Note

Effect of Rice Variant on the Ease of Swallowing Blender-made Rice Gruel

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Ease of swallowing blender-made rice gruel when half of the non-glutinous japonica rice is replaced with glutinous japonica or non-glutinous indica rice was evaluated by physical measurement and sensory evaluation. Sensory evaluation revealed that blender-made rice gruel containing non-glutinous indica rice was stickier than non-glutinous japonica rice gruel, and was evaluated as harder to swallow. Blender-made rice gruel containing glutinous japonica rice was less sticky than non-glutinous rice gruel and was evaluated as easier to swallow. Blender-made rice gruel containing glutinous japonica rice contains less amylose and, combined with the partial degradation of starch due to the \(\alpha\)-amylase in the glutinous rice, results in reduced stickiness of the rice liquid, making the gruel easier to swallow.

Keywords: blender-made rice gruel, swallowing, glutinous rice, amylose, \(\alpha\)-amylase

Introduction

In recent years, Japan’s aging population has resulted in increased numbers of individuals suffering from eating disorders (Nagaya, 2009) and has highlighted the need to provide food that can be properly masticated and swallowed. Preparation of rice, the staple of the Japanese diet, as rice gruel makes it softer and easier to eat (Kishimoto et al. 2006). However, rice gruel easily separates into rice grains and rice liquid, presenting a worryingly high risk for aspiration or choking. This has led to the wide use of “blender-made rice gruel” for the elderly in hospitals and other facilities (Egawa et al. 2012), in which the rice grains are first pulverized by blender and then made into a homogeneous mixture with the rice liquid.

However, blender-made rice gruel is sticky and difficult to swallow because it adheres to the oral cavity (Taguchi et al. 2010). In response, hydrocolloids containing \(\alpha\)-amylase have been developed to reduce the stickiness of the blender-made rice gruel; reports indicate that these additives have helped to make the gruel easier to swallow (Nohara et al. 2009). However, one challenge in the preparation of easy-to-swallow blender-made rice gruel is the lack of knowledge of the characteristics or appropriate amounts of the enzymes to be added.

In this study, we focused on different rice variants in an effort to prepare easy-to-swallow blender-made rice gruel. We prepared blender-made rice gruel by replacing 50% of the non-glutinous japonica rice regularly used in Japan with non-glutinous indica or glutinous japonica rice, and then assessed the impact of the rice variant on the ease of swallowing blender-made rice gruel.

Materials and Methods

Rice samples
Polished grains of non-glutinous japonica rice (NGJ, cultivar Koshihikari, harvested in Shizuoka Prefecture, Japan, in 2012), glutinous japonica rice (GJ, cultivar Himenomochi, harvested in Chiba Prefecture, Japan, in 2012), and non-glutinous indica rice (NGI, cultivar unknown, harvested in the Kingdom of Thailand in 2012) were used. According to measurements entrusted to the Japan Food Research Laboratories (Tokyo, Japan), the amylose content of NGJ and NGI was 17% and

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Preparation of rice gruel and blender-made rice gruel  For the cooking of rice gruel, NGJ and mixed rice in which 50% of NGJ was substituted with either NGI (NGJ+NGI) or GJ (NGJ+GJ) were used. The rice sample (160 g) was washed and soaked in water (1 part rice: 5 parts water) for 1 h at 20°C. After soaking, the rice sample was cooked in an electric rice cooker (EG-B061; Zojirushi Corp., Osaka, Japan) to make the rice gruel. Immediately after cooking, the rice gruel was mixed lightly, transferred to a glass container attached to a blender (BM-RS08; Zojirushi Corp.), and blended at 10,500 rpm for 60 sec. Using a silicon spatula, rice gruel adhering to the inside of the glass container was removed and blended for a further 10 sec. The blending time sufficient for homogenization of the whole grain was determined in a preliminary test.

NGJ and NGJ+NGI were cooked using the water used to soak GJ, and blender-made rice gruel was prepared. GJ (80 g, same amount as that substituted in NGJ+GJ) was washed and soaked in 800 mL water at 20°C for 1 h, and then was strained through a stainless-steel strainer to obtain the GJ soaking water. This soaking water was added to the washed NGJ (160 g) or NGJ+NGI (160 g), and water was then added to increase the amount of water fivefold before soaking the samples at 20°C for 1 h. The resulting soaked rice was then cooked and blended to obtain blender-made rice gruel using the same method as described above. Also, GJ soaking water was heated in hot water to 100°C for 5 min and allowed to cool to 20°C. The resulting heated GJ soaking water was then used to prepare blender-made rice gruel.

Moisture content  Using a moisture analyzer (MOS-120H; Shimadzu Corporation, Kyoto, Japan), the moisture content of the rice gruel and blender-made rice gruel was measured at 120°C in automatic ending mode.

Amount of rice gruel liquid  Measurement of the amount of rice gruel liquid was performed following the slightly modified method of Takahashi et al. (2006). Immediately after cooking, the rice gruel (100 g) was spread evenly in a stainless-steel sieve (diameter, 200 mm; aperture, 1 mm) and covered with a lid. In the course of 5 min at room temperature, the sieve was sharply tapped and shaken ten times from a height of approximately 10 cm by manual operation. After 5 min, the amount of gruel liquid passing through the sieve was weighed.

Textural analysis  Textural properties of the rice gruel and blender-made rice gruel were measured using a universal testing machine (RE2-33005s; Yamaden Co., Ltd., Tokyo, Japan). Rice gruel or blender-made rice gruel was stuffed into a stainless-steel cup (diameter, 40 mm) up to 15 mm thickness, and then compressed twice with a cylindrical plunger (diameter, 20 mm) at a rate of 10 mm/sec and 5 mm clearance (Takahashi et al. 2013). The sample temperature was set at 45 ± 2°C to simulate the intake of warm food. Hardness, cohesiveness and adhesiveness were calculated from the texture profile curve using a software program (TAS-
standard deviation (SD). The results were evaluated using ANOVA and the means were compared by Tukey’s test for significance at \( p < 0.05 \). Sensory scores were evaluated using ANOVA and the means were compared by Bonferroni’s test for significance at \( p < 0.05 \).

**Results and Discussion**

**Rice gruel characteristics** In order to assess the impact of rice variant on the texture of blender-made rice gruel, we began by analyzing the texture of rice gruel before the grains were pulverized.

Before analyzing texture, we measured the moisture content and the amount of rice liquid separation for the rice gruel. The moisture content of rice gruel was 85.1 ± 0.2% for NGJ, 84.9 ± 0.3% for NGJ+NGI and 85.0 ± 0.2% for NGJ+GJ; values not significantly different. The amount of rice liquid separated from 100 g of rice gruel was 4.82 ± 0.17 g for NGJ, 1.45 ± 0.62 g for NGJ+NGI, and 7.56 ± 0.34 g for NGJ+GJ, with NGJ+NGI having significantly less separation compared to NGJ, and NGJ+GJ having significantly more separation compared to NGJ.

The textural parameters of rice gruel are shown in Table 1. For hardness, NGJ+NGI and NGJ+GJ had values that were significantly lower than NGJ. For cohesiveness and adhesiveness, NGJ+NGI had significantly lower values than NGJ and NGJ+GJ.

There was an extremely low amount of rice liquid remaining in the NGJ+NGI. Ema and Kainuma (1996) observed that cooked non-glutinous indica rice swells more than non-glutinous japonica rice. Therefore, the indica rice grains in the NGJ+NGI appeared to absorb more water, resulting in less rice liquid and softer rice grains than NGJ. On the other hand, with the higher levels of rice liquid for NGJ+GJ than for NGJ, the rice gruel appeared to become softer as the starch was partially degraded by the α-amylase in the glutinous rice (Horiuchi, 1967). The cohesiveness of NGJ+NGI was lower than for NGJ and NGJ+GJ, possibly as a result of the lower amount of rice liquid and lower fluidity. Furthermore, NGJ+NGI was assumed to have the lowest adhesiveness because of the smallest amount of viscous rice liquid.

The sensory evaluation scores for rice gruel are shown in Fig. 1. Unlike that observed in the instrumental measurement, there were no significant differences in firmness score among the samples. For mobility from the oral cavity, thickness and amount remaining in the mouth, however, NGJ+NGI was given a significantly higher score than either NGJ or NGJ+GJ, meaning it showed greater ease of flow from the oral cavity, was less sticky, and did not remain in the mouth after eating. These results are consistent with the report by Takahashi et al. (2013), in which gruel made from high-amylose rice remained in the mouth cavity a shorter period of time and was less sticky than gruel made from low- to medium-amylose rice. Furthermore, NGJ+NGI received a higher taste score than NGJ. This trend is consistent with the report by Hamada et al. (1994), in which rice gruel made from Hoshiyutaka, which has similar characteristics to indica rice (amylose content of 28.2%), was preferred due to the low stickiness and the distinct rice grain texture of the gruel. Therefore, these results suggest that if blender-made NGJ+NGI gruel can maintain these characteristics, we could potentially prepare easier-to-swallow blender-made gruel.

**Characteristics of blender-made rice gruel** The three types of rice gruel were pulverized, and then the moisture content was measured and the texture analyzed. The moisture content for blender-made rice gruel was 85.1 ± 0.2% for NGJ, 84.9 ± 0.3% for NGJ+NGI, and 85.0 ± 0.2% for NGJ+GJ, indicating that pulverization had no effect on the moisture content of the rice gruel.

The textural parameters of the blender-made rice gruels are shown in Table 2. Unlike rice gruel, the hardness and adhesiveness of NGJ+NGI were almost double that of NGJ. For NGJ+GJ, however, hardness and adhesiveness were significantly lower than for NGJ. No significant differences in cohesiveness were observed.

These results indicate that replacing NGJ with NGI results in harder and stickier blender-made rice gruel that would be more difficult to eat; conversely, replacing half of the rice with GJ would

<table>
<thead>
<tr>
<th>Rice sample</th>
<th>Hardness (×10³ N/m²)</th>
<th>Cohesiveness (×10³ J/m³)</th>
<th>Adhesiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGJ</td>
<td>6.01 ± 0.59 a</td>
<td>0.64 ± 0.06 a</td>
<td>13.39 ± 0.88 a</td>
</tr>
<tr>
<td>NGJ + NGI</td>
<td>5.18 ± 0.33 b</td>
<td>0.44 ± 0.06 b</td>
<td>9.02 ± 1.97 b</td>
</tr>
<tr>
<td>NGJ + GJ</td>
<td>4.54 ± 0.45 b</td>
<td>0.62 ± 0.05 a</td>
<td>11.98 ± 2.28 a</td>
</tr>
</tbody>
</table>

NGJ: non-glutinous japonica rice; NGJ+NGI: 50% non-glutinous japonica rice and 50% non-glutinous indica rice; NGJ+GJ: 50% non-glutinous japonica rice and 50% glutinous japonica rice

Data are expressed as mean values ± standard deviation (n=12).

Means in a column with different letters are significantly different (\( p < 0.05 \)).
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produce easier to eat blender-made rice gruel.

The sensory evaluation scores for blender-made rice gruels are shown in Fig. 2. Excluding taste, NGJ+NGI had a significantly lower score in all profiles than NGJ. Namely, NGJ+NGI was evaluated as having lower mobility from the oral cavity, greater thickness, and remained in the mouth to a greater extent after eating. Therefore, pulverizing the indica rice grains resulted in blender-made rice gruel that was significantly harder to swallow. On the other hand, NGJ+GJ was evaluated as having significantly higher mobility from the oral cavity, less thickness, and was easier to swallow than NGJ. All of the blender-made rice gruels had a taste score of around 0. Notably, the sensory evaluation panel consisted of young, healthy students, and no panelist consumed blender-made rice gruel on a daily basis. For this reason, the responses centered around 0 (taste neither good nor bad).

**Apparent viscosity and thixotropic area of blender-made rice gruel** The apparent viscosity and thixotropic area of blender-made rice gruels are shown in Table 3. NGJ+NGI had significantly higher apparent viscosity and thixotropic area compared to NGJ and NGJ+GJ. On the other hand, the apparent viscosity for NGJ+GJ was significantly lower than that for NGJ and NGJ+NGI.

For blender-made rice gruel, the aggregation structure is predicted to be formed by the hydrogen bonds in the starch. It is therefore suspected that for NGJ+NGI, which has a larger thixotropic area, more of the amylose, which readily forms hydrogen bonds, flows into the rice liquid compared to NGJ or NGJ+GJ. Because the leached amylose easily forms a gel (Miles et al. 1985), this results in increased apparent viscosity. NGJ+GJ, however, contains less amylose, and combined with the partial degradation of the starches due to α-amylase, these factors are suspected of working together to reduce the apparent viscosity and thixotropic area.

These results imply that the relative ease of swallowing the blender-made rice gruels is influenced by the pulverization of the rice grains, releasing a large amount of amylose into the rice liquid in the case of NGJ+NGI, while in the case of NGJ+GJ, lower
levels of released amylose are combined with the partial starch degradation by α-amylase.

**Gelatinization characteristics of rice gruel**  Unlike NGJ+NGI blender-made gruel, NGJ+GJ blender-made gruel flowed better and was easier to swallow than the respective rice gruel. This appeared to be due to the impact of the α-amylase in GJ. To identify the α-amylase activity, peak viscosity was measured by RVA with and without enzyme inhibitors (Fig. 3). Measured with water (A: no enzyme inhibitors), the peak viscosity for GJ was 1.28 ± 0.05 (×10³ cP), but when measured with the copper sulfate solution (B: enzyme inhibitors added), the peak viscosity increased to 2.47 ± 0.06 (×10³ cP), similar to the reports of Shibuya et al. (1983) and Shoji and Kurasawa (1988). As α-amylase is an extracellular enzyme in plants from the family Poaceae, it leaches into the water during soaking and cooking, and also acts upon starch in NGJ (Tsuyukubo et al. 2013). This appeared to be why the peak viscosity of NGJ+GJ without enzyme inhibitors (A) was lower than that measured with enzyme inhibitors (B). When the rice is soaked in water and at the early stages of heating, the α-amylase in GJ partially breaks down the starch in NGJ, reducing the viscosity of the rice liquid, resulting in non-sticky, easy-to-swallow blender-made rice gruel.

To investigate how the breakdown of NGJ and NGI rice samples by α-amylase from GJ affected the physical properties of blender-made rice gruel, GJ soaking water, estimated to contain the same amount of α-amylase activity eluted from NGJ+GJ, was used to soak the NGJ and NGJ+NGI, then blender-made rice gruel was prepared and the texture parameters were analyzed. The same experiment was also performed for GJ soaking water that had been heated to inactivate the α-amylase activity. As shown in Fig. 4, the blender-made rice gruel prepared from NGJ and NGJ+NGI with α-amylase activity preserved (i.e., prepared with non-heated GJ soaking water) was significantly less hard and sticky than the samples without α-amylase activity (i.e., prepared with heated GJ soaking water). These findings suggested that the α-amylase activity in GJ made the blender-made rice gruel easier to swallow.

**Table 3.** Apparent viscosity and area of thixotropic loop of blender-made rice gruel

<table>
<thead>
<tr>
<th>Rice sample</th>
<th>Apparent viscosity at 20 s⁻¹ (Pa·s)</th>
<th>Area of thixotropic loop (×10³ Pa·s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGJ</td>
<td>2.13 ± 0.07b</td>
<td>1.08 ± 0.44b</td>
</tr>
<tr>
<td>NGJ + NGI</td>
<td>4.42 ± 0.21a</td>
<td>3.26 ± 0.56a</td>
</tr>
<tr>
<td>NGJ + GJ</td>
<td>1.87 ± 0.15c</td>
<td>0.73 ± 0.37b</td>
</tr>
</tbody>
</table>

Abbreviations of rice samples are the same as in Table 1. Data are expressed as mean values ± standard deviation (n=7). Means in a column with different letters are significantly different (p < 0.05).
To verify the effect of 25% and 75% GJ replacement ratio on gruel parameters, we next prepared blender-made rice gruel containing 0%, 25%, 50% and 75% GJ, and performed sensory evaluation using the ranking test (data not shown). The results showed a noticeable increase in the ease of swallowing for the 50% replacement ratio and greater. However, some panelists noted a unique glutinous rice smell at the 75% replacement ratio; thus, the 50% replacement ratio was determined to be the most appropriate.

Conclusion
To prepare easy-to-swallow blender-made rice gruel, it is critical to reduce the amount of amylose that leaches into the rice liquid and to enzymatically degrade the starches, thereby preventing reductions in the fluidity of the rice liquid. An effective way to achieve this is to replace half of the non-glutinous japonica rice component of the gruel with glutinous japonica rice.

References


