



Functional, Cooking, Sensory and Microbial Properties of FARO 44 Brown Rice as Affected by Milling and Germination

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Germinated brown rice (GBR) was produced from FARO 44 rice cultivar by sterilizing the paddy in sodium hypochlorite solution, steeping it in potable water and germination of the de-husked grain. Germination temperatures were maintained at 30 and 40°C for 12 and 36 h. The mould content, functional, cooking and sensory properties of the GBR were compared to non-germinated brown rice (BR) and non-germinated parboiled milled rice (MR) which were used as controls. The results showed that germination temperatures did not significantly affect ($p < 0.05$) the parameters analyzed. The germinating conditions did not encourage the growth of moulds. The foaming capacity (55.73%), foam stability (43.11%), water absorption capacity (1.24 g/g), and oil absorption capacity (1.07 g/g) of BR did not differ significantly ($p < 0.05$) from that of MR but they increased significantly in GBR to the range of 66.43-73.05%, 60.48-74.715%, 2.15-2.88 g/g, and 1.95-3.08 g/g respectively. These values were significantly higher ($p < 0.05$) at germination duration of 36 h than 12 h. The bulk density (0.93 g/cm³) and swelling power (6.78 g/g) of BR did not differ from that of MR but they decreased significantly ($p < 0.05$) in GBR to the range of 0.61-0.90 g/cm³ and 2.67-4.70 g/g respectively. Much significantly lower ($p < 0.05$) values were obtained at a germination duration of 36 h. The cooking time was least in MR (11.0 min) against BR (18.0 min) and GBR (12.0-15.0 min), and the water uptake ratio (g water/ g rice) was also least in MR (2.00) against BR (2.19) and GBR (2.20-2.37). MR and GBR germinated for 12 h were accepted while BR was rejected.

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1. INTRODUCTION

Rice is a popular cereal grain which is reported to be only second to wheat in terms of consumption worldwide [1]. The major layers of rice grain include the husk/hull, bran, germ and endosperm. The husk is the corklike inedible layer and beneath it is the bran layer. The bran layer is composed of the aleurone layer and 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 obtained from the same rice grain; the difference is in the degree of milling [2].

The removal of the husk/hull from rice grain results in brown rice. Thus, brown rice has the bran, germ and the endosperm. The bran layer contains most of the minerals, vitamins, dietary fibre, proteins, fats, antioxidants and phytochemicals of rice [3,2]. Milled rice which is also called white rice is obtained by removing the bran layer and germ, meaning it is composed of only the endosperm. 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 [1]. This is because the endosperm is made up of 85-90% of starch and is poor in proteins, fats, minerals, vitamins, and phytochemicals [4]. 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 [5]. Furthermore, it is also susceptible to hydrolytic rancidity due to a reaction of the endogenous lipases with the free fatty acids [6]. In either case, the end product has undesirable organoleptic attributes characterized by off-flavour and a shorter shelf-life.

The presence of the bran also causes organoleptic problems that militate against the use of brown rice as a staple food. It produces a flavourless texture that is unpleasant to eat and difficult to chew [7]. Recent researches on rice are aimed at solving this textural problem of brown rice to encourage the consumption of rice with the nutrient-dense bran layer [3,5,8]. The cheapest and easiest of these approaches is rice germination to produce germinated brown rice (GBR). Brown rice germination employs the natural proteases, lipases and amylases to degrade the macromolecules such as proteins,

lipids and carbohydrates. These natural enzymes also act on the bran which transforms it to a form that can be easily cooked and chewed with improved aroma and taste.

FARO 44 rice cultivar is the most cultivated rice cultivar in Nigeria [9]. FARO 44 (Sippi 692033) is an interspecific hybrid between the local African rice (*Oriza glaberrima*) and Taiwan rice (*Oriza sativa*) which brings new opportunities for farmers in Nigeria [10]. This rice was introduced to Nigeria in 1990 and farmers prefer them over other traditional and conventional cultivars due to its shorter period of maturity, long slender grain size, its ability to adapt to different types of soil and its optimum yield even under low farm management [9].

Most of the works on GBR are not done using FARO 44 rice cultivar. Again, previous works focused extensively on the effect of germination durations on the physical and sensory attributes with little or no work on the effect of germination temperature. Germination of brown rice is done in a humid environment which is known to support microbial growth including moulds. However, literatures on mould contents of GBR are scarce. In this study, brown rice from FARO 44 cultivar was germinated under controlled conditions. The purpose was to investigate the effects of germination temperature and duration on the mould contents, functional, cooking and sensory properties. The work also compares the GBR with its counterparts from milled rice (MR) and brown rice (BR).

2. MATERIALS AND METHODS

2.1 Source of the Rice

The FARO 44 brown rice cultivar used in this study was provided by Ebony Agro Industries, Ikwo, Ebonyi State, Nigeria.

2.2 Methods

2.2.1 Germinated brown rice production

The method of Ukpong et al. [5] was used for the germination process. The process began by submerging the dehulled rice grains in 0.1% sodium hypochlorite solution 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 30°C and 40°C for 12 h 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°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 Production of non-germinated parboiled milled rice and brown rice

Laboratory rice husker (SATAKE, Australia) was used to remove the husk from FARO 44 paddy rice to obtain the brown rice (BR). Non-germinated parboiled milled rice (MR) on the other hand was produced by soaking the paddy in warm water (40°C) of potable quality for 15 h and steaming for 10 min in a stainless steel pot. The water was drained and the paddy was dried in a hot air oven (Gulfex Scientific DHG 9202, England) initially at 120°C for 10 min and thereafter at 78°C until the moisture content was below 13%. Laboratory rice husker (SATAKE, Australia) was also used to dehusk them and finally they were milled in a laboratory rice mill (LT JIM-2099, China). MR and BR served as controls.

2.2.3 Analysis of presence of moulds on the grains

This was determined using the method of Filho et al. [11]. In this method, clean glass wares were heated in a hot air oven set at 60°C for 10 min after which the glass wares were left to cool. The medium used was Sabouraud dextrose agar. The sample (5 g) was measured and suspended in 100 mL of distilled water and the suspension was allowed to stand for 10 min with constant shaking. Furthermore, 0.1 mL of the suspended samples was inoculated unto the surface of Sabouraud dextrose agar plates using the streak plate method of inoculation. The culture plate was incubated at 25°C for 72 h. After this period of incubation, the plate was examined for the growth of colonies. If the colonies were found,

they would be re-isolated, incubated and identified.

2.2.4 Determination of functional properties of the samples

The samples were ground to pass through a 0.425 mm mesh sieve. The bulk density, water absorption capacity, oil absorption capacity, foaming capacity, foam stability and swelling power were determined on the different flour blends.

2.2.4.1 Bulk density

A little modification of the procedure of Asoegwu et al. [12] was used to determine the bulk density of the flour samples. Fifty grams of flour was measured into a 100 mL graduated measuring cylinder. This was followed by tapping the bottom of the cylinder on the laboratory table until there was no further change in volume after which the volume was recorded. The bulk density (gml^{-1}) was then calculated using Equation 1.

$$\text{BD} = \frac{\text{WF}}{\text{VF}} \quad (1)$$

Where BD = Bulk density (gml^{-1}); WF = Weight of flour (g); VF = Volume of flour (mL).

2.2.4.2 Water absorption capacity

The AOAC [13] method was used to determine the water absorption capacity. One gram of the sample was weighed into a graduated conical flask and 10 mL of distilled water was added. This was followed by whirling for 30 s to mix. The sample was allowed to stand at room temperature ($29\pm 2^{\circ}\text{C}$) for 30 min after which it was centrifuged at 5000 rpm for 30 min. The mixed sample was finally poured into a 10 mL measuring cylinder to determine the volume of the free water. The water absorption capacity was calculated using Equation 2.

$$\text{WAC} = (\text{TWA} - \text{FW}) \times \text{DW} \quad (2)$$

Where WAC = water absorption capacity; TWA = Total water absorbed; FW = Free water (supernatant); DW = Density of water

2.2.4.3 Oil absorption capacity

The AOAC [13] method was used. One gram of the sample was weighed into a graduated conical flask and 10 mL of soya bean oil was added.

This was followed by whirling for 30 s to mix. The sample was allowed to stand at room temperature (29±2°C) for 30 min after which it was centrifuged at 5000 rpm for 30 min. The mixed sample was finally poured into a 10 mL measuring cylinder to determine the volume of the free oil. The oil absorption capacity was expressed as grams of oil absorbed per gram of sample. The oil absorption capacity was calculated using Equation 3.

$$\text{OAC} = (\text{TOA} - \text{FO}) \times \text{DO} \quad (3)$$

Where OAC = Oil absorption capacity; TOA = Total oil absorbed; FO = Free oil (supernatant); DO = Density of oil

2.2.4.4 Foaming capacity

The Foam capacity (FC) was determined according to the procedure of Makri et al. [14] but with little modification. The flour (1.0 g) was measured and mixed with 50 mL distilled water in a graduated cylinder at room temperature 29±2°C. Panasonic (MX-AC 2105) blending machine was used to whip the suspension to homogenize. The increase in the volume of the suspension was noted and recorded. Foaming capacity was then calculated using Equation 4.

$$\text{FC}(\%) = \frac{[(\text{VAH} - \text{VBH}) \times 100]}{\text{VBH}} \quad (4)$$

Where FC= Foam capacity; VAH=Volume after homogenization; VBF=Volume before homogenization.

2.2.4.5 Foam stability

The Foam stability (FS) was determined according to the method of Chandra & Samsher [15]. The flour (1.0 g) was measured and mixed with 50 mL distilled water in a graduated cylinder at room temperature 29±2°C. Panasonic blending machine (MX-AC 2105) was used to whip the suspension for 5 min to foam. The volume of foam formed was measured 1 h after whipping and the foam stability was calculated using Equation 5.

$$\text{Foam stability} = \frac{\text{VAW} - \text{VBW}}{\text{VBW}} \times 100 \quad (5)$$

Where, VAW = Volume of foam after whipping; BW = Volume of foam before whipping

2.2.4.6 Swelling power

The method of Crosbie [16] was used with a little modification by using rice flour instead of

cocoyam flour. The flour sample (0.35 g) was mixed with 12.5 mL of distilled water and the slurry was heated for 30 min in water bath at 60°C. During the heating, the slurry was stirred continuously. This was followed by centrifugation in a centrifuge (L-708-2, Phillips Drucker, Oregon, USA) at 168×g for 15 min. Furthermore, the supernatant was decanted and the residue dried in evaporating disc for 20 min at 100°C after which it was weighed. The swelling power was then calculated using Equation 6.

$$\text{Swelling power} = \frac{\text{WR}}{\text{WS}} \quad (6)$$

Where WR= Weight of residue; WS= Weight of sample

2.2.5 Determination of cooking characteristics of the samples

Cooking time, elongation ratio, cooked rice length/breadth ration and water uptake ratio were determined on the germinated rice grains according to the method described by Sanusi et al. [17].

2.2.5.1 Cooking time

The rice samples (20 g) were cooked in 100 mL of distilled water on an electric cooker at 100°C. After cooking for 10 min, 10 grains were taken at every 2 min intervals for testing until the end of the cooking cycle. The testing was done by selecting 10 grains at random and pressed between two clean glass plates. Cooking time was determined as the time when at least 90% of the grains did not have uncooked centres or opaque cores.

2.2.5.2 Elongation ratio

Twenty cooked grains which were selected at random and their length were measured by the aid of a ruler and a pair of divider. The mean measured length of cooked rice was divided by mean length of uncooked samples.

2.2.5.3 Cooked rice length/breadth ratio

Twenty cooked grains which were selected at random and their length and breadth were measured by the aid of a ruler and a pair of divider. The length/breadth ratio was determined by dividing the cumulative length by the cumulative breadth.

2.2.5.4 Water uptake ratio (WUR)

An electric cooker was used to cook 10 g of whole rice sample in 100 mL of water at 100°C for a minimum cooking time. The water was drained off and the cooked sample was weighed. Equation 7 was used to calculate the water uptake ratio.

$$WUR = (WCR)/(WUCR) \tag{7}$$

Where WUR = water uptake ratio; WCR = weight of cooked rice (g); WUCR= weight of uncooked rice (g).

2.2.6 Sensory evaluation of the samples

A panel of 30 untrained judges was asked to evaluate the appearance, texture, aroma, and taste on a 7-point semi-structured hedonic scale. Weighted arithmetic mean as described by Ukpong et al. [18] was used to calculate the acceptability and the following weight was assigned to each parameter: General appearance 35%, taste 20%, aroma 15%, and texture 30%.

2.2.7 Statistical analysis

The data obtained from the study were further subjected to 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 Mould content as Affected by Milling and Germination Conditions

Table 1 shows the effects of milling, germination time and germination temperature on the mould content of FARO 44 brown rice. It was interesting to observe that no mould growth was found in MR, BR and GBR samples. This finding agrees

with a previous report [19]. The reasons for the absence of mould could be due to shorter duration of germination and high sanitary and hygiene conditions such as sterilization of the paddy rice in sodium hypochlorite solution, use of potable water for the germination, changing of the steep water at every 6 h interval and use of sterile wares and materials in the germination process. Thitinunsomboon et al. [20] however found mould growth in GBR samples germinated for 48 h and 72 h while moulds were absent in the samples germinated for shorter durations.

3.2 Functional Properties as Affected by Milling and Germination Conditions

Table 2 shows the effects of milling, germination time and germination temperature on the functional properties of FARO 44 brown rice. The bulk density of the BR was 0.93 g/cm³ which did not differ significantly ($p < 0.05$) from that of MR (0.96 g/cm³) while those of the GBR ranged from 0.90-0.61 g/cm³. The bulk density decreased significantly as the germination duration was increased and those germinated for 36 h were significantly lower than ($p < 0.05$) those of the control. This could also be due to the breakdown of macromolecules by the enzymes involved in the germination process whose activity increased as the germination duration was increased [21,22]. This is in agreement with previous reports [23,24]. The low bulk density of GBR suggests that its flour could be useful to formulate complementary foods. The temperature of germination however did not significantly affect ($p < 0.05$) the bulk density. The bulk density of this work, however, was higher than the range of 0.67-0.80 g/cm³ earlier reported [23] and the possible reasons for the variation could be due to the differences in rice cultivars as well as the longer period of germination (up to 48 h) employed by Chinma et al. [23].

Table 1. Mould content as affected by milling and germination conditions

Sample*	Mould Growth
MR	No mould growth
BR	No mould growth
Germination at 30°C	
G ₁₂ T ₃₀	No mould growth
G ₃₆ T ₃₀	No mould growth
Germination at 40°C	
G ₁₂ T ₄₀	No mould growth
G ₃₆ T ₄₀	No mould growth

MR= ungerminated parboiled milled rice; BR= ungerminated brown rice; GT= germinated brown rice; subscripts 12 and 36 are germination durations (h); subscripts 30 and 40 are the temperatures of germination (°C)

Table 2. Functional properties as affected by milling and germination conditions

Sample	Functional properties					
	Bulk density (g/cm ³)	Foaming capacity (%)	Foam stability (%)	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Swelling power (g/g)
MR	0.96 ^a _A	51.05 ^d _C	42.10 ^c _B	1.20 ^c _B	1.05 ^c _B	6.85 ^a _A
BR	0.93 ^a _A	55.73 ^c _B	43.11 ^c _B	1.24 ^c _B	1.07 ^c _B	6.78 ^a _A
Germination at 30^oC						
G ₁₂ T ₃₀	0.90 ^a	66.44 ^b	60.50 ^b	2.15 ^b	1.95 ^b	4.70 ^b
G ₃₆ T ₃₀	0.62 ^b	73.05 ^a	74.71 ^a	2.88 ^a	2.95 ^a	2.72 ^c
Mean	0.76_B	69.75_A	67.61_A	2.52_A	2.45_A	3.71_B
Germination at 40^oC						
G ₁₂ T ₄₀	0.81 ^a	66.43 ^b	60.48 ^b	2.19 ^b	1.97 ^b	4.70 ^b
G ₃₆ T ₄₀	0.61 ^b	71.13 ^a	74.62 ^a	2.80 ^a	3.08 ^a	2.67 ^c
Mean	0.71_B	68.78_A	67.55_A	2.50_A	2.53_A	3.69_B

Values with the same superscripts or subscripts in each column are not significant difference at $p < 0.05$. MR= ungerminated parboiled milled rice; BR= ungerminated brown rice; GT= germinated brown rice; subscripts 12 and 36 are germination durations (h); subscripts 30 and 40 are the temperatures of germination (^oC)

The foaming capacity was 51.05% in MR, 55.73% in BR and 66.43-73.05% in GBR. Foam stability was 42.10% in MR, 43.11% in BR and 60.48-74.71% in GBR.

Foaming capacity was significantly higher ($p < 0.05$) in BR than MR while in foam stability, there was no significant difference between them. Foaming capacity and foam stability were both significantly higher ($p < 0.05$) in GBR than MR and BR and they also increased significantly as the germination duration was increased. These results agree with previous reports [23,25]. Rice germination is reported to increase the protein content [26] which could be the reason for higher foaming capacity and foam stability in GBR. The endogenous proteinases employed during rice germination have been reported to break down complex proteins to soluble ones which could also account for the high foaming capacity of GBR [27]. In this work, both foaming capacity and foam stability increased in GBR as the germination duration increased which could be attributed to increase in the activities of proteinases as the germination time increased [21]. Increase in temperature of germination did not significantly affect ($p < 0.05$) the foaming capacity and foam stability of the GBR.

The water absorption capacity was 1.20 g/g in MR, 1.24 g/g in BR and 2.15-1.88 g/g in GBR samples. There was no significant difference ($p < 0.05$) in water absorption capacity between MR and BR but the values in GBR were significantly higher than those of the controls. The values were higher than the range of 1.22-

1.54 g/g as well as 1.14-2.28 g/g reported by Gujral et al. [28] and Chinma et al. [23] respectively and the variations could also be attributed to differences in the rice cultivars. Both authors also observed that the water absorption capacity was higher in GBR than the controls which have agree with the results of this study. The water absorption capacity also increased significantly as the germination duration was increased. High water absorption capacity of GBR could be due to its high protein contents and their conformation [29]. The increase in water absorption capacity with increase in duration of germination observed in this work could be due to the breakdown of complex carbohydrates as well as increase in protein quantity and quality during germination [22]. High water absorption capacity suggests that GBR flours can be used to prepare products that require hydration. Increase in temperature of germination did not significantly affect ($p < 0.05$) the water absorption capacity of the GBR.

The oil absorption capacity was 1.05 g/g in MR, 1.07 g/g in BR and 1.95-3.08 g/g in GBR. There was no significant difference ($p < 0.05$) between MR and BR but the values in GBR were significantly higher than those of the controls. Generally, the range of values was higher than ranges reported by Chinma et al. [23] but less than the range reported by Makinde & Omolori [24]. The reasons could also be due to differences in cultivars and differences in the particle sizes of the flours used by the different researchers. The values were also higher in GBR than in the controls and they increased with an increase in duration of germination which is also

in agreement with previous report [23]. It is most likely that the activities of the enzymes also unfolded and exposed the hydrophobic sites of the amino acids and this could be the reason for the high oil absorption capacity of GBR [30]. Fats help to enhance the flavour and mouthfeel of foods. Thus, the high oil absorption capacity of GBR may positively influence its flavour; this attribute was evident in the result of the sensory evaluation (Table 4). Increase in temperature of germination did not significantly affect ($p < 0.05$) the oil absorption capacity of the GBR.

The swelling power was 6.85 g/g in MR, 6.78 g/g in BR and 2.67-4.70 in GBR. There was no significant difference ($p < 0.05$) between MR and BR but the values in GBR were significantly lower than the controls. The starch content and structure influence the swelling power of flours [31]. Rice germination often results in reduction of starch content due to action on amylases on the starch [21]. Lower quantity of starch in GBR than the controls could be the reason for lower swelling power of GBR flour. The swelling power decreased significantly ($p < 0.05$) as the germination duration was increased and this was in agreement with previous work [24]. Increase in temperature of germination did not significantly affect ($p < 0.05$) the swelling power of the GBR.

3.3 Cooking Properties as Affected by Milling and Germination Conditions

Table 3 shows the effects of milling, germination time and germination temperature on the cooking properties of FARO 44 brown rice. The cooking

time was 11.00 min in MR, 18.00 min in BR and 12.00-15.00 min in GBR. Longer cooking time of BR could be due to the presence of bran. Longer cooking time of BR compared to MR has been previously reported [32,33]. Unlike BR, MR is composed of mainly the starchy endosperm and this could be the reason why it had the shortest cooking time. The cooking time was also shorter in GBR samples than BR and this also was previously reported [32,34]. The reason for this could be due to modification of the rice kernel by the action of the enzymes during rice germination [22]. The change in the temperature of germination did not result in any significant effect ($p < 0.05$) on the cooking time. The cooking time however, decreased significantly as the time of germination was increased and this could also be due to increased level of activity by these enzymes as the germination time was increased [21,22]. Shorter cooking time of GBR compared to BR is advantageous since it will result in reduction of energy cost of cooking.

The elongation ratio was 1.25 in MR, 1.12 in BR and 1.00-1.09 in GBR. The value in MR was significantly higher ($p < 0.05$) than those of BR and GBR and the reason for this could be due to the presence of bran in BR and GBR which could limit the expansion during cooking [35].

There was no significant difference ($p < 0.05$) in elongation ratio between BR and GBR, and an increase in germination duration and germination temperature also did not affect the elongation ratio significantly.

Table 3. Cooking properties as affected by milling and germination conditions

Sample	Cooking properties			
	Cooking time (min)	Elongation Ratio	Cooked rice length/breadth ratio	Water uptake ratio (g water/g rice)
MR	11.00 _C ^c	1.25 _A ^a	2.30 _B ^{bc}	2.00 _C ^c
BR	18.00 _A ^a	1.12 _B ^b	2.24 _B ^c	2.19 _B ^b
Germination at 30°C				
G ₁₂ T ₃₀	15.00 ^b	1.09 ^b	2.37 ^{bc}	2.20 ^b
G ₃₆ T ₃₀	12.00 ^c	1.01 ^b	2.63 ^a	2.37 ^a
Mean	13.50_B	1.05_B	2.50_A	2.29_A
Germination at 40°C				
G ₁₂ T ₄₀	15.00 ^b	1.09 ^b	2.39 ^b	2.21 ^b
G ₃₆ T ₄₀	12.00 ^c	1.00 ^b	2.52 ^a	2.35 ^a
Mean	13.50_B	1.05_B	2.50_A	2.28_A

Values with the same superscripts or subscripts in each column are not significant difference at $p < 0.05$. MR= ungerminated parboiled milled rice; BR= ungerminated brown rice; GT= germinated brown rice; subscripts 12 and 36 are germination durations (h); subscripts 30 and 40 are the temperatures of germination (°C)

Table 4. Sensory properties as affected by milling and germination conditions

Sample	Sensory properties				
	Appearance	Texture	Aroma	Taste	Acceptability
MR	6.32 ^{Aa}	6.45 ^{Aa}	5.09 ^{Bb}	6.00 ^{Bb}	6.11 ^{Aa}
BR	4.01 ^{Bb}	2.18 ^{Cd}	2.55 ^{Cc}	2.11 ^{Cc}	2.86 ^{Cd}
Germination at 30°C					
G ₁₂ T ₃₀	3.37 ^c	6.32 ^a	6.87 ^a	6.30 ^a	5.37 ^b
G ₃₆ T ₃₀	1.15 ^d	4.05 ^c	6.89 ^a	6.20 ^a	3.89 ^c
Mean	2.26_C	5.19_B	6.88_A	6.25_A	4.63_B
Germination at 40°C					
G ₁₂ T ₄₀	3.21 ^c	6.28 ^a	6.90 ^a	6.28 ^a	5.30 ^b
G ₃₆ T ₄₀	1.13 ^d	5.98 ^b	6.88 ^a	6.24 ^a	3.91 ^c
Mean	2.17_C	6.13_B	6.89_A	6.26_A	4.61_B

Values with the same superscripts or subscripts in each column are not significant difference at $p < 0.05$.

MR= ungerminated parboiled milled rice; BR= ungerminated brown rice; GT= germinated brown rice; subscripts 12 and 36 are germination durations (h); subscripts 30 and 40 are the temperatures of germination (°C)

The cooked rice length/breadth ratio was 2.30 and 2.24 in MR and BR respectively, without any significant difference ($p < 0.05$) between them. The values in GBR ranged from 2.37-2.63 which were significantly higher than BR. Change in germination temperature did not affect ($p < 0.05$) the cooked rice length/breadth ratio but the germination duration does; it increased with an increase in germination duration. The water uptake ratio was 2.00 g water/g of rice in MR, 2.19 g water/g of rice in BR and 2.20-2.37 g water/g of rice in GBR. The value in BR was significantly higher than MR. Increase in temperature of germination did not result in any significant effect ($p < 0.05$) on the water uptake ratio. The water uptake ratio increased significantly ($p < 0.05$) as the duration of germination was increased and the values in samples germinated for 12 h did not differ significantly from BR while values for samples germinated for 36 h were higher than that of BR. During rice germination the amylases breakdown complex carbohydrates into dextrins and other lower molecular weight substances which resulted in increased reducing sugars contents [36]. Sugars are hygroscopic and the high sugar content of GBR could enable it to absorb much water compared to MR and BR flours [30].

3.4 Sensory Properties as Affected by Milling and Germination Conditions

Table 4 shows the effects of milling, germination time and germination temperature on the sensory properties of FARO 44 brown rice. MR had the highest score in appearance (6.32) followed by BR (4.01) while GBR had the lowest (1.13-3.37). The scores decreased significantly ($p < 0.05$) in GBR samples as the germination duration was

increased which could be due to increase in the length of the sprouts. MR also had the highest score for texture (6.45) followed by GBR (4.05-6.32) while BR had the lowest score (2.18). The texture of BR sample was disliked very much probably because it was hard to chew due to the presence of the bran layer [37]. The GBR had the highest scores for aroma (6.87-6.90) followed by MR (5.09) while BR had the least (2.55). GBR also had the highest scores for taste (6.20-6.30) followed by that of MR (6.00) while BR also had the least score (2.11). The enhanced aroma and taste of the GBR could be due to the activities of enzymes that modify the grain, break down macro molecules and release the flavour precursors [37]. The result of the calculated acceptability was 6.11 in MR, 2.86 in BR and 3.89-5.37 in GBR.

The result of acceptability showed that MR and GBR germinated for 12 h at any of the germinating temperatures were accepted while BR was rejected by the panel. The organoleptic attributes of BR in terms of unattractive appearance, hard texture and poor flavour could have all contributed to its rejection. The texture, aroma and taste contributed more to this acceptance of GBR germinated for 12 h than the appearance. GBR germinated for 36 h at any of the germinating temperatures were rejected.

4. CONCLUSION

The work revealed that rice milling and germination affected the functional, cooking and sensory properties of FARO 44 brown rice. An increase in germination temperature from 30°C to 40°C did not affect the functional, cooking and sensory properties significantly. Germination of

brown rice resulted in a product with shorter cooking time and soft texture. Brown rice germinated for 12 h had improved aroma and taste and was accepted. Germination of brown rice for 36 h could make it good for complementary food due to increase in bulk density and the flour could also be useful for baked goods due to its high water and oil absorption capacities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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