Physicochemical Properties of Starch from Kaga Lotus Rhizome

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Yuji Honda,1,* Takashi Mishima,2 Hironori Koga,1 Kenji Matsumoto,1 Yuri Maeda,1 Fumi Kawashima,1 Masanori Okazaki1 and Shoji Miwa1

1Faculty of Bioresources and Environmental Science, Ishikawa Prefectural University (1-308 Saematsu, Nonoichi, Ishikawa 921-8836, Japan)
2Graduate School of Regional Innovation Studies, Mie University (1577 Kurinamachiya-cho Tsu, Mie 514-8507, Japan)
3Ishikawa Agriculture and Forestry Research Center (295-1 Saida, Kanazawa, Ishikawa 920-3198, Japan)

Abstract: The physicochemical properties of starch from Kaga lotus (Shina-shirohana cultivar derived from Chinese lotus) cultivated in Ishikawa Prefecture were investigated in comparison with starch from Chinese lotus cultivated in Ibaraki Prefecture. RVA analysis indicated starch from Kaga lotus had high peak viscosity compared with starch from Ibaraki lotus. Morphological observations showed that starch granules from Kaga lotus had a longer shape than starch granules from the Ibaraki lotus. The amylose content of starch from Kaga lotus was 11.3%, while that from Ibaraki lotus was 14.7%. The phosphorus content was comparable in both starches. Taken together, these results suggest the lower amylose content of starch from Kaga lotus contributes to its high stickiness.

Key words: lotus, Nelumbo nucifera Gaertn., rhizome, Shina-shirohana cultivar, starch
The samples were fixed with vapor from 1% OsO₄ in 0.05 M cacodylate buffer at pH 7.2 for 1 h then coated with 8-nm-thick platinum using an ion-sputter (Hitachi E-1010, Hitachi High-Technologies Corp., Tokyo, Japan). The metal-coated specimens were observed under a field emission scanning electron microscope (Hitachi S-4700) at 15 kV. The chain-length distribution of the lotus starch was determined according to previously reported methods.9,10) The starch granule size was measured with a Microtrac MT3300 EXII laser diffraction instrument (Nikkiso Co., Ltd., Tokyo, Japan) after sonication in water. The size was determined at 10, 50 and 90% from the frequency distribution data where 50% represents the average granule size. T-tests were carried out on independent samples using StatMate IV (ATMS, Tokyo, Japan). Differences were considered significant at \( p < 0.05 \).

Figure 1 shows RVA pasting curves of starches derived from Kaga and Ibaraki lotuses. RVA parameters are summarized in Table 1. The peak viscosity value of Kaga lotus starch was 8% higher than that of Ibaraki lotus starch. Kaga lotus starch had a pasting temperature 2°C lower than that for Ibaraki lotus, indicating that starch from Kaga lotus becomes viscous more readily than starch from Ibaraki lotus. The setback value for Kaga lotus starch was 85% of the value for Ibaraki lotus starch, suggesting that starch from the Kaga lotus was insensitive to retrogradation compared with starch from the Ibaraki lotus. Table 2 shows the thermodynamic parameters of starch from lotus rhizomes determined by DSC analysis. The peak and onset temperatures for Kaga lotus starch had a 1.8°C lower peak temperature and a 1.7 lower onset temperature of DSC. The \( \Delta H \) of starch from Kaga lotus was also just 71% of that from the Ibaraki lotus. These results suggest that starch from the Kaga lotus is more readily susceptible to gelatinization compared with starch from the Ibaraki lotus. The X-ray diffraction patterns of starches from Kaga and Ibaraki lotus rhizomes were quite similar (data not shown). Suzuki et al.4) reported that the X-ray diffraction pattern of starch from lotus cultivated in Tokushima prefecture was a C type which was the same as the patterns observed in this study. Figure 2 shows the ultrastructures of the starch granules from Kaga and Ibaraki

![Fig. 1. RVA profiles of starches from Kaga and Ibaraki lotuses.](image)

Solid line, Kaga lotus starch; dashed line, Ibaraki lotus starch; dotted line, temperature.

![Fig. 2. Scanning electron micrographs of starches from Kaga (A) and Ibaraki (B) lotuses.](image)

The dotted circles indicate a hilum at the end of the starch granules.

| Table 1. RVA parameters of starches from Kaga and Ibaraki lotuses. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Sample          | Pasting temperature (°C) | Peak temperature (°C) | Peak viscosity (RVU) | Minimum viscosity (RVU) | Final viscosity (RVU) | Breakdown (RVU) | Setback (RVU) |
| Kaga lotus      | 65.8             | 66.1             | 588.9            | 215.3            | 247.9            | 373.6            | 32.6           |
| Ibaraki lotus   | 67.8             | 68.9             | 545.3            | 251.1            | 289.3            | 294.3            | 38.2           |
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Table 2. DSC parameters for starches from Kaga and Ibaraki lotuses.

<table>
<thead>
<tr>
<th>Sample</th>
<th>To (°C)</th>
<th>Tp (°C)</th>
<th>Tc (°C)</th>
<th>ΔH (J/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaga lotus</td>
<td>55.8 ± 0.6</td>
<td>59.9 ± 1.0</td>
<td>66.5 ± 1.5</td>
<td>10.8 ± 0.2</td>
</tr>
<tr>
<td>Ibaraki lotus</td>
<td>57.5 ± 0.0</td>
<td>61.7 ± 0.0</td>
<td>69.5 ± 0.3</td>
<td>15.3 ± 0.2</td>
</tr>
</tbody>
</table>

To, Tp, Tc and ΔH indicate onset, peak and conclusion temperatures and enthalpy change. These parameters are given as the average value ± standard deviation (n = 3).

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lotuses obtained by scanning electron microscopy. Hilum was observed at the end of starch granules from both lotus rhizomes, resulting in the characteristic marks.\(^4\)\(^5\)\(^6\) The average starch size was similar in both starches (data not shown). The ratio of the long to short axes of starch granules (Fig. 3), calculated on the basis of microscope photographs, was significantly higher for the Kaga lotus than for the Ibaraki lotus (p < 0.001; n = 35). Many reports have indicated that a high proportion of DP 6-10 unit chain in amylopectin affects the high viscosity of starches.\(^1\)\(^2\)\(^3\)\(^4\)\(^5\)\(^6\)\(^7\)\(^8\) However, the chain content between DP 6 and 9 of starch from Kaga lotus was similar to that from Ibaraki lotus (data not shown). In general, the phosphorus content of starch from potato is a very important factor in determining its viscosity.\(^9\)\(^10\)\(^11\)\(^12\)\(^13\)\(^14\) The apparent amylose content of starch from Kaga lotus (13.1 ± 1.8%) was lower than that of starch from Ibaraki lotus (14.7 ± 0.5%). However, the phosphorus content in the starches from Kaga and Ibaraki lotuses at 154 and 156 ppm, respectively, were very similar. The amylose to amylopectin ratio of starch is known to be an important determinant of its physicochemical properties.\(^14\)\(^15\) The lower amylose content of starch from the Kaga lotus was a key characteristic which resulted in its viscosity being higher than that of starch from Ibaraki lotus.

In conclusion, RVA analysis has shown that the peak viscosity of starch from the Kaga lotus was higher than that from the Ibaraki lotus. Our analyses have indicated that the major differences between the starches are the apparent amylose content and the shape. At present, we consider that the amylose content in starch from the Kaga lotus would affect its physicochemical properties. We are currently investigating the properties of starches from Kanasumi No. 20 and Kaga lotus rhizomes cultivated at the same farm in Ishikawa Prefecture and will report these results in due course.