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Difference in the Physical Properties of White-Core and Non-White-Core Kernels of the Rice Varieties for Sake Brewing is Unrelated to Starch Properties

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Abstract : This study was designed to determine whether or not the difference in the physical properties between white-core and non-white-core kernels of the rice varieties for sake brewing is associated with their starch properties. We used two rice cultivars for sake brewing, Senbon-nishiki and Yamada-nishiki, from three different plots in Hiroshima prefecture. Hardness values of kernels were significantly higher in non-white-core than in white-core kernels in both varieties. Vickers hardness (VH) values were lowest at the center of the kernel in both types of kernels. VH values of white-core tissues of white-core kernels were significantly lower than those of corresponding tissues of non-white-core kernels. No significant differences were observed between the two types of kernels in VH values of the surrounding translucent tissues and in the starch properties (amylose content, pasting properties analyzed using a rapid viscoanalyzer and gelatinization properties analyzed using a differential scanning calorimetry). These results suggest that the difference in physical properties between the two types of kernels of the rice varieties for sake brewing are associated with the difference in structure of endosperm cells and not in starch properties.

Key words : Brewer's rice, Hardness, Non-white-core kernel, Starch, White-core kernel.

Non-glutinous rice varieties with large kernels are used for brewing rice wine (sake). The kernels often have white, opaque tissue at the center, which is termed as “white-core.” Varietal differences exist in the appearance ratio and type of the white-core in the kernel, and they are genetically controlled (Ikegami and Seko, 1995; Akiyama et al., 1997).

Numerous airspaces are present and less starch is accumulated in white-core tissues (Nagato and Ebata, 1958; Del Rosario et al., 1968; Ando and Ichikawa, 1974; Yanagiuchi et al., 1996; Takahashi et al., 1999; Yoshii, 2000). Del Rosario et al. (1968) and Ando and Ichikawa (1974) observed a loose arrangement of starch granules in white-core tissues; this contrasted with their compact arrangement in the surrounding translucent tissues. White-core tissues promote the gelatinization of steamed rice during the rice wine brewing process and induce the invasion of Koji fungus. Thus, they are important for brewing rice wine (Nagato and Ebata, 1959; Koura, 1972; Hanamoto, 1976; Yanagiuchi et al., 1996; Yoshii, 2000; 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 for sake brewing has been aimed at enlarging the white core (Akiyama et al., 1997; Ikegami, 1997).

Differences in the physical properties, such as grain rigidity, milling qualities, specific gravity, and hardness between white-core kernels and non-white-core kernels of the same rice varieties, have been reported (Nagato and Ebata, 1959; Yanagiuchi et al., 1993, 1996; Aramaki et al., 1995; Iemura et al., 1996). These differences in the physical properties between white-core and non-white-core kernels are considered to be associated with structural differences in the endosperm cells (Nagato and Ebata, 1958 ; Del Rosario et al., 1968 ; Ando and Ichikawa, 1974 ; Yanagiuchi et al., 1996 ; Takahashi et al., 1999 ; Yoshii, 2000).

No differences were observed in the chemical components between white-core and non-white-core kernels in the same varieties for sake brewing (Iemura et al., 1996; Yanagiuchi et al., 1996). Excluding the study on amylose content by Iemura et al. (1996), no studies have been made on the starch properties of white-core kernels and non-white-core kernels. Previously (Tamaki et al., 2003), we reported that varietal differences in physical properties of brewer's rice were related to differences in not only the structure of endosperm cells but also starch properties. Differences in physical properties between white-

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Abbreviations : DSC, differential scanning colorimetry; RVA, rapid viscoanalyzer; VH, vickers hardness.

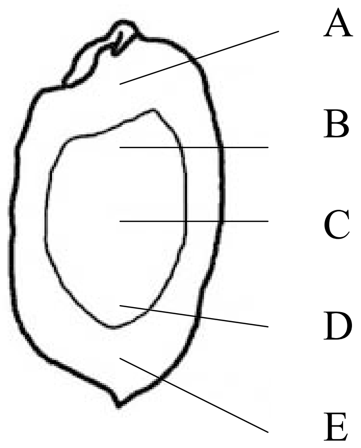


Fig. 1. VH values were measured at five points along the axis from the apical end to the basal end in the longitudinal section of white-core kernels.
C: center of the kernel; B and D: edges of white-core tissues close to the apical end and the basal end, respectively; A and E: the middle between the apical ends of the kernel and the white-core tissue and between the basal ends of the kernel and white-core tissue, respectively. In non-white-core kernels, VH values were measured at the points corresponding to those of white-core kernels.

core kernels and non-white-core kernels of the same varieties may be also related to differences in not only the structure of endosperm cells but also starch properties.

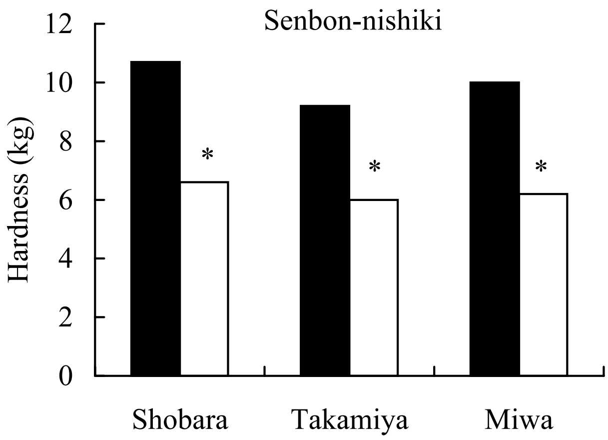
This study was designed to determine whether the starch properties participate in the difference in physical properties between white-core and non-white-core kernels of the rice varieties for sake brewing.

Materials and Methods

We used two rice cultivars for sake brewing: Senbon-nishiki and Yamada-nishiki. Rice plants were cultivated in different three plots in Hiroshima prefecture : Hiroshima Prefectural University (Shobara city) and farmer's paddy field (Takamiya town and Miwa town). After harvest, the moisture content of brown rice was adjusted to 13.8% in conformity with the National Standard Analysis Method (Research Association for Brewer's Rice, 1996). The hardness of kernels and the hardness distribution of kernels were measured using brown rice. The brown rice was then milled to 70%, and the moisture content of milled rice was adjusted to 13.5% in conformity with the National Standard Analysis Method (Research Asociation for Brewer's Rice, 1996). The milled rice was then crushed with an autocrusher (AC1A, Satake Co. Ltd., Japan) and analyzed for starch properties.

1. Hardness of kernels

Fifty each of white-core and non-white-core kernels were selected from each of Senbon-nishiki and Yamada-nishiki varieties. The hardness was measured



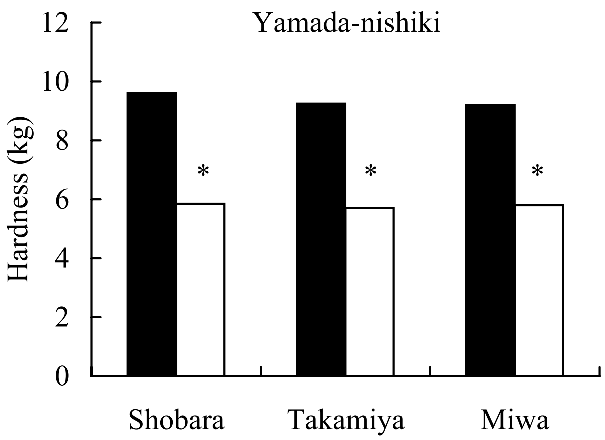


Fig. 2. Hardness of white-core and non-white-core kernels in Senbon-nishiki (upper) and Yamada-nishiki (lower).
Open column: white-core kernels, closed column: non-white-core kernels.
* indicates significant differences between white-core and non-white-core kernels at 5% level.

by crushing the kernels with a grain rigidity tester (Kiya Co. Ltd., Japan). Experiments were performed with three replicates. The data of white-core kernels and non-white-core kernels of the same varieties from each plot were subjected to the t-test ($p < 0.05$).

2. Hardness distribution in kernels

Thirty each of white-core and non-white-core kernels were selected from each of Senbon-nishiki and Yamada-nishiki varieties. Five kernels were fixed to a plate (40×17 mm) using a bonding agent along the longitudinal axis. The bonding agent was applied to the lower surface of the kernels. After 20 min, the kernels were cut longitudinally with a razor blade.

Using a micro-hardness tester (Akashi, Co. Ltd. Japan), a preloaded (15 g) diamond pyramid was forced into the even plane of the kernel section for 15 s, and the length of the diagonal of the quadrate impression was measured using a microscope. The Vickers hardness (VH) was then calculated as:

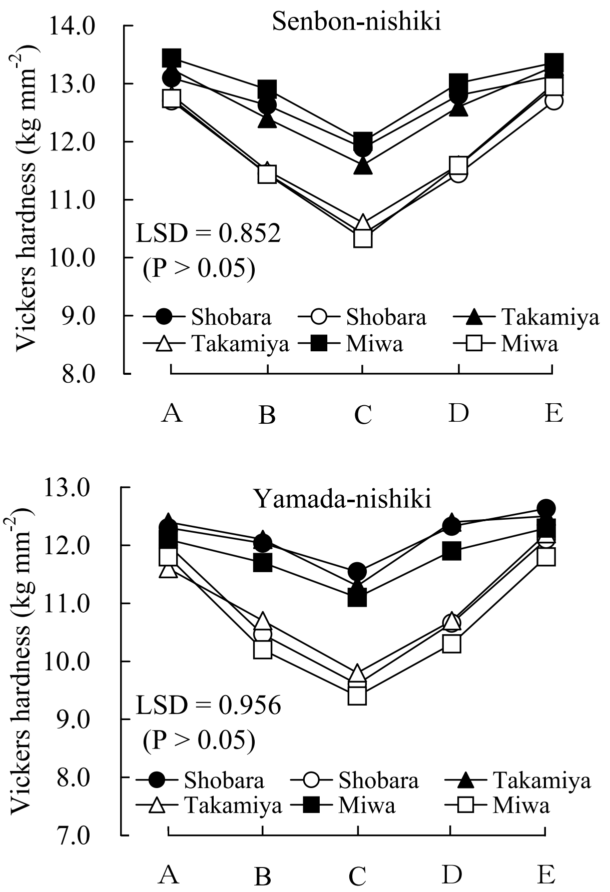


Fig. 3. Hardness distribution in white-core and non-white-core kernels in Senbon-nishiki (upper) and Yamada-nishiki (lower).
Open symbols: white-core kernels, closed symbols: non-white-core kernels.
For A, B, C, D, E see Fig. 1.

$$VH = 2P\sin(\theta/2)\ d^{-2} \times 1000 = 1854.4\ P\ d^{-2}\ (\mathrm{kg\ mm^{-2}})$$

where "P" is the load (15 g), "θ" is the angle of the diagonal phases of the diamond pyramid, and "d" is the length of the diagonal of the quadrate impression (μm).

In the longitudinal section of white-core kernels, VH values were measured at five points along the axis from the apical to the basal end (Fig. 1). These were the center of the kernel (C), the edge of the white-core tissue close to the apical end and the basal ends (B and D, respectively), and the middle between the apical ends of the white-core tissue and kernel, and between the basal ends of the white-core tissue and kernel (A and E, respectively). In non-white-core kernels, VH values were measured at the points corresponding to those of white-core kernels.

The effects of the bonding agent on VH were not examined; however, we considered that no changes occurred in VH because the bonding agent dried quickly. The experiments were conducted at a temperature of 20°C and 70% relative humidity with two replicates, i.e., a total of 12 replicates with five kernels each. The data were subjected to analysis of variance (ANOVA) and the least significant differences (LSD) test ($p < 0.05$).

Table 1. Amylose contents of white-core and non-white-core kernels in Senbon-nishiki and Yamada-nishiki.

Variety	Kernel type	Amylose content
Senbon-nishiki	White-core	24.1
	Non-white-core	24.8^{NS}
Yamada-nishiki	White-core	24.8
	Non-white-core	24.4^{NS}

^{NS} indicates no significant difference between white-core and non-white-core kernels at 5% level.

3. Starch properties

Since there were no significant differences among the three sampling plots in the hardness of kernels and hardness distribution of kernels in white-core and non-white-core kernels of either variety (Fig. 2 and Fig. 3), starch properties were analyzed using the plants cultivated at Hiroshima Prefectural University.

Amylose content was analyzed by the iodine-colorimetric method (Juliano, 1971). The pasting temperature, peak viscosity, holding strength (minimum paste viscosity), and final viscosity of rice flour were analyzed with a rapid viscoanalyzer (RVA) (RVA-3D, Newport Scientific Co. Ltd., Australia) according to the method of Aramaki et al. (2004a) and 2.8 g of rice flour to which distilled water was added to make total weight of 28 g. The gelatinization-onset temperature, peak temperature, concluding temperature, and enthalpy were analyzed by a differential scanning colorimetry (DSC) (DSC-50, Shimadzu Co. Ltd., Japan), using 10 mg of rice flour to which 30 μl of distilled water was added. Each experiment was performed with three replicates. The data of white-core kernels and non-white-core kernels of each variety were subjected to the t-test ($p < 0.05$).

Results

Fig. 2 shows the hardness values of the kernels. The values were significantly lower in white-core kernels than in non-white-core kernels in both varieties in each plot; The result was similar to those of Nagato and Ebata (1959) and Aramaki et al.(1995).

Fig. 3 shows the VH values at different points along the axis from the apical end to the basal end in the longitudinal section of the kernels. VH values were lowest at the center (C) of both white-core kernels and non-white-core kernels in both varieties from each plot. VH values of the white-core tissues of white-core kernels (B, C, and D) were significantly lower than those of the corresponding tissues of non-white-

Table 2. RVA parameters of white-core and non-white-core kernels in Senbon-nishiki and Yamada-nishiki.

Variety	Kernel type	Peak viscosity (cP)	Holding strength (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Pasting temperature (°C)
Senbon-nishiki	White-core	1706	707	1004	1361	659	63.2
	Non-white-core	1817^{NS}	720^{NS}	1098^{NS}	1369^{NS}	649^{NS}	63.3^{NS}
Yamada-nishiki	White-core	1625	718	907	1393	676	61.6
	Non-white-core	1748^{NS}	756^{NS}	993^{NS}	1431^{NS}	675^{NS}	61.1^{NS}

^{NS} indicates no significant difference between white-core and non-white-core kernels at 5% level.

Table 3. DSC parameters of white-core and non-white-core kernels in Senbon-nishiki and Yamada-nishiki.

Variety	Kernel type	Onset temperature (°C)	Peak temperature (°C)	Concluding temperature (°C)	Enthalpy (-J/g)
Senbon-nishiki	White-core	56.82	64.97	76.47	3.99
	Non-white-core	57.07^{NS}	65.05^{NS}	76.98^{NS}	3.99^{NS}
Yamada-nishiki	White-core	55.64	64.10	76.41	3.98
	Non-white-core	55.27^{NS}	63.60^{NS}	75.75^{NS}	4.23^{NS}

^{NS} indicates no significant difference between white-core and non-white-core kernels at 5% level.

core kernels. However, no significant differences were observed between the white-core and non-white-core kernels in the VH values of the adjacent translucent tissues or surrounding translucent tissues in both varieties from each plot (A and E).

Table 1 shows the amylose content of the kernels. No significant differences in the amylose content were observed between white-core kernels and non-white-core kernels in both varieties, which is similar to the results of Iemura et al. (1996).

Table 2 shows the pasting parameters of the kernels analyzed using RVA. No significant differences in these parameters were observed between white-core kernels and non-white-core kernels in both varieties.

Table 3 shows the gelatinization parameters of the kernels analyzed by DSC. There were no significant differences in these parameters between white-core kernels and non-white-core kernels in both varieties.

Discussion

Nagato (1962) and Nagato and Kono (1963) measured the VH values at different points on the transection of the kernels of rice for sake brewing. For the breeding selection or the observation of the apparent quality of rice kernels, longitudinal section of the rice kernels has been evaluated. Therefore, in this study, VH was measured on the longitudinal section of the kernels. The results were similar to the study on the transection of kernels reported by Nagato (1962) and Nagato and Kono (1963).

Yanagiuchi et al. (1996) reported that white-core kernels are easily broken during polishing as compared with non-white-core kernels and that the specific gravity of white-core kernels was lower than that of non-white-core kernels. Nagato and Ebata (1959) also reported that the specific gravity around the central tissues of white-core kernels was lower than that of non-white-core kernels. Nagato and Ebata (1959) and Aramaki et al. (1995) reported that the hardness values of white-core kernels were lower than those of non-white-core kernels, which was similar to the results of the present study. In addition, Aramaki et al. (1995) reported that as the polishing degree increased, the hardness values and the polishing time decreased more greatly in white-core kernels than in non-white-core kernels. In this study, the VH values in the white-core tissues were significantly lower than those in the surrounding peripheral translucent tissues in white-core kernels and the values were significantly lower than those of the corresponding tissues in non-white-core kernels, which were similar to the results of Nagato (1962) and Nagato and Kono (1963). However, no significant differences between the two types of kernels were observed in the VH values of the surrounding translucent tissues. These differences in physical properties between white-core kernels and non-white-core kernels can be explained by the presence of numerous airspaces and less accumulation of starch in the white-core tissues (Nagato and Ebata, 1958; Del Rosario et al., 1968; Ando and Ichikawa, 1974; Yanagiuchi et al., 1996; Takahashi et al., 1999; Yoshii, 2000) and also by a loose arrangement of the starch granules in the white-core tissues (Del Rosario et al., 1968; Ando and Ichikawa, 1974).

Asaoka et al. (1994), Toyoshima et al. (1997), Jane et al. (1999), and Aramaki et al. (2004a, b) reported a high correlation between amylose content and pasting parameters analyzed using RVA in various rice varieties and crops. There were no significant differences in the amylose content between white-core kernels and non-white-core kernels in both varieties, which is similar to the results of Iemura et al. (1996). Therefore, there will be no significant differences in the pasting properties between the two types of kernels.

Yanagiuchi et al. (1996) reported that white-core kernels have superior water absorptivity and digestibility than non-white-core kernels varieties; however, both types of kernels have similar chemical components; crude protein, manganese, and potassium. In addition, they reported that no significant differences were observed in the water absorptivity and digestibility of the rice flour between white-core kernels and non-white-core kernels. Therefore, we suggest that differences in physical properties between white-core kernels and non-white-core kernels in the rice varieties for sake brewing are related to the differences in the structure of endosperm cells rather than starch properties or chemical components.

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** Translated from Japanese by the present authors.