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

Adekola Mukaila Babatunde*

Department of Environmental Management and Toxicology, Federal University of Agriculture Abeokuta, Ogun State, Nigeria

*Corresponding author: adekolamb@funaab.edu.ng

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, α-oryzanol, aminobutyric acid (GABA), α-tocopherol, and γ-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 7º 10' 0” North, 3º 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.](image)
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:

Food energy (kCal/g) = (CP × 4) + (F × 9) + (CHO × 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
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 1. The percentage proximate composition of the four variety samples of rice |
|--------------------------------|----------------|-------------|----------|
| Composition (%)               | 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
Table 2. The percentage of Selected Metals in the four variety samples of the rice

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

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

<table>
<thead>
<tr>
<th>Vitamins (mg 100 g⁻¹)</th>
<th>Rice varieties</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brown</td>
<td>Mokwa</td>
<td>Ofada</td>
<td>Imported</td>
</tr>
<tr>
<td>Thiamine</td>
<td>0.26±0.01</td>
<td>0.20±0.01</td>
<td>0.31±0.01</td>
<td>0.24±0.01</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.07±0.00</td>
<td>0.05±0.00</td>
<td>0.08±0.00</td>
<td>0.06±0.00</td>
</tr>
<tr>
<td>Niacin</td>
<td>2.88±0.02</td>
<td>2.95±0.01</td>
<td>3.03±0.01</td>
<td>2.89±0.01</td>
</tr>
</tbody>
</table>

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


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 amylase 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
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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


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