International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(6): 555-559
www.biochemjournal.com
Received: 27-04-2024
Accepted: 30-05-2024

Monika Sood
Division of Post Harvest Management, FoH&F, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu & Kashmir, India

Julie D Bandral
Division of Post Harvest Management, FoH&F, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu & Kashmir, India

Neeraj Gupta
Division of Post Harvest Management, FoH&F, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu & Kashmir, India

Nishu
Division of Post Harvest Management, FoH&F, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu & Kashmir, India

RK Salgotra
Institute of Biotechnology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu & Kashmir, India

Corresponding Author:
Monika Sood
Division of Post Harvest Management, FoH&F, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu & Kashmir, India

Effect of germination on functional and nutritional quality characteristics of brown rice

Monika Sood, Julie D Bandral, Neeraj Gupta, Nishu and RK Salgotra

DOI: https://doi.org/10.33545/26174693.2024.v8.i6Sg.1376

Abstract
The objective of this study was to investigate the effect of germination on the functional and nutritional quality characteristics of brown rice. Brown rice (Pusa basmati 1121) were soaked in water for 12 hours at 28±2 °C, followed by incubation at 28±2 °C for time interval of about 48 hours. The germinated brown rice were evaluated for various functional and nutritional quality parameters. The findings revealed that germination resulted in increase L* (58.37±0.17), a* (5.92±0.10) and b* (19.51±0.13) values of BR. The germinated brown rice flour recorded higher crude protein (9.86±0.12%), crude fibre (1.34±0.04%) and ash content (1.57±0.07%). Significant increase in iron (9.73 mg/100 g), calcium (28.92 mg/100 g), potassium (229.31 mg/100 g) and magnesium (150.16 mg./100 g) content was observed with germination. The total phenol and antioxidant activity also improved with germination from 74.20±0.15 to 84.75±0.12 mg GAE/100 g and 48.97±0.09 to 61.30±0.07%, respectively. Further, germination also considerably improved the water absorption capacity and bulk density from 128±0.14 to 128±0.14%, 0.76±0.02 to 0.86±0.03 g/ml and 0.84 to 0.79 whereas, decrease in oil absorption capacity was observed from 0.84±0.02 to 0.79±0.01%, respectively. Thus germination could effectively be used to enhance the nutritional value and functional quality of brown rice.

Keywords: Brown rice, functional, germinated brown rice, physical, proximate composition

Introduction
Rice is a staple crop that is eaten by most of the country's population. It is an inexpensive source of energy, accounting for about 41% of their daily calorie intake and 31% of their protein intake. Due to its superior cooking and eating qualities, cooked milled rice is a staple food for the majority of people (Juliano 2007) [12]. However, the consumption of rice and its products is sometimes limited by its high glycemic index due to its high starch content, low protein content and quality, and low bioavailability of minerals due to the presence of anti-nutritional factors. Still, consuming this type of rice on a daily basis may lead to nutritional deficits because the majority of its nutrients are found in the bran layers, which are usually lost during the milling process when the seed coat separates (Babu *et al*., 2009) [4]. Brown rice has a higher nutritional value than milled rice; it is currently being advocated as an alternative. Minerals like iron, zinc, manganese, selenium, and magnesium are abundant in brown rice. According to Babu *et al*. (2009) [4] and Roohinejad *et al*. (2009) [20], it has significant levels of protein, dietary fiber, vitamin E, vitamin B complex, unsaturated fats, γ-oryzanol, γ-amino butyric acid (GABA), antioxidants, phenolic compounds, and other phytochemicals. Because of its characteristic off-taste, dark appearance, difficulty in cooking, and hard texture when cooked. Brown rice is consumed in relatively small quantities in the country despite its obvious health advantages (Ohtsubo *et al*. 2005) [17]. Additionally, phytic acid, an anti-nutritional component that reduces the body's ability to absorb nutrients, is present in it.

Germinated brown rice is also called as 'sprouted brown rice'. It is different from normal brown rice in that it has undergone the process of germination; more specifically, the rice embryo is sprouted under suitable environmental conditions. A brown rice kernel is soaked in water for 24 hours to initiate germination, after which the sprout appears (Komatsuzaki *et al*. 2005) [13]. Smaller units of chemicals, including as simple sugars, peptides, amino acids, and fatty acids, are produced during germination when particular hydrolytic enzymes break down high-molecular-weight molecules (Panchan and Naiviku 2009) [18].

The developing sprout frequently uses these chemicals for cellular production and transpiration before embryogenesis. As a result, the bio-functional compounds produced by these degradative chemicals improve the flavour and texture of brown rice. The enzymatic changes during germination improve functional properties of flour, such as lower viscosity, greater water and oil absorption, and improved foaming capacity. Germinated brown rice is an emerging health food that has been receiving attention due to its nutritional composition. This study was therefore conducted to evaluate the effects of germination on the functional and nutritional quality characteristics of brown rice.

Materials and Methods

Brown rice (Pusa basmati 1121) was procured from M/S Jatinder Rice Mill, R.S. Pura, Jammu. The procured brown rice grains were cleaned manually and sorted to remove any foreign matter. The rice grains were then washed and soaked in water for 12 hours at 28±2 °C, followed by incubation at 28±2 °C for time interval of about 48 hours. After that, the germinated brown rice samples were dried in a tray dryer at 50±3 °C until the moisture content drops below 12 percent (Mohmmed *et al*., 2021) [16]. Then, the germinated samples were milled by using laboratory flour mill followed by sieving using 80-100 mesh sieves. The sieved sample was packed in airtight containers till further use.

Functional parameters

The water absorption capacity of samples was determined by the method described by Al-Khuseibi *et al*. (2005) [2] with slight modifications. The sample (1.0 g) was mixed in centrifuge tubes with 10 ml distilled water. The sample was stirred intermittently over a period of 30 minutes and centrifuged at 2000 rpm for 10 minutes. The aqueous supernatant obtained after centrifugation was decanted and the test tubes were inverted and allowed to drain for 5 minutes on paper towel. By weighing the residue, water absorption capacity was calculated and expressed as percentage of water absorbed per gram of sample. The oil absorption capacity of samples was determined by the method described by Elkhalifam *et al.* (2010) [8] with modifications. The sample (1.0 g) was mixed in centrifuge tubes with 10 ml sunflower oil. The sample was stirred intermittently over a period of 30 minutes and centrifuged at 2000 rpm for 10 minutes. The aqueous supernatant obtained after centrifugation was decanted and the test tubes were inverted and allowed to drain for 5 minutes on paper towel. By weighing the residue, oil absorption capacity was calculated and expressed as percentage of oil absorbed per gram of sample. The flour samples (100 g each) were gently filled in 500 ml graduated cylinder, previously tarred. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to 500 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/ml).

Nutritional Quality Characteristics

The colour of germinated brown rice based cookies was measured using a Hunter's lab colour analyser (Hunter Lab Color Flex Reston VA, USA S.No. CX 2013). The equipment was calibrated using white and black standard ceramic tiles. In the Hunter's lab colorimeter, the color of the sample is denoted by the three dimensions L*, a* and b*. L* refers to lightness of the colour of the sample and ranges from black = 0 to white = 100. A negative value of a* indicates a green colour where the positive value indicates red-purple colour. A positive value of b* indicates a yellow colour and negative value a blue colour.

Moisture content in the samples was determined by following the oven drying method as the loss in weight due to evaporation from sample at a temperature of 105±1 °C. The weight loss in each case represented the amount of moisture present in the sample (AOAC, 2012) [3]. The crude protein content of the cookies was determined by micro Kjeldahl method, using the factor 5.95 for converting nitrogen content into crude protein (AOAC, 2012) [3]. The crude fat content was determined by the Soxhlet extraction technique (AOAC, 2012) [3]. The crude fibre content was determined by the method given by AOAC (2012) [3]. Ash content of the samples was determined by using muffle furnace (AOAC, 2012) [3]. The carbohydrate content was estimated by the difference method given by AOAC (2012) [3] and it was calculated by subtracting the sum of percentage of moisture, crude fat, crude protein and ash contents from 100 (AOAC, 2012) [3]

Total phenolic content was determined by Folin-Ciocalteau assay (Ahmed and Abozed, 2015) [1] which is an electron transfer based assay. The absorbance was measured at 765 nm against a reagent blank using a UV-visible spectrophotometer (Model UV4, Unicam and Cambridge, UK). Gallic acid was used as the calibration standard and the results were calculated as mg of Gallic acid equivalents (mg GAE/100 g) of samples. Free radical scavenging activity of samples were determined by DPPH (1, 1, diphenyl - 2 picrylhydrazyl) method. The absorbance was determined at 517 nm using blank as 80 percent methanol. The free radical scavenging activity was evaluated by comparing the absorbance of the sample solution with control solution to which distilled water was added instead of sample (Luo *et al*., 2009) [15].

The mineral contents were determined after the ash content determination. The ash residue of each formulation was digested with perchloric acid and nitric acid (1:4) solution (AOAC 2012**)** [3]. The samples were used separately to determine the mineral content of calcium, iron, potassium and magnesium in the sample by using an Atomic Absorption spectrophotometer (Spectra AA 220, USA Varian).

Results & Discussion

The functional properties *viz*., water absorption capacity, bulk density and oil absorption capacity in brown rice were observed as 128±0.14 percent, 0.76±0.02 g per ml and 0.84±0.02 percent, respectively (Fig 1), which were in line with the findings of Toan and Vinh (2018) [21].The data pertaining to the physical parameters of raw materials (Table 1) revealed that the hunter colour values L*, a* and b* in brown rice were observed as 56.12±0.15, 5.08±0.08 and 19.20±0.16, respectively, which were in accordance with the findings of Durgarao *et al*. (2017) [7] in brown rice. The moisture, crude protein, crude fat, crude fibre, ash, carbohydrates and energy values were recorded as 9.41±0.07 percent, 8.24±0.11 percent, 2.78±0.07 percent, 1.17±0.03 percent, 1.46±0.05 percent, 78.26±0.31 percent and 369.67±0.42 kcal per 100 g, respectively (Table 1). Chen *et al*. (2012) [6] also observed similar results in raw brown rice. The total phenolic content, antioxidant activity, iron, calcium, potassium and magnesium in brown rice were observed as 74.20±0.15 mg GAE per 100 g, 48.97±0.09 percent, 3.48±0.09 mg per 100 g, 24.31±0.11 mg per 100 g, 224.92±0.32 mg per 100 g and 145.23±0.24 mg per 100 g, respectively (Table 2 & Fig 2), which were in accordance with the findings of Upadhyay and Karn (2018) [22] in brown rice.

In germinated brown rice, the water absorption capacity, bulk density and oil absorption capacity in germinated brown rice were observed as 150±0.15 percent, 0.86±0.03 g per ml and 0.79±0.01 percent, respectively (Fig 1), which were in line with the findings of Parnsakhorn and Langkapin (2013) [19]. Hunter colour values L*, a* and b* were observed as 58.37±0.17, 5.92±0.10 and 19.51±0.13, respectively. The increase in colour values with germination might be due to enzymatic activities during the germination process, which results in the hydrolysis of starch into simple sugar. On the other hand, the sugar and protein can induce the Maillard reaction (Islam *et al*., 2012) [11], responsible for lightness and yellowness values in GBR. The colour is an important performance characteristic of rice flour affecting the appearance of finished products since rice flour generally serves as the foundational ingredient for rice-based products. Parnsakhorn and Langkapin (2013) [19] also observed similar results in germinated brown rice. The moisture, crude protein, crude fat, crude fibre, ash, carbohydrates and energy values were observed as 8.73±0.06 percent, 9.86±0.12 percent, 2.63±0.08 percent, 1.34±0.04 percent, 1.57±0.07 percent, 77.06±0.29 percent and 372.70±0.43 kcal per 100 g, respectively (Table 1), which were in accordance with the findings of Islam *et al.* (2012). In germinated brown rice, the enhancement of protein during germination might be a result of the bio-synthesis of proteases during germination (Elobuike *et al.*, 2021) [9]. The decrease in fat content might be attributed to utilization of fat as a source of energy during germination (Bains *et al*., 2014) [5]. The increase in crude fibre and ash might be due to the protein-enzyme-mineral bond resulting in the release of nutrients (Liu *et al*., 2018) [14]. The total phenolic content, antioxidant activity, iron, calcium, potassium and magnesium in germinated brown rice were observed as 84.75±0.12 mg GAE per 100 g, 61.30±0.07 percent, 9.73±0.08 mg per 100 g, 28.92±0.09 mg per 100 g, 229.31±0.28 mg per 100 g and 150.16±0.26 mg per 100 g, respectively (Table 2 & Fig 2). The reduction in total phenolic content might be due to leaching of the compounds into the soaking water and also due to enzymatic activity during germination. The decrease in antioxidant activity in processed mungbean might be due to reduction in total phenolic content, as there is positive correlation between total phenolic content and antioxidant activity (Gujral *et al.*, 2013) [10]. The mineral content in germinated brown rice increased which might be attributed to the increase in activity of phytase, which breaks down protein-enzyme-mineral bond to release minerals (Gujral *et al.*, 2013) [10].

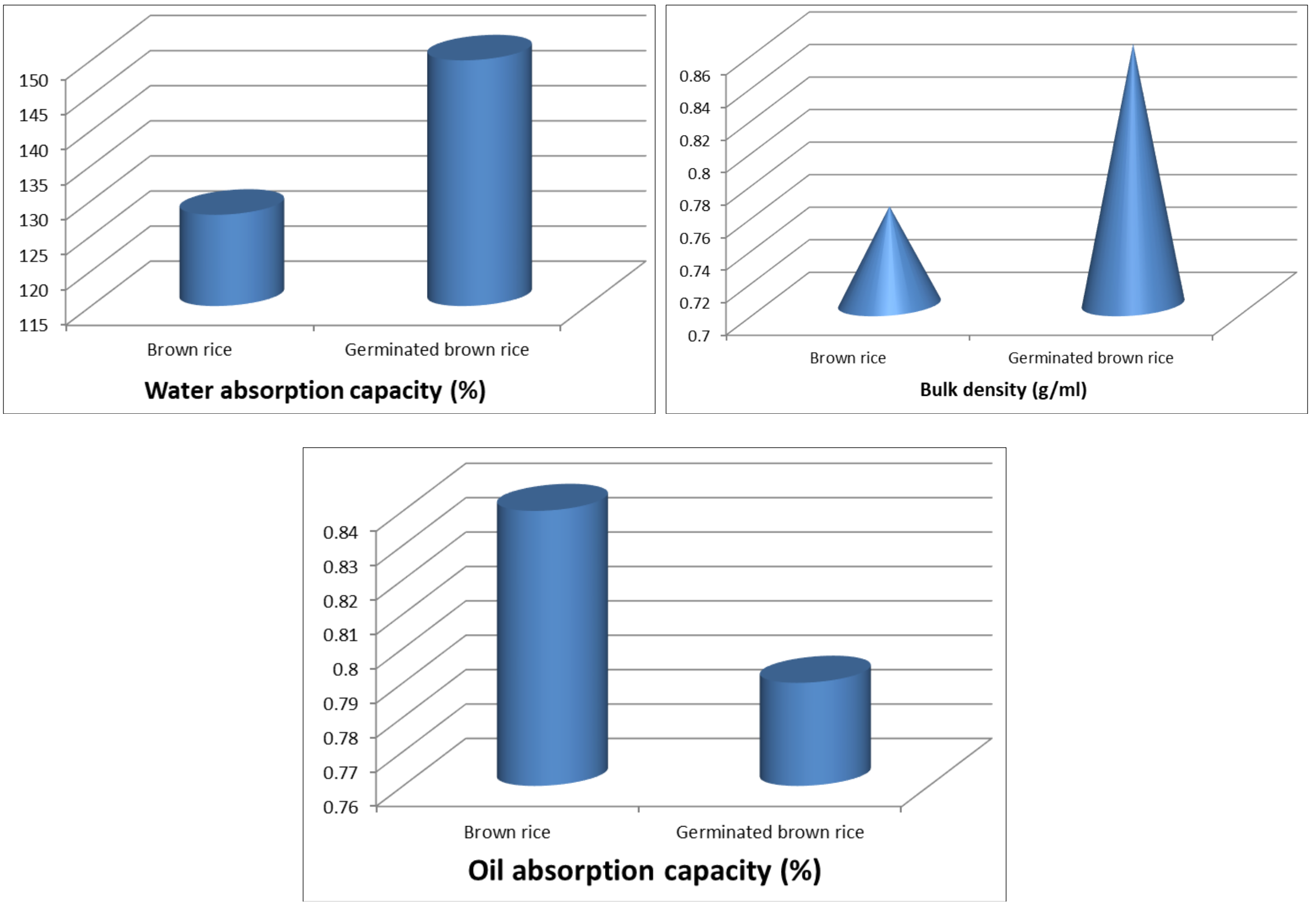


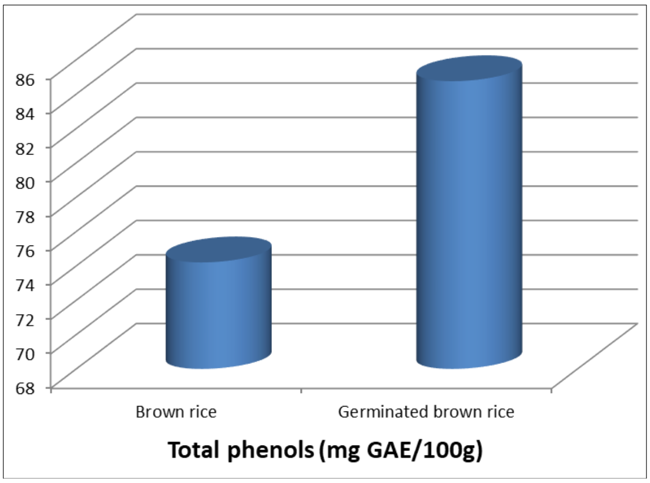
Fig 1: Functional parameters of un-germinated and germinated brown rice

Table 1: Physical and proximate composition of brown rice and germinated brown rice

Parameters	Brown rice	Germinated brown rice
Hunter Colour Values		
L* (Lightness)	56.12±0.15	58.37±0.17
a* (redness)	5.08±0.08	5.92±0.10
b* (yellowness)	19.20±0.16	19.51±0.13
Proximate composition		
Moisture (%)	9.41±0.07	8.73±0.06
Crude protein (%)	8.24±0.11	9.86±0.12
Crude fat (%)	2.78±0.07	2.63±0.08
Crude fibre (%)	1.17±0.03	1.34±0.04
Ash (%)	1.46±0.05	1.57±0.07
Carbohydrates (%)	78.26±0.31	77.06±0.29
Energy (Kcal/100 g)	369.67±0.42	372.70±0.43

Table 2: Mineral composition of brown rice and germinated brown rice

Parameters	Brown rice	Germinated brown rice
Iron (mg/100 g)	3.48±0.09	9.73±0.08
Calcium (mg/100 g)	24.31±0.11	28.92±0.09
Potassium (mg/100 g)	224.92±0.32	229.31±0.28
Magnesium (mg/100 g)	145.23±0.24	150.16±0.26



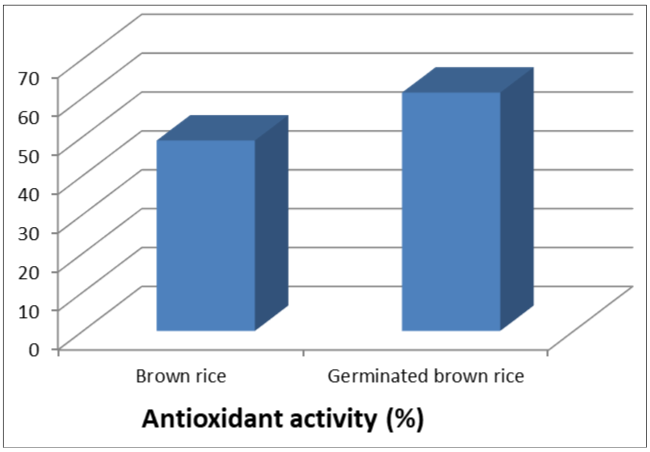


Fig. 2: Bioactive components of un-germinated and germinated brown rice

Conclusion
Germination had a significant effect on the functional and nutritional characteristics of germinated brown rice, as was confirmed from the results obtained in the study. Germination improved protein, fibre, minerals and bioactive compounds (total phenols and antioxidant activity). The functional parameters of germinated were also observed to be higher than the non germinated brown rice. Thus, germinated brown rice can be used to develop various food formulations to meet the requirements of different subgroups of consumers, such as elders, pregnant women, children and individuals with risks for various chronic metabolic disorders. Also, awareness on the health benefits of germinated brown rice based food products compared to rice-based products should be promoted for enhanced production and consumption of germinated brown rice, owing to their health benefits.

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