the aromatic amino acid precursors including neurotransmitters and other bioactive components that are required for the proper functioning of the brain (Kerns *et al*., 2015). Riboflavin (Vitamin B2) serves as a precursor for the synthesis of two flavoprotein coenzymes, flavin adenine dinucleotide (FAD) and flavin mononucleotide (FMN), which are determinants in many enzymatic reactions. These flavoproteins play vital roles by supplying protons during the degradation of proteins, carbohydrates, and fats (Said and Ross, 2014), they serve as cofactors to breakdown fatty acids in the brain (Sinigaglia-Coimbra *et al*., 2011), also involved in the assimilation and utilisation of iron, and in regulating thyroid glands (Powers *et al*., 2011; Rivlin, 2007). Insufficient or lack of riboflavin would affect the regulation of any of the aforementioned reactions or processes which could lead to malfunction of the brain. The constituents derived from riboflavin exhibit free radical scavenging activities which raise the capacity of the system to prevent oxidation, important contributing factors in the glutathione redox cycle (Ashoori and Saedisomeolia, 2014). Generally, the levels of vitamins in the studied rice varieties were low with the exception of niacin. However, the ranges were in the levels reported by Singh and Singh (2019) but relatively higher than those reported for *O. sativa* and *O. glaberrima* by Saleh *et al.* (2019). The trends of niacin and riboflavin in the studied samples were similar to or higher than the values observed by Olalekan *et al.* (2019) in varieties of rice in Nigeria. Ofada rice showed a marginal edge in amounts of the three vitamins (Thiamine, Riboflavin, and Niacin) among the four varieties studied. This may be due to the ability of coloured/unpolished rice varieties to retain vitamins among other materials in the bran layer, as reported by Rathna *et al*. (2019).

Conclusion

This study provides a record of the nutritive value of Nigerian rice varieties (*Oryza glaberrima*) in comparison to a more popular imported control (*Oryza sativa*). Mokwa and Ofada and Brown rice varieties were quite at par with the imported variety in terms of ash, crude fat, carbohydrate, fibre, crude protein, vitamins, and energy value, with the Ofada variety edging out the rest in crude protein and energy. Ofada rice had the highest levels of Iron; Brown rice was highest in Zinc but the two varieties also had high levels of lead, a heavy metal. Measures should be put in place to reduce the lead content in Ofada and Brown rice varieties by targeted scrutiny of the production, post-harvest handling, and processing aspects of these varieties.

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Competing interest

The author declares that there is no competing interest.

References

AACC. Approved Methods of the American Association of Cereal Chemists. The United States: American Association of Cereal Chemists; 2000.

Abdullahi, A. N., Musa, J., Usman, M., Alhassan, F. B. and Nahantsi, S. 2019. Consumer demand and preference of local and imported rice among households in Sokoto metropolis, Nigeria. *Direct Research Journal of Agriculture* and *Food* Science 7(10): 295-301.

Adebamowo, S. N., Eseyin, O., Yilme, S., Adeyemi, D., Willett, W. C., Hu, F. B., Spiegelman, D., and Adebamowo, C. A. 2017. The Global Nutrition Epidemiologic Transition Initiative (2017) A Mixed-Methods Study on Acceptability, Tolerability, and Substitution of Brown Rice for White Rice to Lower Blood Glucose Levels among Nigerian Adults. *Frontiers in Nutrition* 4: 33. doi: 10.3389/ fnut.2017.00033

Amagliani, L., O'Regan, J., Kelly, A. L., and O'Mahony, J. A. 2017. The composition, extraction, functionality, and applications of rice proteins: A review. *Trends in Food Science and Technology* 64: 1-12. https://doi.org/10.1016/j.tifs.2017. 01.008

AOAC 2000. Official Methods of Analysis of Association of Official Analytical Chemists. 17th edn. Maryland, USA. 452 - 456.

AOAC, 1990. Official Methods of Analysis of Association of Official Analytical Chemists. 15th edn. Arlington Va, USA. pp. 1 - 50.

AOAC, 1997. Official methods of analysis of the Association of Official Analytical Chemists. 16th edn. Washington, USA.

Ashoori, M. and Saedisomeolia, A. 2014. Riboflavin (vitamin B2) and oxidative stress: A review. *British Journal of Nutrition* 111: 1985 - 1991.

Awuchi, C. G., Igwe, V. S. and Echeta, C. K. 2019. The Functional Properties of Foods and Flours. *International Journal of Advanced Academic Research* 5(11): 139-160. ISSN: 2488-9849.

Briffa, J., Sinagra, E. and Blundel, R. 2020. Heavy metal pollution in the environment and their toxicological effects on humans: A Review. Heliyon 6 (2020) e04691.

Cherie, D. A. and Dagnaw, L. A. 2019. Nutritional composition analysis of improved and released rice varieties in Ethiopia. *International Journal of Research and Review* 6(2): 69-73.

Chompoopong, S., Jarungjitaree, S., Punbanlaem, T., Rung ruang, T., Chongthammakun, S., Kettawan, A. and Ta echowisan, T. 2016. Neuroprotective e ffects of germinated brown rice in rotenone-induced Parkinson's-like disease rats. *Neuromolecular Medicine* 18: 334-346. https://doi.org/10.1007/s12017-016-8427-5

Devi, G. N., Padmavathi, G., Babu, V. R., Waghray, K. 2015. Proximate nutritional evaluation of rice (Oryza sativa L.). *Journal of Rice Research* 8(1): 23-32.

Fresco, L. 2005. Rice is life. *Journal of Food Composition and Analysis* 18(4): 249-253.

Godwin, U. 2012. *Rice farm, milling plant: Sure money-spinner*. Retrieved from http://nationalmirroronline.net

Gong, E. S., Luo, S. J., Li, T., Liu, C. M., Zhang, G. W., Chen, J., Zeng, Z. C. and Liu, R. H. 2017. Phytochemical proûles and antioxidant activity of brown rice varieties. *Food Chemistry* 227: 432-443. https://doi.org/10.1016/j.food chem.2017.01.093

Huang, Y., Tong, C., Xu, F., Chen, Y., Zhang, C. and Bao, J. 2016. Variation in mineral elements in grains of 20 brown rice accessions in two environments. *Food Chemistry* 192: 873-878. https://doi.org/10.1016/ j.foodchem.2015.07.087

Kerns, J. C., Arundel, C. and Chawla. L. S. 2015. Thiamin deficiency in people with obesity. *Advances in Nutrition International Review Journal* 6: 147-153.

Longvah, T., Ananthan, R., Bhaskarachary, K. and Venkaiah, K. 2017. Proximate principles and dietary fiber. Hyderabad, India: Indian Food Composition Tables, National Institute of Nutrition, Department of Health Research, Ministry of Health and Family Welfare, Government of India; 3.

Masuzaki, H., Kozuka, C., Okamoto, S., Yonamine, M., Tanaka, H., and Shimabukuro, M. 2018. Brown r ice-speciûc ã -oryzanol as a promising prophylactic avenue to protect against diabetes mellitus and obesity disease in humans. *Journal of Diabetes Investigation* 10: 18-25. https://doi.org/10.1111/ jdi.12892

Mbatchou, V. C. and Dawda, S. 2013. The nutritional composition of four rice varieties grown and used in different food preparations in Kassena-Nankana District, Ghana. *International Journal* of *Research* in *Chemistry* and *Environment* 3(1): 308-315.

Nielsen, S.S. 2009. Food analysis, 4th edition. Perdue University West Lafayette, IN 47907, USA, 151-168.

Nkwazema, S. 2016. Rice debate: Why Nigeria can't meet local Rice Production Demand. Retrieved from *www.thisdaylive.com/index.php/2016/11/ 05thericedebate*

Oko, A. O., Ubi, B. E., Efisue, A. A. and Dambaba, N. 2012. Comparative analysis of the chemical nutrient composition of selected local and newly introduced rice varieties grown in the Ebonyi State of Nigeria. *International Journal of Agriculture* and *Forestry* 2(2): 16-23.

Olalekan, A. S. A., Timothy, B. O., Adebusayo, A. T., Folake, I. A. Kehinde, T. H. and Omowonuola, A. O. A. 2019. Nutritional Composition and Heavy Metal

Profile of Nigerian Rice Varieties. *Current Research in Nutrition and Food Science* 7(2): 576-583. doi: http://dx.doi.org/10.12944/CRNFSJ.7.2.26.

Osaretin, A., Ebuehi, T. and Oyewole, A. C. 2017. Effect of cooking and soaking on physical characteristics, nutrient composition and sensory evaluation of indigenous and foreign rice varieties in Nigeria. *African Journal of Biotechnology* 6(8): 1016-1020.

Osborn, D. R. and Voogt, P. 1978. Calculation of calorific value. *In*: The Analysis of Nutrients in Foods. New York, USA: Academic Press. 239-240.

Pang, Y., Ahmed, S., Xu, Y., Beta, T., Zhu, Z., Shao, Y. and Bao, J. 2018. Bound phenolic compounds and antioxidant properties of whole-grain and bran of white, red and black rice. *Food Chemistry* 240: 212-221.https://doi.org/10.1016/j.foodchem.2017.07.095

Powers, H. J., Hill, M. H., Mushtaq, S., Dainty, J. R., Majsak-Newman, G., and Williams, E. A., 2011. Correcting a marginal riboflavin deficiency improves hematologic status in young women in the United Kingdom (ribofem). *American Journal of Clinical Nutrition* 93: 1274-1284.

Rabbani, G.H. and Ali, M. 2009. New ideas and concepts, rice bran: a nutrient dense mill-waste for human nutrition. *The Orion Medical Journal* 32(3): 458-62.

Rathna P. T. S., Ann Raeboline, L. E. N., Kavitha, R. and Usha, A. 2019. Nutritional and functional properties of colored rice varieties of South India: a review. *Journal of Ethnic Foods* 6: 1-11.

Reddy, C. K., Kimi, L., Haripriya, S., and Kang, N. 2017. Effects of Polishing on Proximate Composition, Physicochemical Characteristics, Mineral Composition and Antioxidant Properties of Pigmented Rice. *Rice Science* 24(5):241"252.

Rivlin, R. S. 2007. Riboflavin (vitamin B2). In Handbook of Vitamins, 4th ed.; Zempleni J, Rucker RB, McCormick DB, Suttie JW, Eds.; CRC Press: Boca Raton, FL, USA, 2007.

Robet, E. J., Konan, B., Amoikon, K. E. 2020. Comparative Study of Nutritional Value of Wheat, Maize, Sorghum, Millet, and Fonio: Some Cereals Commonly Consumed in Côte d'Ivoire. *European Scientific Journal* 16(21): 118-131.

Rout, G. R. and Sahoo, S. 2015. Reviews in Agricultural Science, 3:1-24. doi: 10.7831/ras.3.1

Said, H.M. and Ross, A.C. 2014. Riboflavin. In Modern Nutrition in Health and Disease, 11th ed.; Ross, AC, Caballero B, Cousins RJ, Eds.; Lippincott Williams and Wilkins: Baltimore MD, USA, 325–330.

Saikia, S., Dutta, H., Saikia, D., Mahanta, C. L. 2012. Quality characterization and estimation of the phytochemical content capacity of aromatic pigmented and non-pigmented rice varieties. *Food Research International* 46(1): 334-340.

Saleh, A.S.M., Wang, P., Wang, N., Yang, L. and Xiao, Z. 2019. Brown Rice Versus White Rice: Nutritional Quality, Potential Health Benefits, Development of Food

Products, and Preservation Technologies. *Comprehensive Reviews in Food Science and Food Safety.* 00: 1-27. https://www.researchgate.net/publication/333605399

Seo, W. D., Kim, J. Y., Song, Y. C., Cho, J. H., Jang, K. C., Han, S. I. and Nam M. H. 2013. Comparative analysis of physicochemical and antioxidative properties in new red rice (*Oryza sativa* L. cv. gunganghongmi). *Journal of Crop Science and Biotechnology* 16(1): 63-68.https://doi.org/10.1007/s12892-012-0057-3

Sharif, M. K., Butt, M. S., Anjum, F. M. and Khan, S. H. 2014. Rice b ran: A novel functional ingredient. *Critical Reviews in Food Science and Nutrition* 54: 807-816. https://doi.org/10.1080/10408398.2011.608586

Singh, N. and Singh, D. 2019. The Nutritional Composition of Local Rice Varieties in Guyana. *Greener Journal of Agricultural Science* 9(2): 138-145. http://doi.org/10.15580/GJAS.2019.2.022819041.

Sinigaglia-Coimbra, R., Lopes, A. C. and Coimbra C. G. 2011. Riboflavin deficiency, brain function, and health. In Handbook of Behavior, Food and Nutrition; Springer: Berlin, Germany 2427-2449.

Sompong, R., Siebenhandl-Ehn, S., Linsberger-Martin, G. and Berghofer, E. 2011. Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China and Sri Lanka. *Food Chemistry* 124: 132-40.

Sowunmi, F. A., Omigie, O. C., and Daniel, D. T. 2014. Consumers' Perception on Ofada Rice in Ibadan North Local Government Area of Oyo State, Nigeria. *Journal of Economics and Sustainable Development* 5(16): 1-9

Tegegne, B., Belay, A. and Gashaw T. 2020. Nutritional potential and mineral profiling of selected rice variety available in Ethiopia. *Chemistry International* 6(1): 21-29. https://doi.org/10.5281/zenodo.2592831

Thomas, R., Wan-Nadiah, W. A, and Bhat, R. 2013. Physiochemical properties, proximate composition, and cooking qualities of locally grown and imported rice varieties marketed in Penang, Malaysia. *International Food Research Journal* 20(3): 1345-1351.

Twinomuhwezi, H., Awuchi1, C. G. and Rachael, M. 2020. Comparative Study of the Proximate Composition and Functional Properties of Composite Flours of Amaranth, Rice, Millet, and Soybean. *American Journal of Food Science and Nutrition* 6(1): 6-19. https://www.researchgate.net/publication/339043536

Umar, M. A., Ugonor, R., Akin-Osanaiye, C. B. and Kolawole, S. A. 2013. Evaluation of Nutritional Value of Wild Rice from Kaduna State, Central Nigeria. *International Journal of Scientific and Technology Research* 2(7): 141-147.

Verma, D. K. and Srivastav, P. P. 2017. Proximate Composition, Mineral Content, and Fatty Acids Analyses of Aromatic and Non-Aromatic Indian Rice. *Rice Science* 24(1): 21-31.

Vlachos, A. and Arvanitoyannis, I. S. 2008. A review of rice authenticity/adulteration methods and results. *Critical Reviews* in *Food Science* and *Nutrition* 48: 553-598.

Zhang, M., Pinson, S. R. M., Tarpley, L., Huang, X. Y., Lahner, B., Yakubova, E. and Salt, D. E. 2014. Mapping and validation of quantitative trait loci associated with concentrations of 16 elements in unmilled rice grain. *Theoretical and Applied Genetics* 127: 137-165. https://doi.org/10.1007/s00122-013-2207-5