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Effect of germination time on physicochemical properties of brown rice flour and starch from different rice cultivars

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ABSTRACT

The present work was designed to obtain information on the effect of germination time on the selected physicochemical properties of brown rice flour and starch prepared from three different rice cultivars. Changes in total starch, amylose and amylopectin contents of flour, amylopectin/amylose ratio and molecular weight of starch, gelatinization, pasting, rheological, and morphological properties of flour and starch during 5 days of germination were investigated. Significant changes of pasting and rheological properties of brown rice flour were found during germination, but only small changes of these properties could be found in isolated starch. Scanning electron micrographs of flour showed that the continuous matrix structure of flour was highly destroyed after germination and scanning electron micrographs of isolated starch showed that after three days of germination, pits and holes were discovered on the surface of some starch granules. Germination had little effect on the average molecular weight of starch, but the polydispersity value in germinated brown rice (2–5 days germination) was higher than that in non-germinated brown rice. The changes observed in physicochemical properties of brown rice flour and starch after germination provided a crucial basis for understanding flour and starch modification mechanisms with potential applications for an industrial scale.

1. Introduction

Rice is a major cereal crop and the staple food for half of the world's population. Brown rice (BR) is hulled directly from rough rice, which contains more nutritional components than ordinary milled rice (Lamberts et al., 2007). In spite of the elevated content of nutritional components, brown rice is not considered a suitable table rice due to its poor texture, off-putting bran odor, and the not-easy-to-cook characteristic (Komatsuzaki et al., 2007). Germinated brown rice (GBR) is produced by soaking brown rice grain in water until it germinates. The decomposition of the high-molecular-weight polymers during germination leads to the generation of bio-functional substances and the improvement of organoleptic qualities due to softening of texture and an increase in the amount of flavor components (Ohtsubo et al., 2005; Wu et al., 2011). In our previous review, we have summarized the changes in nutritional components during brown rice germination and the health benefits of germinated brown rice (Wu et al., 2013). The numerous health benefits obtained from GBR consumption include antihyperlipidemia, antihypertension, psychosomatic health effect, and the reduction in the risk of some chronic diseases, such as cancer, diabetes, cardiovascular disease, and Alzheimer's disease (Wu et al., 2013).

Recently, much attention has been paid to the study of nutritional components in GBR. However, information regarding the effect of germination on physicochemical properties of brown rice flour and starch is relatively limited. Xu et al. (2012) evaluated the changes in some characteristics of BR flour and starch after 24 h of germination, but only one rice cultivar was investigated and no further comparison of different germination stages was made by them. It is noted that the germination process increases the quantity of most nutritional compounds through endogenous enzyme activation, and the amounts of most active components, such as dietary fiber, γ-aminobutyric acid, γ-oryzanol, ferulic acid, and most free amino acids, increased by prolonging germination time (Jannoey et al., 2010; Ohtsubo et al., 2005; Roohinejad et al., 2010). As most chemical components changed as germination

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proceeded, and the prolonging of germination time led to an increase in the bioactive components, thus a comparison of the differences in physicochemical properties among GBR from different germination stages is necessary. This can provide reference information for better use of GBR as the main material or in combination, considering their nutritional properties and physicochemical properties to develop new food products. In addition, as rice cultivars are categorized according to amylose content into three groups: low, medium and high amylose content cultivars and different rice varieties differ in physicochemical properties, simultaneous studies of the effect of germination time on these three types of rice cultivars can provide more comprehensive information.

The objective of this study was to evaluate changes in physicochemical properties of brown rice flour and starch during 5 days of germination for three different rice cultivars, to provide reference information for GBR food product development.

2. Materials and methods

2.1. Materials

Three Chinese rice cultivars, Zhengxian (a long-grained indica cultivar which belongs to the high amylose content cultivars, designated as ZX), Nanjing (a medium-grained japonica cultivar which belongs to the medium amylose content cultivars, designated as NJ), and Yannuo (a medium-grained waxy cultivar, designated as YN) were purchased from Wuxi Xuelang grain management (Jiangsu, China).

2.2. Preparation of germinated brown rice

Germination of BR was carried out by the method of our previous paper (Wu et al., 2011). 5 levels of germination time (1, 2, 3, 4, and 5 days) were investigated. Rice grains were dehusked by a grain sheller (JGMJ8098, Shanghai Jiading Oils and Grains Apparatus Co. Ltd., China) and cleaned manually to remove disfigured and other extraneous materials. Brown rice grains were sterilized in 0.1% sodium hypochlorite for 30 min, followed by a thorough washing in deionized water. The germination of brown rice was conducted by soaking the brown rice grains in deionized water at a controlled temperature of 25 °C in the dark. The soaking water was changed every 6 h. Samples were taken on the 1st, 2nd, 3rd, 4th, and 5th days of germination. After reaching the required germination period, the grains were dried at 50 °C to a moisture content of $14 \pm 2\%$. The rice grains were ground into fine flour using a mill, and the non-germinated brown rice was pulverized into flour that served as the control. All samples passing through a 100-mesh sieve were packed in hermetically sealed plastic bags and stored at 4 °C until used.

2.3. Extraction of rice starch

The isolation of starch from rice flour was performed according to the method described by Lin and Chang (2006) involving steeping rice flour in 0.1% NaOH solution. The isolated starch was dried in an oven at 40 °C for about 24 h to produce a moisture content close to that of rice flour (about 14%). The dried starch was ground into powder and screened through a 100-mesh sieve.

2.4. Determination of total starch content and amylopectin/amylose ratio

The total starch and amylose content of flour was determined using the Megazyme amylose and amylopectin assay kit (Megazyme International, Wicklow, Ireland) according to the procedure described by Gibson et al. (1997). Amylopectin content was calculated as total starch content minus amylose content, so that the amylopectin/amylose ratio could be calculated.

2.5. Differential scanning calorimetry measurement (DSC)

Thermal properties of rice flour and starch were analyzed using a Pris 1 DSC (Perkin–Elmer Inc., USA) under an ultrahigh purity nitrogen atmosphere. Rice flour or starch (3 mg) was weighed into an aluminum pan and deionised water (6ul) was added. Samples were hermetically sealed and allowed to stand for 12 h at room temperature before testing. An empty pan was used as a reference, and the system was calibrated with indium. Scans were performed from 25 to 100 °C at a controlled constant rate 10 °C/min. The gelatinization enthalpy (ΔH) and transition temperatures, namely the onset temperature (To), peak temperature (Tp), and conclusion temperature (Tc), were determined, based on the DSC heating curves.

2.6. Determination of pasting properties

The pasting properties were determined with a Rapid Visco-Analyzer (RVA-4, Newport Scientific Pvt. Ltd, Warriewood, Australia). Rice flour or starch (6% w/w, dry basis) was dispersed in 25 ml distilled water in a RVA canister. The slurry was mixed at 960 rpm for 10 s to allow thorough dispersion; then the speed was reduced to 160 rpm for the remainder of the run. The heating and cooling cycles were programmed in the following manner. The slurry was held at 50 °C for 1 min, heated to 95 °C within 3.5 min and then held at 95 °C for 3 min. It was subsequently cooled to 50 °C within 3.5 min and then held at 50 °C for 2 min, while maintaining a rotation speed of 160 rpm. The parameters recorded were peak viscosity, trough viscosity, final viscosity, breakdown, and setback. All measurements were done in triplicate.

2.7. Rheological measurement

Rice flour or starch gels were prepared by mixing the rice flour or starch samples (5 g) with deionised water (10 ml) and then heating the mixture in a boiling water bath for 30 min with mild agitation provided by a magnetic stirrer. Dynamic viscoelastic properties of the freshly prepared rice flour and starch gels were measured using a dynamic rheometer (Carri-Med CSL2-100, TA Instruments Ltd, Surrey, UK) equipped with a parallel plate system (4 cmdia). The gap size was set at 500 mm and the instrument was set at 25 °C. Rheological properties such as elastic modulus (G') and viscous modulus (G'') were measured at 1% strain and frequency of 0.1–10 HZ.

2.8. Scanning electron microscopy (SEM)

Morphological properties of the samples were studied using a scanning electron microscope (Quanta-200, FEI Company, Netherlands). Dried, finely ground samples were mounted on an aluminum stub using a double-sided stick tape and were coated with a thin film of gold (10 nm). An accelerating potential of 5 kV was used during micrography.

2.9. Molecular weight distribution analysis

The molecular weight distribution of starches was determined by high-performance size-exclusion chromatography (HPSEC) equipped with multi-angle laser-light scattering (MALLS) and refractive index (RI) detectors according to the method described