Vol 6 No 2 June 2025 Pages 44-52 e-ISSN 2708-5694

Journal of Agriculture, Food and Environment (JAFE)

Journal Homepage: https://journal.safebd.org/index.php/jafe

https://doi.org/10.47440/jafe.2025.6206

Research Article

OPEN ACCESS

Evaluation of brown rice's nutritional, functional and pasting qualities in relation to variety and germination time

Omohimi CI[1*], Adegoke AF[1], Olowu AR[1], Onabegun RT[1], Ayeni M[1], Morenikeji OE[1], Oke KE[2], Adebayo AO[1], Sanni, LO[1,3]

[1]Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria
[2]Department of Food Science and Technology, University of Medical Sciences, Ondo, Ondo State, Nigeria
[3]International Institute of Tropical Agriculture, Ibadan, Nigeria

Article History

Received: 08 April 2025

Accepted: 25 June 2025

Published: 30 June 2025

***Corresponding Author**

Omohimi CI (E-mail: omohimici@funaab.edu.ng)

Keywords

Brown rice; Germination; Proximate composition; Minerals; B Vitamins; Techno-functional properties

How to cite: Omohimi CI, Adekola AF, Olowu AR, Onabegun RT, Ayeni M, Morenikeji OE, Oke KE, Adebayo AO, Sanni, LO 2025: Evaluation of brown rice's nutritional, functional and pasting qualities in relation to variety and germination time. J. Agric. Food Environ. 6(2): 44-52.

ABSTRACT

This investigation evaluated how nutritional composition and techno-functional qualities of three brown rice varieties were affected by varying time of germination and variety. FARO 44, *Ofada* and Igbemo rice varieties were germinated at room temperature between 12 and 72 hours. Changes in proximate, minerals and B vitamins composition, functional and pasting characteristics of the germinated rice samples were examined. Pronounced change in proximate composition of the GBR samples occurred between 36 h and 48 h, except for carbohydrate. Germination positively enhanced all the minerals analysed, with peak values (P - 361.67 mg/100g; K - 403.41 mg/100g; Na - 444.09 mg/100g; Ca - 410.19 mg/100g; Mg - 452.08 mg/100g; Mn - 0.26 V; Cu - 0.11 V; Fe - 2.67 mg/100g; Zn - 0.33 mg/100g) noted between 60 h and 72 h. FARO 44 however gave the highest values. Highest increase in Vit B1 was observed at 48 h in *Ofada* (0.23 mg/100g) but between 60 h and 72 h for B2 (0.80 mg/100g) and B3 (0.27 mg/100g) in Igbemo variety. A decrease in all the viscosity parameters was observed in FARO 44 with longer time in germination, while *Ofada* rice substantially ($p<0.05$) rose at 48 h. Peak increase in bulk density (0.77-0.99), foaming capacity (1.41-3.31%), oil (68.67-94.31%) and water (85.0-179.33%) absorption capacities occurred at 36 h for both FARO 44 and Igbemo varieties while that of *Ofada* occurred between 48 h and 60 h of germination. Prolonged germination time enhanced the nutritional composition of the GBR samples.

© 2025 The Authors. Published by Society of Agriculture, Food and Environment (SAFE). This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0)

INTRODUCTION

In many regions of the world, rice, which is botanically called *Oryza sativa*, is well-known and consumed as a staple by about two-thirds of the global populace (Ukpong *et al.*, 2021b). According to Ravichanthiran *et al.* (2018), based on worldwide consumption data of rice, it was reported to be second to wheat among all other cereal crops. Brown rice, also referred to as paddy rice, which has the bran and germs intact is considered more nutritious than polished rice because of considerable quantities of essential nutrients like vitamins, fibres, minerals and phytochemicals which are located in the parts of the grain (Gujral *et al.*, 2012). Brown rice has double the protein level of white rice, and has been found to be an important source of nutrients such as manganese, magnesium and selenium. Despite the nutritional composition of brown or un-milled rice, factors such as grains' susceptibility to both oxidative and hydrolytic rancidity, dark colour, hard texture, longer cooking duration, end products' undesirable organoleptic characteristics such as off-flavour, nutty flavour and poor taste have been highlighted as major reasons hampering its general use (Chung *et al.*, 2016; Parnsakhorn and Langkapin, 2018). Based on Wu *et al.* (2013), Moongngarm *et al.* (2014) and Ukpong *et al.* (2021b) reports, modification through germination is one of the ways to overcome the undesirable characteristics and enhance brown rice's nutritional qualities.

A biological process termed "germination" is known to improves nutritional and functional qualities by breaking down complex compounds into simpler bioavailable form. Enzymes like protease and amylase play vital roles in this process leading to increased nutrient availability and bioactive compounds (Nascimento *et al*., 2022).

Due to its high amount of carbohydrate, rice is a major staple consumed in Nigeria (Mohammed *et al*., 2019). Abakaliki, *Kwandala*, Jamila, *Ofada*, and Igbemo are among the known rice varieties in Nigeria. *Ofada* acts as a general descriptor for all rice varieties grown in the rice-producing zones of Ogun State and the nearby regions in South-western Nigeria and it's recognized for its unique taste and fragrance (Adekoyeni *et al*., 2018). *Igbemo* rice derived its name from Igbemo town in Ekiti State where it is largely cultivated (Nwosu and Daramola, 2017). Its consumption is predominantly during special celebrations. International Institute of Tropical Agriculture (IITA) and National Cereal Research Institute developed Federal Agriculture Research Oryza (FARO 44) rice; a cross between native African and Taiwanese rice. It is an improved semi-dwarf cultivar of rice that is highly nutritious, contains more fibre, antioxidants and protein than most popular grains (Bristone *et al*., 2024).

There are documented research works on how germination conditions affected nutritional composition, behaviour, physicochemical properties, and bioactive elements of brown rice cultivars such as NERICA 8, FARO 57, MTU 1010, KNM 118 (Ukpong *et al*., 2023; Mohmmed *et al*., 2021). Thus, this research described how variety and germination time affected the nutritional, pasting and functional qualities of FARO 44, *Ofada* and Igbemo rice cultivars.

MATERIALS AND METHODS

Materials

Rice types utilised for this research were *Ofada*, Igbemo and Faro 44, and they were sourced from Odeda, Abeokuta, Ogun state, Igbemo, Ekiti State and IITA Ibadan, respectively.

Methods

Brown rice germination

The procedure outlined by Mohmmed *et al*. (2021) was adopted. Each rice variety was soaked separately for 12 h at 28±2ºC after being sorted to get rid of dirt and other debris, to prevent fermentation, the water was replaced every three hours. Germination of the moist grains was done at 28±2ºC for 72 h and terminated at 12 h interval. Germinated samples were oven dried at 50ºC until average moisture content of 13% was achieved. Flour was obtained by milling and sieving dried germinated grains through a 250 μm mesh sized screen.

Chemical composition of germinated brown rice flour

AOAC (2006) method was used to determine proximate parameters except carbohydrate, which was quantified by difference calculation. A protocol outlined by Omar *et al*. (2016) was employed to remove starch along with sugar from the germinated rice flour sample with the use of hot ethanol. Phenol-sulfuric acid was used as colour developing reagent for the calorimetric quantification of sugar and starch from the supernatant and digest, respectively.

Absorbance was read at 490 nm in wavelength.

$$\%\ \text{Sugar} = \frac{\text{Absorbance} - \text{I}(0.0044)}{\text{sample wt x } 0.55}$$

$$\%\ \text{Starch} = \frac{(\text{Absorbance} - 0.0044)4}{\text{sample wt x } 0.55}$$

Mineral composition

AOAC (2015) protocol was used to determine the flour samples' mineral composition. Five milliliters of 6N HCl were added to two grams (2 g) of each sample, which had been ashed at 550°C for 6 h in a muffle furnace. Sample mixture was then put into a steam batch for evaporative drying. After collection of the filtrate with No 1 Whatman filter paper, it was put in a volumetric flask (100 ml) followed by mixture with distilled water to complete the volume. Atomic absorption spectrophotometer was then used to read the filtrate solution.

B vitamins determination

Thiamine (vit B_1) and riboflavin (vit B_2) determination followed AOAC (2005) procedure while Vitamin B_3 (niacin) was quantified using Adeyeye *et al.* (2020) method.

Functional characteristics of flour from germinated brown rice

Determination of bulk density

The method described by Wang and Kinsella (1976) but cited by Moongngarm *et al*. (2013) was used to calculate bulk density. Gentle and continuous tapping of 25 ml graduated cylinder with 10 g flour sample was done on a benchtop within height 5 to 8 cm for 10 times. A final volume (g/ml) measurement of test flour sample was done.

Determination of flour's capacity for water and oil absorption

As Elkhalifa *et al*. (2004) explained, the capacity to take up water as well as oil was assessed. Centrifuge tubes were filled with two grams flour sample with distilled water (20 ml) introduced to make a mixture. For one minute, the mixtures in the tubes were vortexed, centrifuged for 25 minutes at 4000 rpm after being left to stand at 25 °C for approximately 30 minutes.

After the tubes have been inverted over absorbent paper to remove any excess water, samples were left to drain. Twenty milliliters of refined sunflower oil were substituted for water to aid in oil absorption. The weight difference between the water and bound oil samples was computed.

Least gelation determination

To flour samples in test tubes, 5 ml distilled water was added to get suspensions of up to 20% (w/v) at 2% interval, thereafter heated in water bath for an hour and cooled under running water. The concentration that prevented falling or slipping out of the material from the inverted tubes was identified as the least gelation concentration (Sathe *et al*., 1981).

Capacity for foaming determination

Narayana and Narsinga (1982) procedure was used to evaluate the samples' capacity to foam. About 2 g flour and 100 ml distilled water were mixed at 27°C in a blender for 6 min. Foam volume was measured after prompt transfer of the mixture into 250 millilitre measuring cylinder. Percentage volume rise was used to express flour samples' capacity to foam.

Pasting properties of germinated brown rice flour

The pasting parameters of the material were ascertained using a Rapid Visco Analyser (RVA TECMASTER, perten instrument-2122833, Australia). Briefly, a dried, empty canister was filled with 3 g of sample, and then the jar containing the sample was filled with 25 millilitres of distilled water. The canister was attached to the analyzer after thorough mixing of the content to prevent lump formation. The experiment proceeded instantly by automatically drawing the paste characteristic curve.

Data analysis

Each analysis was conducted in duplicate, and version 25.0 of the statistical program for social science was used to do a one-way analysis on the collected data. At $p \leq 0.05$ level of significance, Duncan's Multiple Range Test was used to compare and differentiate means.

RESULTS AND DISCUSSION

Proximate composition of germinated *brown rice*

Table 1 presents the proximate makeup of samples that was not germinated and the germinated ones. Before germination, the rice samples' initial moisture content varied between 13.33% and 15.33%; Igbemo rice had the highest while *Ofada* rice had the lowest values, respectively. As the germination period rose, a notable decline was noted, with Igbemo rice having the most decrease. Reduction in moisture is expected due to drying process immediately after germination. Because of the low moisture content found in this investigation, the samples may be kept for extended storage duration (Ojediran *et al*., 2020).

Table 1: Proximate composition of germinated brown rice as affected by variety and germination time

Germination Time	Variety	Moisture content (%)	Total ash (%)	Crude fat (%)	Crude fibre (%)	Crude protein (%)	Total carbohydrate (%)	Total sugar (%)	Total starch
Ungerminated	Faro	13.5 ± 0.00^{ae}	2.50 ± 0.01^{a}	1.00 ± 0.00^{ab}	2.50 ± 0.0^{ad}	9.76 ± 0.04^{be}	70.73 ± 0.06^{ab}	36.16 ± 0.47^{bc}	51.11 ± 3.38^{be}
	Ofada	13.33 ± 1.15^{ae}	2.47 ± 0.23^{ab}	1.90 ± 0.17^{a}	1.84 ± 0.01^{bd}	8.58 ± 0.04^{ce}	71.88 ± 1.24^{ab}	38.32 ± 1.18^{bc}	50.65 ± 0.7^{be}
	Igbemo	15.33 ± 1.15^{ae}	1.60 ± 0.40^{ab}	2.33 ± 0.58^{ac}	1.97 ± 0.01^{d}	8.27 ± 0.05^{ae}	70.49 ± 1.68^{a}	34.72 ± 0.06^{abc}	77.51 ± 3.87^{ae}
12 Hours	Faro	5.50 ± 0.50^{ab}	2.25 ± 0.01^{ab}	2.67 ± 0.58^{bc}	1.48 ± 0.14^{ab}	8.76 ± 0.04^{bd}	79.35 ± 0.3^{be}	33.76 ± 0.12^{ab}	61.85 ± 0.23^{bd}
	Ofada	4.33 ± 0.58^{ab}	2.37 ± 0.06^{b}	3.00 ± 0.00^{bbc}	1.95 ± 0.01^{b}	9.11 ± 0.04^{cd}	79.24 ± 0.65^{be}	35.06 ± 0.12^{ab}	51.11 ± 1.51^{bd}
	Igbemo	6.33 ± 0.58^{ab}	2.50 ± 0.10^{b}	1.67 ± 0.58^{bc}	1.96 ± 0.02^{b}	8.23 ± 0.04^{ad}	79.31 ± 0.14^{ae}	31.76 ± 0.21^{a}	57.65 ± 0.95^{ad}
24 Hours	Faro	5.00 ± 0.00^{ad}	2.10 ± 0.01^{a}	3.00 ± 0.00^{bcd}	1.37 ± 0.03^{a}	8.19 ± 0.04^{bc}	80.35 ± 0.03^{b}	34.72 ± 0.06^{b}	47.71 ± 4.3^{ab}
	Ofada	9.33 ± 0.58^{ad}	2.20 ± 0.20^{ab}	1.90 ± 0.17^{bcd}	1.9 ± 0.01^{ab}	8.89 ± 0.04^{c}	75.78 ± 0.4^{b}	36.12 ± 3.11^{b}	46.09 ± 3.56^{ab}
	Igbemo	13.67 ± 1.53^{ad}	2.13 ± 0.12^{ab}	3.67 ± 0.58^{cd}	1.82 ± 0.01^{a}	7.66 ± 0.05^{ac}	71.05 ± 1.4^{ab}	34.72 ± 0.06^{ab}	48.31 ± 5.49^{a}
36 Hours	Faro	5.50 ± 0.50^{a}	2.59 ± 0.01^{ac}	3.00 ± 0.00^{b}	1.48 ± 0.14^{ab}	10.11 ± 0.04^{bf}	77.31 ± 0.61^{bf}	36.82 ± 1.62^{b}	55.11 ± 2.48^{bc}
	Ofada	4.67 ± 0.58^{a}	2.20 ± 0.20^{bc}	1.87 ± 0.23^{bb}	1.90 ± 0.01^{b}	8.86 ± 0.03^{cf}	80.48 ± 0.6^{bf}	33.96 ± 0.25^{b}	54.11 ± 1.63^{bc}
	Igbemo	4.33 ± 0.58^{a}	2.67 ± 0.23^{bc}	1.67 ± 0.58^{bc}	2.01 ± 0.01^{b}	8.45 ± 0.04^{af}	80.88 ± 0.28^{af}	34.96 ± 0.25^{ab}	49.18 ± 4.52^{ac}
48 Hours	Faro	7.17 ± 0.76^{ac}	1.62 ± 0.01^{a}	3.00 ± 0.00^{bd}	1.93 ± 0.15^{ac}	6.3 ± 0.04^{ab}	79.98 ± 0.95^{bde}	34.89 ± 2.54^{ab}	49.45 ± 1.29^{ab}
	Ofada	8.33 ± 0.58^{ac}	2.30 ± 0.17^{ab}	2.00 ± 0.00^{bd}	1.88 ± 0.01^{bc}	8.83 ± 0.09^{ac}	76.68 ± 0.75^{bde}	33.99 ± 3^{ab}	48.51 ± 2.23^{ab}
	Igbemo	3.67 ± 0.58^{ac}	2.43 ± 0.06^{ab}	4.67 ± 0.58^{cd}	1.89 ± 0.01^{c}	7.97 ± 0.05^{a}	$79.37\pm0.5a^{de}$	29.96 ± 0.25^{a}	45.18 ± 2.43^{a}
60 Hours	Faro	8.17 ± 0.29^{ac}	1.68 ± 0.01^{ab}	2.67 ± 0.58^{bd}	2.23 ± 0.06^{ad}	6.57 ± 0.04^{b}	78.68 ± 0.75^{bc}	36.96 ± 3.05^{bc}	55.85 ± 0.23^{bc}
	Ofada	5.33 ± 0.58^{ac}	2.37 ± 0.06^{ab}	1.50 ± 0.50^{bd}	1.98 ± 0.01^{bd}	9.11 ± 0.23^{bc}	79.58 ± 0.32^{bc}	36.79 ± 3.15^{bc}	44.58 ± 2.78^{bc}
	Igbemo	6.33 ± 1.15^{ac}	2.73 ± 0.12^{ab}	5.33 ± 0.58^{cd}	2.00 ± 0.01^{d}	8.41 ± 0.05^{ab}	75.2 ± 1.69^{ac}	34.06 ± 0.12^{abc}	56.05 ± 3.7^{abc}
72 Hours	Faro	5.83 ± 0.58^{abc}	2.42 ± 0.01^{ac}	3.20 ± 0.35^{bc}	1.57 ± 0.15^{ab}	9.46 ± 0.04^{be}	77.52 ± 0.68^{bcd}	37.76 ± 0.68^{bc}	46.58 ± 2.43^{ab}
	Ofada	7.67 ± 0.58^{abc}	2.33 ± 0.12^{bc}	1.50 ± 0.50^{bbc}	1.79 ± 0.01^{b}	8.36 ± 0.04^{ce}	78.41 ± 0.2^{bcd}	39.96 ± 0.06^{bc}	47.51 ± 0.23^{ab}
	Igbemo	4.33 ± 0.58^{abc}	2.50 ± 0.10^{bc}	2.67 ± 0.58^{bc}	2.13 ± 0.01^{b}	8.98 ± 0.05^{ae}	79.39 ± 0.9^{acd}	33.36 ± 1.53^{ac}	54.45 ± 3.93^{ab}

Values are means of duplicate determination ± standard deviation.
At the 5% level, mean values in the same column with different superscripts differ statistically.

Prior to germination, total ash content of the three rice varieties were 2.50%, 1.60% and 2.47% for Faro, Igbemo and *Ofada* rice, respectively. This showed that FARO 44 is richer in ash content that the other brown rice. An increase in ash content in FARO 44 was observed at 36 h while other germination times resulted in decrease. Seemingly, Igbemo rice was observed to have an increase and the greatest value obtained at 60 h (2.73%). Contrastingly, there was a decline in *Ofada* sample during different times germination was carried out. *Ofada* rice's decreasing ash content is consistent with Bulatao and Romero (2014) and Singh *et al*. (2017) findings. However, the values found in this study for both germinated and ungerminated rice cultivars are higher than those Mohmmed *et al*. (2021) reported for MTU 1010 and KNM 118 brown rice varieties, before and after germination.

Prior to germination, levels of crude fat for Faro, *Ofada*, and Igbemo samples were 1.00%, 1.90%, and 2.33%, respectively. Increase in crude fat content was observed but at different germination time. *Ofada* rice had an increase at 24 h, after which a progressive decrease was observed. However, over 200% and 120% increase was observed in FARO 44 and Igbemo samples at 72 h and 60 h, respectively. Observed decrease in *Ofada* is similar to the report of Bulatao and Romero (2014) and Singh *et al*. (2017) and may be connected to the utilisation of fat as a source of energy for protein synthesis and embryonic growth (Tortayeva *et al*. 2014). On the other hand, increase activities of lipolytic enzymes that is responsible for breaking down lipid components into fatty acids and glycerol may be responsible for the rise in fat content of FARO 44 and Igbemo (Chinma *et al*., 2009).

The un-germinated brown rice crude fibre concentration ranged from 1.84% to 2.50%, with FARO 44 having the highest while *Ofada* rice had the lowest value. As the germination time progressed, the amount of crude fibre in FARO 44 considerably reduced from 2.50% to 1.37% (24 h); although, between 12 and 72 h germination time, it was highest (2.23%) at 60 h. However, a progressive increase was observed in *Ofada* from 12 to 60 h, highest increase (1.98%) was observed at 60 h, after which a decrease beyond the value for ungerminated sample occurred. For Igbemo rice, crude fibre was at peak (2.13%) at 72 h. These results show that increased crude fibre content in the rice varieties was favoured between 60 and 72 h. Mohmmed *et al*. (2021) documented elevated values (1.07 – 2.00%) at early stage of germination (24 h). However, Ukpong et al. (2022) noted that the higher fibre content of germinated rice may be related to new cell walls formation.

Of all the brown rice varieties used in this study, FARO 44 had the highest (9.76%) protein content, while the lowest value (8.27%) was observed in Igbemo prior germination. Protein content was significantly impacted by cultivar and germination time. A decrease was observed in FARO 44 at the different times of germination except at 36 h, when about 3.6% increase was observed. For *Ofada*, a significant increase was observed from 12 to 60 h, after which a decrease occurred at 72 h. Contrarily for Igbemo, a decrease was noted up until 72 h, when 8.60% increase was observed. This result revealed that the rice varieties behaved differently under same germination condition, which was comparable with Mohmmed *et al*. (2021) report. Megat Rusydi *et al*. (2011) as well as Moongngarm and Saetung (2010) also observed significant effects. Germination, being a biochemical process, has the ability to modify both protein and amino acid profile of rice under any germination condition and the modification could be due to the molecular weights of the protein or the nitrogenous hydrolysis action of enzyme protease (Wunthunyarat *et al*., 2020)

Carbohydrate contents for the un-germinated brown rice were 70.73%, 71.88% and 70.49% for FARO 44, *Ofada* and *Igbemo*, respectively. An increase was observed in FARO 44 at different hours of germination, however, 24 h germinated sample gave the highest percentage increase (80.35%). Similarly, for *Ofada* and Igbemo, an increase occurred at all hours of germination, 36 h germination time gave the highest percentage increase (80.48% and 80.88%, respectively). The increase achieved in this study is comparable to Singh *et al*. (2017) along with Mohmmed *et al*. (2021) findings.

The main reserve ingredient in cereal grains such as rice is starch. A complex metabolic process such as germination has been identified as one of the methods for its modification (Oliveira *et al*., 2022).

Total starch content of the rice cultivars before germination were 51.11%, 50.65% and 77.51% for FARO 44, *Ofada* and Igbemo, respectively. After germination, a significant increase was observed for FARO 44 and *Ofada* cultivars, with peak values at 12 h (61.85%) and 36 h (54.11%), respectively. Contrarily, notable decline was noted in Igbemo all through the germination period. This could be due to prolong germination time which could have enhanced higher percentage of reduction in starch (Świeca and Gawlik-Dziki, 2015). However, factors such as enzyme activity, grain humidity and temperature might have contributed to the germination time thereby causing the starch concentration to decrease.

The level of total sugar for ungerminated rice cultivars ranged between 34.72% (Igbemo) and 38.32% (*Ofada*); the ungerminated rice cultivars had varying levels of total sugar. FARO 44 sugar content increased from 36 h to the end of the germination phase; high value was obtained at 72 h (39.96%). However, at 72 and 36 hours, a 4.3% and 0.7% rise was noted for *Ofada* and Igbemo, respectively. Xu *et al*. (2012) established that germination has a beneficial effect on reducing the amount of sugar in brown rice. Hydrolysis of starch into free sugars may have contributed to the rise in the total sugar content (Muñoz Llandes *et al*., 2023).

Composition of minerals and vitamins of germinated brown rice

Table 2 displays how the mineral content of germinated rice samples was influenced by variety and germination time. The three brown rice types' mineral content was considerably ($p < 0.05$) affected by germination. Prior germination, *Ofada* rice was observed with the highest content of macro minerals (mg/100g) such as P (318.33), Mg (397.92), K (345.89), Na (380.77), Ca (351.71) and also Cu (0.04), a micro mineral, while the highest levels of Mn (0.27 mg/100g), Fe (2.75 mg/100g) and Zn (0.34 mg/100g) was recorded in Igbemo rice. However, after germination, FARO 44 rice gave all the peak values and this occurred between 60 and 72 h while slight increase observed in Igbemo and *Ofada* for some of the minerals occurred between 48 h and 72 h. For germinated brown rice and quinoa, Chima and Fasuan (2021) and Maldonado-Alvarado *et al*. (2023) noted similar pattern. One possible explanation for the observed rise in mineral levels in germinated samples compared to non-germinated ones is that minerals become more accessible as anti-nutrients decrease (Chima and Fasuan, 2021). Minerals and vitamins have been classified as micronutrients that are required for the body to function properly because they help to reduce risk of diseases and ensure maintenance of good health (Awuchi *et al*., 2020). Calcium helps to keep bones and teeth healthy, as well as to regulate blood pressure. It is also important for blood coagulation and for regulating blood's acid-base balance to keep it from becoming acidic. Iron is essential in carrying oxygen throughout the body and preventing anemia while potassium is required for the regulation of the body's water content, blood pressure, heartbeat and excitability of the neuromuscular (Chima and Fasuan, 2021).

Vitamins B_1, B_2 and B_3 contents (mg/100g) in ungerminated rice samples were 0.18 – 0.23, 0.53 – 074 and 0.03 – 0.1, respectively (Table 3); highest amounts were observed in Igbemo. However, after germination, the values (mg/100g) were from 0.16 – 0.23, 0.45 – 0.8 and 0.03 – 0.24, respectively. Germination caused a significant rise in B_2 (0.80) and B_3 (0.27) between 60 h and 72 h, and this occurred in Igbemo rice. An observed rise in vitamin B_1 was also observed in *Ofada* and FARO 44 rice samples between 48 h and 72 h. According to Kim *et al*. (2012) and Zilic *et al*. (2015), sprouts developed during germination process have the ability to synthesize more vitamins, hence giving a significant rise in B vitamins. Consistent with this work is the submission of Watanabe *et al*. (2004) with Moongngarm and Saetung (2010) that vitamins are synthesised during the latter period of germination process.

Table 2: Mineral composition (mg/kg) of brown rice that has germinated as influenced by variety and germination time

Germination Time	Variety	Phosphorus	Manganese	Copper	Potassium	Sodium	Iron	Calcium	Zinc	Magnesium
Ungerminated	Ofada	318.33±2.89^{b}	0.11±0.00ae	0.04±0.00ac	345.89±55.39ab	380.77±60.97ab	1.11±0.01be	351.71±56.32ab	0.14±0.00ae	397.92±3.61b
	Faro	270.00±0.00^{bc}	0.17±0.00be	0.01±0.00ab	321.3±0.00ac	353.7±0.00ac	1.72±0.01ae	326.7±0.00ac	0.21±0.00be	337.5±0.00bc
	Igbemo	216.67±10.41^{ab}	0.27±0.00ce	0.02±0.00a	257.83±12.39a	283.83±13.63a	2.75±0.01ce	262.17±12.59a	0.34±0.00ce	270.83±13.01ab
12 Hours	Ofada	311.67±7.64^{bc}	0.16±0.00ab	0.1±0.00ce	374.85±5.95bc	412.65±6.55bc	1.67±0.01b	381.15±6.05bc	0.2±0.00ab	389.58±9.55bc
	Faro	321.67±2.89^{c}	0.11±0.00b	0.03±0.00be	400.63±29.35c	441.03±32.31c	1.14±0.01ab	407.37±29.84c	0.14±0.00b	402.08±3.61c
	Igbemo	290±13.23^{ac}	0.12±0.00bc	0.09±0.00ae	335.98±2.99ac	369.86±3.3ac	1.2±0.01bc	341.62±3.05ac	0.15±0.00bc	362.5±16.54ac
24 Hours	Ofada	231.67±10.41b	0.11±0.00a	0.1±0.00c	281.24±3.83ab	309.6±4.21ab	1.09±0.01ab	285.96±3.89ab	0.13±0.00a	289.58±13.01b
	Faro	311.67±7.64bc	0.15±0.00ab	0.01±0.00bc	364.54±3.83ac	401.3±4.21ac	1.57±0.01a	370.66±3.89ac	0.19±0.00ab	389.58±9.55bc
	Igbemo	266.67±2.89ab	0.12±0.00ac	0.04±0.00ac	317.33±3.44a	349.33±3.78a	1.2±0.01ac	322.67±3.49a	0.15±0.00ac	333.33±3.61ab
36 Hours	Ofada	281.67±10.41b	0.16±0.00ad	0.02±0.00cd	335.18±12.39ab	368.98±13.63ab	1.63±0.01bd	340.82±12.59ab	0.2±0.00ad	352.08±13.01b
	Faro	290±13.23bc	0.12±0.00bd	0.1±0.00bd	335.98±2.99ac	369.86±3.3ac	1.25±0.01ad	341.62±3.05ac	0.15±0.00bd	362.5±16.54bc
	Igbemo	223.33±10.41ab	0.15±0.00cd	0.04±0.00ad	265.77±12.39a	292.57±13.63a	1.56±0.01cd	270.23±12.59a	0.19±0.00cd	279.17±13.01ab
48 Hours	Ofada	256.67±2.89ab	0.11±0.00ac	0.1±0.00cg	293.93±21.85ab	323.57±24.05ab	1.08±0.01bc	298.87±22.21ab	0.13±0.00ac	320.83±3.61ab
	Faro	270±15.00ac	0.19±0.00bc	0.09±0.00bg	324.87±12.87ac	357.63±14.17ac	2±0.01ac	330.33±13.09ac	0.24±0.00bc	337.5±18.75ac
	Igbemo	236.67±17.56a	0.11±0.00c	0.11±0.00ag	287.19±29.88a	316.15±32.89a	1.17±0.01c	292.01±30.38a	0.14±0.00c	295.83±21.95a
60 Hours	Ofada	265±8.66bc	0.26±0.00sf	0.11±0.00cf	320.11±2.06b	352.39±2.27b	2.63±0.02bf	325.49±2.1b	0.32±0.00af	331.25±10.83bc
	Faro	361.67±7.64c	0.2±0.00bf	0.1±0.00bf	403.41±53.92bc	444.09±59.36bc	2.04±0.01af	410.19±54.83bc	0.25±0.00bf	452.08±9.55c
	Igbemo	273.33±5.77ac	0.25±0.00cf	0.01±0.00af	321.7±0.69ab	354.14±0.76ab	2.53±0.00cf	327.1±0.70ab	0.31±0.00cf	341.67±7.22ac
72 Hours	Ofada	270±0.00ab	0.26±0.00ag	0.1±0.00bc	321.3±0.00ab	353.7±0.00ab	2.67±0.01bg	326.7±0.00ab	0.33±0.00ag	337.5±0.00ab
	Faro	250±8.66abc	0.25±0.00bg	0.01±0.00b	293.53±3.44ac	323.13±3.78ac	2.53±0.01ag	298.47±3.49ac	0.31±0.00bg	312.5±10.83ac
	Igbemo	270±15.0ab	0.25±0.00cg	0.02±0.00ab	335.98±28.57a	369.86±31.45a	2.61±0.01cg	341.62±29.05a	0.32±0.00cg	337.5±18.75a

Values are the duplicate determination means ± standard deviation.
Mean values with different superscripts within the same column are significantly different at 5% level.

Table 3: B vitamins composition (mg/100g) of germinated brown rice as affected by variety and germination time

Germination Time	Variety	B1	B2	B3
Ungerminated	Ofada	0.18±0.00ab	0.53±0.05ab	0.03±0.00a
	Faro	0.18±0.00ab	0.71±0.1b	0.04±0.00ab
	Igbemo	0.23±0.01b	0.74±0.05bc	0.1±0.01ac
12 Hours	Ofada	0.21±0.00ad	0.66±0.00ac	0.14±0.00ad
	Faro	0.20±0.00ad	0.63±0.01bc	0.10±0.01bd
	Igbemo	0.22±0.01bd	0.84±0.05c	0.20±0.01cd
24 Hours	Ofada	0.16±0.01a	0.66±0.00a	0.11±0.01ab
	Faro	0.18±0.00a	0.53±0.01ab	0.09±0.01b
	Igbemo	0.20±0.00ab	0.65±0.03ac	0.06±0.01bc
36 Hours	Ofada	0.21±0.00ad	0.59±0.04ab	0.09±0.00acd
	Faro	0.21±0.00ad	0.61±0.00b	0.14±0.00bcd
	Igbemo	0.22±0.00bd	0.73±0.01bc	0.19±0.00cd
48 Hours	Ofada	0.23±0.00ab	0.77±0.07ac	0.13±0.01ac
	Faro	0.17±0.01ab	0.7±0.06bc	0.17±0.02bc
	Igbemo	0.19±0.00b	0.67±0.09c	0.11±0.00c
60 Hours	Ofada	0.17±0.00a	0.53±0.04a	0.1±0.01ae
	Faro	0.21±0.00a	0.78±0.05ab	0.17±0.02be
	Igbemo	0.17±0.00ab	0.45±0.09ac	0.27±0.01ce
72 Hours	Ofada	0.21±0.00ac	0.56±0.02sb	0.15±0.01af
	Faro	0.23±0.00ac	0.58±0.01b	0.24±0.01bf
	Igbemo	0.18±0.00bc	0.8±0.01bc	0.22±0.00cf

Values are means of duplicate determination ± standard deviation. Mean values with distinct superscripts within the same column differ significantly at 5% level.

Brown rice's functional characteristics after germination

Presented on Table 4 is the rice samples functional properties as influenced by germination temperature. A flour or starch sample's weight is measured to determine its bulk density, which is then utilised to evaluate sample's packaging requirements (Hasmadi *et al*., 2020).

Among the three ungerminated brown rice samples, bulk density values differed from 0.77 to 0.92 g/ml; with FARO 44 and Igbemo samples having the lowest and highest values, respectively. Bulk density increased in rice samples all through the germination time, however, samples germinated at 36 h gave the highest values for FARO 44 (0.94 g/ml) and Igbemo (0.99 g/ml) while sample germinated at 60 h gave the highest increase for *Ofada* (0.94 g/ml).

However, the result obtained for bulk density from this investigation did not match results from Moongngarm *et al.* (2014) and Mohmmed *et al.* (2022) works, this might be due to different varieties of rice used in these studies. Low bulk density observed in the current research, however, could be advantageous when formulating complementing foods (Oke *et al*., 2020).

The smallest flour quantity required for creating gel in specific volume of water is known as least gelation concentration (LGC) (Ohizua *et al*., 2017). Values for the ungerminated brown rice samples are 6.00%, 10.0% and 12.00% for *Ofada*, FARO 44 and Igbemo, respectively. The observed increase in least gelation during the germination process occurred at 24 h and 48 h for FARO 44 (14.0%) and *Ofada* (10%) rice samples, respectively, while a decrease was observed in Igbemo all through the period of germination. This implies that FARO 44 and *Ofada* will form gel better than Igbemo variety. The amount of flour required to make a gel increases with increasing LGC, and the ability of the flour to gel improves with a lower LGC (Adebowale *et al*., 2005).

Flour's ability to foam is determined by its foaming capacity, which is reliant on the presence of flexible protein molecules that lowers surface tension of water (Ohizua *et al*., 2017).

The foaming capacity of flour is a measure of its ability to foam and is dependent on the availability of flexible protein molecules that reduce the surface tension of water.

Ungerminated Igbemo, *Ofada* and FARO 44 rice had foaming capacities of 1.41%, 1.72% and 2.98%, respectively. Germinated FARO 44 (3.31%) and Igbemo (1.52%) rice samples had highest capacity at 36 h while *Ofada* rice (1.88%) had the highest at 60 h. This is an indication that longer germination time does not favour high foaming in both FARO 44 and Igbemo rice unlike *Ofada* rice. There has been report linking the amount of solubilized protein to foamability. Mohmmed *et al*. (2022) also noted that brown rice capacity to foam increased as germination time increased.

The ungerminated samples' capacity to absorb water varied between 83.67 and 91.67%. Igbemo and *Ofada* rice samples gave the highest and lowest values, respectively. The rice samples' ability for water absorption was improved by germination. The ability of FARO 44, Igbemo and *Ofada* samples to absorb water was at peak when germinated at 12, 36 and 60 h, respectively. The germinated rice samples' increased water absorption ability, as obtained here, may be due to increase in food material's water interaction and holding site as a result of polysaccharide molecule's breakdown. Moongngarm *et al.* (2014) and Mohmmed *et al.* (2022) also reported same observation.

Germination of the rice samples also favoured their ability to absorb oil. The oil absorption ability of germinated FARO 44 rice increased significantly from 79.67% to 94.33% at 36 h. Germinated *Ofada* increased from 87.30% to 158.33% at 12 h, while Igbemo increased from 68.67% to 89.33% at 12 h. Moongngarm *et al.* (2014) and Mohmmed *et al.* (2022) confirmed same rise in OAC as a result of germination.

Table 4: Effect of variety and germination time on functional properties of brown rice

Germination Time	Variety	Bulk density (g/ml)	Least gelation capacity (%)	Foaming capacity (%)	Oil absorption capacity (%)	Water absorption capacity (%)
Ungerminated	Faro	0.77±0.02ᵃ	10.0±0.00ᵃ	2.98±0.01ᶜᵈ	79.67±4.51ᵃᵇ	85.00±2.65ᵃᶜ
	Ofada	0.86±0.01ᵃᵇ	6.0±0.00ᵃᵇ	1.72±0.01ᵇᵈ	87.0±2.65ᵃ	83.67±0.58ᵃ
	Igbemo	0.92±0.02ᵃᶜ	12.0±0.00ᵃᵇ	1.41±0.04ᵃᵈ	68.67±3.79ᵃᵇ	91.67±2.08ᵃᵇ
12 Hours	Faro	0.85±0.05ᵃᵇ	14.0±0.00ᵃᵉ	2.36±0.06ᶜ	78.67±0.58ᵃᵇ	162.33±2.52ᶜᵈ
	Ofada	0.89±0.01ᵇ	8.00±0.00ᵇᵉ	1.79±0.01ᵇᶜ	78.67±0.58ᵇ	86.00±2.65ᵃᵈ
	Igbemo	0.95±0.04ᵇᶜ	10.0±0.00ᵇᵉ	1.46±0.06ᵃᶜ	89.33±2.52ᵃᵇ	95.00±4.0ᵇᵈ
24 Hours	Faro	0.78±0.01ᵃ	8.00±0.00ᵃᶜ	1.23±0.01ᵃᶜ	77.33±1.15ᵃᵉ	123.67±2.08ᵇᶜ
	Ofada	0.89±0.01ᵃᵇ	6.00±0.00ᵇᶜ	1.79±0.01ᵃᵇ	158.33±10.69ᵇᵉ	86.00±1.73ᵃᵇᶜ
	Igbemo	0.85±0.01ᵃᶜ	10.0±0.00ᵇᶜ	1.31±0.02ᵃ	88.00±4.36ᵃᵉ	85.00±1.00ᵇᶜ
36 Hours	Faro	0.94±0.02ᵃᵈ	6.00±0.00ᵃ	3.31±0.06ᶜᵉ	94.33±2.08ᵈ	121.33±1.53ᶜᵉ
	Ofada	0.92±0.01ᵇᵈ	8.00±0.00ᵃᵇ	1.84±0.02ᵇᵉ	106.67±2.52ᵃᵇᵈ	89.33±2.08ᵃᵉ
	Igbemo	0.99±0.01ᶜᵈ	6.00±0.00ᵃᵇ	1.52±0.01ᵃᵉ	86.00±1.73ᵈ	179.33±11.37ᵇᵉ
48 Hours	Faro	0.84±0.01ᵃᵇ	6.00±0.00ᵃᶜ	1.08±0.01ᵃᶜ	83.00±3.0ᵃᵈ	107.67±1.53ᶜᵇ
	Ofada	0.9±0.02ᵇ	10.0±0.00ᵇᶜ	1.8±0.03ᵃᵇ	113.67±1.53ᵃᵇᵈ	87.67±1.53ᵃᵇ
	Igbemo	0.95±0.03ᵇᶜ	8.00±0.00ᵇᶜ	1.46±0.05ᵃ	83.67±1.53ᵈ	94.67±3.21ᵇ
60 Hours	Faro	0.93±0.02ᵃᶜ	12.00±0.00ᵃᵈ	1.67±0.01ᵇᶜ	90.67±4.93ᵃᵈ	108.67±1.53ᵇᶜ
	Ofada	0.94±0.01ᵇᶜ	6.00±0.00ᵇᵈ	1.88±0.02ᵇ	99.33±1.15ᵇᵈ	92.00±1.00ᵃᵇ
	Igbemo	0.92±0.01ᶜ	10.00±0.00ᵇᵈ	1.41±0.01ᵃᵇ	87.00±1.73ᵃᵈ	91.67±0.58ᵇ
72 Hours	Faro	0.83±0.01ᵃᵇ	6.00±0.00ᵃᵇ	2.91±0.06ᶜᵈ	83.67±2.08ᵃᶜ	114.67±2.08ᶜ
	Ofada	0.85±0.01ᵇ	8.0±0.00ᵇ	1.71±0.01ᵇᵈ	93.33±2.31ᵇᶜ	84.33±1.53ᵃᶜ
	Igbemo	0.96±0.01ᵇᶜ	8.0±0.00ᵇ	1.47±0.01ᵃᵈ	85.0±4.36ᵃᶜ	103.67±1.15ᵇᶜ

Values are the duplicate determination means ± standard deviation.
Within a single column, mean values with distinct superscripts differ significantly at the 5% level.

Pasting properties

Table 5 displays the pasting property values for the brown rice cultivars. Peak, trough, breakdown, final, with setback viscosities of the ungerminated samples ranged from 49-274 RVU, 42-205 RVU, 7-72.5 RVU, 79-1089.5 RVU and 37-884.5 RVU, respectively. Lowest values for all the viscosity parameter were observed in *Ofada* rice while Igbemo gave the highest for peak, trough, final and setback viscosities. The ranges for pasting temperatures and peak time were 66.92-95.3℃ and 6.57-7.0 min, respectively with *Ofada* having the lowest values for both parameters and the highest values were observed in Igbemo cultivar.

In FARO 44 however, all of the viscosity parameters measured showed a substantial decrease after germination period, similarly for Igbemo cultivar, except peak viscosity which was found to have 78% increase after 48 hours germination. *Ofada* rice showed a distinct trend: every viscosity metric rose noticeably ($p<0.05$) throughout the germination period, with highest values obtained at 48 h.

Ukpong *et al.* (2021) defined peak viscosity as the highest viscosity attained either immediately after or during the heating of starch-based foods, and also an indication of starch granule swelling before physical breakdown. The increase in peak viscosity of *Ofada* and Igbemo cultivars is similar to the findings of Cornejo and Rosell (2015) but contrary to what was reported by Ukpong *et al.* (2023) and Makinde and Omolori (2020), who reported similar decrease trend observed in FARO 44. The later authors ascribed the decline to the starch content being broken down by enzymes during the germination process. Germinated *Ofada* and Igbemo brown rice may be suitable to make foods with stiff dough due to their high peak viscosity (Dandaba *et al.*, 2012).

Trough viscosity of starch is its stability under heat and its ability to resist break down when cooled (Ukpong *et al.*, 2021). Significant reduction in trough viscosity of FARO 44 and Igbemo implies that germination won't favour the stability of the rice cultivars under heat treatment, unlike *Ofada*. Increased starch modification by amylase enzymes due to prolonged germination might be the reason for the reduction (Chaijan and Panpipat, 2020). Adebowale *et al.* (2005) opined that a flour or starch's resistance to heat and shear stress decreases with increasing breakdown viscosity. It is evident from the current study that extension of germination time to 48 h for *Ofada* and Igbemo cultivars increased the breakdown viscosity, hence they might not be stable when heated. However, Iwe *et al.* (2016) considered high breakdown viscosity as an indicator of palatability. Which means that the two cultivars stand the chance for application in foods requiring palatability.

Indicators of retrogradation tendency which is associated with the structure of amylose and amylopectin include setback and final viscosities (Makinde and Omolori, 2020). Retrogradation and staling rate might be higher in germinated FARO 44 and Igbemo rice cultivars due to reduction in final and setback viscosities throughout the period of germination.

Table 5: Pasting properties of germinated brown rice as affected by variety and germination time

Germination Time	Variety	Peak Viscosity (RVU)	Trough (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (min)	Pasting Temperature (°C)
Ungerminated	Faro	267±8.49b	194.5±7.78be	72.5±0.71a	1039±1.41be	844.5±9.19bg	7.0±0.00a	94.21±2.32c
	Ofada	49±2.83a	42.00±4.24ae	7±1.41.00a	79.0±5.66ae	37.0±1.41ag	6.57±0.52a	66.92±0.70a
	Igbemo	274.5±16.26b	205±14.14ce	69.5±2.12ab	1089.5±19.09ce	884.5±4.95cg	7.0±0.00a	95.3±19.03c
12 Hours	Faro	40.0±0.00a	35.5±0.71b	4.5±0.71a	59.0±1.41bc	23.5±2.12bd	7.0±42.43a	93±2.33c
	Ofada	47.5±0.71a	40±0.00ab	7.5±0.71a	81.0±7.07ac	41.0±7.07ad	6.93±0.0a	65.09±0.23a
	Igbemo	118.5±3.54ab	89±4.24bc	29.5±0.71ab	398.5±19.09c	309.5±14.85cd	6.7±0.42a	93.1±2.69c
24 Hours	Faro	49.0±2.83a	42±4.24bcd	7.0±1.41a	79.0±5.66be	37.0±1.41bf	6.57±0.52a	90.71±0.71c
	Ofada	47.5±0.71a	40.0±0.00acd	7.5±0.71a	89.0±1.41ae	48±1.41af	6.87±0.09a	65.37±3.54a
	Igbemo	193.5±2.12ab	145.5±0.71cd	48±1.41ab	731.0±1.41ce	585.5±0.71cf	7.0±0.00a	86.6±5.40bc
36 Hours	Faro	48.5±2.12a	41.0±2.83b	7.5±0.71a	79.0±0.00b	38.0±2.83b	6.9±0.04a	86.3±1.35bc
	Ofada	45.5±0.71a	40.0±0.00ab	5.5±0.71a	88±1.41ab	48.0±1.41ab	6.93±0.00a	64.7±3.13a
	Igbemo	90±1.41ab	75.5±0.71bc	14.5±2.12ab	177.5±0.71bc	102±1.41bc	6.87±0.19a	79.7±0.00b
48 Hours	Faro	57.5±2.12ab	49±0.00bc	8.5±2.12ab	94.0±0.00bc	45.0±0.0bc	6.1±0.81a	74.19±4.17b
	Ofada	88±1.41ab	74±0.00ac	13.5±0.71ab	183.5±3.54ac	109.5±3.54ac	6.84±0.23a	76.81±3.74b
	Igbemo	488±268.7b	95.5±4.95c	392.5±263.75b	292±2.83c	196.5±2.12c	3.8±3.39a	73.93±29.8b
60 Hours	Faro	83.5±0.71a	66±0.00bd	17.5±0.71a	146.5±4.95bd	80.5±4.95be	7.0±0.00a	71.23±2.99b
	Ofada	51±0.00a	44±1.41ad	7.0±1.41a	96.0±2.83ad	52.0±1.41ae	6.9±0.14a	68.01±3.05a
	Igbemo	158.5±2.12ab	125±4.24cd	33.5±2.12ab	537.5±2.12xd	412.5±2.12ce	7.0±0.00a	71.25±2.89b
72 Hours	Faro	55.5±4.95a	46.5±4.95ab	9±0.00a	93.5±3.54ab	47±1.41ab	6.97±0.05a	70.11±0.02b
	Ofada	48±0.00a	40.5±0.71a	7.5±0.71a	86.0±0.00a	45.5±0.71a	6.93±0.00a	66.7±2.65a
	Igbemo	43.5±3.54a	40.5±0.71ac	4.5±0.71ab	30.5±34.65ca	24±1.41ac	6.65±0.35a	67.03±0.58a

Duplicate determination means are expressed as means ± standard deviation.
At 5% level, mean values with distinct superscripts within the same column differ significantly.

According to the current findings, pasting temperature of the three germinated rice cultivars significantly decreased while a non-significant decrease was also observed for peak time. The reduced cooking time gives an indication that the rice flour will be cooked for a short time (Ukpong *et al*., 2021).

CONCLUSION

Germination between 60 and 72 h favoured increase in crude fibre, fat protein and ash content, whereas the samples' carbohydrate content decreased. Ungerminated *Ofada* had higher amount of macrominerals than Igbemo and FARO 44, while Igbemo had more of the microminerals. However, desirable positive effect of germination was more pronounced in FARO 44 than other varieties between 60 and 72 h. Igbemo had the highest values for vitamins B1, B2 and B3 before germination and also gave the peak values after germination between 60 and 72 h, except for B1. Germination at 36 h gave the highest bulk density, foaming capacity and oil absorption capacity in FARO 44 and Igbemo samples, while higher germination time between 48 h and 60 h enhanced those of *Ofada* rice. A decrease in all the viscosity parameters was observed in FARO 44 rice variety with an increased germination time, while *Ofada* rice showed a substantial ($p<0.05$) increase at 48 h.

REFRENCES

Adebowale KO, Olu-Owolabi B, Olawumi EK and Lawal OS 2005: Functional properties of native, physically and chemically modified breadfruit (*Artocarpus artillis*) starch. *Industrial Crop Production*, **21**: 343-351.

Adekoyeni OO, Adegoke AF and Sogunle KA 2018: Volatile aromatic components of two varieties of parboiled Nigerian rice. *Ife Journal of Science*, **20**(1): 67-75.

Adeyeye SAO, Bolaji OT, Abegunde TA, Tiamiyu HK, Adebayo-Oyetoro AO and Idowu-Adebayo F 2020: Effect of natural fermentation on nutritional composition and anti-nutrients in soy-wara (a Nigerian fried soy-cheese). *Food Research* **4** (1): 152-160.

AOAC 2005: Official method of analysis. 18th ed. Washington, DC: Association of Official Analytical Chemists.

AOAC 2015: Official methods of Association of Official Analytical Chemist. Washington DC.

Awuchi CG, Igwe VS, Amagwula IO and Echeta CK 2020: Health benefits of micronutrients (vitamins and minerals) and their associated deficiency diseases: A systematic review. *International Journal of Food Sciences*, **3**(1): 1-32.

Bristone C, Eke MO, Ikya JK and Ariahu CC 2024: Influence of malting and/ or fermentation on proxi ate composition of FARO 44 rice plus soybean based complementary foods. *Dutse Journal of Pure and Applied Sciences*, **10**(2a): 1-15.

Bulatao RM and Romero MV 2014: Effects of germination on the proximate composition, antioxidant property and eating quality of brown rice (Oryza sativa L.). *Philipp Agric. Scientist*, **97**(1): 19-27.

Chaijan M and Panpipat W 2020: Nutritional composition and bioactivity of germinated Thai indigenous rice extracts: A feasibility study. *PLoS One*, **15**(8): e0237844

Chima JU and Fasuan TO 2021: Symbiotic and adverse interplay of hypogeal germination periods on brown rice and non-nutrient characteristics. *Food, Production, Processing and Nutrition*, **3**(34).

Chinma CE, Adewuyi O and Abu JO 2009: Effect of germination on the chemical, functional and pasting properties of flour from brown and yellow varieties of tigernut (*Cyperus esculentus*). *Food research International*, **42**(8): 1004-1009.

Chung SI, Lo LMP and Kang MY 2016a: Effect of germination on the antioxidant capacity of pigmented rice (*Oryza sativa* L. cv. *Superjami and Superhongmi*). *Food Science and Technology Research*, **22**: 387-394.

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

Danbaba N, Anounye JC, Gana AS, Abo ME, Ukwungwu MN and Maji AT 2012: Physical and pasting properties of *Ofada* rice (*Oryza sativa* L.) varieties. *Nigerian Food Journal*, **30**(1): 18-25.

Elkhalifa AEO, Schiffler B and Bernhardt R 2004: Effect of fermentation on the functional properties of sorghum flour. *Food Chemistry*, **92**(1): 1-5.

Gujral HS, Sharma P, Kumar A and Singh B 2012: Total phenolic content and antioxidant activity of extruded brown rice. *International Journal of Food Properties*, **15**: 301-311.

Hasmadi M, Noorfarahzilah M, Noraidah H, Zainol MK and Jahurul MHA 2020: Functional properties of composite flour: A review. *Food Research*, **4**(6): 1820-1831.

Iwe MO, Onyeukwu O, Agiriga AN and Yildiz F 2016: Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. *Cogent Food and Agriculture*, **2**(1), https://doi.org/10.1080/23311932.2016.1142409

Kim HY, Hwang IG, Kim TM, Woo KS, Park DS, Kim JH, Kim DJ, Lee J, Lee YR and Jeong HS 2012: Chemical and functional components in different parts of rough rice (*Oryza sativa* L.) before and after germination. *Food Chemistry*, **134**(1): 288-293.

Makinde F and Omolori D 2020: Improvement of nutritional, functional and pasting properties of long and short local rice grains during germination. *Croatian Journal of Food Science and Technology*, **12**(2); 193-202.

Maldonado-Alvarado P, Pavon-Vargos DJ, Abarca-Robles J, Valencia-Chamorro S and Haros CM 2023: Effect of germination on the nutritional properties, phytic acid content, and phytase activity of quinoa (*Chenopodium quinoa* Wild). *Foods*, **12**(2). 10.3390/foods12020389

Megat Rusydi MR, Noraliza CW, Azrian A and Zulkhairi A 2011: Nutritional changes in germinated legumes and rice varieties. *International Food Research Journal*, **18**: 688-696.

Mohammed UA, Ibrahim S, Hayatu M and Mohammed FA 2019: Rice (*Oryza sativa* L.) production in Nigeria: Challenges and prospects. *Dutse Journal of Pure and Applied Sciences (DUJOPAS)*, **5**(2b): 67-75.

Mohmmed N, Kuna A, Sarkar S, Azam MM and Prasanna L 2022: Effect of germination on the physical and functional properties of brown rice. Asian *Journal of Dairy and Food Research*, 10.18805/ajdfr.DR-1799.

Mohmmed M, Aparna K, Sarkar S, Azam M, Lakshmi K and Kira V 2021: Effect of germination on yield, physico-chemical properties, nutritional composition and GABA content in germinated brown rice. *Oryza- An International Journal on Rice*, **58**(4): 496-505.

Moongngarm A, Moontree T, Deedpinrum P and Padtong K 2014: Functional properties of brown rice as affected by germination. *APCBEE Procedia*, **8**, 41-46.

Muñoz Llandes CB, Martínez-Villaluenga C, Palma-Rodríguez HM, Román-Gutiérrez AD, Castro-Rosas J and Guzmán-Ortiz FA 2023: Effect of germination on starch. doi: 10.1007/978-3-031-35843-2_19

Narayana K and Narasinga RMS 1982: Functional properties of raw and heat processed winged bean (*Psophocarpus tetragonolobus*) flour. *Journal of Food Science*, **42**: 534-538.

Nascimento LA, Abhilasha A, Singh J, Elias MC and Colussi R 2022: Rice germination and its impact in technological and nutritional properties: A review. *Rice Science*, **29**(3): 201-215.

Nwosu C and Daramola R 2017: Effect of soaking method on the eating qualities of Igbemo Rice. *American Journal of Food Science and Nutrition Research*, **4**(3): 112-117.

Ojediran JO, Okonkwo CE, Adeyi AJ, Adeyi O, Olaniran AF, George NE and Olayanju AT 2020: Drying characteristics of yam slices (*Dioscorea rotundata*) in a convective hot air dryer; Application of ANFIS in the prediction of drying kinetics. *Heliyon*, **6**(3), e03555.

Ohizua ER, Adeola AA, Idowu MA, Sobukola OP, Afolabi TA, Ishola RO, Ayansian SO, Oyekale TO and Falomo A 2017: Nutrient composition, functional and pasting properties of unripe cooking banana, pigeon pea and sweetpotato flour blends. *Food Science and Nutrition*, **5**(3): 750-762

Oke EK, Idowu MA, Sobukola OP and Bakare HA 2020: Nutrient composition, functional, physical and pasting properties of yellow yam (*Dioscorea cayanensis*) and jack bean (*Canavalia ensiformis*) flour blends. *Carpathian Journal of Food Science and Technology*, **12**(5): 52-71.

Oliveira MEAS, Coimbra PPS, Galdeano MC, de Carvalho CWP and Takeiti CY 2022: How does germinated rice impact starch structure, products and national evidences? A review. *Trends in Food Science & Technology*. https://doi.org/10.1016/j.tifs.2022.02.015

Omar KA, Salih BM, Abdulla NY, Hussein BH and Rassul S 2016: Evaluation of starch and sugar content of different rice samples and study their physical properties. *Indian Journal of Natural Sciences*, **36**(6): 1-11.

Parnsakhorn S and Langkapin J 2018: Effects of drying temperature on physicochemical properties of germinated brown rice. *Songklanakarin Journal of Science and Technology*, **40**(1): 127-134.

Ravichanthiran K, Ma ZF, Zhang H, Cao Y, Wang CW, Muhammad S, Aglago EK, Zhang Y, Jin Y and Pan B 2018: Phytochemical profile of brown rice and its nutrigenomic implications. *Antioxidants*, **7**(6):71-87.

Sathe SK, Deshpande SS and Salunkhe DK 1981: Functional properties of black gram (*Phaseolus mango* L) proteins. *Lebensm-wiss. U. Technol*. **16**: 69-74.

Singh A, Sharma S and Singh B 2017: Effect of germination time and temperature on the functionality and protein solubility of sorghum flour. *Journal of Cereal Science*, **76**: 131-139.

Świeca M and Gawlik-Dziki U 2015: Effects of sprouting and postharvest storage under cool temperature conditions on starch content and antioxidant capacity of green pea, lentil and young mung bean sprouts. *Food Chemistry*, **185**, 99–105. https://doi.org/10.1016/j.foodchem. 2015.03.108

Tortayeva DD, Horax R, Eswaranandam S, Jha A and Hettiarachchy NS 2014: Effects of germination on nutrient composition of long grain rice and its protein physico-chemical and functional properties. *Journal of Food and Nutrition*, **1**: 1-9.

Ukpong ES, Onyeka EU, Omeire GC and Ogueke C 2021b: Farro 57 Rice cultivar: A comparative study of the nutritional composition of its parboiled milled rice, brown rice and germinated brown rice. *Asian Food Science Journal*, **20** (3), 52–60. 10.9734/afsj/2021/v20i330278

Ukpong ES, Okpalanma EF and Ezegbe CC 2022: Effects of milling, germination durations and germination temperatures on bioactive composition of FARO 57 brown rice cultivar. *Journal of Food Chemistry and Nanotechnology*, **8**(4): 181-191.

Ukpong ES, Onyeka EU and Oladeji BS 2023: Bioactive compounds, nutrients and pasting properties of parboiled milled rice, brown rice and germinated brown rice of selected cultivars and the effects of germination durations. *Food Chemistry Advances* **2** (2023) 100234. https://doi.org/10.1016/j.focha.2023.100234

Wang JC and Kinsella JE 1976: Functional properties of novel proteins: Alfalfa lead proteins. *Journal of Food Science*, **41**: 286-290.

Wu F, Na Y, Toure A, Jin Z and Xu X 2013: Germinated brown rice and its role in human health. *Critical Reviews in Food Science and Nutrition*, **53**(5): 451-463.

Wunthunyarat W, Seo H and Wang Y 2020: Effects of germination conditions on enzyme activities and starch hydrolysis of long-grain brown rice in relation to flour properties and bread qualities. *Journal of Food Science*, **85**, 349-357.

Xu J, Zhang H and Qian H 2012: The impact of germination on the characteristics of brown rice flour and starch. *Journal of the Science of Food and Agriculture*, **92**, 380-387. .

Zilic S, Delic N, Basic Z, Ignjatovic-Micic D, Jankovic M and Vancetovic J 2015: Effects of alkaline cooking and sprouting on bioactive compounds, their bioavailability and relation to antioxidant capacity of maize flour. *Journal of Food and Nutrition Research*, **54**, 155-1654.