Journal of Cereal Science 74 (2017) 121–126

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

Soaking time of rice in semidry flour milling was shortened by increasing the grains cracks

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ARTICLE INFO

Article history:
Received 7 July 2016
Received in revised form
17 January 2017
Accepted 21 January 2017
Available online 25 January 2017

Keywords:
Soaking time
Magnetic resonance images
Semidry-milling
Grains cracks

ABSTRACT

To shorten the soaking time of rice grains in the process of semidry-milling, the changes in moisture absorption, damaged starch, and magnetic resonance images during soaking, as well as effect of increasing grains cracks on moisture absorption were investigated. As the results, the soaking time to reach the maximum moisture of Glutinous and Indica rice grains was 40 min and 20 min, respectively, but was 3 h and 30 min to reach the minimum damaged starch contents in rice flour. The moisture penetrated quickly from the embryo attachment site, ventral side, and cracks into the inside, and then diffused through the cracks. The result showed that homogeneous distribution of moisture in the rice grains was necessary to reduce damaged starch. Moreover, owing to the increase of grains cracks, the soaking time of Glutinous and Indica rice grains was shortened from 3 h to 1 h, and from 30 min to 10 min, respectively, by increasing drying temperature to 60 °C.

1. Introduction

Sweet dumplings produced from Glutinous rice and rice noodles produced from Indica rice as traditional rice products are widely consumed because of their unique taste. The processing of these products is still traditional in China (Lu et al., 2005; Chen et al., 2010). In material processing stage of this traditional process, wet-milling of rice with an overnight soaking in water is commonly used (Chiang and Yeh, 2002; Fu, 2008; Zhu et al., 2010). This process can get a good taste, but the long soaking time results in a risk of harmful bacterial growth and some environmental problems caused by wastewater discharges (Charles et al., 2007). Numerous studies indicate that the dry-milled rice flour shows higher content of damaged starch; lower whiteness; poorer properties of pasting and hydration in comparison to wet-milled rice flour; and thereby leading to it cannot be used in traditional rice products processing (Kumar et al., 2008; Heo et al., 2013; Asmeda et al., 2016). To eliminate the adverse effects of dry-milling on characteristics of rice flour and its products qualities, two previous studies were performed to focus on the semidry-milling method of polished Japonica Glutinous rice and Indica rice (Tong et al., 2015, 2016). The semidry-milling at 33% moisture by soaking 24 h showed better characteristics of Glutinous rice flour and better qualities of sweet dumplings by reducing the degree of starch damage and protecting the integrity of the starch granules to the same level as wet-milled rice flour (Tong et al., 2016). Similarly, quality of rice noodles produced by the semidry-milled rice flour at 30% moisture by soaking 24 h was much better than that of the dry-milled rice noodles, and was comparable to that of the wet-milled rice noodles (Tong et al., 2015).

Although there is no wastewater, the 24 h soaking time of semidry-milling in the two previous studies is so long that it probably increase the risk of harmful microbes. In addition, the long soaking time is not conducive to large-scale industrial continuous milling process. Therefore, the present study focused on how to shorten the soaking time in the process of semidry-milling. To shorten the soaking time, the penetration and distribution of moisture in rice grains during soaking was observed by a technique of magnetic resonance imaging (MRI) (Horigane et al., 2006, 2013; Hong et al., 2009), and characterized by profile of nuclear magnetic resonance (NMR) signal intensities. Horigane et al. (2014) reported

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http://dx.doi.org/10.1016/j.jcs.2017.01.011
0733-5210/

that the water penetrated quickly from the ventral side and embryo attachment site to the inside, and then diffused through transverse cracks. This finding indicated that increase of grains cracks might be able to accelerate water penetration, thereby shortening the soaking time. However, whether the increase of rice grains cracks can shorten the soaking time and maintain the content of damaged starch in rice flour not to increase is still unknown.

In the present study, the changes in moisture absorption of rice grains of Glutinous and Indica and damaged starch content of rice flour during different soaking time were measured. The magnetic resonance (MR) images of rice grains during soaking were observed. Furthermore, effects of increased grains' cracks induced by drying to shorten the soaking time of semidry-milling on the moisture absorption of rice grains and on the damaged starch content of rice flour were measured.

2. Materials and methods

2.1. Materials

The materials used in the present study were polished Japonica Glutinous rice of the *New fragrant glutinous rice* variety (harvested in 2014.10, polished at a yield of 85%) and polished early Indica rice of the *Hunan fragrant rice* variety (harvested in 2014.08, polished at a yield of 85%) which were provided by Henan Huangguo Cereals Industry Co., Ltd. (Xinyang, China) and Hunan Jinjian Cereals Industry Co., Ltd. (Changde, China), respectively. The Glutinous rice contained 90.48 $\pm$ 0.34% total starch, 1.73 $\pm$ 0.10% amylose, 7.34 $\pm$ 0.12% proteins, 1.02 $\pm$ 0.09% crude fat, and 0.27 $\pm$ 0.05% ash. The Indica rice contained 88.39 $\pm$ 0.45% total starch, 24.02 $\pm$ 0.22% amylose 6.11 $\pm$ 0.17% proteins, 1.62 $\pm$ 0.13% crude fat, and 0.36 $\pm$ 0.05% ash. All results were reported on a dry weight basis, and all chemical compositions of rice were determined based on dry basis in triplicate for each rice sample.

2.2. Determination of basic chemical components

The total starch content was determined using a Total Starch Assay Kit (JKY/K-TSTA 07/11, Megazyme International Ltd., Wicklow, Ireland) by the American Association for Clinical Chemistry (AACC) approved method 76.13. The amylose content was determined using an Amylose/Amylopectin Assay Kit (JKY/K-AMYL 07/11, Megazyme International Ltd., Wicklow, Ireland). Total nitrogen content of rice was determined by Kjeldahl method using a Kieltec analyzer (Foss Tecator AB, Höganäs, Sweden), and a conversion factor of 5.95 was used to estimate the protein content (AOAC, 984.13). The crude fat of rice was determined using the analytical method of Association of Official Agricultural Chemists (AOAC, 945.16).

2.3. Determination of moisture absorption rate of rice

Five grams of rice grains were weighed (W_0), and steeped in 50 mL deionized water at 25 °C. At selected interval, grains were weighed (W_1) again after rubbing with filter paper to remove the water attached at the surface of grains. Moisture absorption rate was calculated by the following formulae.

$$\text{Moisture absorption rate } (\%) = (W_1 - W_0)/W_0 \times 100$$

2.4. Preparation of semidry-milled rice flour

The preparation of semidry-milled rice flour was carried out according to our previous study (Tong et al., 2015). For semidry-milled flour, 200 g polished rice grains (15% moisture content) were steeped in 1 L deionized water at 25 °C. At selected interval, grains were collected, and quickly rubbed with filter paper to remove any water attached at the surface. The rice grains were ground into flour using a cyclone mill and passed through 100 mesh sieve (CT410, FOSS Scino (Suzhou) Co., Ltd., Suzhou, China). All rice flours were freeze-dried to obtain the rice flours with 5% moisture and stored at 4 °C for further analysis.

2.5. Determination of damaged starch content

Changes in damaged starch content of semidry-milled rice flour of Glutinous and Indica during soaking at different times were measured using the enzymatic colorimetric method with a Starch Damage Assay Kit (K-SDAM, Megazyme International Ltd., Wicklow, Ireland).

2.6. MRI measurement

Moisture distributions in rice grains were measured according to a published method with some modifications (Horigane et al., 2013). A MRI system equipped with a 500-MHz high-resolution NMR spectrometer (Magnet System 500 Ascend, Bruker, Karlsruhe, Germany) with a vertical 11.74 T magnet was used. The microimaging system was operated with NMR Software (Version: TopSpin 3.2 pl 5, Bruker). Soaked an individual grain was held on a thin plastic plate in a 5 mm (o.d.) NMR tube, and an MR image was measured immediately. Measurement conditions were as follows: Repetition time = 3.0 ms; Echo time = 1.5 ms; Flip angle = 50°; Field of view = $6 \times 10 \times 6$ mm^3; Matrix size = $120 \times 200 \times 24$; Acquisition time = 3 m 50 s 400 ms; Spatial resolution = $65 \times 65 \times 50$ μm^3. The original data was processed using 3D slicer Software (Version: 4.5). MRI measurements were repeated for three soaked grains from each sample.

2.7. NMR signal intensity

NMR signal intensities in rice grains were measured according to a published method with some modifications (Horigane et al., 2014). NMR signal intensities were obtained from the center position of a rice grains. In these MR images, NMR signals derived from the original moisture of rice grains were eliminated by image processing. The NMR signal intensities for each time points were averaged for three grains.

2.8. Drying and milling of rice grains

The rice grains were dried at 40 °C and 60 °C for 10 min, 20 min, and 30 min, respectively. For dry-milled flour, dried rice grains was ground into flour using a cyclone mill and passed through 100 mesh sieve (CT410, FOSS Scino (Suzhou) Co., Ltd., Suzhou, China).

2.9. Preparation of glutinous rice dumplings and Indica rice noodle

The Glutinous rice dumplings were prepared according to a reported method of Tong et al. (2016). The rice noodles were prepared according to a reported method using a GY-MF rice noodle machine (Guangzhou National Institute Machinery Equipment Manufacturing Co., Ltd., Guangzhou, China)(Tong et al., 2015).

2.10. Texture profile analysis (TPA) and cooking qualities of products

The texture profile of the Glutinous rice dumplings and Indica