



# **Farro 57 Rice Cultivar: A Comparative Study of the Nutritional Composition of its Parboiled Milled Rice, Brown Rice and Germinated Brown Rice**

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. The first draft was written by author ESU and authors EUO, GCO, CO had made their input before it was finally assembled by the author ESU. All authors read and approved the final manuscript.*

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## **ABSTRACT**

This work analyzed the nutritional composition of germinated brown rice (GBR) produced from FARRO 57 rice cultivar and compared it with that of ungerminated brown rice (UBR) and ungerminated parboiled milled/white rice (UWR) from the same cultivar which were used as controls. The aim was to evaluate and compare the nutritional composition of UBR, UWR and GBR of the rice cultivar. The experimental design used was a completely randomized design. GBR was produced by soaking brown rice grains in distilled water for 24 h and then made to germinate in a laboratory incubator at 35° C for 12, 24 and 36 h. The parameters determined included proximate composition, energy value, minerals, vitamins, total starch, amylose and total reducing sugar contents and they were determined in triplicates. It was found that GBR had significantly higher contents of protein (14.54-15.01%), ash (3.36.98%), total dietary fibre (9.23-9.31), phosphorus (130.55-187.15 mg/100 g), iron (6.22-9.94 mg/100 g), calcium (455.0-560.0 mg/100 g), zinc (2.51-2.72 mg/100 g), selenium (92.10-107.50 µg/100 g), vitamin B<sub>2</sub> (2.35-2.92 mg/100 g) and vitamin E (1.82-2.68 mg/100g) than UBR and UWR. Furthermore, there was no significant difference between the contents of vitamins A (19.45-19.72 IU), B<sub>1</sub> (0.33-0.34 mg/100g) and B<sub>6</sub> (1.00-1.10 mg/100g) of GBR and UBR samples, however they were all significantly higher than that of UWR. The GBR also had significantly lower amount of total carbohydrate (64.21-71.09%), total starch

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(54.91-60.92%), amylose (22.05-28.14%), and total reducing sugar (5.14-11.23%) than UBR and UWR. Amongst the GBR samples, the ash, protein, and the minerals increased with increase in duration of germination while the total carbohydrate, starch and amylose decreased with increase in duration of germination. GBR was recommended over UBR and UWR due to its optimum levels of the nutrients.

*Keywords: Germination brown rice; minerals; parboiled milled rice; vitamins.*

## 1. INTRODUCTION

Rice is a well-known cereal grain used as staple food in many regions of the world. It is reported that amongst the cereal grain, rice is only second to wheat in terms of consumption worldwide [1]. The major layers of rice grain include the husk/hull, bran, aleurone layer, sub-aleurone layer, germ and endosperm. The husk is the corklike inedible layer and beneath it is the bran layer. Beneath the bran layer is the aleurone layer which is followed by the sub-aleurone layer which houses the endosperm. The germ is located just after the sub-aleurone layer with some parts of it embedded in the endosperm. Brown rice and milled/white rice are got from the same rice grain; the difference is in the degree of milling.

The removal of only the husk/hull from rice grain results in what is called brown rice. Thus, brown rice has the bran, aleurone layer, sub-aleurone layer, germ and the endosperm. The bran layer contains most of the minerals, vitamins, dietary fibre, proteins, fats, antioxidants and phytochemicals of rice grains [2,3]. Milled rice which is also called white rice is got by removing the bran, the aleurone layer, sub-aleurone layer and germ [4]. Due to the removal of these layers together with its nutrients and health substances to obtain white rice, brown rice is considered more nutritious than white rice [3,5]. These layers are removed from brown rice to extend its shelf-life since brown rice is susceptible to oxidative rancidity due to the reaction of unsaturated fatty acid in the bran with oxygen [6]. Furthermore, it is also susceptible to hydrolytic rancidity due to a reaction of the natural lipases with the free fatty acids [4]. In either case, the end product has undesirable organoleptic attribute characterized by off-flavour and hence, a shorter shelf-life. Other factors militating against the use of brown rice as a staple food include its nutty flavour, longer cooking duration, hard to chew texture irrespective of the extent of cooking, and poor taste [7,8].

There are a few attempts to improve the nutritional composition of white rice. One of such

is by parboiling. In this method, the rough rice/paddy is soaked in water for at least 12 h followed by boiling before milling and polishing. This is done so that some of the nutrients from the bran will leach into the endosperm during the parboiling process. Another attempt is by fortification with some of the essential nutrients. The United States FDA for example, has mandated that fully milled and polished white rice must be fortified with iron and vitamins B<sub>1</sub> and B<sub>3</sub> [5]. However, fortification will add to the cost of production. Also, fortification or enrichment may not replace all the lost nutrients in their original form. For example, the lost dietary fibers are never replaced in polished rice.

The most recent method of improving the nutritional composition of rice is by a biological process of germination. In this method, brown rice is soaked in water for sometimes before subjecting it to germination. During germination, the natural lipases, proteases and  $\alpha$ -amylases are employed to breakdown fats, proteins and carbohydrates to simpler substances [3]. As a result, not only the quantity and bioavailability of important nutrients will be increased but the synthesis of different bioactive compounds will also be enhanced [7,9]. Other important characteristics of GBR include good texture, aroma and taste and are easier to cook [10]. Germinated brown rice is scarce in many regions of the world including Nigeria. Nutritional information on germinated brown rice from FARRO 57 is also not found in literatures. The aim of this study was to produce germinated brown rice from Nigeria FARRO 57 rice cultivar and compare its nutritional composition with that of its counterpart brown rice and the conventional milled rice.

## 2. MATERIALS AND METHODS

### 2.1 Source of the Rice

The FARRO 57 brown rice cultivar used in this study was provided by Ebony Agro Industries, Ikwo, Ebonyi State, Nigeria. The analyses were carried out at Analytical Laboratory, department of Home Science, University of Nigeria Nsukka,

Enugu State, Nigeria. All the reagents were obtained from the same laboratory.

## 2.2 Methods

### 2.2.1 Germinated brown rice production

A modified method of Abbas et al. [11] was used for the germination process. The process began by submerging the dehulled rice grains in 0.1% sodium chloride for 30 min for sterilization, followed by rinsing 5 times with distilled water to remove the salt. This was followed by steeping the grains in distilled water (1 part grains to 10 parts water w/v) at ambient temperature ( $29 \pm 2^\circ \text{C}$ ) for 24 h. During this period the steeped water was changed every 6 h. At the end of steeping, the water was drained off. The rice grains were spread on a layer of damp sterile jute bag kept in a laboratory cabinet incubator (Gulfex Scientific DNP-9082, England) to germinate at  $35^\circ \text{C}$  for 12, 24 and 36 h. The other layer of the damp jute bag was used to cover the rice kernels. During germination, distilled water was sprinkled at every 6 h to maintain uniform relative humidity. Germination was followed by drying of the grains at  $50^\circ \text{C}$  in hot air oven (Gulfex Scientific DHG 9202, England) to moisture content below 12%. The grains were stored in plastic cans until they were needed for analyses.

### 2.2.2 Determination of proximate composition and energy value

Hammer mill was used to mill the samples to flour and the proximate composition of the various flour samples were determined using official AOAC [12] methods. The total carbohydrate (phenol and sulphuric acid method), crude protein (Kjeldahl,  $\text{N} \times 6.25$ ), total dietary fibre (enzymatic-gravimetric method), fat (solvent extraction with petroleum ether), ash and moisture contents were determined. The Atwater formula was used to calculate the energy value. Here, the values of carbohydrate, protein and fat were multiplied by 4.0 kCal/100 g, 4.0 kCal/100 g and 9.0 kCal/100 g respectively and the results summed up to give the energy value in kCal/100 g.

### 2.2.3 Determination of mineral composition

The AOAC [12] method was used to determine the mineral composition of the flours. Two gramme of the sample was measured into a muffle furnace which was used to ash it for 6 h at  $550^\circ \text{C}$ . After allowing it to cool, it was mixed with 5 ml of 6N HCl after which they were poured into

a steam batch for drying by evaporation. It was filtered through Whatman No. 1 filter paper into 100 ml volumetric flask and distilled water was added to the filtrate to make up the volume. This filtrate was then used for the mineral determination.

Calcium was determined by pipetting 10 ml of the ashed solution into 250 ml beaker and was followed by addition of 1 ml 30% citric acid solution, 5 ml 5%  $\text{NH}_4\text{Cl}$  solution and distilled water to make it up to 100 ml before boiling it. Then there were additions of 10 drops of 0.04% bromocresol green solution, 30 ml of saturated ammonium oxalate solution, drops of concentrated HCl to dissolve the precipitate and drops of  $\text{NH}_3$  for neutralization. The beaker and its contents was steamed for 30 min in water bath, 50 ml of  $\text{H}_2\text{SO}_4$  was added to dissolve the precipitate and this was followed by filtering through filter paper, and distilled water was used to rinse the filter paper until the filtrate reached 100 ml. It was followed by heating the filtrate to  $80^\circ \text{C}$  and titrating with 0.02N  $\text{KMnO}_4$  solution until the colour turned pink. The absorbance was read using a spectrophotometer (Genway 6305, England) and the concentration of the mineral was calculated from Equation 1.

$$C_m (\text{mg}/100\text{g}) = (A \times B)/(C \times D) \quad (1)$$

Where  $C_m$  = Concentration of the mineral; A = Absorbance of the sample; B = Concentration of standard; C = Absorbance of standard; D = weight of sample.

For magnesium, 10 ml of the ashed solution was pipette into a 250 ml beaker after which 25 ml of buffer (pH 10.0) and 25 ml of distilled water were added. It was followed by addition of 0.1 g of EBT indicator and swirling until the solution changed to wine colour. Finally, it was titrated against 0.01N EDTA until a clear blue colour was obtained. The absorbance was read using a spectrophotometer (Genway 6305, England) and the concentration of the mineral was calculated from Equation 1.

For zinc, 10 ml of the ashed solution was pipette into 30 ml test tube after which acetate buffer (5 ml), 1 ml 2% sodium thiosulphate solution and 5 ml 0.05% dithizone solution were added and left for 5 min before addition of 3 ml of  $\text{CCl}_4$  which separated the solution into 2 layers. The absorbance of the upper layer was read using a spectrophotometer (Genway 6305, England) at 540 nm wavelength and the concentration of the mineral was calculated from Equation 1.

For iron, 10 ml of the ashed solution was pipette into 30 ml test tube after which 1 ml of hydroxylamine hydrochloride was added and was left for 5 min before addition of 5 ml acetate buffer and 1 ml ortho- phenanthroline. The absorbance of the resulting pink coloured solution was read using a spectrophotometer (Genway 6305, England) at 510 nm wavelength and the concentration of the mineral was calculated from Equation 1.

For selenium, 10 ml of the ashed solution was pipette into 30 ml test tube after which 1 ml of 2% KI solution and 1ml 1M HCl were added and was shaken until a yellow colour was obtained. It was followed by addition of 0.5 ml of 0.02% Safranin O and 2 ml acetate buffer solution (pH 4.0). The absorbance was read using a spectrophotometer (Genway 6305, England) at 532 nm wavelength and the concentration of the mineral was calculated from Equation 1.

For phosphorus, 10 ml of the ashed solution was pipette into 30 ml test tube followed by addition of 2 ml vanado-molybdate. It was followed by addition of 0.2 ml H<sub>2</sub>SO<sub>4</sub> and was stoppered to mix and left for 10 min. The absorbance was read using a spectrophotometer (Genway 6305, England) at 660 nm wavelength and the concentration of the mineral was calculated from Equation 1.

#### **2.2.4 Determination of composition of vitamins**

Vitamin A was determined using the method of Jakutowicz et al. [13]. The protein was precipitated using 3 ml ethyl alcohol. Heptane (5 ml) was used for extraction and the absorbance was read using a spectrophotometer (Genway 6305, England) at 450 nm wavelength against the blank.

The AOAC [12] method was used to determine the quantity of vitamins B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub>, B<sub>6</sub> and B<sub>9</sub>. The flour sample (5 g) was measured into a conical flask and was followed by extraction and digestion. For B<sub>1</sub>, the extraction was done with 50 ml ethanolic sodium hydroxide before filtering through Whatman No. 1 filter paper. Potassium dichromate (10 ml) was added to the filtrate before reading the absorbance in a spectrophotometer (Genway 6305, England) at 360 nm wavelength. For B<sub>2</sub>, extraction was done with 100 ml ethanol before filtering through Whatman No. 1 filter paper. Furthermore, the filtrate was mixed with 10 ml KMnO<sub>4</sub> and 10 ml

3% hydrogen peroxide and then heated in a water bath for 30 min and was followed by addition of 2 ml of 40% Na<sub>2</sub>SO<sub>4</sub>. It was followed by centrifuging at 1500 rpm and reading the supernatant in spectrophotometer (Genway 6305, England) at 510 nm wavelength. For B<sub>3</sub>, the extraction was done with 50 ml of 1N H<sub>2</sub>SO<sub>4</sub> for 30 min. This was followed by addition of 0.5 ml NH<sub>3</sub> solution and filtering through Whatman No. 1 filter paper. Furthermore, 10 ml of the filtrate was mixed with 5 ml of 0.5% potassium cyanide and was followed by acidification with 5 ml of 0.02N H<sub>2</sub>SO<sub>4</sub>. Spectrophotometer (Genway 6305, England) was used to read the absorbance of the resultant solution at 420 nm wavelength. For B<sub>6</sub>, the extraction was done with 10 ml 0.1M HCl accompanied with vigorous shaking for 10 min. The sample was filtered through Whatman No. 1 filter paper and the filtrate was made to 10 ml by addition of distilled water. Furthermore, 5 ml of the slightly acidic filtrate was treated with 1 ml 0.40% ferric chloride. The optical density of the resultant brown solution was measured in a spectrophotometer at 450 nm against the blank.

Vitamin E was determined by AOAC [14] method. Here, 1 g of the sample was measured and extracted with 50 ml petroleum ether and was concentrated to dry. The residue was mixed with 5ml of 0.1M KOH for saponification and was then refluxed. Another 20 ml of petroleum ether was added to extract the unsaponified matter and the filtrate was concentrated to dry. The concentrate was mixed with ethanol (20 ml) after which 1 ml was measured into a test tube and 1 ml 0.2% ferric chloride and 1 ml 0.5% dipyrindyl in ethanol were added. The solution was made up to 5 ml by addition of ethanol. The absorbance of the solution was then read at 520 nm against a blank.

The absorbance obtained from each of the sample extracts was converted to their respective vitamin concentration by means of their calibration curve generated using different standard concentrations.

#### **2.2.5 Determination of total starch, amylose and reducing sugar compositions**

The rapid total starch method [15] was used to determine the total starch content, and the absorbance of the sample was read against the blank at 510 nm wavelength. The ISO [16] method was used to determine the amylose contents. In this method, the 0.1 g of each flour sample, blank or standard was measured into a 100 ml volumetric flask after which 1 ml of 95%

ethyl alcohol and 9 ml of 1 M sodium hydroxide were added. The flask together with the mixture was transferred to a water bath that contained boiling water and the mixture was heated for 20 min after which it was allowed to cool to ambient temperature. The volume was made up to 100 ml by addition of distilled water. A vortex mixer was used to mix 0.5 ml of test sample, standard or blank, 0.1 ml of 5% acetic acid, 0.2 ml of iodine and 9.2 ml distilled water in a 10 ml test tube and the absorbance was read at 720 nm wavelength against the blank. A calibration curve was obtained using standard graded amylose (Fluka chemicals, Germany), and the percentage amylose was extrapolated from the curve.

The total reducing sugar was determined by AOAC [14] method and D-glucose was used as standard. The quantity of reducing sugar was calculated using Equation 2.

$$RS = \frac{[100(X \times Y)]}{Z} \quad (2)$$

Where, RS = Reducing sugar (in %); X= D-glucose used to reduce 20 ml soxhlet reagent (in ml); Y= Concentration of D-glucose standard used to reduce 20 ml soxhlet reagent; Z= weight of the sample titrant used (in g)

### 2.3 Statistical Analysis

The data obtained from the study were further subjected to a One-Way Analysis of Variance (ANOVA) with the aid of SPSS package version 17.0. Significant differences at  $p > 0.05$  were determined using Fisher's Least Significant Difference (LSD) and Duncan Multiple Range Tests.

## 3. RESULTS AND DISCUSSION

### 3.1 Proximate Composition and Energy Value

The proximate compositions of the ungerminated parboiled milled/white rice (UWR), brown rice (UBR) and germinated brown rice (GBR) are presented in Table 1. The protein content was highest in GBR (14.54-15.01%) followed by UBR (10.99%) and least in UWR (10.16%). Higher protein content in GBR was previously reported [17,18]. The reason for this could be due to the action of proteases on some bound proteinous substances [8]. The ash content was also highest in GBR (3.36-3.98%) followed by UBR (1.32%) and least in UWR (1.26%). The ash content

indicates the mineral composition of food and thus minerals may be higher in GBR than UBR and UWR. Higher ash content of GBR was also previously reported [18]. Amongst the GBR samples the quantities of both protein and ash increased with increasing duration of germination. Rice grain is reported to contain high quantity of phytic acid which is a potent mineral inhibitor [19]. This phytic acid is acted upon by an enzyme called phytase and phytase activity increases with increase in duration of germination [19]. Thus, increase in ash content with duration of germination could be due to increase in phytase activity.

The moisture contents were generally low and fall below 14% reported for prolonged storage life of rice grains [8]. The fat content was lower in UWR (1.00%) than UBR (2.46%) and GBR (2.90-2.93%). There was no significant difference ( $p > 0.05$ ) between the fat content of UBR and GBR. The low fat content of UWR could be due to the removal of the germ and the bran during rice milling. The total dietary fibre was highest in GBR (9.23-9.31%) followed by UBR (8.20%) and least in UWR (5.20%). The possible reason for high dietary fibre in GBR could be due to a combination of factors such as the removal of the bran and the aleurone layers during rice milling and polishing [3] as well as the formation of new cell wall components during germination [20]. No significant difference existed in total dietary fibre amongst the GBR samples. High dietary fibre in GBR was also previously reported [17,21]. High dietary fibre in food is advantageous due to its role in regulation of glucose absorption, reduction in the amounts of blood cholesterol and glycemic index, prevention of Type 2 diabetes and obesity as well as acting as substrate for beneficial bacteria in the colon [1,7].

The total carbohydrate was highest in UWR (77.15%) while UBR and GBR had values of 72.49% and 64.21% - 71.09% respectively. The high total carbohydrate content of UWR could be due to removal of most of the other nutrients along with the bran, the aleurone layer and the germ during rice milling thus making carbohydrate the only remaining major nutrient in the grain [3]. The total carbohydrate also decreased with increase in germination duration in GBR samples and this could be due to increase in amylase activity [22]. The energy content was 358.24 kCal/100g for UWR, 356.06 kCal/100g for UBR and 343.25-368.62 kCal/100g for GBR. The total carbohydrate contributed more to the energy value, followed by protein

while fat contributed the least. Just like total carbohydrate, the energy content also decreased with increase in germination duration. From the data obtained it could be said that germination for 12 h led to the production of rice with the best combination of nutrient composition.

### 3.2 Mineral Composition

The composition of minerals in the samples is as shown in Table 2. The phosphorus content was highest in germinated brown rice (GBR) samples (130.55-187.15 mg/100g) followed by that of ungerminated brown rice (UBR) which was 69.75 mg/100g while the parboiled milled rice (UWR) had the least (18.05 mg/100g). Iron is a micro nutrient that forms a major part of the protein called myoglobin, whose function is to supply the muscles with oxygen. Iron helps the cells to develop, grow and function appropriately and helps the body to produce hormones [23]. A condition called anaemia which is characterized by loss of blood is as a result of deficiency of iron. The iron content of UWR increased by almost 4 times in UBR (4.65 mg/100 g) and almost 6 to 9 times in GBR (6.22-9.94 mg/100 g). The body requires calcium for proper bone development. Calcium was 50.0 mg/100g in UWR, but increased to 106.0 mg/100g in UBR and to 455-560 mg/100 g in GBR. The calcium content of GBR was 9 to 11 times higher than

that of UWR. Magnesium content of GBR (119.0-272.0 mg/100g) was 2.7 to 6.3 times higher than that of UBR (43.58 mg/100g) and 3.0 to 7.0 times higher than that of UWR (39.22 mg/100g). Magnesium functions as a cofactor for numerous biological enzymes [24]. Selenium induces DNA repair, helps the body to eliminate damaged cells and also helps the liver to deactivate toxins [25]. The selenium content was higher in GBR (92.10-107.50 µg/100g) than UBR (82.20 µg/100g) and UWR (43.30 µg/100g). Zinc was also higher in GBR (2.51-2.72 mg/100g) than UBR (1.70 mg/100g) and UWR (1.03 mg/100g). Zinc helps in growth and cell division, in the metabolism of lipids, proteins, carbohydrates and energy, boosts the immune system and prevents infection [26].

It is worthy to note that apart from these minerals being higher in GBR than UBR and UWR, the increase in these minerals in GBR followed a particular trend; they increased in quantities with increase in germination duration. The only exception to this trend was zinc. The increase in these minerals could be due to the decrease in phytic acid content with increase in duration of germination following a corresponding increase in phytase activity [19]. The enzyme phytase has been reported to break down phytic acid thereby increasing the availability of the bound minerals [19].

**Table 1. Proximate and energy compositions of the samples**

Sample	Protein (%)	Ash (%)	Moisture (%)	Fats (%)	Total dietary fibre (%)	Total CHO (%)	Energy (kCal/100 g)
UWR	10.16 <sup>d</sup>	1.26 <sup>c</sup>	10.46 <sup>b</sup>	1.00 <sup>b</sup>	5.20 <sup>c</sup>	77.15 <sup>a</sup>	358.24 <sup>a</sup>
UBR	10.99 <sup>c</sup>	1.32 <sup>c</sup>	11.98 <sup>a</sup>	2.46 <sup>a</sup>	8.20 <sup>b</sup>	72.49 <sup>b</sup>	356.06 <sup>b</sup>
GBR-12	14.54 <sup>b</sup>	3.36 <sup>b</sup>	10.90 <sup>b</sup>	2.90 <sup>a</sup>	9.23 <sup>a</sup>	71.09 <sup>b</sup>	368.62 <sup>a</sup>
GBR-24	14.77 <sup>ab</sup>	3.82 <sup>a</sup>	10.88 <sup>b</sup>	2.92 <sup>a</sup>	9.25 <sup>a</sup>	66.99 <sup>c</sup>	353.32 <sup>b</sup>
GBR-36	15.01 <sup>a</sup>	3.98 <sup>a</sup>	10.86 <sup>b</sup>	2.93 <sup>a</sup>	9.31 <sup>a</sup>	64.21 <sup>d</sup>	343.25 <sup>c</sup>

Values with the same superscripts in each column are not significant difference at  $p > 0.05$ . CHO= carbohydrate; UWR= ungerminated parboiled milled rice; UBR= ungerminated brown rice; GBR= germinated brown rice; 12, 24 and 36 are germination durations (h)

**Table 2. Mineral composition of the samples**

Sample	P (mg/100 g)	Fe (mg/100 g)	Ca (mg/100 g)	Mg (mg/100 g)	Se (mg/100 g)	Zn (mg/100 g)
UWR	18.05 <sup>d</sup>	1.27 <sup>d</sup>	50.00 <sup>e</sup>	39.22 <sup>e</sup>	43.30 <sup>d</sup>	1.03 <sup>c</sup>
UBR	69.75 <sup>c</sup>	4.65 <sup>c</sup>	106.00 <sup>d</sup>	43.58 <sup>d</sup>	82.20 <sup>c</sup>	1.70 <sup>b</sup>
GBR-12	130.55 <sup>b</sup>	6.22 <sup>b</sup>	455.00 <sup>c</sup>	119.00 <sup>c</sup>	92.10 <sup>b</sup>	2.51 <sup>a</sup>
GBR-24	180.27 <sup>a</sup>	9.92 <sup>a</sup>	520.00 <sup>b</sup>	200.61 <sup>b</sup>	103.50 <sup>a</sup>	2.72 <sup>a</sup>
GBR-36	187.15 <sup>a</sup>	9.94 <sup>a</sup>	560.00 <sup>a</sup>	272.31 <sup>a</sup>	107.50 <sup>a</sup>	2.72 <sup>a</sup>

Values with the same superscripts in each column are not significant difference at  $p > 0.05$ .; UWR= ungerminated parboiled milled rice; UBR= ungerminated brown rice; GBR= germinated brown rice; 12, 24 and 36 are germination durations (h)

### 3.3 Vitamin Composition

The composition of the vitamins in the samples is as shown in Table 3. Vitamin A is a well known vitamin whose deficiency causes night blindness. Vitamin A was 10.71 IU in UWR but was higher in UBR (19.72 IU) and GBR (19.49-19.53 IU) samples. A previous work by Abbas et al. [11] showed that vitamin A was higher in GBR than UWR. There was no significant difference ( $p>0.05$ ) between vitamin A content of UBR and GBR samples.

Thiamin (vitamin B<sub>1</sub>) content of UWR (0.08 mg/100g) was increased by more than 4 times in UBR and GBR samples. Just like vitamin A, no significant difference existed in the amount of vitamin B<sub>1</sub> between UBR and GBR samples. Riboflavin (vitamin B<sub>2</sub>) was highest in GBR (2.35-2.92 mg/100 g) followed by UBR (1.66 mg/100 g) and lowest in UWR (0.81 mg/100 g). Naicin (vitamin B<sub>3</sub>) values were generally low and its content in UWR (0.80 mg/100g) did not differ significantly ( $p>0.05$ ) from that of UBR and GBR samples. Vitamin B<sub>6</sub> was lower in UWR (0.68 mg/100 g) than UBR and GBR samples (1.00-1.10 mg/100 g) and there was no significant difference between UBR and GBR samples. Rice grain is not a source of Vitamin B<sub>9</sub> and that could be the reason why it was not detected in UWR and was negligible in UBR and GBR samples.

Vitamin E is a well-known antioxidant that enhances metabolic processes and helps to improve the immune system of the body [1]. Vitamin E was highest in GBR (1.82-2.68 mg/100g) followed by UBR (1.38 mg/100g) while UWR had the lowest value (0.24 mg/100g). This is in agreement with the previous works by Kaur et al. [19] and Lin et al. [27] who also reported significantly higher values of vitamin E in GBR than UBR and UWR. Amongst the GBR samples, it was found that increase in the duration of germination did not have any significant effect on the values of the vitamins assayed.

### 3.4 Total Starch, Amylose and Total Reducing Sugar Contents

The content of total starch, amylose and total reducing sugars are shown in Table 4. The white rice (UWR) had the highest total starch content (76.06%) followed by brown rice (UBR) whose total starch was 67.09% while the germinated brown rice (GBR) had the least values (60.92-54.91%). The amylose content of UWR (35.87%) did not differ significantly ( $p>0.05$ ) from that of the UBR but the values of amylose were lower in GBR (22.05-28.14%). Chinma et al. [18] and Kaur et al. [19] also reported lower total starch and amylose contents in GBR than UWR. It was observed amongst the GBR samples that both the total starch and the amylose decreased with

**Table 3. The composition of vitamins**

Sample	Vitamin A (IU)	Vitamin B1 (mg/100 g)	Vitamin B2 (mg/100 g)	Vitamin B3 (mg/100 g)	Vitamin B6 (mg/100 g)	Vitamin B9 (mg/100 g)	Vitamin E (mg/100 g)
UWR	10.71 <sup>b</sup>	0.08 <sup>b</sup>	0.81 <sup>c</sup>	0.80 <sup>a</sup>	0.68 <sup>b</sup>	nil	0.24 <sup>d</sup>
UBR	19.72 <sup>a</sup>	0.33 <sup>a</sup>	1.66 <sup>b</sup>	0.80 <sup>a</sup>	1.04 <sup>a</sup>	0.01 <sup>a</sup>	1.38 <sup>c</sup>
GBR-12	19.53 <sup>a</sup>	0.34 <sup>a</sup>	2.35 <sup>a</sup>	0.81 <sup>a</sup>	1.10 <sup>a</sup>	0.01 <sup>a</sup>	1.95 <sup>a</sup>
GBR-24	19.49 <sup>a</sup>	0.34 <sup>a</sup>	2.61 <sup>a</sup>	0.83 <sup>a</sup>	1.04 <sup>a</sup>	0.01 <sup>a</sup>	2.68 <sup>a</sup>
GBR-36	19.50 <sup>a</sup>	0.34 <sup>a</sup>	2.92 <sup>a</sup>	0.86 <sup>a</sup>	1.00 <sup>a</sup>	0.01 <sup>a</sup>	1.82 <sup>a</sup>

Values with the same superscripts in each column are not significant difference at  $p>0.05$ .; UWR= ungerminated parboiled milled rice; UBR= ungerminated brown rice; GBR= germinated brown rice; 12, 24 and 36 are germination durations (h)

**Table 4. Total starch, amylose and total reducing sugar compositions**

Sample	Total starch (%)	Amylose (%)	Total reducing sugars (%)
UWR	76.06 <sup>a</sup>	35.87 <sup>a</sup>	2.16 <sup>d</sup>
UBR	67.09 <sup>b</sup>	35.10 <sup>a</sup>	1.67 <sup>e</sup>
GBR-12	60.92 <sup>c</sup>	28.14 <sup>b</sup>	5.14 <sup>c</sup>
GBR-24	57.65 <sup>d</sup>	26.72 <sup>c</sup>	11.23 <sup>a</sup>
GBR-36	54.91 <sup>e</sup>	22.05 <sup>d</sup>	8.88 <sup>b</sup>

Values with the same superscripts in each column are not significant difference at  $p>0.05$ . UWR= ungerminated parboiled milled rice; UBR= ungerminated brown rice; GBR= germinated brown rice; 12, 24 and 36 are germination durations (h)

increase in germination duration. This was akin to the report by Chinma et al. [18] and Kaur et al. [19] and reason for this could be due to increase in amylase activity which is also reported to increase with increase in duration of germination [22]. The total reducing sugar was highest in GBR (5.14-11.23%) followed by UWR (2.16%) while UBR had the lowest total reducing sugar content (1.67%). High amount of reducing in GBR than UWR and UBR was previously reported [22,28] and this may be due to increase in amylase activity. Amongst the GBR samples, it was observed that the total reducing sugar increases when the duration of germination was increased from 12 to 24 h, a further increase in germination duration to 36 h resulted in a significant decrease ( $p>0.05$ ) in total reducing sugar content. It is likely that the sprouts started utilizing these sugars for growth at 36 h of germination. Thus, low total starch and amylose content and high total reducing sugar content indicate a better nutritional quality of GBR over UWR and UBR.

#### 4. CONCLUSION

The findings from this study showed that germinated brown rice (GBR) had better nutritional quality in terms of higher protein, total dietary fibre, ash, total reducing sugar, minerals, and vitamins B<sub>2</sub> and E, and lower total carbohydrate, total starch and amylose than ungerminated brown rice and parboiled milled rice. Thus production and consumption of germinated brown rice (GBR) instead of brown rice or parboiled milled rice is recommended. The production process of germinated brown rice is very simple which could easily be adopted by rice producing industries. This will lead to the production of highly nutritious product for the overall health benefits of the consumers.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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