Varietal Difference of Polishing Characteristics and Suitability for Sake Brewing in "Hattan-Type Varieties" of Rice Suitable for Brewing Original Hiroshima Sake

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Abstract : By successive crossing using Hattan-type varieties originating from "Hattanso" as a parent, "Hattan-type varieties" of rice suitable for brewing the original Hiroshima sake have been bred. The varieties were improved inheriting the flavor of Hattan-type sake, and Hattan-nishiki No.1 and No.2 were bred in 1984. However, neither variety was suitable for brewing high-grade sake such as Ginjoshu and Daiginjoshu, which require high-degree polishing of rice grains. Therefore, their parent cultivar, Hattan No. 35, is attracting attention for the production of high-grade sake. We have been trying to breed a new variety, which retains the sake-brewing suitability of Hattan-type varieties but can endure high-degree polishing. In this study, to establish a guideline for further breeding, we examined the polishing characteristics and suitability for sake brewing of six Hattan-type varieties derived from Hattanso. In the process of breeding of "Hattan-type varieties" of rice, grain size, white-core size and % of white-core grains increased resulting in an increased suitability for sake brewing, such as water absorptivity and digestibility, in Hattan No.35, Hattan-nishiki No.1 and Hattan-nishiki No.2. However, Hattan-nishiki No.1 and No.2 had many ellipsoidal-white-cores with large white tissue, which cause the grains to be easily broken during high-degree polishing. On the other hand, Hattan No.35, having grains with relatively many lined-white-cores with small white tissue, was superior for high-degree polishing. In the future, breeding of a new variety, which has the superior cultivation characteristics of Hattan-nishiki No.1 and No.2, but with improved white-core characteristics, is expected.

Key words : Brewer's rice, Hattan-type varieties of rice, Polishing, Suitability for sake brewing, White-core grain.
degree polishing, keeping suitability for sake brewing useful for breeding the varieties that can endure high-

from Hattanso, and to search for genetic characters characteristics of six Hattan-type varieties originating in the suitability for sake brewing and polishing (Maeshige and Kobayashi, 2000).

is being used for brewing Ginjoshu and Danginjoshu and are not easily broken by high-degree polishing, No.35, whose kernels have smaller white-core tissues easily broken by high-degree polishing. Thus, Hattan nishiki No.1 and No.2 have large white tissue and are suitable for common sake brewing.

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to those of common nonglutinous rice, and have high yielding ability and lodging resistance similar to the suitability for sake brewing in Japan. In Hiroshima Prefecture, however, quite different cultivars, Hattan No.35, Hattan-nishiki No.1 and Hatan-nishiki No.2 are mainly cultivated. These cultivars are cultivated only in Hiroshima Prefecture but are notable as the rice suitable for common sake brewing, and were sold to sake brewers in 32 prefectures in 2003.

The history of breeding of Hattan-type varieties started from private breeding of Hattanso, the origin of Hattan-type varieties, in 1875. Since 1907, the Hiroshima Prefecture Agriculture Experiment Station (the present Hiroshima Prefecture Agriculture and Forest Experiment Station) tried to improve these varieties so as to develop the white-core, which is required for rice suitable for sake brewing in addition to disease resistance, lodging resistance and yielding ability. As a result, Hattan No.35 (Takei et al., 1968) was bred in 1962, and Hattan-nishiki No. 1 (Maeshige et al., 1984a) and Hattan-nishiki No.2 (Maeshige et al., 1984b) in 1984. Hattan-nishiki No.1 was bred as a variety for the higher altitude area (400m) and Hattan-nishiki No.2 for a hilly area (250-350m) and Hattan-nishiki No.2 for a higher altitude area (400m). These two varieties have high yielding ability and lodging resistance similar to those of common nonglutinous rice, and have improved suitability for sake brewing.

Sake brewers have pointed out that grains of Hattan-nishiki No.1 and No.2 have large white tissue and are easily broken by high-degree polishing. Thus, Hattan No.35, whose kernels have smaller white-core tissues and are not easily broken by high-degree polishing, is being used for brewing Ginjoshu and Danginjoshu (Maeshige and Kobayashi, 2000).

The aim of this study is to clarify the changes in the suitability for sake brewing and polishing characteristics of six Hattan-type varieties originating from Hattanso, and to search for genetic characters useful for breeding the varieties that can endure high-degree polishing, keeping suitability for sake brewing of Hattan-type varieties.

### Materials and Methods

Six Hattan-type varieties bred from Hattanso in Hiroshima Prefecture (Hattanso, Hattan No.10, No.35, No.40, Hattan-nishiki No.1 and No.2) were used. The seeds were sown on April 25, 2002, at the Hiroshima Prefecture Agriculture Research Center, transplanted on May 21 and harvested at maturity. Chemical fertilizers were applied at the rate of 3.0 g N, P₂O₅, K₂O per m² as basal dressing and 2.0g N, P₂O₅, K₂O per m² as top dressing on June 25, 2002. After harvest, water content of brown rice and polished rice (apparent polishing rate, 70%) was adjusted to 13.8 and 13.5%, respectively (Research association for brewer’s rice, 1996), and used for the following experiments.

The present study was conducted only in 2002; however, Ohdoi et al. (2000) and Mizuma et al. (2001) reported that the growth and yield of rice suitable for sake brewing varied with the year, while the characters related to the suitability for sake brewing didn’t vary with the year. Therefore, we presumed that the suitability for sake brewing is inherent in the variety, and we can discuss about the varietal differences based on the results of a single year experiment.

1. **Evaluation of the degrees of loading**

   The degrees of loading were evaluated at maturity on a scale of 1 to 5; 1 = no lodging and 5 = complete lodging.

2. **Examination of the characters of brown rice**

   One hundred brown rice randomly selected were cut in vertical and longitudinal directions, and the cut surface was observed to classify the white-cores into white-bellied-core, ellipsoidal-white-core, lined-white-core, dotted-white-core and non-white-core (Ebata and Nagato, 1960; Takahashi et al., 1999). Percentage of grains with a white-core (%) of white-core grains) was determined from the observation of 100 brown-rice grains. Using 200 brown rice grains randomly selected, length, width, and thickness of grains and white-core rate (percentage of white tissue area (white-core) to

### Table 1. Date of heading and maturity, and degrees of lodging at maturity in Hattan-type varieties.

| Variety       | Heading date | Maturity date | Degree of lodging* |
|---------------|--------------|---------------|--------------------|
| Hattanso      | Aug. 11      | Sep. 24       | 5                  |
| Hattan No. 10 | Jul. 31      | Sep. 5        | 3                  |
| Hattan No. 35 | Jul. 30      | Sep. 5        | 3                  |
| Hattan No. 40 | Aug. 2       | Sep. 10       | 4                  |
| Hattan-nishiki No. 1 | Jul. 29 | Sep. 5        | 2                  |
| Hattan-nishiki No. 2 | Jul. 28 | Sep. 5        | 1                  |

*1 ; no lodging, 2; inclination of plant was 0-45°, 3 ; inclination of plant was almost 45°, 4; inclination of plant was 45-90°, 5 ; complete lodging.

(malted rice). Thus, the presence of broken grains is not suitable for brewing (Mizuma et al., 2000).

In addition to cultivars Yamada-nishiki and Omachi, Kamennoo-type varieties, Gohyakumangoku, and Miyama-nishiki, etc. are cultivated as rice cultivars suitable for sake brewing in Japan. In Hiroshima Prefecture, however, quite different cultivars, Hattan No.35, Hattan-nishiki No.1 and Hatan-nishiki No.2 are mainly cultivated. These cultivars are cultivated only in Hiroshima Prefecture but are notable as the rice suitable for common sake brewing, and were sold to sake brewers in 32 prefectures in 2003.

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the cut surface area of the grains) were measured using a shape analyzer (RIA-1A, Satake Co. Ltd., Japan). The hardness of rice grains was measured with a durometer (Kiya Co. Ltd., Japan) using 50 grains randomly selected. The experiment was repeated three times.

3. Test of suitability for sake brewing

Based on the National Standard Analysis Method of Materials for Sake Brewing (Research Association for Brewer’s Rice, 1996), 1000-grain weight, polishing rate (apparent polishing rate, net polishing rate, void polishing rate), broken grain rate, water absorptivity (20-min absorption rate, 120-min absorption rate), digestibility (absorbed water after steaming, Brix and formorl-N), crude protein and potassium contents were analyzed. The experiment was repeated three times.

Results and Discussion

Table 1 shows the date of heading and maturity, and lodging rate at maturity of each variety. The date of heading and maturity were the latest in Hattanso followed by Hattan No.40, and were nearly the same in the other four varieties. The degrees of lodging were the highest in Hattanso and was low in Hattan-nishiki No.1 and No.2.

Table 2 shows the varietal difference in the white-core shape in Hattan-type varieties. The appearance of the white-core in the rice grain varies with the variety, and the white-core is classified into white-bellied-core, ellipsoidal-white-core, lined-white-core, dotted-white-core and non-white-core (Ebata and Nagato, 1960; Takahashi et al., 1999). In Hattanso, the percentage of grains with a white-core ( % of white-core grains) was 66%, but it increased in the process of breeding. In Hattan No.40, Hattan-nishiki No.1 and Hattan-nishiki No.2, the rate of ellipsoidal-white-core, the round large white tissue on the cut surface, was relatively high, and in Hattan No.10 and Hattan No.35, the rate of lined-white-core, lined white tissue on the cut surface, was relatively high.

Table 3 shows the varietal difference in the shape of brown rice and white-core rate in Hattan-type varieties. Ikegami (1997) reported a positive correlation between the grain width and % of white-core grains. In the present experiment with Hattan-type varieties also, a significant correlation (r = 0.94**) was observed between them (Fig. 1). A significant correlation was also observed between the grain thickness and % of white-core grains (r = 0.91**), but no significant correlation between the grain length and % of white-core grains. Thus, grain enlargement seemed to contribute to the increase in white-core rate, and

| Variety         | Non-white-core (%) | White-bellied-core (%) | Ellipsoidal-white-core (%) | Lined-white-core (%) | Dotted-white-core (%) | White-core grains (%) |
|-----------------|--------------------|------------------------|-----------------------------|----------------------|-----------------------|-----------------------|
| Hattanso        | 34                 | 29                     | 24                          | 8                    | 5                     | 66                    |
| Hattan No. 10   | 20                 | 33                     | 23                          | 20                   | 4                     | 80                    |
| Hattan No. 35   | 11                 | 19                     | 36                          | 30                   | 4                     | 89                    |
| Hattan No. 40   | 11                 | 37                     | 47                          | 4                    | 1                     | 89                    |
| Hattan-nishiki No.1 | 3              | 25                     | 59                          | 12                   | 1                     | 97                    |
| Hattan-nishiki No.2 | 5              | 32                     | 50                          | 10                   | 3                     | 95                    |

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

| Variety         | Length (mm) | Width (mm) | Thickness (mm) | White-core rate (%) |
|-----------------|-------------|------------|----------------|---------------------|
| Hattanso        | 5.38a       | 3.05b      | 2.07b          | 47b                 |
| Hattan No. 10   | 5.14bc      | 3.15a      | 2.12ab         | 56ab                |
| Hattan No. 35   | 5.00c       | 3.16a      | 2.19ab         | 60a                 |
| Hattan No. 40   | 5.27ab      | 3.14a      | 2.13ab         | 63a                 |
| Hattan-nishiki No.1 | 5.22ab | 3.18a      | 2.26a          | 67a                 |
| Hattan-nishiki No.2 | 5.20abc | 3.18a      | 2.23a          | 65a                 |

Values with same letters are not significantly different (P<0.05 by LSD).
also in % of white-core grains. In the process of the breeding, the lined-white-core in Hattan No.10 and Hattan No.35 seemed to remain unexpectedly.

Table 4 shows the varietal difference in the 1000-grain weight, polishing characteristics and grain hardness in Hattan-type varieties. Since the grain size tended to increase in the process of breeding (Table 3), 1000-grain weight also tended to increase in the process. The polishing characteristics are superior in the variety with a low void polishing rate and low broken grain rate, but the void polishing rate was between 1.4 and 3.0% in all varieties examined, showing no significant varietal difference. Hattan No.35 had a low broken-grain rate, and had superior polishing characteristics. Hattanso, Hattan No.10, Hattan-nishiki No.1 and Hattan-nishiki No.2 showed a broken-grain rate of more than 12%, and are inferior in polishing characteristics. This is probably because these varieties have been bred to increase grain size, white-core size and % of white-core grains, except Hattanso. Tamaki et al. (2002) reported that the distribution of hardness in the grain is different between the grains with an ellipsoidal-white-core that has large white tissue and the grains with a lined-white-core that has small white tissue, because the cellular structure of the white-core of them differs. They also suggested that the grains with ellipsoidal-white-core, which have a large positional difference in the hardness of endosperm tissue, are easily deformed by polishing load and easily broken. Therefore, grains of Hattan-nishiki No.1 and No.2 with a high % of ellipsoidal-white-core may be more easily broken during polishing than grains of Hattan No.35 with a relatively high % of lined-white-core. This may be why the Hattan-nishiki No.1 and No.2 were inferior in polishing characteristics. Generally, the characteristics of rice suitable for sake brewing are examined using the rice grains at an apparent polishing rate of 70% according to the national standard analysis method of materials for sake brewing (Research association for brewer’s rice, 1996). In this study also, we used rice grains at an apparent polishing rate of 70% to compare with the data already reported. Preparation of uniform grains at a higher-than-70% polishing rate is difficult due to the limited ability of the person in charge and adjustability of the machine. Therefore, the examination of the varietal differences using such grains is difficult. However, since the aim of this study is to find varieties that can endure high-degree polishing, further studies with grains at a higher-than-70% polishing rate are necessary.

The grain hardness was low in Hattan-nishiki No.1 and No.2 (4.3 and 4.4 kg, respectively), which shows that grains of Hattan-nishiki No.1 and No.2 are fragile. Hattan No.10 had a low percentage of ellipsoidal-white-core grains and had as high as 5.5 kg hardness of grains. Nevertheless, it had poor polishing characteristics. The reason is uncertain, and further examination on the cellular structure of the endosperm will be necessary.

Table 5 shows the varietal difference in the suitability for sake brewing in Hattan-type varieties. Water absorptivity shown by the 20-min water absorption rate was as high as 28% in Hattan No.35, Hattan No.40, Hattan-nishiki No.1 and Hattan-nishiki No.2 are fragile. Hattan No.10 had a low percentage of ellipsoidal-white-core grains and had as high as 5.5 kg hardness of grains. Nevertheless, it had poor polishing characteristics. The reason is uncertain, and further examination on the cellular structure of the endosperm will be necessary.

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have longitudinally developed endosperm cells and absorb water rapidly. The varietal difference in the maximum water absorption shown by a 120-min water absorption was similar to that shown by a 20-min water absorption, though the varietal difference was small. The rate of absorbed water after steaming was slightly higher (about 34%) in Hattan No.10, Hattan-nishiki No.1 and Hattan-nishiki No.2, but its varietal difference was similar to that shown by the 120-min water absorption rate.

The Brix value that shows the solubility of unrefined rice (moromi) was as high as about 10% in Hattan No.35, Hattan No.40, Hattan-nishiki No.1 and Hattan-nishiki No.2, and its varietal difference was similar to that shown by the 120-min water absorption rate.

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Table 4. Varietal difference in the 1000-grain weight, polishing characteristics and grain hardness in Hattan-type varieties.

| Variety        | 1000-grain weight (g) | Polishing rate | Broken grain rate (%) | Grain hardness (kg) |
|----------------|-----------------------|----------------|-----------------------|---------------------|
|                |                       | Apparent (%)  | Net (%)               | Void (%)           |                     |
| Hattanso       | 26.1bc                | 70.0          | 71.4                  | 1.4                | 12.6ab              | 4.7                |
| Hattan No. 10  | 27.0b                 | 70.0          | 72.5                  | 2.5                | 14.6a               | 5.5                |
| Hattan No. 35  | 25.1c                 | 70.0          | 73.0                  | 3.0                | 7.0c                | 4.8                |
| Hattan No. 40  | 27.4b                 | 70.0          | 72.9                  | 2.9                | 10.0b               | 4.9                |
| Hattan-nishiki No. 1 | 29.2a             | 69.9          | 72.9                  | 3.0                | 12.3ab              | 4.3                |
| Hattan-nishiki No. 2 | 27.6b             | 70.0          | 72.6                  | 2.6                | 14.6a               | 4.4                |

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

Table 5. Varietal difference in the suitability for sake brewing in Hattan-type varieties.

| Variety        | Water absorption 20 min (%) | Absorbed water after steaming (%) | Digestibility | Crude protein | K (ppm/D.W) |
|----------------|-----------------------------|-----------------------------------|---------------|---------------|-------------|
|                | 120 min (%) | Brix (%) | F-N (%) | %/D.W |               |            |
| Hattanso       | 23.0b        | 32.1     | 8.7b    | 0.6 | 4.9       | 420a       |
| Hattan No. 10  | 26.4ab       | 33.6     | 9.7a    | 0.7 | 5.2       | 430a       |
| Hattan No. 35  | 28.3a        | 31.7     | 9.9a    | 0.7 | 5.0       | 357ab      |
| Hattan No. 40  | 28.1a        | 31.5     | 10.3a   | 0.7 | 5.4       | 437a       |
| Hattan-nishiki No. 1 | 28.5a    | 33.8     | 10.1a   | 0.7 | 5.2       | 313b       |
| Hattan-nishiki No. 2 | 27.6a    | 33.6     | 9.8a    | 0.7 | 5.3       | 311b       |

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

1) F-N ; Formol-N.
introducing rice blast resistance (Takei et al., 1968), and Hattan No.40 was bred in 1965. Then, stable high-yielding ability was introduced to Hattan No.35, and Hattan-nishiki No.1 (Maeshige et al., 1984a) and Hattan-nishiki No.2 (Maeshige et al., 1984b) were bred in 1984. Hattan-nishiki No.1 was bred as a variety for a hilly area (250-350m) and Hattan-nishiki No.2 for a higher latitude area (400m). These varieties have yielding ability and lodging resistance similar to those of common nonglutinous rice, and improved suitability for sake brewing. Thus, the varieties suitable for sake brewing have been bred aiming to enlarge the white-core and to increase the rate of grains with a white-core. These attempts at breeding have been mostly to improve the cultivation properties.

Since Hattan-type varieties have been bred by selecting for large grain, large white-core and high % of white-core grains, the water absorptivity and digestibility increased (Fig. 2). These characters may affect the invasion of Koji yeast and the amount of brewed sake. However, for brewing Ginjoshu and Daiginjoshu, high-degree polishing is indispensable, and rice varieties that are not easily broken during polishing are desirable. Hattan-nishiki No.1 and No.2 have superior suitability for sake brewing but inferior polishing characteristics, and are not suitable for brewing Ginjoshu and Daiginjoshu.

The present results are summarized as follows. (I) Hattanso has inferior suitability for sake brewing. It is not superior in polishing characteristics and has inferior cultivation characteristics. (II) Hattan No.10 and No.40 have superior suitability for sake brewing but inferior polishing and cultivation characteristics. (III) Hattan No.35 has superior polishing characteristics and suitability for sake brewing but inferior cultivation characteristics. (IV) Hattan-nishiki No.1 and No.2 have large grains and are superior in cultivation and suitability for sake brewing, but inferior in polishing characteristics. These results show that Hattan-type varieties bred from Hattanso in Hiroshima Prefecture had been bred aiming to increase grain size, white-core rate and % of white-core grains. Therefore, the suitability for sake brewing, such as water absorptivity and digestibility, increased. Hattan No.10 and No.35, in particular Hattan No.35, have high % lined-white-core grains, which are not easily broken and can endure high-degree polishing. On the other hand, Hattan-nishiki No.1 and No.2 had a relatively high % of ellipsoidal-white-core grains; and, grains can not endure high-degree polishing.

The shape and size of white-core tissue largely influence the quality of sake (Yanagiuchi et al., 1996). Yamada-nishiki, which is used for brewing high-grade sake such as Ginjoshu and Daiginjoshu, has a lined-white-core in grains, and sake brewers consider that the endurance to high-degree polishing is due to this type of a white-core, "lined-white-core". There is a possibility that Hattan No.10 and Hattan No.35 still have a genetic trait related to a lined-white-core. Therefore, by crossing with these varieties, rather than with other varieties, it may be possible to breed a variety suitable for brewing high-grade sake with the superb taste of Hattan-nishiki No.1 and No.2.

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* In Japanese, with English abstract or summary.
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