Effects of Water Soaking on Bread-Making Quality of Brown Rice Flour

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We found that brown rice flour produced using a jet mill after soaking for more than 12 h yielded a better formulation of rice/gluten bread, giving an equivalent specific loaf volume (SLV) as bread made with white rice flour. Quality analysis of the brown rice flour showed that soaking for more than 12 h resulted in a lower damaged starch content. There was a significant inverse correlation between damaged starch content and SLV. Substitution of 10% white rice flour with rice bran had little effect on final SLV. Furthermore, endogenous α-amylase activity in brown rice flour produced after soaking was approximately 5 to 12 times higher than that of white rice flour, but there was no correlation with SLV. These results indicate that the improved SLV in brown rice/gluten bread was predominantly due to the decrease in damaged starch content, which depends on soaking time.

Keywords: rice bread, brown rice flour, water soaking, damaged starch

Introduction

Rice (Oryza sativa L.) is an important source of nutrition and energy, and is one of the most suitable cereal grains used for preparing foods. Rice flour can be used as a wheat flour substitute and processed into bread. However, rice storage proteins do not possess the viscoelastic properties that are typical of wheat gluten. In wheat, gliadins (prolamins) are responsible for the dough’s cohesiveness, while the glutelins (glutelins) are apparently responsible for the dough’s resistance to extension (Hoseney, 1994). The gluten network constructed by these two proteins provides the dough with unique viscoelastic properties and the ability to retain gases, making it a good quality raw material for the production of yeast-leavened products. However, rice flour lacks these properties; hence, the qualities of gluten-free rice bread and wheat-rice bread with a high proportion of rice flour are generally inferior.

Rice flour is used for bread-making in three flour mixtures: rice/wheat flour; rice flour/vital gluten; and gluten free. It has been reported that in the case of rice/wheat flour bread, substitution of wheat flour with up to 30% rice flour is acceptable without compromising the sensory qualities (Watanabe et al., 2004; Nakamura et al., 2009). There have been few reports on bread-making quality with the addition of vital gluten to rice flour (Yamauchi et al., 2004; Araki et al., 2009; Aoki et al., 2010). The enzymatic processing of rice flour in gluten-free bread has been investigated in order to further improve the bread-making performance by promoting protein cross-linkage with transglutaminase (Gujral and Rosell, 2004; Renzetti et al., 2008) or protein hydrolysis via protease treatment (Renzetti and Arendt, 2009). Recently, improvements in gluten-free bread by addition of glutathione to rice batter have also been reported (Yano, 2010).

Brown rice provides more desirable nutritional properties and biofunctional components such as inositol, dietary fiber and gamma aminobutyric acid (GABA), as compared with white rice (Ohtsubo et al., 2005). The content of GABA, an important non-protein amino acid, in pre-germinated brown rice is twice that in ordinary brown rice and ten times that in white rice (Saikusa et al., 1994). However, the use of brown rice flour with wheat and/or gluten as an ingredient in bread-making remains limited (Okadome et al., 2007), as it has a tendency to prevent dough-rising when compared with white rice flour.

To date, although some studies have investigated the effects of germination on the quality of brown rice bread, the reasons for the lack of rising in rice flour/gluten bread made with brown rice flour remain unclear. Efficient low-cost milling methods to produce high quality flour from brown rice are thus necessary. In this study, we evaluated the effects of water soaking on the flour and bread-making properties of brown
brown rice.

Materials and Methods

Rice flour Rice of the cultivar Koshihikari, grown in an experimental field at the National Institute of Crop Science (Tsukuba, Japan) and harvested in 2009, was used to produce flour samples in this study. Brown rice and white rice as controls were used. Rice was washed with water, and 3 kg of each was soaked in excess water (> 20 L) at room temperature (25°C). The soaking water was changed every 12 h. Brown rice grains were sampled after 2, 5, 12, 24, 36 and 48 h of soaking. White rice grains having the outside 10% removed as rice bran were soaked for 2 h. Soaked rice was then drained and ground using a jet mill (SPM-R290; Nishimura Machine Works Co., Ltd., Osaka, Japan) under wet conditions without excess water. The flour was dried in a dryer at a controlled temperature of 60°C overnight.

Analysis of flour properties Damaged starch content was determined according to the method of the American Association of Cereal Chemists (AACC method 76 – 31, 2000) using a starch damage assay kit (Megazyme International Ireland, Ireland). The flour particle size distribution and median particle size were measured using a particle size analyzer (LS 13 320; Beckman Coulter, Fullerton, CA). Moisture content was calculated as a measure of weight loss after drying at 135°C using a moisture meter (MA35; Sartorius Mechatronics Japan, Tokyo, Japan). An α-amylase assay of rice flour samples was carried out using a kit for the assay of cereal α-amylase (Ceralpha; Megazyme International Ireland, Ireland). The flour particle size distribution in the crumbs. These observations suggest that bread crumbs with larger gas pores, which are assumed to be due to increased fermentation by α-amylase, have a positive effect on the hardness and texture of brown rice bread.
in white rice bread (GABA, not detectable; inositol, 20 mg; γ-oryzanol, 0.6 mg; ferulic acid, 3.9 mg; and dietary fiber, 0.7 g). These data indicate that the biofunctional components of brown rice were elevated by soaking and were present in the final product.

Quality of soaked brown rice flour

The moisture content of rice flours was in the range of 6.8% to 10.3% (Table 1). As the desired value for wheat flour is ≤ 14% (Atwell, 2001), the rice flours used in this study appeared to be adequately dry.

Brown rice flours milled after 12 h of soaking showed little difference in damaged starch content (1.9% to 2.3%), which was similar to that of white rice flour (Table 1). Our data indicate a strong association between the SLV of brown rice/gluten breads increased with soaking time (Fig. 1). The lowest SLV was 3.24 cm³/g in 2-h soaked brown rice, which is a generally sufficient time for white rice (4.12 cm³/g). The flour from rice soaked for 5 h still resulted in insufficient bread swelling (3.58 cm³/g), and the SLV remained within the range 3.94–4.04 cm³/g with flour prepared after 12 h of soaking (Table 1). A significant negative correlation was confirmed between the SLV and the damaged starch content, as discussed below.

It has been reported that germinated brown rice provides higher levels of biofunctional components such as inositol, dietary fiber and GABA, as compared with white rice (Ohtsubo et al., 2005). We also analyzed some biofunctional components in rice/gluten bread prepared from brown rice milled after 24 h of soaking. The amounts of various biofunctional components (GABA, 5.0 mg; inositol, 96 mg; γ-oryzanol, 9.8 mg; ferulic acid, 14 mg; and dietary fiber, 2.0 g) in 100 g of brown rice bread were significantly higher than those in white rice bread (GABA, not detectable; inositol, 20 mg; γ-oryzanol, 0.6 mg; ferulic acid, 3.9 mg; and dietary fiber, 0.7 g). These data indicate that the biofunctional components of brown rice were elevated by soaking and were present in the final product.

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The damaged starch content of brown rice flours showed a gradual decline with increased soaking time. In this study, the flour made from rice soaked for 2, 5 and 12 h had 9.7%, 7.4% and 2.2% damaged starch contents, respectively. Brown rice flours milled after 12 h of soaking showed little difference in damaged starch content (1.9% to 2.3%), which was similar to that of white rice flour (Table 1). Our data indicate a strong association between the SLV of brown rice/gluten breads increased with soaking time (Fig. 1). The lowest SLV was 3.24 cm³/g in 2-h soaked brown rice, which is a generally sufficient time for white rice (4.12 cm³/g). The flour from rice soaked for 5 h still resulted in insufficient bread swelling (3.58 cm³/g), and the SLV remained within the range 3.94–4.04 cm³/g with flour prepared after 12 h of soaking (Table 1). A significant negative correlation was confirmed between the SLV and the damaged starch content, as discussed below.

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### Table 1. Summary of rice flour and bread properties.

<table>
<thead>
<tr>
<th>Soaking time (h)</th>
<th>Moisture content (%)*</th>
<th>Damaged starch content (fw%)**</th>
<th>Median particle size (µm)*</th>
<th>α-amylase activity (mU/g flour)**</th>
<th>Specific loaf volume (cm³/g)**</th>
<th>Hardness (g)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>White rice</td>
<td>2</td>
<td>10.3</td>
<td>2.0 ± 0.1 c</td>
<td>21.8</td>
<td>14.1 ± 0.1 g</td>
<td>4.12 ± 0.05 a</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7.7</td>
<td>9.7 ± 0.4 a</td>
<td>76.5</td>
<td>101.8 ± 0.2 c</td>
<td>3.24 ± 0.06 c</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>8.8</td>
<td>7.4 ± 0.2 b</td>
<td>68.8</td>
<td>72.9 ± 0.3 f</td>
<td>3.58 ± 0.10 b</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>8.1</td>
<td>2.2 ± 0.0 c</td>
<td>53.7</td>
<td>75.2 ± 0.3 e</td>
<td>3.94 ± 0.13 a</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>6.9</td>
<td>2.3 ± 0.0 c</td>
<td>50.1</td>
<td>86.1 ± 0.3 d</td>
<td>4.03 ± 0.04 a</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>7.9</td>
<td>2.1 ± 0.1 cd</td>
<td>51.2</td>
<td>128.4 ± 0.4 b</td>
<td>3.99 ± 0.13 a</td>
</tr>
<tr>
<td>Brown rice</td>
<td>2</td>
<td>7.7</td>
<td>9.7 ± 0.4 a</td>
<td>76.5</td>
<td>101.8 ± 0.2 c</td>
<td>3.24 ± 0.06 c</td>
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<td></td>
<td>5</td>
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<td>3.99 ± 0.13 a</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>7.9</td>
<td>1.9 ± 0.0 d</td>
<td>51.0</td>
<td>171.7 ± 1.0 a</td>
<td>4.04 ± 0.07 a</td>
</tr>
</tbody>
</table>

* Average of duplicate measurements.

** Mean values ± standard errors of three replicates. Mean values followed by the same lower case letter are not significantly different (P < 0.05)
gluten bread and the damaged starch content of brown rice flours ($r = 0.987$). This is consistent with a previous report showing the relationship between the SLV of white rice flour bread and damaged starch contents (Araki et al., 2009).

Furthermore, we investigated the effects of rice bran on the SLV of white rice flour bread (Fig. 2). When rice bran, obtained from normal polishing of dried brown rice, was added to white rice flour (10% w/w substitution of white rice flour) in bread-making, rice bran had very little effect on SLV when compared with white rice flour (control). Flour with 2.0% damaged starch produced by wet-jet milling resulted in bread with a similar SLV with and without rice bran, 4.04 and 4.20 cm$^3$/g, respectively (Fig. 2 A and B). Flour with higher damaged starch (8.7%) produced by dry-jet milling resulted in bread with lower SLV when compared with that by wet-jet milling, but there were no significant differences between breads with and without rice bran, 3.46 and 3.54 cm$^3$/g, respectively (Fig. 2 C and D). These data indicate that the SLV of brown rice/gluten depends on damaged starch content rather than the rice bran component. In this study, all bread-making was performed with flour having a 72% water content. However, we need to investigate the effects of water content on bread rising, as the volume of water is decided by farinograph characteristics in bread-making with wheat and/or gluten.

Particle size distribution and median particle size in rice flours are shown in Fig. 3 and Table 1, respectively. The distribution profile of jet-milled brown rice showed that whole particle size shifted to a smaller range with increased soaking time. The distribution became constant with a peak at 50–60 μm, a shoulder at 20–30 μm, and a small fraction of particles at 200–300 μm after 12 h of soaking. The distribution after soaking beyond 24 h was omitted from Fig. 3 because it was similar to that at 24 h. The largest particles are thought to be derived from rice bran, as white rice flour showed no peaks in the same area. These data indicate that water soaking and wet-jet milling produce high-quality brown rice flour with fine particles and lower damaged starch content. This is consistent with previously reported results that damaged starch content is affected by milling device and conditions (i.e., dry or wet milling). The damaged starch content of rice flour is lower with wet-jet milling than with dry-jet milling (Nishita et al., 1982; Arisaka et al., 1992).
α-Amylase is required for starch digestion. It plays a significant role in seed germination and is strongly expressed under the influence of plant growth hormones such as gibberellic acid, which are produced in response to water exposure (Muralikrishna and Nirmala, 2005). α-Amylase is approximately 30% of the total protein synthesized during germination and is mainly observed at the early stages of seed germination (Muralikrishna and Nirmala, 2005; Mitsunaga et al., 2001). This indicates that α-amylase is the most influential enzyme factor to bread making with soaked brown rice, although other enzyme activities also change during germination. Low α-amylase activity is related to poorer quality end products (Mares and Mrva, 2008). Therefore, the improvement in SLV of brown rice/gluten is likely due to increased α-amylase activity as a result of soaking.

We thus investigated the effects of α-amylase activity on bread swelling. The α-amylase activity in brown rice flours is summarized in Table 1. Brown rice flour produced with grains that had been soaked for 2 h initially possessed higher activity (101.8 mU/g flour). In contrast, flour produced after 5 and 12 h of soaking showed decreased activity (72.9 and 75.2 mU/g flour, respectively), but the reason for this is unclear. After 12 h of soaking, the activity gradually increased and was approximately 12 times higher at 48 h (171.7 mU/g flour), as compared with white rice flour after 2 h of soaking (control) (14.1 mU/g flour). These higher activities may be synthesized de novo through water signals. However, our data indicated that there was no relationship between the SLV of brown rice/gluten bread and the α-amylase activity of brown rice flour (r = 0.105), in contrast to the relationship between SLV and damaged starch content (r = 0.987) (Table 1). These results suggest that α-amylase activity is a minor factor in the rising properties of brown rice/gluten bread and that the induction of α-amylase by normal water soaking is insufficient to affect bread rising.

Conclusions

The improvement in SLV of bread made with brown rice flour/gluten after soaking the brown rice in water before jet milling was due to a reduction in damaged starch content. Rice bran had little effect on bread rising. α-Amylase in brown rice affects crumb softness through yeast fermentation rather than bread rising. The present milling method provided brown rice flour with good nutritional and physical properties for bread-making.

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References


