



## Improvement of nutritional, functional and pasting properties of long and short local rice grains during germination

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### ABSTRACT

Poor nutritive value of cereals results in the prevalence of disease and poor physical development among the vulnerable groups in developing African nations. Most importantly, germination of these edible seeds had been shown to increase nutrient content further and reduce anti-nutrients. The objective of the current research was to investigate the effects of germination on nutritional, functional and pasting properties of long and short grain rice grown in the northern part of Nigeria. The rough paddy rice (long and short grain) was cleaned, washed thoroughly in water and soaked in water 1:2 w/v for 24 hr at ambient temperature ( $26 \pm 2$  °C). The drained rice was placed in the jute bags and germinated at temperature  $35 \pm 2$  °C and relative humidity  $95 \pm 2\%$  for 1, 3 and 5 days. After germination, the grains were dried to 12% moisture content. Non-germinated grains were included as control. Nutritional, functional and pasting properties were determined in grain flours using standard methods. Germination process significantly ( $p \leq 0.05$ ) increased the protein, fat and fibre content of both rice types. Germination also caused a significant interference in the calcium, potassium and zinc concentration of both rice types. Bulk density values ranged between 0.74-0.94 and 0.66-0.86 g/mL for long and short grain, respectively. There was a significant difference ( $p \leq 0.05$ ) among the samples in water absorption capacity (1.54-2.60 g/mL), oil absorption capacity (1.78-3.75 g/mL) and swelling power (2.87-4.56 g/g) with the non-germinated samples having the highest values. Similarly, there were significant differences in pasting properties such as viscosity and pasting time of non-germinated and germinated rice types. Therefore, germination process enhanced nutritional and functional properties though pasting properties of both rice types were adversely affected. Germinated flour from long and short grain rice could be used to improve the nutritional status of rice-consuming population, especially children.

### Introduction

Cereals belong to the monocot families, 'Poaceae or Gramineae' and are cultivated widely to obtain the edible components of their fruit seeds (Ukwuru et al., 2018). Botanically, these fruits are called 'caryopsis' and are composed of endosperm, germ and bran. Cereals are grown in greater quantities and provide more food energy worldwide than any other food crops. The major cereals cultivated in Nigeria include maize, sorghum, millet and rice (Ismaila et al., 2010).

Rice (*Oryza sativa* L.), a member of the grass family is one of the crops in which the human species largely subsist. Rice production worldwide has increased from about 200 million tonnes of rough rice in 1960 to more than 690 million tonnes in 2012, and milled rice is about 68% of rough rice by weight (IRRI, 2014). The top three rice producers are China (29.4% of world production), India (21.8%), and Indonesia (8.5%) as of the year 2012. The United States account for 1.3% of global rice (IRRI, 2014) production. Rice is also a staple food in many countries in Africa, including Nigeria. In 2016, the quantity of rice

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production in Nigeria was estimated at 4.8 million tonnes (FAO, 2016) which points to the fact that this crop is backbone of the Nigerian agriculture. It is a rich source of carbohydrate with starch as its main component (Verma and Srivastav, 2017). Rice grain contains a moderate amount of protein and fat, and is a source of vitamin-B complex and minerals such as calcium, magnesium and phosphorus as well as some traces of iron, copper, zinc and manganese (Oko et al., 2017). Besides being a food free of enzyme inhibitors that impair the absorption of nutrients, rice has got a bland taste, white colour and hypoallergenic properties (Neumann and Bruemmer, 1997). According to Yimaki et al. (1991), rice flour can be used as a wheat flour replacement since it lacks gluten, contains low level of sodium and a high amount of easily digestible carbohydrates, making it desirable in celiac diets.

Quality desired in rice varies from one geographical region to another and a consumer demands certain varieties and favours specific for home cooking (Danbaba et al., 2012). Cooked rice texture largely depends on the rice type, as long grain rice produces drier and fluffier rice in comparison to medium and short grain rice after cooking (Han, 2015). Medium and short grain rice is stickier and more adhesive upon cooking. Also, the colour of rice kernel could be white, brown, reddish, purplish or blackish. Brown rice is majorly consumed in Nigeria. Brown rice is the unpolished whole grain rice that is produced by removing only the hull and the husk using a mortar and pestle or rubber rolls, having a mild nutty flavour, chewier than white rice. Retention of the bran in brown rice provides more nutrients than white rice but its intake is limited because of its chewy texture and reduced digestibility. This problem may be overcome by subjecting the rice grain to germination process. Most importantly, efforts are being made by the food industry to enhance the use of whole rice grain and to create new products. Whole grain brown rice could be subjected to germination with the aim of improving its nutritional and sensorial qualities. Germinated brown rice is considered as a more nutritious and palatable cooked product than conventional brown rice (Han, 2015). During germination, dormant enzymes activate and changes occur from the process of converting the stored carbohydrates, lipids, and proteins into the energy required for the germination process as reported by Navam et al. (2014). As germination duration increases, the rice kernel and starch granule become weakened, thus resulting in softer, faster cooking rice with more nutrients retained. Germinated rice is effectively digested and assimilated in the body and considered to be a functional food with a high content of nutrients that are beneficial to the human

body. It contains ferulic acid,  $\gamma$ -aminobutyric acid (GABA) and other components which suppress liver inflammation and fibrosis and hence reduce the risk of liver cirrhosis and cancer (Wunjuntuk et al., 2016).

Beside the improvement of nutritional quality of rice grains as a result of germination, the process may change their compositions and may therefore alter the functional properties and pasting characteristics of the final product. The objectives of this research were to germinate rough long and short grain rice, and to investigate the changes in nutritional, functional and pasting properties of the resultant flours.

## Materials and methods

### *Experimental site*

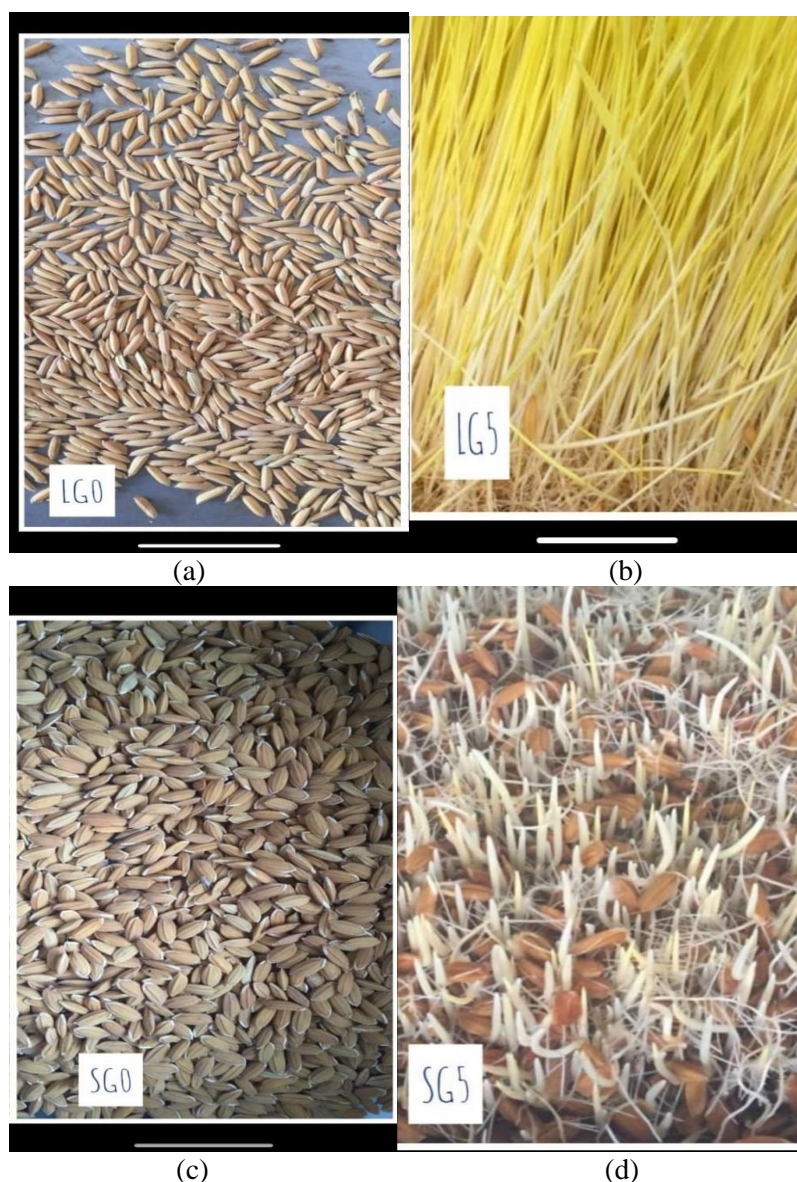
The experiment was conducted at Bowen University from December 2018 to June 2019 in Food Science and Technology laboratory.

### *Sample preparation*

Long and short rough grains were obtained from a local market in Kano state, Nigeria. The grains were cleaned manually to remove foreign matters and damaged grains. Cleaned grains were then stored in zip lock bags prior to germination and subsequent laboratory analyses. The chemicals used for the analyses were of analytical grade and they were purchased from Sigma Chemical Company, St. Louis, MO, USA.

### *Germination of rough grains*

The germination was done by the method reported by Ayernor and Ocloo (2007). Two kilograms of rough rice (long and short grain) were cleaned, washed thoroughly in water and soaked in water 1:2 w/v for 24 hr at ambient temperature. The seeds were placed on a jute sack, incubated under ambient temperature (30 °C) and watered (250 mL) twice daily for the germ to develop. Approximately 300 g of germinated rice was collected after the first, third and fifth day of incubation, respectively. The non-germinated rough rice sample (0 day) was used as a control. The samples were dried at 60 °C using air oven (Memmert, Germany) to reach a moisture content of 12%, which is ideal for avoiding microbial growth prior to further analyses. Fig. 1 shows non-germinated and germinated long and short grain rice.



**Fig. 1.** Non- germinated and germinated long and short grain rice. (a) Non- germinated long grain rice; (b) Germinated long grain rice (5<sup>th</sup> day); (c) Non- germinated short grain rice; (d) Germinated short grain rice (5<sup>th</sup> day)

#### *Preparation of flour from germinated rice*

Dried non-germinated and germinated rice samples were milled using disc attrition mill (Straub model 4E Grinding mill, Straub Co PHILA, USA) and screened through an 80 mesh sieve to obtain a uniform particle size. The rice samples were stored in airtight glass containers pending analysis.

#### *Chemical Analyses*

##### *Proximate composition*

Standard methods according to the AOAC (2012) were used to determine moisture, fat by soxhlet

extraction and ash by combustion. Protein content (Nx6.25) was determined by micro Kjeldahl method. Carbohydrate content was determined by difference. The caloric value was estimated (kCal/g) by multiplying the percentage crude protein, crude lipid and carbohydrate by the recommended factors of 2.44, 8.37 and 3.57, respectively and then taking the sum as described by Ekanayake et al. (1999). All analyses were carried out in triplicate.

##### *Mineral composition*

Analysis of potassium content of the samples was carried out using flame photometry (AOAC, 2012). The other elemental contents (calcium and zinc) were

determined, after wet digestion of sample ash with an atomic absorption spectrophotometer (Hitachi Z6100, Tokyo, Japan). All the determinations were carried out in triplicate.

#### *Determination of functional properties*

The bulk density of rice flours was determined by the gravimetric method described by Appiah et al. (2011). Water and oil absorption capacities were determined using the procedures described by Sofi et al. (2013). Additionally, the swelling power of rice samples was determined using the method reported by Wani et al. (2015).

#### *Determination of pasting properties*

The pasting behaviour of the flour samples was measured in a Rapid Visco Analyzer (Model: RVA-4, Newport Scientific Pty. Ltd., Sydney, Australia, 1995) and Thermocline for Windows software was used to evaluate the pasting properties. The viscogram profile shows the relationships between time, viscosity, and temperature during cooking processes.

#### *Statistical analysis*

Determinations were carried out in triplicate and the errors were reported as standard deviation from the mean. Analysis of Variance (ANOVA) was performed and the least significant differences were calculated with the Statistical Package for Social Scientist (SPSS) software for Windows, version 16.00; SPSS Inc., Chicago IL, USA. Significance was accepted at  $p \leq 0.05$  levels.

## **Results and discussion**

#### *Effect of germination on nutritional composition of long and short rice flour*

The moisture content of non-germinated and germinated flour samples of rice types varied between 10.75% and 11.46 % in long grain and 11.88% and 12.79% in short grain, respectively, as shown in Table 1. It could be inferred that moisture content decreased after germination. Navam et al. (2014) found similar observation in germinated long grain rice. As germination proceeds, rice grains took up water from the surroundings in order for the metabolic process to commence. Dry grain rice may absorb water slowly, influenced by the structure of the cereal. The decrease in water uptake with time during germination may be due to the decreasing number of cells within the seed becoming hydrated (Nonogaki et al., 2010). The lower

moisture of the long grain rice compared with short grain type could be attributed to differences in size and the orientation of amino acids in proteins/peptides. Moisture content affects the keeping quality of all forms of rice. Sound dry rice can be maintained for a year if properly stored, but only a few days are required for wet rice to spoil. The result showed significant difference ( $p \leq 0.05$ ) within and between different types of rice. However, the values reported in this study fall within the range of 9-13 % given by Kent (1984) on cereals.

Germination process affected differently the protein content, depending on rice type. The protein content after the third day of germination tends to decrease in the long grain type, indicating nitrogen breakdown and translocation to the embryonic tissues. Slight decrease (although not significant) in protein content from 7.8% to 7.4% was observed in the long grain rice type at the fifth day of germination. Decreased protein content is related to increased amino acid content as a consequence of proteases activation (Veluppillai et al., 2009). However, successive increase in protein content noted in short grain rice over germination time may be attributed to a passive variation due to decrease in the carbohydrate compound used for respiration. Martinez et al. (2011) also identified an increase in protein content during the germination process and justified that the increase was due to an enzymatic synthesis or other components losses. Therefore, the protein content in rice grains depends on the balance between protein degradation and biosynthesis during germination. The result showed significant difference ( $p \leq 0.05$ ) between different types of rice. However, the values of protein reported in this study fall within the range of 7.3-7.5 % given by Navam et al. (2014). The results obtained in this study showed that germination could be used to significantly enhance the protein content of rice grain which is often found in limited amounts and in biologically unavailable form in most rice varieties.

The lipid content in long grain rice type increased after the first day of germination. However, a decrease was not noted till the fifth day of germination. This decrease could be explained due the use of lipid for the seeds growth, because according to Hahm et al. (2009), the fatty acids are used as energy for germination, and will be oxidized into carbon dioxide and water. Megat et al. (2011) found a significant lipid reduction during the germination process for soy, white, black, red and brown rice. Contrarily, the crude oil content of short grain rice type increased simultaneously from the first day until the fifth day of germination. During germination, the biosynthesis of lipids occurred, as it has been described for unsaturated and polyunsaturated fatty acids (Nickerson et al.,

1975). Short grain rice provided significantly higher oil content than long grain rice type. However, the fat content of rice is generally low as it is contained in the bran and substantial quantity is removed during milling. The results showed significant difference between the different types of rice.

In relation to ashes, it was possible to observe a reduction of ash content with increasing germination time. Similarly, significant differences were observed in the ash content between short and long grain rice types. Ash content of long grain rice flour decreased from 2.1% to 1.7%, while short grain rice decreased from 2.7% to 2.4% during germination. Decreased ash content could be explained by lixiviation losses during soaking and watering during germination (Megat et al., 2011). The range of ash content in this study was close to values ranging from 1.60 to 2.06 % reported by Mohan et al. (2010) on India and Japonica malted brown rice.

The range of crude fibre of rice types, long and short, were 1.26-2.51 % and 1.58-2.20 %, respectively. Crude fibre content increased in germinated rice from day 1 to day 5. In germinated rice, the amount of crude fibre may be contributed by the presence of bran layer, an outer layer of rice that contained fibre. Earlier study had reported the increase in crude fibre of germinated brown rice (Megat et al., 2011). The effect of germination on dietary fibre content of sprouted grains is often inconsistent and strictly depends on fibre fraction, germination time and genotypes (Nelson et al., 2013). Germination caused a slight decrease of carbohydrates of rice types. The soaking, germination and heating treatments given to rice grains decreased the total carbohydrate contents from 76.9 to 75.9 % in long rice and 73.4 to 70.7 % in short rice, respectively.

In general, long grain rice provided larger available carbohydrates than short grain rice. Mohan et al. (2010) explained that the decrease of carbohydrate in germinated brown rice was due to the starch degradation presumably being involved in the action of several enzymes such as  $\alpha$ -amylase,  $\beta$ -amylase and invertase. In relation to calorie content, the time of germination caused a significant interference ( $p \leq 0.05$ ) in values. The calorie values of the rice samples ranged from 298.73 to 307.63 kcal/100g. Similarly, variation exists in calorie values of non-germinated and germinated rice types.

The mineral composition of non-germinated and germinated rice types is shown in Table 2. The concentration of calcium varied from 2.04 to 4.90 mg/100 g in long grain rice and 1.51 to 1.62 mg/100 g in short grain rice, respectively. Non-germinated long grain rice had the highest calcium content (4.90 mg/100 g) which was significantly ( $p \leq 0.05$ ) higher than the calcium content of non-germinated short grain rice. However, germination of rice grains resulted in significant loss of calcium. The content of zinc varied from 3.87 to 5.42 mg/100 g in long grain rice and 4.02 to 5.02 mg/100 g in short grain rice, respectively. Long grain rice had the lower zinc concentration after germination for 5 days than short grain rice. However, short grain rice had significantly higher ( $p \leq 0.05$ ) potassium than long grain rice. Germination of rice grain resulted in significant loss of potassium. Mineral elements are concentrated in outer layers of brown rice or in the bran fraction. However, there are losses during milling process. This accounted for the lower concentrations in germinated and milled rice samples.

**Table 1.** Proximate composition of germinated and non-germinated long and short grain rice flour

Germination Days	Moisture (%)	Crude Fat (%)	Crude protein (%)	Crude fibre (%)	Total ash (%)	Carbohydrate (%)	Calorie (kcal/100 g)
LG <sub>0</sub> (Control)	11.46±0.03 <sup>e</sup>	1.65±0.02 <sup>f</sup>	6.54±0.02 <sup>f</sup>	1.26±0.01 <sup>e</sup>	2.10±0.02 <sup>c</sup>	76.98±0.05 <sup>a</sup>	304.59±0.15 <sup>b</sup>
LG <sub>1</sub>	10.45±0.02 <sup>h</sup>	1.77±0.02 <sup>e</sup>	8.06±0.01 <sup>d</sup>	1.96±0.02 <sup>c</sup>	1.25±0.02 <sup>g</sup>	76.51±0.07 <sup>b</sup>	307.63±0.07 <sup>a</sup>
LG <sub>3</sub>	10.87±0.03 <sup>f</sup>	1.49±0.02 <sup>g</sup>	7.80±0.02 <sup>e</sup>	2.16±0.02 <sup>b</sup>	1.48±0.02 <sup>f</sup>	76.20±0.06 <sup>c</sup>	303.53±0.05 <sup>bc</sup>
LG <sub>5</sub>	10.75±0.02 <sup>g</sup>	1.66±0.02 <sup>f</sup>	7.44±0.02 <sup>e</sup>	2.51±0.02 <sup>a</sup>	1.69±0.03 <sup>d</sup>	75.94±0.08 <sup>d</sup>	303.15±0.11 <sup>bc</sup>
SG <sub>0</sub> (Control)	12.79±0.02 <sup>a</sup>	2.25±0.04 <sup>d</sup>	7.35±0.03 <sup>f</sup>	1.58±0.02 <sup>d</sup>	2.65±0.02 <sup>a</sup>	73.38±0.04 <sup>e</sup>	298.73±0.08 <sup>f</sup>
SG <sub>1</sub>	12.59±0.01 <sup>b</sup>	2.68±0.02 <sup>c</sup>	8.48±0.02 <sup>c</sup>	2.15±0.02 <sup>b</sup>	1.58±0.02 <sup>e</sup>	72.51±0.08 <sup>f</sup>	301.98±0.05 <sup>d</sup>
SG <sub>3</sub>	12.19±0.02 <sup>c</sup>	2.75±0.02 <sup>b</sup>	9.08±0.02 <sup>b</sup>	2.17±0.01 <sup>b</sup>	2.05±0.02 <sup>c</sup>	71.76±0.06 <sup>g</sup>	301.36±0.13 <sup>d</sup>
SG <sub>5</sub>	11.88±0.02 <sup>d</sup>	2.83±0.02 <sup>a</sup>	9.99±0.02 <sup>a</sup>	2.20±0.02 <sup>b</sup>	2.36±0.04 <sup>b</sup>	70.73±0.11 <sup>h</sup>	300.58±0.55 <sup>e</sup>

Means within a column with the same superscript were not significantly different at 5% level of significance. LG<sub>0</sub>-Non germinated long grain rice (Control); LG<sub>1</sub>- Long grain rice germinated for 1 day; LG<sub>3</sub>- Long grain rice germinated for 3 days; LG<sub>5</sub>- Long grain rice germinated for 5 days; SG<sub>0</sub>-Non germinated short rice (Control); SG<sub>1</sub>- Short grain rice germinated for 1 day; SG<sub>3</sub>- Short grain rice germinated for 3 days; SG<sub>5</sub>- Short grain rice germinated for 5 days



**Table 2.** Mineral composition of germinated and non-germinated long and short grain rice flour (mg/100 g)

Germination Days	Calcium	Zinc	Potassium
LG <sub>0</sub> (Control)	4.90±2.13 <sup>a</sup>	3.87±1.02 <sup>f</sup>	39.00±1.42 <sup>c</sup>
LG <sub>1</sub>	2.96±1.02 <sup>b</sup>	5.42±0.04 <sup>a</sup>	27.81±1.01 <sup>f</sup>
LG <sub>3</sub>	1.91±0.03 <sup>d</sup>	5.37±0.03 <sup>b</sup>	27.55±0.09 <sup>g</sup>
LG <sub>5</sub>	2.04±0.02 <sup>c</sup>	4.56±0.52 <sup>e</sup>	32.04±1.12 <sup>e</sup>
SG <sub>0</sub> (Control)	1.62±0.05 <sup>e</sup>	4.02±1.04 <sup>d</sup>	44.13±1.03 <sup>a</sup>
SG <sub>1</sub>	1.92±0.01 <sup>d</sup>	4.53±0.05 <sup>e</sup>	33.99±1.02 <sup>d</sup>
SG <sub>3</sub>	1.58±0.02 <sup>f</sup>	4.70±0.02 <sup>d</sup>	37.25±0.92 <sup>b</sup>
SG <sub>5</sub>	1.51±0.02 <sup>f</sup>	5.02±0.02 <sup>c</sup>	39.46±0.75 <sup>b</sup>

Means within a column with the same superscript were not significantly different at 5% level of significance. LG<sub>0</sub>-Non germinated long grain rice (Control); LG<sub>1</sub>- Long grain rice germinated for 1 day; LG<sub>3</sub>- Long grain rice germinated for 3 days; LG<sub>5</sub>- Long grain rice germinated for 5 days; SG<sub>0</sub>-Non germinated short rice (Control); SG<sub>1</sub>- Short grain rice germinated for 1 day; SG<sub>3</sub>- Short grain rice germinated for 3 days; SG<sub>5</sub>- Short grain rice germinated for 5 days

Generally, the mineral composition of the grain rice depends considerably on geographic origin, crop varieties, sampling, preparation, and the analytical methods adopted (Marles, 2017). Grains are important dietary sources of minerals, so apparent decline as a result of processing should not have significant implications on mineral nutrient intake by humans. The small estimated declines in mineral content of germinated rice samples could be addressed by consuming recommended number of servings per day of mineral rich foods such as fruits and vegetables.

Generally, the variation exists in the nutritional composition of germinated long and short grain rice and their respective control. Contemporaneous analysis of different varieties of the same crop grown side-by-side have confirmed that some varieties are lower in some nutrients than other varieties due to a dilution effect of increased yield by accumulation of carbohydrate (starch, sugar and/or fibre) without a proportional increase in certain other nutrients (Marles, 2017).

#### *Effect of germination on functional properties of long and short rice flour*

Table 3 shows the functional properties of rice flour samples. Germination process had a significant effect ( $p \leq 0.05$ ) on the functional parameters under consideration. Values obtained for water absorption capacity, oil absorption capacity, bulk density and swelling capacity ranged from 1.75 to 2.60 mL/g, 1.78 to 3.75 mL/g, 0.74 to 0.94 g/cm<sup>3</sup> and 2.87 to 3.50 g/g, in long grain rice, respectively and 1.54 to 2.10 mL/g, 1.94 to 2.94 mL/g, 0.66 to 0.86 g/cm<sup>3</sup> and 3.18 to 4.56 g/g in short grain rice, respectively. Bulk density showed significant difference ( $p \leq 0.05$ ) between non-germinated samples and samples germinated for 1 to 5 days. Similarly, significant difference ( $p \leq 0.05$ ) was observed between the long grain type and short grain type studied. Gradual increase in germination duration

showed decrease ( $p \leq 0.05$ ) in the bulk density of short and long grain rice flours. The observed reduction in bulk density might have been the result of reduction in weight of the flour due to the breakdown of complex denser compounds inherent in rice grains into simpler ones during germination (Gernah et al., 2011).

There was a significant difference ( $p \leq 0.05$ ) among the samples in water absorption capacity with the non-germinated samples (long and short grain) having the highest values. Water absorption characteristics symbolize the ability of a product to associate with water under conditions where water is restrictive and considered to be an index of the capability of protein to absorb and retain water. Germination decreased water absorption capacity of the samples. However, this result is in contrast to the work of Gernah et al. (2011), but in line with the work of Imtiaz et al. (2011). According to Okaka and Potter (1997), water holding capacity depends on the water bounding capacities of food components. Soaking of seeds is necessary before the germination of seeds. Seed priming is a treatment during which seeds are hydrated with a solution that allows them to imbibe and go through the first reversible stage of germination, but does not allow radicle protrusion through the seed coat (Lutts et al., 2016). During soaking, the various soaking properties differ due to the distribution exhibit by different hydration rates and other hydration properties depending upon the size of pore, hygroscopic properties of seed reserve material, concentration gradient, elasticity of seed coat and its permeability (Sibian et al., 2013). Fissures are naturally present in soaked and germinated grains, however, the coat or covering of a seed generally restricts the rate of water absorption to some degree and in some cases, the seed covering is impermeable to water, hence no water can be absorbed (Turhan et al., 2002). It could be inferred that germinated long and short grain rice used in this study were less permeable to water compared with their respective controls.

Germination process also decreased the oil absorption capacity (OAC) of short and long grain rice flours. Surface availability of hydrophilic amino acids and other non-polar amino acid chains in germinated rice grains are responsible for the oil absorption property of the flour. Oil absorption capacity of cereal flours is an essential property in developing novel food products and storing them for a long period. Fat molecules present in flour affect to some extent the flavour and mouth feel of resultant food products.

There was a significant difference ( $p \leq 0.05$ ) in swelling capacity of the samples with the non-germinated long and short rice type having the highest values. Germination of rice types significantly ( $p \leq 0.05$ ) decreased the swelling capacity of rice flour when compared to the control flours. Germination decreased the swelling power of the samples probably as a result of disruption of hydrogen atoms inherent in rice flour by amylases and proteases into sugars and amino acids, respectively (Egwim and Ademonom, 2009). Swelling power of starch depends on the capacity of starch molecules to form hydrogen bonding with water. Although germinated and non-germinated rice undergo similar milling method, particle size of non-germinated rice flour was larger than the particle size of germinated rice flour sample as attested by higher bulk density (Table 3). There is a correlation between the bulk density and particle size of flour. The larger the particle size, the higher the bulk density. The variations observed may also be related to the size difference of starch granules existing in rice samples. Williams et al. (1987) reported that the extent of starch damage during milling was directly proportional to the hardness of the kernel and the particle size of flour. In this study, germinated rice flour samples had finer particles than their respective controls. This is an indication that non-germinated rice samples were more prone to damage during milling than germinated

rice samples. Rice samples, especially the ones with the high amount of damaged starch, can increase the water absorption and hence increase the swelling power (Kemashalini et al., 2018). Rice flour with high low damage starch content absorbs less water due to close intact of amylose chains with starch granules. Food eating quality is often connected to the retention of water in swollen starch granules of food ingredients (Oates and Powel, 1996).

#### *Effect of germination on the pasting profile of long and short rice flour*

The pasting properties of raw and germinated rice samples are shown in Table 4. Pasting characteristics represent the behaviour of aqueous suspension of flours during heating, cooking and cooling in terms of changes in viscosity as measured by Rapid Visco Analyser (RVA). In essence, changes in viscosity could be useful for predicting food product quality. Pasting profiles of germinated brown rice flours were significantly different from their respective controls. Peak viscosity ranged from 24.27 to 128.27 RVU for short grain rice and 2.86 to 193.39 RVU for long grain rice. The peak viscosity values were significantly higher in non-germinated long grain rice compared to short grain rice. Similarly, germination duration had a significant effect ( $p \leq 0.05$ ) on the peak viscosity of samples. Low peak viscosity values recorded in samples produced from germinated rice grains compared to their respective controls was probably due to the degradation of starch by enzyme activity during the germination process. Peak viscosity indicates the water binding capacity of the starch or a mixture and it occurs at the equilibrium point between swelling, causing an increase in viscosity rupture, and alignment, causing its decrease (Adegunwa et al., 2011).

**Table 3.** Functional properties of germinated and non-germinated long and short grain rice flour

Germination Days	Bulk density (g/cm <sup>3</sup> )	Oil absorption capacity (mL/g)	Water absorption capacity (mL/g)	Swelling power (g/g)
LG <sub>0</sub> (Control)	0.94±0.04 <sup>a</sup>	3.75±0.04 <sup>a</sup>	2.60±0.01 <sup>a</sup>	3.50±0.01 <sup>c</sup>
LG <sub>1</sub>	0.92±0.01 <sup>a</sup>	2.59±0.03 <sup>c</sup>	2.52±0.01 <sup>b</sup>	3.46±0.04 <sup>c</sup>
LG <sub>3</sub>	0.84±0.01 <sup>b</sup>	2.03±0.03 <sup>f</sup>	1.82±0.01 <sup>f</sup>	3.08±0.15 <sup>de</sup>
LG <sub>5</sub>	0.74±0.01 <sup>b</sup>	1.78±0.01 <sup>h</sup>	1.75±0.01 <sup>g</sup>	2.87±0.06 <sup>e</sup>
SG <sub>0</sub> (Control)	0.86±0.01 <sup>b</sup>	2.94±0.04 <sup>b</sup>	2.10±0.01 <sup>c</sup>	4.56±0.09 <sup>a</sup>
SG <sub>1</sub>	0.72±0.01 <sup>c</sup>	2.36±0.04 <sup>d</sup>	2.05±0.01 <sup>d</sup>	3.86±0.13 <sup>b</sup>
SG <sub>3</sub>	0.69±0.01 <sup>d</sup>	2.26±0.02 <sup>e</sup>	1.86±0.01 <sup>e</sup>	3.64±0.03 <sup>bc</sup>
SG <sub>5</sub>	0.66±0.01 <sup>d</sup>	1.94±0.01 <sup>g</sup>	1.54±0.01 <sup>h</sup>	3.18±0.13 <sup>d</sup>

Means within a column with the same superscript were not significantly different at 5% level of significance. LG<sub>0</sub>-Non germinated long grain rice (Control); LG<sub>1</sub>- Long grain rice germinated for 1 day; LG<sub>3</sub>- Long grain rice germinated for 3 days; LG<sub>5</sub>- Long grain rice germinated for 5 days; SG<sub>0</sub>- Non germinated short rice (Control); SG<sub>1</sub>- Short grain rice germinated for 1 day; SG<sub>3</sub>- Short grain rice germinated for 3 days; SG<sub>5</sub>- Short grain rice germinated for 5 days

**Table 4.** Pasting properties of germinated and non-germinated long and short grain rice flour

Germination days	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (min)	Pasting temperature (°C)
LG <sub>0</sub> (Control)	193.39±1.97 <sup>a</sup>	175.82±2.90 <sup>a</sup>	17.17±0.58 <sup>b</sup>	419.47±9.00 <sup>a</sup>	243.42±11.69 <sup>a</sup>	6.29±0.16 <sup>a</sup>	69.58±0.98 <sup>b</sup>
LG <sub>1</sub>	122.00±1.73 <sup>c</sup>	104.50±9.81 <sup>b</sup>	17.50±8.08 <sup>b</sup>	264.36±12.31 <sup>b</sup>	159.83±22.16 <sup>b</sup>	5.99±0.23 <sup>ab</sup>	70.25±0.09 <sup>b</sup>
LG <sub>3</sub>	5.08±0.00 <sup>e</sup>	2.56±0.20 <sup>e</sup>	2.53±0.19 <sup>c</sup>	5.22±0.09 <sup>d</sup>	2.83±0.29 <sup>d</sup>	4.71±0.04 <sup>e</sup>	ND
LG <sub>5</sub>	2.86±0.03 <sup>e</sup>	1.03±0.03 <sup>e</sup>	1.84±0.01 <sup>c</sup>	2.01±0.02 <sup>d</sup>	1.03±0.03 <sup>d</sup>	3.73±0.01 <sup>g</sup>	ND
SG <sub>0</sub> (Control)	128.27±6.15 <sup>b</sup>	87.33±12.41 <sup>c</sup>	40.94±6.25 <sup>a</sup>	261.09±19.63 <sup>b</sup>	173.75±7.21 <sup>b</sup>	5.71±0.16 <sup>bc</sup>	75.77±1.44 <sup>a</sup>
SG <sub>1</sub>	27.39±0.51 <sup>d</sup>	13.23±0.25 <sup>d</sup>	14.43±0.02 <sup>b</sup>	52.91±0.04 <sup>c</sup>	39.95±0.06 <sup>c</sup>	5.37±0.12 <sup>cd</sup>	75.82±0.03 <sup>a</sup>
SG <sub>3</sub>	27.08±0.86 <sup>d</sup>	12.02±0.53 <sup>d</sup>	15.31±0.33 <sup>b</sup>	48.97±2.51 <sup>c</sup>	36.94±1.97 <sup>c</sup>	5.07±0.12 <sup>de</sup>	74.47±0.38 <sup>a</sup>
SG <sub>5</sub>	24.27±0.25 <sup>d</sup>	2.43±0.27 <sup>e</sup>	21.51±0.06 <sup>b</sup>	6.00±0.14 <sup>d</sup>	3.77±0.03 <sup>d</sup>	4.09±0.16 <sup>f</sup>	ND

Means within a column with the same superscript were not significantly different at 5% level of significance. ND- Not detected. LG<sub>0</sub>-Non germinated long grain rice (Control); LG<sub>1</sub>- Long grain rice germinated for 1 day; LG<sub>3</sub>- Long grain rice germinated for 3 days; LG<sub>5</sub>- Long grain rice germinated for 5 days; SG<sub>0</sub>-Non germinated short rice (Control); SG<sub>1</sub>- Short grain rice germinated for 1 day; SG<sub>3</sub>- Short grain rice germinated for 3 days; SG<sub>5</sub>- Short grain rice germinated for 5 days

Germination process also had significant ( $p \leq 0.05$ ) effect on trough, breakdown, final and setback viscosity values of the samples. Values obtained for these parameters ranged from 1.03 to 175.82 RVU; 1.84 to 17.17 RVU; 2.01 to 419.47 RVU and 1.03 to 243.42 RVU, respectively in the long rice variety while the short variety ranged from 2.43 to 87.33 RVU; 21.51 to 40.94 RVU; 6.00 to 261.09 RVU and 3.77 to 173.75 RVU, respectively. Non-germinated rice flour from two rice types had a significantly ( $p \leq 0.05$ ) higher trough than samples subjected to germination. Similarly, samples produced from germinated rice all had significantly ( $p \leq 0.05$ ) lower breakdown viscosity than their respective controls. The breakdown viscosity is related to the stiffness of swollen granules whilst the amylopectin is responsible for susceptibility of swollen granules to disintegration when the gelatinized starch slurry is heated and stirred (Reka and Andras, 2008). The heating of the slurry not only causes starch gelatinization but it also activates the enzymes produced in germinated grains to hydrolyze the starch. As a result of this, the viscosity of the slurry decreases significantly.

The final viscosity of non-germinated long grain rice (419.47 RVU) was significantly higher than short grain rice (261.09 RVU). The setback viscosity was significantly lower in germinated rice types compared to control samples. Similarly, germination of rice grains over time was observed to decrease the final viscosity values of the resultant flour samples. The final and setback viscosities are indicative of the retrogradation tendency that relates to the structure of amylase and amylopectin. Generally, the low setback viscosities recorded in raw and germinated rice samples suggest their insusceptibility to retrogradation, hence they would be useful ingredient in retarding staling of bakery products especially bread (Watanabe et al., 2004). Similar changes in pasting profile by germination have been documented (Mohan et al., 2010; Watcharaparpaiaboon et al., 2010). Lower

peak time was recorded for germinated rice flours compared to non-germinated samples. Generally, germination time significantly decreased pasting viscosity of long and short rice flours though pasting temperature of germinated rice types and their respective controls were unaffected by germination. The effect of germination on viscosity of rice flours could adversely affect quality of baked products. Substitution of wheat flour with up to 30% germinated brown rice flour is feasible in bread production though the loaf volume and texture were compromised (Charoenthakij et al., 2010). Hence, the use of germinated brown rice flour in food formulations should be optimised to ensure products with desirable qualities and sensorial acceptability.

## Conclusions

The study indicated that germination has got tremendous effects on nutritional, functional and pasting properties of long and short rice types. Germinated samples performed better in terms of nutrient density. Similarly, there were indications of improved functionality. The pasting viscosity of germinated rice types were lower than respective controls which may affect the quality and sensorial acceptability of intended food products.

**Author Contributions:** This work was carried out in collaboration between both authors. Author FM designed the study, wrote the protocol and interpreted the data. Author DO anchored the field study, gathered the initial data and performed preliminary data analysis. Both authors conducted the literature search, produced the initial draft and read and approved the final manuscript.

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