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Effect of puffing on physical and antioxidant properties of brown rice

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ABSTRACT

The objective of this study was to investigate the effect of puffing process on the physical, antioxidant properties and mineral composition of brown rice. Bulk density significantly varied ($P < 0.05$) among the puffing stages and was lowest in expanded rice. From Hunter colour analysis, the lowest L^* value and highest a^* and b^* values were observed for parboiled rice ($P < 0.05$). A-type of diffraction pattern, observed in raw rice was altered by puffing process and led to the formation of B- and V-type patterns. Raman spectrum showed the intense peaks in raw rice and the intensity of those peaks was decreased during the puffing process. Scanning electron microscopy revealed a highly porous structure of expanded rice kernel. Significant decrease in the antioxidant properties was observed upon puffing process as compared to raw rice samples. Hence the present study demonstrates that the puffing process leads to the significant changes in the properties of brown rice.

1. Introduction

Cereal grains like wheat, rice, barley, corn and oat are not only prominent source of carbohydrates but also provide minerals, bioactive components and dietary fibre (Liang, Han, Han, Nout, & Hamer, 2007; Madhujith & Shahidi, 2006). Rice is one of the important cereal crops, which plays an important role in human nutrition (Mir & Bosco, 2014). Nowadays, due to change in life style and increase in health consciousness among the consumers, brown/de-husked rice is receiving increased interest because of its excellent health beneficial properties. Attention is currently being given to the antioxidative properties of brown rice because of its potential to provide and promote human health (Nam, Choi, Kang, Koh, & Friedman, 2006). Brown rice is considered as a rich source of antioxidants, dietary fibre, vitamins and minerals, which are essential for human health (Wu et al., 2013).

Rice is commonly used for puffing purpose due to its taste, texture and nutritional profile. Puffed rice is a popular snack product prepared by parboiling the paddy under the specified conditions followed by high temperature short time treatment of the parboiled rice in hot air or sand (Chinnaswamy & Bhattacharya, 1983; Murugesan & Bhattacharya, 1991). It is mainly appreciated for its crispness, lightness and qualities related to its cellular structures (Hoke, Housova, & Houska, 2005).

To change the rice grain from compact to expanded structure, it has to pass through many stages, which alters the physical properties and nutritional profile of the rice grain due to thermal process during the puffing treatments. Rice parboiling is a hydrothermal process, which modifies the qualitative and processing behaviour of rice (Dutta & Mahanta, 2012). During the parboiling process starch granules are gelatinised and retrograded; as a result various changes occur in rice, which affects its quality parameters. The parboiling treatment principally brings the characteristic change in rice grain, which leads to expansion during puffing. On puffing, appreciable physical, conformational, structural and crystallinity changes occur in rice grain due to the order-disorder transitions, which takes place at the molecular level, leading to the change in the morphology and texture of rice grain (Shih, King, Daigle, An, & Ali, 2007). Little is known about the changes occurring during puffing stages of rice grain, so the objective of the present investigation was to study the physical and nutritional changes occurring during the puffing process.

2. Materials and methods

2.1. Materials

Three rice cultivars used in this study, namely, Jehlum, SKAU-345 and SKAU-382 were collected from Sher-e-Kashmir University of Agriculture Science and Technology, Kashmir, India. The grains were dried and cleaned manually to remove foreign matters and stored at 5 °C and then taken for the experimentation.

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2.2. Preparation of puffed rice

Paddy was soaked in pre-heated water at 80 °C for 6 h. The water was drained off and the soaked paddy was spread on small wire-mesh trays, and steamed in an autoclave at a pressure of 1.5 kg/cm^2 for 10 min. The paddy was then dried at 40 °C in a tray drier to 14% moisture and de-husked in a Satake Testing Rice Husker (THU-34A, Satake, Japan). Afterwards, rice was expanded in iron pan containing sand at ~220 °C for 45–60 s and vigorously stirred with the sand to ensure uniform heating. The sand temperature was measured with an electronic thermometer. The expanded rice was put on the clean marble floor, to bring it to room temperature.

2.3. Length/breadth ratio

Brown rice kernels at different stages of puffing (raw, parboiled, expanded) were randomly selected from each cultivar and their length and breadth were measured by using a Vernier caliper.

2.4. Bulk density

The bulk density was determined using the mass/volume relationship by filling an empty plastic container of predetermined volume and tare weight with the grains by pouring from a constant height, striking off the top level and weighing (Mir, Bosco, & Sunooj, 2013).

2.5. Colour

The colour of grain samples at different stages of puffing were determined by CIE colour scales L^*, a^* and b^* using Hunter Lab digital colourimeter (Model D25M, Hunter Associates Laboratory, Reston, VA). Where L^* indicates the degree of lightness or darkness of the sample extended from 0 (black) to 100 (white), a^* and b^* indicates degree of redness ($+a$) to greenness ($-a$) and whereas b^* indicates the degree of yellowness ($+b$) to blueness ($-b$), respectively.

2.6. X-ray diffraction

X-ray diffraction analysis of samples was performed using X-ray diffractometer (Shimadzu, XRD 7000) operated at 30 mA (tube current) and 40 kV (target voltage) with Cu K_α filtered radiation. The scanning range for 2θ values was set from 10° to 70° to cover all significant diffraction peaks of sample crystallites with a scan speed of 2°/min.

2.7. Scanning electron microscopy

Structure of rice grain at different puffing stages was analysed by scanning electron microscopy (HITACHI Model S-3000H). The samples were mounted on scanning electron microscopy aluminium stubs using double sided adhesive tape to which the samples were fixed and coated with a thin layer of gold. An acceleration of 15 kV and magnification ×100 was used during micrography.

2.8. Raman spectroscopy

The Raman spectra were recorded with a Raman spectrometer (model inVia) produced by Renishaw (UK), working in confocal mode. The rice samples were placed on an aluminium holder and were excited with 785 nm laser line of HP NIR diode laser Renishaw (UK). The laser power was kept low enough to ensure that it did not damage the sample. Measurements were performed with microscope and spectra were taken from the same spot size of each sample in the range of 1600–400 cm^{-1}.

2.9. Antioxidant activity

2.9.1. Preparation of brown rice extract

Rice samples were well ground using Mini Grain Mill (A11B, IKA Inc.) and sifted through 125 μm sieve. Ten grams of each powdered sample were extracted for 8 h with 50 ml of acidified methanol in an electrical shaker (Technico, India) at 30 °C. Extract was centrifuged at 1000×g for 15 min. and the supernatant was stored in a sealed container at −4 °C until used for further analysis.

2.9.2. Determination of total phenolic content

Total phenolic content of samples was determined using the Folin–Ciocalteu method (Liu & Yao, 2007) with some modifications. 200 μl of brown rice extract was mixed with 1 ml of Folin–Ciocalteu reagent diluted to 1:10 with water. The dispersion was shaken vigorously and 1 ml of 10% Na_2CO_3 was added and the final volume was made up to 5 ml with distilled water. The dispersion was then left to stand for 2 h at room temperature and the absorbance at 765 nm was measured using a UV–Vis Spectrophotometer (UV-1800, Shimadzu, Japan). The results of total phenolic content were expressed as mg gallic acid equivalents per g of brown rice extract.

2.9.3. Determination of total flavonoid content

Total flavonoid content of rice extract was determined using the method described by Jia, Tang, and Wu (1998). Rice extract (250 μl) was diluted with 1.25 ml of distilled water and 75 μl of 5% $NaNO_2$ solution was then added. The dispersion was allowed to stand at room temperature for 6 min followed by the addition of 150 μl of 10% $AlCl_3$. Again, this dispersion was allowed to stand for further 5 min and 0.5 ml of 1 M NaOH was added. The solution was shaken vigorously and the absorbance was measured at 510 nm. The results were expressed as μg catechin equivalents per g of brown rice.

2.9.4. Determination of DPPH radical scavenging activity (DPPH)

DPPH radical scavenging activity was determined using the method described by Blois (1958). A portion (0.1 ml) of the extract solution was well mixed with 3.9 ml of methanol and 1.0 ml of 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution (1.0 mM in methanol). The dispersion was kept in dark at ambient temperature for 30 min and the reduction in the absorbance was read at 517 nm. The scavenging activity was calculated by the following equation.

$$\text{DPPH radical scavenging } (\%) = [1 - (\text{Absorbance}_{517\text{nm control}} / \text{Absorbance}_{517\text{nm sample}})] \times 100$$

2.9.5. Determination of reducing power

The reducing power of rice extract was measured according to the method reported by Yen and Duh (1993) with some modifications. Each rice extract (2.5 ml) was mixed with 2.5 ml of 0.2 M sodium phosphate buffer (pH 6.6). The diluted sample was then mixed with 2.5 ml of 1% potassium ferricyanide and the dispersion was incubated at 50 °C for 20 min. Trichloroacetic acid (2.5 ml, 10%) was added to the dispersion, which was then centrifuged at 6000×g for 10 min. The upper solution (2.5 ml) was mixed with distilled water (2.5 ml) and 0.5 ml of ferric chloride (1.0%). The absorbance was measured at 700 nm.

2.10. Mineral content

Mineral analysis was determined using the method of Bhol and Bosco (2014) with some modifications. The analysis was performed using WD-XRF (Wavelength dispersive spectrometer-X-ray fluorescence), Bruker AXS, S4-Pioneer Germany. Two grams

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