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Effect of dry- and wet-milled rice flours on the quality attributes of gluten-free dough and noodles

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ABSTRACT

The rheological and cooking properties of gluten-free noodles prepared with dry- and wet-milled rice flours were characterized. Dry-milled rice flour with a higher degree of starch damage exhibited greater water hydration properties than wet-milled rice flour at room temperature. However, the pasting results of rice flour suspensions demonstrated that wet-milled rice flour showed a higher value of peak viscosity due to its great swelling power upon starch gelatinization. The similar thermo-mechanical tendency was observed in a rice dough system by Mixolab. In the planar extensional test, the noodle dough sample prepared with dry-milled rice flour exhibited higher elongational viscosity which could be favorably correlated to more resistance of dry-milled rice noodle strands to extension. When rice noodles were cooked, increased cooking loss was observed in dry-milled rice noodles which was attributed to great water solubility derived from a higher degree of starch damage.

1. Introduction

Recently, there are increasing consumer demands for gluten-free products due to their beneficial health effects such as reduced risk of celiac diseases and allergic reactions (Torbica et al., 2010). Thus, the non-wheat diets prepared with rice, buckwheat, and corn have been recommended for celiac patients. Specially, rice has been widely used as a primary gluten-free flour base for scientific and industrial purposes (Demirkesen et al., 2010; Park et al., 2012). However, there is still a challenge to formulate gluten-free products with rice because rice flour does not have the functionality of wheat gluten, which is called an essential structural protein (Gallagher et al., 2004). It has been recognized that rice dough has low elastic property, weak resistance to stretch, and poor mixing tolerance (Cham and Suwannaporn, 2010), negatively contributing to the formation of a cohesive and viscoelastic dough structure. Therefore, a great deal of effort has been made to produce rice foods comparable in quality to wheat-based products. However, the primary research focus of gluten-free foods has been placed on baked products such as bread. Therefore, there is a need to pay more extensive attention to other types of food products such as noodles which are the second most consumed foods in the world, next to bread (Jayasena et al., 2008).

Noodles are regarded as a part of the main diets in many Asian countries and also become popular in other countries outside of Asia (Fu, 2008). Noodles can be made from various cereal flours such as wheat, rice, buckwheat, and so on. Noodles, specifically wheat-based noodles are generally prepared by mixing raw materials, dough sheeting, and cutting (Kruger et al., 1996). On the other hand, rice noodles are produced in two ways – extrusion (vermicelli) and sheeting of a rice batter (flat rice noodles) (Fu, 2008). The relatively poorer cohesive and extensible textural properties of rice noodles compared to wheat-based noodles are probably due to the absence of gluten. Thus, several trials have been made to improve the noodle-making property of rice flour by adding hydrocolloids such as soluble oat bran fiber, locust bean gum, and xanthan gum (Inglett et al., 2005; Yalcin and Basman, 2008). Rice flour was also subjected to hydrothermal treatments (Cham and Suwannaporn, 2010; Hormdok and Noomhorm, 2007) which might partially compensate for the role of gluten by increasing the binding of rice flour particles. In addition, there has not been comprehensive analysis on the fundamental factors to affect the quality attributes of rice noodles as compared with wheat-based noodles. Specially, most rheological studies on rice noodles were carried out by using typical instrumental methods such as tensile and TPA (texture profile analysis) measurements by a texture analyzer (Bhattacharya et al., 1999; Lu et al., 2003). More detailed systematic rheological approaches are therefore necessary to elucidate the role of rice flour in a dough system for noodle-making. Recently, a new thermo-rheological instrument called Mixolab has been introduced in the area of cereal science

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(Kahraman et al., 2008; Rosell et al., 2007). However, there is still limited information on the thermo-mechanical properties of rice flour in a dough system by Mixolab.

In this study, two rice flours were prepared from dry- and wet-milling and their physicochemical properties were then evaluated and compared. Also, they were utilized to produce gluten-free rice noodles of which rheological, textural, and cooking properties were investigated.

2. Materials and methods

2.1. Preparation of dry- and wet-milled rice flours

Polished rice (Shindonjin variety, harvested in 2011) was obtained from a commercial source. For dry-milled flour, the rice kernels were ground into flour by using a roller mill (SJ-201, Shinwoo Machinery co., Incheon, Korea) and then subjected to air-jet milling (ACM-500, Hankook Crusher co., Incheon, Korea). In the case of wet-milled flour, the rice was steeped in water at 25 °C for 4 h, ground by the same roll mill, and then dried in an oven at 40 °C for 24 h, followed by air-jet milling. Both rice flours were passed through a 100 mesh sieve (Chung Gye Inc., Seoul, Korea), packed in airtight plastic bags, and stored at 4 °C until further analysis. All chemicals used in this study were of analytical grade.

2.2. Physicochemical characterization of rice flour

2.2.1. Starch damage

The degree of starch damage of rice flour was measured by the enzymatic colorimetric method with a Megazyme starch damage kit (Megazyme International Ltd., Wicklow, Ireland).

2.2.2. Water hydration properties

The water hydration properties of dry- and wet-milled rice flours and their mixture (5:5) were investigated based on the method of Ohishi et al. (2007) with modifications. Rice flour (0.1 g) was mixed with distilled water (20 mL), agitated at 25 and 100 °C for 30 min, and then centrifuged at 15,000g for 30 min. The supernatant was dried in an oven at 105 °C until the constant weight was obtained. Water absorption index (WAI), water solubility (WS), and swelling power (SP) were calculated by the following equations (Lai and Cheng, 2004):

$$\text{WAI} = \text{wet sediment weight}/\text{dry sample weight}$$

$$\text{WS}(\%) = \text{dry supernatant weight}/\text{dry sample weight} \times 100$$

$$\text{SP} = \text{wet sediment weight}/[\text{dry sample weight} \times (1 - \text{WS}(\%)/100)]$$

2.2.3. Pasting profiles

The pasting properties of dry- and wet-milled rice flours and their mixture (5:5) were determined using a starch pasting cell attached to a controlled-stress rheometer (AR1500ex, TA Instruments, New Castle, DE, USA). Rice flour was added in an aluminum canister with distilled water to produce a 28 g suspension (10.7%, w/w) of which viscosity was monitored during the programmed heating–cooling cycle. The rice flour suspension was equilibrated at 50 °C for 1 min, heated to 95 °C at a rate of 12 °C/min, held at 95 °C for 2.5 min, cooled to 50 °C at a rate of 12 °C/min, and held at 50 °C for 5 min.

2.2.4. Thermo-mechanical properties

The thermo-mechanical properties of dry- and wet-milled rice flours and their mixture (5:5) were investigated by using a Mixolab (Chopin, Tripetteet Renaud, Paris, France). Rice flour was loaded into the Mixolab bowl and mixed with distilled water to produce 90 g of rice dough (70% water absorption). The dough sample was subjected to dual-mixing (120 rpm) during a programmed heating and cooling cycle where it was held at 30 °C for 8 min, heated to 90 °C at 4 °C/min, maintained at 90 °C for 7 min, cooled to 50 °C for 4 °C/min, and allowed to stand at 50 °C for 10 min.

2.3. Characterization of rice dough and noodles

2.3.1. Preparation of rice dough and noodles

Rice noodles were prepared by mixing rice flour (300 g), NaCl (3 g), and xanthan gum (3 g), according to the formulation of Yalcin and Basman (2008) with modifications. Distilled water was added to obtain a total water content of 42% which was determined from preliminary experiments. Salt and xanthan gum were dissolved in distilled water which was mixed with rice flour by using a KitchenAid mixer (St. Joseph, MI, USA) for 10 min. The mixture was transferred to a laboratory noodle machine with single screw (La Monferrina, Asti, Italy) and then extruded through multiple opening (3 mm diameter) in a circular die.

2.3.2. Planar extensional properties

The extensional property of rice noodle dough was investigated by a texture analyzer (TMS-Pro, Food Technology Co., Virginia, USA) calibrated with a 25 N load cell. Based on the formulation of rice noodles, all ingredients were mixed at speed 1 for 10 min by using a KitchenAid mixer (St. Joseph, MI, USA), followed by hand-kneading for 2 min. The dough was loaded into a dough sheeter (1.4 mm thickness) and then cut with a cookie cutter (5 cm diameter). According to the method of Morgenstern et al. (1996) with slight modifications, dough sheet was placed between two Plexiglas plates with a circular hole (3 cm diameter) in the center and was deformed by lowering a cylindrical probe (1 cm) at a crosshead speed of 100 mm/min.

2.3.3. Tensile properties

The tensile properties of extruded rice noodle stands were investigated by using a Kieffer dough and gluten extensibility rig on a texture analyzer (Katagiri and Kitabatake, 2010). While a single strand of each noodle sample was stretched with the hook at a speed of 3.3 mm/s, the maximum force and distance at the extension limit were obtained.

2.3.4. Cooking properties

The cooking qualities of rice noodles were determined according to the method of Lee et al. (2008). After rice noodles (5 g, 5 cm length) were boiled in distilled water (150 mL) for 10 min, they were allowed to drain for 5 min by using a strainer and the cooked water was collected. After the volume of the cooked water was adjusted to 200 mL with distilled water, the collected water (10 mL) in an aluminum dish was dried in an oven (105 °C) and weighed. Cooking loss was obtained from the solid loss during cooking. In addition, the turbidity of the solution was measured at 675 nm. In the case of water absorption, it was obtained from the weight differences of noodles before and after cooking as follows;

$$\text{Water absorption}(\%) = \frac{\text{Weight of cooked noodles} - \text{Weight of uncooked noodles}}{\text{Weight of uncooked noodles}} \times 100$$

2.4. Statistical analysis

Five measurements of planar extensional and noodle tensile properties were conducted and other experiments were carried