Relation of Rheological Properties with Starch Components among Glutinous, Sticky, Less-sticky Non-glutinous Rice Starches

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Received July 31, 1972

The difference of eating and cooking qualities among species of rice may be attributed to the physico-chemical properties of rice. Horiiuchi concluded that the glutinous rice starch was the most sticky type, the Japonica non-glutinous rice starch sticky type and the Indica non-glutinous rice starch elastic type. Juliano et al. showed that, in studying properties of Indica glutinous and non-glutinous rice, non-glutinous rice amylopectin showed higher intrinsic viscosity than glutinous rice amylopectin. Nara and Maeda found that the glutinous rice starch showed higher maximum viscosity by Brabender amylogram than non-glutinous rice starch. Juliano et al., in studying properties of Japonica glutinous rice, have shown that good-quality rice showed higher pasting temperature and higher peak viscosity than poor-quality rice.

In the previous papers we studied the relation between the properties of stickiness, less-sticky non-glutinous rice varieties and the properties of starches from these rice varieties. In this paper, we studied the relation between the properties of glutinous, sticky, less-sticky non-glutinous rice varieties and the properties of starch from these rice varieties.

Material
Glutinous varieties: Koganemochi, Echigonebari and Heiwaso, sticky non-glutinous varieties: Honenwase, less-sticky non-glutinous varieties: Norin No. 43, Aikoku No. 20 and Okumasari were used.

Physico-chemical properties of milled rice
The palatability of cooked rice was tested by sensory evaluation. At the same time, the cohesiveness of cooked rice was determined by the modified table balance method. The starch-iodine blue value and the dissolved matter content in the hot water extract of milled rice were determined by the method of Dawson. The increase of weight after cooking was determined by the method in previous paper. The disintegration of milled rice in alkaline solution (alkali test) was investigated by the Little’s method. In this experiment, milled rice was polished by the soft brush.

Amylose content of rice starch
Amylose content was obtained by Schoch’s method.

Rheological properties of rice starch
Starch samples were prepared from rice powder by soaking in 0.2% sodium hydroxide solution at 5°C. The starch granules thus obtained did not contain any damaged granule when tested by congo-red staining method. Rheological properties of rice starch were determined by Brabender amylograph, Ostwald viscometer, and Brookfield viscometer (B-type viscometer).

Characteristics of rice starch
The palatability and the cohesiveness of cooked rice and the blue value are shown in Table I. By the organoleptic test for the stickiness of cooked rice, a glutinous rice showed high value, a sticky non-glutinous rice ranked medium and a less-sticky non-glutinous rice low. Cooked glutinous rice was most glossy, a sticky non-glutinous rice fairly glossy and less-sticky non-glutinous rice white and dull.

By the modified balance method for the cohesiveness of cooked rice, the glutinous rice showed high value, the sticky non-glutinous rice ranked medium and the less-sticky non-glutinous rice low. As for the increase ratio of weight after cooking, sticky non-glutinous rice showed low value and less-sticky non-glutinous rice showed high value. By the method of Dawson for the content of dissolved matter after cooking, glutinous rice showed high value, sticky, less-sticky non-glutinous rice showed low value and sticky, less-sticky non-glutinous rice showed low value.

Cooking qualities of glutinous, sticky non-glutinous, less-sticky non-glutinous rice varieties, and rheological properties of starches from these varieties were shown in Table II, and Fig. 1.

The difference of eating and cooking qualities among glutinous, sticky, less-sticky non-glutinous rice may be attributed to the histological structures of rice and the chemical properties of components.

We prepared rice starch samples from various rice varieties and carried out the rheological studies with these rice starch samples.

As for non-glutinous rice variety, the relation of rheological properties between sticky and less-sticky non-glutinous rice starch reported in the previous paper were same as that reported in this paper.

Amyloheat viscogram observed by Ostwald viscome-
ter—Change of viscosity of 10% starch suspension while heating was studied. For glutinous rice suspension the sharp rise of viscosity was observed at 60~61°C. For sticky non-glutinous rice, a sharp rise of viscosity was observed at 56~58°C. For less-sticky non-glutinous rice, a sharp rise of viscosity was observed at 53~54°C. For the temperature at which sudden viscosity increase occurred, a glutinous rice starch was the highest, a sticky non-glutinous rice starch was medium and a less-sticky non-glutinous rice starch was the lowest. This temperature may correspond to the swelling temperature. So the easiness of swelling of starch granules may be in the order of less-sticky, sticky non-glutinous and glutinous varieties. For 2% starch suspension prepared from glutinous rice, a sharp rise of viscosity was observed at 63°C. The sticky non-glutinous rice was observed at 81°C. The less-sticky non-glutinous rice was observed at 90°C. So the distintegrating temperature of rice starch granule was the highest for less-sticky non-glutinous rice and sticky non-glutinous rice and glutinous rice starch granule followed in this order. From these results, the starch from glutinous rice appeared to be swollen and distintegrated between 60 to 65°C, while that from

### TABLE I. COOKING QUALITY OF GLUTINOUS AND NON-GLUTINOUS RICE

<table>
<thead>
<tr>
<th>Variety</th>
<th>Palatability of cooked rice</th>
<th>Cohesiveness of cooked rice (by balance method)</th>
<th>Blue value of milled rice (g)</th>
<th>Dissolved matter content of milled rice (mg/10 ml)</th>
<th>Increase of weight after cooking (g)</th>
<th>Alkali value (Spreading)</th>
<th>Clearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glutinous rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kogane-mochi</td>
<td>High</td>
<td>High</td>
<td>70</td>
<td>140</td>
<td>1</td>
<td>1</td>
<td></td>
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<tr>
<td>Echigone-bari</td>
<td>High</td>
<td>High</td>
<td>70</td>
<td>140</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Heiwa-mochi</td>
<td>High</td>
<td>High</td>
<td>73</td>
<td>145</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sticky non-glutinous rice</td>
<td>Medium</td>
<td>Medium</td>
<td>49</td>
<td>0.444</td>
<td>148</td>
<td>245</td>
<td>3</td>
</tr>
<tr>
<td>Honen-wase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less-sticky non-glutinous rice</td>
<td>Low</td>
<td>Low</td>
<td>33</td>
<td>0.452</td>
<td>210</td>
<td>250</td>
<td>2</td>
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<tr>
<td>Aikoku No. 70</td>
<td>Low</td>
<td>Low</td>
<td>13</td>
<td>0.475</td>
<td>222</td>
<td>255</td>
<td>4</td>
</tr>
<tr>
<td>Okumasari</td>
<td>Low</td>
<td>Low</td>
<td>13</td>
<td>0.475</td>
<td>222</td>
<td>255</td>
<td>4</td>
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</tbody>
</table>

### TABLE II. RELATION BETWEEN COOKING QUALITY OF RICE AND PHYSICO-CHEMICAL PROPERTIES OF RICE STARCH

<table>
<thead>
<tr>
<th>Variety</th>
<th>Glutinous rice</th>
<th>Sticky non-glutinous rice</th>
<th>Less-sticky non-glutinous rice</th>
<th>Aikoku No. 7</th>
<th>Okumasari</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kogane-mochi</td>
<td>61</td>
<td>38</td>
<td>44</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Heiwa-mochi</td>
<td>59</td>
<td>39</td>
<td>44</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Honen-wase</td>
<td>60</td>
<td>45</td>
<td>44</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Aikoku No. 7</td>
<td>60</td>
<td>55</td>
<td>60</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Okumasari</td>
<td>57</td>
<td>53</td>
<td>54</td>
<td>53</td>
<td>54</td>
</tr>
<tr>
<td>B-type viscometer</td>
<td>0.32 N</td>
<td>0.35 N</td>
<td>0.30 N</td>
<td>0.27 N</td>
<td>0.27 N</td>
</tr>
<tr>
<td>Amylose content (%)</td>
<td>0</td>
<td>0</td>
<td>18.7</td>
<td>19.8</td>
<td>22.1</td>
</tr>
</tbody>
</table>
Relation of Rheological Properties with Starch Components among Rice Starches

Heiwamochi and Koganemochi are glutinous rice, Honenwase is sticky non-glutinous rice and Okumasari is less-sticky non-glutinous rice.

Alkali viscogram observed by B-type viscometer—
The alkali-swelling value of starch granule was studied with Brookfield (B-type) viscometer. With glutinous rice starch suspension, viscosity rised sharply at 0.35 N alkali concentration. With sticky non-glutinous rice starch suspension, viscosity rised sharply at 0.3 N alkali concentration, and with less-sticky non-glutinous rice starch suspension, viscosity rised sharply at 0.27 N alkali concentration. The glutinous rice starch granule was not easy to swell, the sticky non-glutinous rice starch granule swelled easily and less-sticky non-glutinous rice starch granule swelled most easily. The relation observed between the order of the alkali-swelling value obtained with rice starch and the order of the distintegration by alkali test obtained with milled rice did not agree completely. It seemed therefore that the order of alkali test could not solely attributed to the nature of starch granules but might be related to another components.

Amyloheat viscogram observed by Brabender amylograph—The standard model Brabender Amylograph (Pin model, spring type) was used.

The temperature at which maximum viscosity is recorded may show the distintegrating temperature of starch granule. As for this temperature, less-sticky non-glutinous rice starch granule showed the highest value (90°C), sticky non-glutinous rice starch granule showed medium value (82°C) and glutinous rice starch granule showed the lowest value (68°C – 71°C). A break down value may show a distintegrating degree of starch granule. As for this value, a glutinous rice showed the highest value (300 – 400 BU), sticky non-glutinous rice a medium value (260 BU) and less-sticky non-glutinous rice the lowest value (35 BU). A set-back value may show retrogradation degree when starch paste was cooled. As for this value, less-sticky non-glutinous rice starch showed the highest value (60 BU), sticky non-glutinous rice starch medium value (0 BU) and a glutinous rice starch the lowest value (−200 – −250 BU). The maximum viscosity may show a stickiness of starch solution. As for the maximum viscosity, glutinous rice starch showed the highest value (650 – 750 BU), sticky non-glutinous rice starch showed a medium (550 BU) and less-sticky non-glutinous rice starch the lowest (450 BU).

The amylose content of starch from sticky non-glutinous rice was 18.7%, while that of starch from less-sticky non-glutinous rice was 19.8 – 22.1%.

As for the stickiness recorded by Brabender amylogram, glutinous rice starch granule showed high value, sticky non-glutinous rice starch granule continued on medium value, less-sticky non-glutinous rice starch granule showed low value. Retrogradation tested by...
Brabender amylogram was found to be most readily in less-sticky non-glutinous rice starch, less easily in sticky non-glutinous rice starch and least in glutinous rice starch. By Brabender amylogram, glutinous rice starch was shown to be most disintegrated, followed by sticky non-glutinous rice starch and less-sticky non-glutinous rice starch was not easily to disintegrate.

When the starch suspension was heated, the starch granules were swollen to allow a part of amylose to dissolve, and then the swollen starch granules were disintegrated. The sticky and less-sticky non-glutinous starch granule showed a higher disintegration at low temperature but was more stable at higher temperature than glutinous starch granule. The glutinous starch granules were more stable at low temperature but showed more disintegration at high temperature than the non-glutinous starch granules.

On heating the starch suspension, glutinous rice starch granules (so-called amylopectin) were more stable at low temperature than non-glutinous rice starch granules, while the former starch granules showed more disintegration at high temperature than latter rice starch granules. This may be presumed that, on heating, sticky and less-sticky non-glutinous starch granules are disintegrated by dissolving of amylose molecule at lower temperature, but at higher temperature amylose molecules protect the disintegration of amylopectin molecules.

The cooking property of sticky non-glutinous rice seems to have intermediate property between glutinous rice and less-sticky non-glutinous rice, and similarly the physicochemical properties of sticky non-glutinous rice starch seems to have intermediate property between glutinous rice starch and less-sticky non-glutinous rice starch.

Acknowledgement. This work was supported in part by research grant from the Ministry of Education, Japan and also from the Mishimakaiun Kinenzaidan. The authors wish to express their gratitude to Emeritus Prof. Ziro Nikuni, Osaka University and to Prof. Michinori Nakamura, Tokyo University for many discussion.

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