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Relationship between the Starch Properties of White-Core Tissue and Polishing Characteristics in Brewers' Rice Kernels

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Abstract : The kernels of Hattan-nishiki No. 1 and Kairyō-omachi have larger air spaces in the white-core tissue and are broken easily during the process of polishing when compared with those of Senbon-nishiki and Yamada-nishiki. The polishing characteristics of brewers' rice kernels are closely related with the structure of the white-core tissue of kernels. In this study, the varietal differences in the starch properties of white-core tissue of brewers' rice kernels on polishing characteristics were studied. The starch properties were studied by rapid visco analysis (RVA) and differential scanning calorimetry (DSC); the amylose content of the rice flour of each variety was also analysed. No significant differences were observed in the amylose content among the four varieties. The two RVA parameters, peak viscosity and breakdown, were higher in Hattan-nishiki No. 1 and no significant differences were observed in them among Senbon-nishiki, Yamada-nishiki and Kairyō-omachi. The DSC parameters, gelatinization onset and peak and conclusion temperatures, were higher in Hattan-nishiki No. 1, lower in Senbon-nishiki and Yamada-nishiki, and intermediate between them in Kairyō-omachi. These results suggest that the polishing characteristics of brewers' rice kernels are related with not only the endosperm structure but also the starch property of white-core tissue, except for Kairyō-omachi.

Key words : Brewers' rice, Polishing property, Starch property, White-core kernel.

Brewers' rice—large non-glutinous rice used for the brewing of rice wine (sake)—possesses a white and opaque (chalky) tissue at the center of the kernel; this tissue is termed as the “white-core”. This tissue has numerous air spaces and a low starch content (Del Rosario et al., 1968; Evers and Juliano, 1976; Yanagiuchi et al., 1996). The white-core promotes the gelatinization of steamed rice during the brewing of rice wine and induces the invasion of the *Koji* fungus (Yanagiuchi et al., 1996; Yoshii and Aramaki, 2001). Rice kernels with a large white-core have been considered to be suitable for brewing rice wine (sake brewing), and the breeding of rice varieties for sake brewing has been aimed at enlarging the white-core tissue (Akiyama et al., 1997). However, there are many interstices in the white-core tissue, and it lacks physical hardness. Thus, the grains with the white-core tissues are easily broken during polishing. Since broken and unbroken grains differ in weight and are polished differently, the rate of steam absorption is not uniform when broken grains are mixed. This has an unfavorable effect on the solubility of unrefined sake and produces inferior-quality *Koji*. Thus, the presence of broken grains is not suitable for brewing.

Previously (Tamaki et al., 2007), we reported that the kernels of the brewers' rice varieties Hattan-nishiki No. 1 and Kairyō-omachi were broken easily during

the process of polishing when compared with those of Senbon-nishiki and Yamada-nishiki. In addition, in the former varieties more air spaces were observed in the white-core tissues of the kernels than in the latter varieties and few structural differences were observed in the peripheral translucent tissues surrounding the white-core tissues among varieties. Therefore, we concluded that polishing characteristics are closely related with the endosperm structure of the white-core tissues, which is characterized by the density of amyloplasts.

Starch properties and endosperm structure are known to be different between chalky and translucent rice kernels and chalky rice kernels showed lower peak and final viscosities, in RVA, and contained less amylose than the translucent rice kernels (Sandhya-Randi and Bhattacharya, 1989; Kim et al., 2000; Lisle et al., 2000). In addition, they reported that the amyloplasts in the chalky kernels were loosely packed compared with those in the translucent kernels.

Polishing characteristics of brewers' rice kernels are one of the important properties for sake brewing. Since some studies showed that the relationships exist between the starch properties were related with the endosperm structure of rice kernels (Sandhya-Randi and Bhattacharya, 1989; Kim et al., 2000; Lisle et al., 2000), the starch properties of the white-core tissue of

Table 1. RVA parameters of rice flour from the white-core tissue of brewers' rice kernels.

Variety	Peak viscosity (cP)	Holding strength (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Pasting temperature (°C)
Senbon-nishiki	1706±0 b ¹⁾	707±2	1004±2 b	1361±1	659±2	63.2±0.1
Yamada-nishiki	1625±78 b	718±49	907±29 b	1393±58	676±9	61.6±0.3
Hattan-nishiki No. 1	2025±47 a	749±37	1276±10 a	1408±40	659±3	63.1±0.1
Kairyo-omachi	1753±49 b	740±40 NS	1014±9 b	1368±47 NS ²⁾	639±7 NS	62.7±0.4 NS

¹⁾ Values with the same letters are not significantly different ($P < 0.05$ by LSD).

²⁾ NS indicates no significant difference among varieties ($P < 0.05$ by LSD).

Table 2. DSC parameters of rice flour from the white-core tissue of brewers' rice kernels.

Variety	T_o ¹⁾ (°C)	T_p (°C)	T_c (°C)	ΔH (-J/g)
Senbon-nishiki	56.82±0.03 b ²⁾	64.97±0.24 b	76.47±0.08 b	3.99±0.08
Yamada-nishiki	55.64±0.11 b	64.10±0.11 b	76.41±0.10 b	3.98±0.05
Hattan-nishiki No. 1	59.59±0.25 a	67.22±0.28 a	78.92±0.71 a	4.28±0.19
Kairyo-omachi	58.17±0.39 ab	65.67±0.21 ab	77.61±0.50 ab	4.11±0.13 NS ³⁾

¹⁾ T_o =onset temperature, T_p =peak temperature, T_c =conclusion temperature, ΔH =enthalpy.

²⁾ Values with the same letters are not significantly different ($P < 0.05$ by LSD).

³⁾ NS indicates no significant difference among varieties ($P < 0.05$ by LSD).

different brewers' rice varieties also must be studied to determine the polishing characteristics for sake brewing. The purpose of this study was to determine the varietal differences in the starch properties of the white-core tissue of brewers' rice kernels.

Materials and Methods

Four cultivars of brewers' rice—Senbon-nishiki, Yamada-nishiki, Hattan-nishiki No. 1 and Kairyo-omachi—were used in this study. The rice plants were cultivated in an experimental paddy field in Hiroshima Prefectural University (Shobara, Hiroshima, Japan) in 2001. To examine the involvement of the starch properties on the varietal differences in the polishing characteristics, materials we used were the same as those used in our previous study (Tamaki et al., 2007).

Head rice kernels with the white-core at the center of the kernels were selected with the naked eye from each rice variety. Brown rice was polished to 70% using a grain-testing mill (Satake Co. Ltd., Japan) in conformity with the National Standard Analysis Method (Research Association for Brewer's Rice, 1996). For the analysis of starch properties, white-core tissues were excised with a razor blade. Thereafter, they were crushed using an autocrusher (AC1A, Satake, Japan). Rice flour was passed through a 300 μ m mesh sieve.

1. Analysis of starch properties

The pasting properties of the starches, i.e., peak viscosity, holding strength (minimum paste viscosity), breakdown, final viscosity, setback and the pasting temperature were measured by RVA (Model RVA-3D, Newport Scientific, Australia) according to the method

of Aramaki et al. (2004); distilled water was added to 2.8 g of rice flour to make the total weight to 28 g. Each suspension was equilibrated at 50°C for 1 min, heated at a rate of 5°C min⁻¹ to 95°C, maintained at that temperature for 5 min, cooled to 50°C at a rate of 5°C min⁻¹ and then maintained at that temperature for 6 min. A constant rotating paddle (160 rpm) was used.

The thermal properties of the starches, i.e., gelatinization onset temperature, peak temperature, conclusion temperature and enthalpy were measured by differential scanning calorimetry analysed by DSC (DSC-50, Shimadzu, Japan) according to the method of Aramaki et al. (2004); 10 mg of rice flour was weighed in sample pans, mixed with 30 μ L of distilled water and sealed. The suspensions were heated at the rate of 2°C min⁻¹ from 20°C to 80°C. Distilled water (30 μ L) was used as the reference standard.

Amylose content was measured by the iodine colorimetric method (Juliano, 1971).

2. Statistical analysis

Each analysis of the starch properties was repeated twice. The data were subjected to analysis of variance (ANOVA) and the least significant differences (LSD) test ($p < 0.05$).

Results

Table 1 shows the pasting parameters in RVA of the rice flour from the white-core tissue of each variety. The peak viscosity and breakdown were higher in Hattan-nishiki No. 1 than in the others, and no significant differences were observed among Senbon-nishiki, Yamada-nishiki and Kairyo-omachi. Another RVA

parameters showed no significant varietal differences.

Table 2 shows the thermal parameters in DSC of the rice flour from the white-core tissue of each variety. The three DSC parameters, gelatinization onset, peak and conclusion temperatures were higher in Hattan-nishiki No. 1 and lower in Senbon-nishiki and Yamada-nishiki, and intermediate between them in Kairyo-omachi. Enthalpy showed no significant varietal differences.

Table 3 shows the amylose content of rice flour from the white-core tissue of each variety. The amylose content was the highest in Yamada-nishiki, but not significantly among the varieties used in the study.

Discussion

The results of this study showed that the starch properties (analysed by RVA and DSC) of the white-core tissue of brewers' rice kernels differ among different varieties of the rice.

Sandhya-Randi and Bhattacharya (1989), Kim et al. (2000) and Lisle et al. (2000) reported that starch properties were related with the endosperm structure and that chalky rice kernels showed lower peak and final viscosities, in RVA, and less amylose compared with the translucent rice kernels of the same variety. In addition, they observed that amyloplasts in the endosperm of chalky kernels were loosely packed compared with those in the endosperm of translucent kernels.

In this study, we compared the starch properties of the white-core tissue of different brewers' rice varieties. The results indicated that the RVA parameters, peak viscosity and breakdown, were higher in Hattan-nishiki No. 1 than in Senbon-nishiki, Yamada-nishiki and Kairyo-omachi. All of the DSC parameters, except

for enthalpy, were also higher in Hattan-nishiki No. 1 than in Senbon-nishiki and Yamada-nishiki. The SEM observation in our previous study (Tamaki et al., 2007) showed that Hattan-nishiki No. 1 and Kairyo-omachi had more air spaces in the white-core tissues of the kernels than Senbon-nishiki and Yamada-nishiki. These results suggested that starch properties were related to the endosperm structure, except for Kairyo-omachi.

The relationships between starch properties and structure of the white-core tissues observed in this study were different from those reported by Sandhya-Randi and Bhattacharya (1989), Kim et al. (2000) and Lisle et al. (2000). This is probably because they compared the starch properties of the chalky kernels with those of the translucent rice kernels. This point should be examined further.

The amylose content of the rice kernels ripened at a lower temperature was higher (Asaoka et al., 1985; Lisle et al., 2000; Koseki et al., 2004) than that in kernels ripened at a higher temperature. In rice kernels ripened at a higher temperature, the peak viscosity and breakdown measured by RVA (Lisle et al., 2000; Koseki et al., 2004) and the gelatinization onset, peak and concluding temperatures measured by DSC (Asaoka et al., 1984, 1985; Koseki et al., 2004) were higher. Heading and maturity occurred earlier in Hattan-nishiki No. 1 and later in Yamada-nishiki; however, accumulated temperature during ripening period showed no differences between these two varieties (Table 4). Inatsu (1979) and Asaoka et al. (1984) observed that the amylose contents are strongly affected by the temperature during the early ripening period. Their observations show that the starch properties are affected by the temperature during the early ripening period. Accumulated temperature for 20 d from heading, during the early ripening period, was higher in Hattan-nishiki No. 1 and lower in Senbon-nishiki, Yamada-nishiki and Kairyo-omachi (Table 4). Therefore, in this study, the peak viscosity and breakdown in RVA were higher in Hattan-nishiki No. 1 and lower in Senbon-nishiki, Yamada-nishiki and Kairyo-omachi. The DSC parameters, gelatinization onset, peak and concluding temperatures were higher in Hattan-nishiki No. 1 and lower in Senbon-nishiki and Yamada-nishiki. The temperature during the early

Table 3. Amylose contents of rice flour from the white-core tissue of brewers' rice kernels.

Variety	Amylose content
Senbon-nishiki	24.1
Yamada-nishiki	24.8
Hattan-nishiki No. 1	24.3
Kairyo-omachi	23.9 NS ¹⁾

¹⁾ NS indicates no significant difference among varieties (P<0.05 by LSD).

Table 4. Date of heading and maturity of brewers' rice and accumulated temperature.

Variety	Heading date	Maturity date	Temperature	
			Accumulated ¹⁾	20 d ²⁾
Senbon-nishiki	Aug. 18	Sep. 29	887	437
Yamada-nishiki	Aug. 24	Oct. 11	940	426
Hattan-nishiki No. 1	Aug. 6	Sep. 15	940	497
Kairyo-omachi	Aug. 18	Sep. 29	887	437

¹⁾ Accumulated temperature during the ripening period.

²⁾ Accumulated temperature for 20 d from heading.

ripening period in Kairyō-omachi was lower than that in Hattan-nishiki No. 1 and similar to those in Senbon-nishiki and Yamada-nishiki. This might explain why the RVA and DSC parameters in Kairyō-omachi were not significantly different from those in Senbon-nishiki and Yamada-nishiki, although the endosperm structure of the white-core tissue of kernels in Kairyō-omachi was different in that in Senbon-nishiki and Yamada-nishiki. Though there was a 0.9% difference in the amylose content among varieties, differences were not significant. This might be due to the low number of relications.

These results suggest that the polishing characteristics of brewers' rice kernels might be related with not only the endosperm structure but also the starch property of white-core tissue of brewers' rice kernels. However, clear results were not obtained in Kairyō-omachi. Further studies must be carried out to determine the relationship between the starch property and the endosperm structure of different types and/or different varieties of rice having the white-core tissue. In addition, the temperature during the early ripening period will also have to be considered.

Previously (Tamaki et al., 2005), we reported that there was no significant differences in the starch properties of the white-core tissue among six Hattan-type varieties. Hattan-type varieties were bred by successive crossing using Hattan-type varieties originating from the same parent 'Hattanso'. This might account for the absence of significant differences in the starch properties.

This study was conducted using materials used in our previous study (Tamaki et al., 2007) in order to clarify the effects on the polishing characteristics reported in our previous study. However, it is necessary to conduct further experiments using materials collected for several years since the starch properties and the endosperm structures are affected by the climatic conditions. In addition, Matsue et al. (1994) reported that the protein and amylose contents varied with the position of the grain in the panicle. The starch properties (analyzed by RVA and DSC) and/or the endosperm structures may also vary with the position of the grains in the panicle. Therefore, in the next study we will use samples collected from the same position of the panicle to obtain precise results.

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