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Quality controlling of brown rice by ultrasound treatment and its effect on isolated starch

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ABSTRACT

Ultrasonic treatment (UT) was applied to brown rice at two different conditions: mild (25 °C, 30 min) and harsh (50 °C, 60 min) after soaking for several times (2, 3, 5, and 8 h). After UT, starch was isolated from the brown rice grains, and the physicochemical properties of the starch, as well as the textural and nutritional properties of the grains, were compared. After UT, the cooked brown rice grains was softer in proportion to soaking time, and the hardness of brown rice soaked for 8 h and then ultrasound treated at harsh condition was similar to that of cooked milled rice. Untreated brown rice grain has much more thiamin, riboflavin, and niacin contents than milled rice (0.546 vs. 0.069, 0.054 vs. 0.018, and 4.56 vs. 1.21 mg/100 g, respectively), and the thiamin and niacin contents in brown rice treated even at the most harsh condition were still higher than those in milled rice (0.193 vs. 0.069, and 1.6 vs. 1.21 mg/100 g, respectively). The isolated starch from brown rice grains treated at the harsh condition exhibited a lower pasting temperature and higher breakdown in pasting properties than that treated at the mild condition. The crystalline structure of starch became more homogeneous by UT at both conditions with longer soaking times. Both of the melting enthalpy and relative crystallinity of starch significantly decreased by UT, however A-type crystal form was maintained.

1. Introduction

Rice is the most commonly consumed in the form of milled rice because of its softness and easy digestion. Brown rice is nutritionally superior to milled rice in terms of protein, dietary fiber, vitamin B, minerals, and even functional antioxidants which are mostly existed in external parts like hull and bran (Juliano, 2010); however, those nutrients are easily removed during the milling process. With increasing health concerns, the health-promoting functions of brown rice have received the attention of consumers, and the demand for brown rice consumption has increased greatly. The bran in brown rice, however, restricts water diffusion during cooking, resulting in a harder texture and lower palatability than milled rice (Piggot, Morrison, & Clyne, 1991).

Soaking is the simplest method for softening the texture of brown rice. Longer soaking times shorten the cooking time of brown rice; however, microbial contamination can occur during long soaking time. To shorten soaking time, warm water soaking is needed, and the higher the soaking temperature, the faster the rate of moisture absorption (Han & Lim, 2009). However, the softening effect on the cooked brown rice texture is not enough by only soaking. There are several trials that have been developed to reduce the cooking time and soften the texture of brown rice. As a physical method, heat treatment was devised by Hirokawa et al. (1986), which was to develop fissures in the bran layer by heating and immediate cooling. Through this fissures, moisture can readily penetrate into the endosperm so that cooking is also readily achieved, and the easy cooking was made only by sufficient absorbed heat energy (60 kcal or more per 1 kg of brown rice) was applied. Das, Banerjee, and Bal (2008) used xylanase and cellulase enzymes to decrease cooking time and increase water uptake ratio for brown rice, although the results were not satisfactory when compared with those of white rice (30 min vs. 18 min for cooking time, and 2.8 vs. 3.6 for water uptake ratio). Germination is another method for softening brown rice, and longer germination time could decrease the hardness of brown rice (Jiamyangyuen & Ooraikul, 2008); the hardness decreased from 46 to 30 kg by 12 h soaking and 25 h germination, however there was no comparison in texture between brown rice and milled rice in their report. So, there are still needs for textural improvement to resolve the low quality of brown rice after cooking.

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Ultrasound treatment has merits such as short processing time, high reproducibility, and lower energy consumption, so the treatment has been applied to several foods processing such as extraction, emulsification, homogenization, crystallization, filtration, separation, viscosity alteration, defoaming, and extrusion (Jambrak et al., 2010; Knorr, Zenker, Heinz, & Lee, 2004; McClements, 1995). The ultrasonic process has also been used with starches and other polysaccharides as an efficient processing method for solubilization, modification, and purification (Czechowska-Biskup, Rokita, Lotfy, Ulanski, & Rosiak, 2005; Iida, Tuziuti, Yasui, Towata, & Kozuka, 2008). Ultrasound treatment can affect the physico-chemical properties of starch in different ways depending on operation time, temperature, power, frequency, and the differences in the botanical origin (Czechowska-Biskup et al., 2005; Iida et al., 2008). As seen above, the most of studies on the effect of ultrasound have been performed in starch solutions. Cui, Pan, Yue, Atungulu, and Berrios (2010) applied ultrasonic treatment to brown rice and reported that cooking time reduced by 17% after treatment at 55 °C for 30 min, however there was no information about textual and nutritional changes of cooked brown rice by treatments in their report. The objective of this experiment is to improve the texture of brown rice by ultrasound treatment comparable to milled rice. The effect of soaking time before ultrasound treatment was also measured. By several preliminary experiments, we set two different ultrasound condition; mild (at 25 °C for 30 min) and harsh (at 50 °C for 60 min) treatments accompanied by different soaking time were applied to brown rice grains. After treatment, the textural and nutritional (thiamin, riboflavin, and niacin contents) properties of cooked brown rice were measured and compared with those of cooked milled rice. Because physical treatment to rice grains could induce change of starch molecules which is relevant to the texture of cooked rice (Cameron & Wang, 2005), the physico-chemical properties of isolated starch from the grains were also investigated.

2. Materials and methods

2.1. Materials

Japonica type brown rice (*Ilpum*) harvested in 2013 was purchased from the local market in Seoul. Standards for thiamine hydrochloride, riboflavin, and nicotinic acid (niacin) were purchased from Sigma–Aldrich Chemical Co., Ltd. (St. Louis, MO, USA) and all reagents for vitamin analysis were of HPLC grade (Fisher, Merck, Whitehouse Station, NJ, USA).

2.2. Ultrasound treatment (UT) and approximate water absorption

Brown rice grains (300 g) were soaked in distilled water (2 L) at room temperature for 2, 3, 5, or 8 h, and then the soaked grain was immersed for ultrasonic treatment (UT) in wire basket using a ultrasonic bath (Branson 5510 DTH, Branson Ultrasonics Corp. Danbury, CT, USA). The applied ultrasound frequency and input power were 400 kHz and 185 W, respectively.

Two different ultrasonic treatment conditions were set by preliminary experimental results which could make differences in the texture of brown rice: 30 min at 25 ± 2 °C (mild treatment, M, with 162 J/cm^3 input energy) and 60 min at 50 ± 3 °C (harsh treatment, H, with 333 J/cm^3 input energy). After UT, the basket was removed from the chamber and then drained for 10 min. To compare water absorption pattern between brown rice and milled rice, each rice kernels (20 g) was soaked in water (40 mL) for up to 24 h at room temperature. At regular time intervals, kernels were drained and quickly blotted with paper towels 6–7 times to remove residual surface moisture, weighed, and then expressed by water content (Lu, Siebernmorgen, & Archer, 1994). Approximate value of water uptake ratio was determined by measuring the weight difference before and after soaking followed by UT.

2.3. Starch isolation

From the brown rice soaked and ultrasound treated differently, starch was isolated using the alkali method (Lim, Lee, Shin, & Lim, 1999). Each batch of rice grains (100 g) was ground with 0.2% NaOH solution (300 mL). The slurry was stirred for 2 h and then precipitated. After remove the supernatant, the above procedure repeated three times. After remove the supernatant, the starch precipitate was resuspended in 100 mL of distilled water and neutralized to pH 7.0 by adding 0.1 N HCl solution. The starch dispersion was centrifuged (at 1800 × *g* for 15 min), and the starch residue was washed twice with distilled water and washed with 200 mL of 95% ethanol. The starch collected by centrifugation was dried at 40 °C for overnight. The starch isolated from brown rice soaked for the shortest soaking time (2 h) without UT was used as a control. To evaluate the purity of isolated starch, both of the total crude protein and total lipid contents were measured by Kjeldahl and Soxylet methods, respectively (AOAC, 2000).

2.4. Cooking

The weight ratio of each batch of rice (200 g) to water was set to 1:1.9, and then cooked in an automatic electric rice cooker (CR-0632FV, CUCKOO, Yangsan, Korea). The cooking procedure was automatically controlled by the cooker which automatically switched off when cooking was done. For comparison, both of milled rice and brown rice soaked for 2 h at room temperature without UT were used. The experiment was repeated for three times.

2.5. Texture measurement

The textural properties of cooked brown rice were measured using a texture analyzer (TX-XT2, Stable Micro Systems, UK). 5 g of cooked rice on each batch was transferred to the cylinder shaped container (3 × 0.7 cm) and spread evenly. TPA test was performed at 2.0 mm/s using a cylinder probe (20 mm diameter). The distance was 75%, and the force threshold was 5.0 g. Ten measurements were performed on each sample.

2.6. Determination of the thiamin, riboflavin, and niacin contents

Sample preparation was according to Agilent Technologies (2001). Ultrasound treated brown rice (15 g) was homogenized (IKA-T 25 digital ULTRA-TURRAX, Staufen, Germany) with 20 mL 0.1 N HCl for 1 min and then centrifuged at 700 × *g* for 10 min. The supernatant was filtered through a 0.45 μm PTFE syringe filter. Measurements were performed using an Ultimate 3000 HPLC System (Thermo Fisher Scientific Co., Ltd., MA, USA) and an Acclaim 120 column (C18 5 μm, 6 × 150 mm, Dionex, Sunnyvale, CA, USA), and the column and sample were maintained at ambient temperature. The instrumentation details are: quaternary pump; vacuum degasser; a 10 mL injection loop and an FLD-UV detector, controlled by HP ChemStation software; mobile phase: water (containing 0.1% formic acid)/acetonitrile 95: 5; detection at 254 nm; flow 1.0 mL/min. Calibration curve was prepared using standard materials dissolved in 0.1 N HCl. Three measurements were conducted for each experimental parameter. For comparison, the three kinds of vitamin contents of milled rice were measured with same method. Three measurements were conducted for each experimental parameter.