An Efficient Method for Evaluating the Palatability Deterioration During Storage in Rice

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Abstract: This study was conducted to establish an efficient selection method for breeding highly palatable rice cultivars with less deterioration in palatability during storage. The palatability of the rice stored at room temperature for one yr (old rice) negatively and significantly correlated with the content of free fatty acids in the polished rice and the hardness/adhesion ratio (H/-H ratio) of the cooked rice. Thus, we examined the correlation coefficients of the content of free fatty acids and the H/-H ratio for the old rice and rice stored in a stability-testing chamber (STC) kept at 40°C and relative humidity of 95% for various periods (10, 20, 30 and 60 d). The highest correlation coefficient was observed between the values in the old rice and those in the rice stored in the STC for 30 d. The palatability of the old rice did not correlate with the content of free fatty acids after a 30-d stored in the STC, but negatively and significantly correlated with the H/-H ratio after a 30 d stored in the STC. These results show that we can efficiently evaluate the palatability deterioration during storage in rice by measuring the H/-H ratio of the cooked rice after the stored in the STC for 30 d. The content of the free fatty acids is an effective indicator of palatability deterioration in the old rice, but that in the rice stored in the STC for 30 d is not.

Key words: Free fatty acids, Old rice, Paddy rice, Palatability, Stability-testing chamber, Texture characteristics.

Since rice is stored and marketed mainly as brown rice, the prevention of deterioration in palatability of brown rice during storage is important for stable supply. Consumers expect rice with superior palatability to be supplied all the year round. Shigyo and Ono (1991) pointed out the importance of an appropriate post-harvest technique including the method of storage for the improvement of the palatability of rice produced in Kyushu, Japan. From these points of view, less deterioration during storage in terms of palatability is an important agricultural characteristic requirement for new rice cultivars.

There are many reports showing the palatability deterioration and the changes in various components that cause the deterioration of other qualities during storage (Yasumatsu et al., 1965a, 1965b; Shibuya et al., 1974). Even in the cultivars with superior palatability, palatability deterioration after a long storage varies with the cultivar, and the presence of cultivars with superior and inferior palatability has been reported (Matsue et al., 1991; Wada et al., 2001). Furthermore, it has been reported that texture characteristics and free fatty acids are effective indicators of palatability deterioration after a long storage (Matsue et al., 1991; Otahara et al., 1995; Wada et al., 2001).

At present, in the rice breeding business for selecting the strains with less deterioration during storage, the palatability is evaluated in the year after the end of the raining season. Now, the shortening of breeding years is requested, and under such situations, a labor-saving and efficient method for the selection of the rice cultivars with less deterioration during storage is needed.

Therefore, an efficient screening method, by which the palatability deterioration during storage in rice can be evaluated within a short period, before sowing in the next year, is urgently needed.

In this study, we tried to evaluate the palatability deterioration during storage by examining the characters of the rice stored in a stability-testing chamber (STC) kept at a certain temperature and humidity, to establish an efficient selection method for breeding highly palatable rice cultivars with less deterioration during storage.

We examined the relationship between the texture characteristic of the rice after the short storage in STC and that of the old (1-yr storage) rice, and also the relationship between the content of free fatty acids in the rice after the short storage in STC and that in the old rice, to evaluate the palatability deterioration during storage for a short period.

Materials and Methods

The experiments were conducted in the paddy field with sandy loam at the Crop Production Research Institute, Fukuoka Agricultural Research Center, in 1999 and 2000. The materials used were four extremely early, seven early, three medium and four late varieties, 18 cultivars in total (Table 1). The seedlings at the 3.5 leaf stage were planted by mechanical transplanting, 3-4 seedlings per hill, at a density of 30 cm-inter-row and 15 cm intra-row spacing (22.2 hills m-2) on June 18. The
Table 1. Cultivars used and their heading dates.

| Earliness       | Cultivars     | Production year |
|-----------------|---------------|-----------------|
|                 |               | 1999  | 2000  |
| Extremely early | Koshihikari   | Aug.14| Aug.9 |
|                 | Yumetsukushi  | Aug.15| Aug.10|
|                 | Mineasahi     | Aug.17| Aug.12|
|                 | Chikushi 45   | Aug.17| Aug.12|
|                 | Nipponbare    | Aug.22| Aug.19|
|                 | Hohoemi       | Aug.18| Aug.14|
|                 | Tsukishiwase  | Aug.25| Aug.22|
|                 | Nankai 137    | Aug.18| Aug.17|
|                 | Chikushi 46   | Aug.22| Aug.17|
|                 | Nankai 151    | Aug.22| Aug.19|
|                 | Hokuriku 180  | Aug.19| Aug.15|
| Early           | Hinohikari    | Aug.28| Aug.25|
|                 | Tsukishihomare| Sept. 2| Aug.29|
|                 | Chikushi 43   | Aug.31| Aug.28|
| Medium          | Reihou        | Sept. 3| Aug.30|
|                 | Yumehikari    | Sept. 7| Sept. 2|
|                 | Saikai 230    | Sept. 4| Sept. 1|
|                 | Saikai 241    | Sept. 3| Aug.30|

Table 2. Correlation coefficients (r) of the palatability with the content of free fatty acids and the H/H ratio in the old rice stored for one yr in 18 cultivars.

|                | Production year |               |               | 1999 % | 2000 % | H/H ratios |
|----------------|-----------------|---------------|---------------|--------|--------|------------|
| Free fatty acid content | 1999 | 2000 | 1999 | 2000 |
| - 0.518* | - 0.408† | - 0.720*** | - 0.778*** |

†, *: Significant at p < 0.1, 0.05 and 0.001, respectively.
‡: Production year.

Fig. 1. Stability-testing chamber (STC).

Fig. 2. Relationship between the heading date and the content of free fatty acids in the old rice.

Fig. 2. Relationship between the heading date and the content of free fatty acids in the old rice.

* : Significant at p < 0.01, ns : not significant.

In brief, rice was polished at a milling percentage of 90-91% with a Toyotester rice-polishing machine MC-90A (Toyo Rice-polishing Machine Factory, Japan), and powdered with a laboratory mill 3100 (Perten Co. Ltd., USA). Twenty gram of the powdered rice was extracted with acetone, and the extract with 25 mL phenolphthalein alcohol added was titrated with standard 0.05 N sodium hydroxide. The texture characteristic, hardness/adhesion ratio (H/H ratio), was measured with a texturometer GTX-2 (Zenken Co. Ltd., Japan) using the same polished rice as mentioned above. A very small amount of cooked rice was used according to the method of Endo et al. (1980).

Results and Discussion

1. Correlation of the palatability of the old rice with the content of free fatty acids in the polished rice and the H/H ratio of the cooked rice

Table 2 shows the correlation coefficients of the palatability of the old rice for the content of free fatty acids in the polished rice and for the H/H ratio of the
cooked rice. The palatability of the old rice negatively correlated with the content of free fatty acids at 5% significance level in 1999, and at 10% level in 2000. This result is consistent with the report of Matsue et al. (1991), but the correlation coefficient in the year 2000 was low.

Taira et al. (1979) showed a positive correlation between the content of free fatty acids and ripening temperature. In this study, a significant negative correlation was observed between the content of free fatty acids and the heading date in 2000, though not in 1999, showing that the earlier the heading, the higher the content of free fatty acids (Fig. 2). This suggests that ripening temperature, which varies with the heading date, strongly affected the content of free fatty acids in 2000. Thus, the effect of ripening temperature, which varies with the heading date, and that of the cultivar (difference among cultivars) on the content of free fatty acids were compared. We substituted the production year for the ripening temperature, and the differences in the content of free fatty acids between production years and among cultivars were examined by analysis of variance with non-repetition two-way layout (Table 3). Components of variance between the production years and among cultivars (Snedecor and Cochran, 1984) are also shown in Table 3. The component of variance between production years was larger than that among cultivars, suggesting that the content of free fatty acids varies with the production year more strongly than among cultivars. This suggests that the ripening temperature strongly influences the content of free fatty acids. Therefore, the low correlation coefficient of palatability for the content of free fatty acids in the year 2000 (Table 2) may be attributed to the larger difference of the ripening temperature, which varies with the heading date, than the varietal difference.

The palatability of the old rice negatively correlated with the H/H ratio at 0.1% level in both years (Table 2). This is consistent with the report of Wada et al. (2001) who pointed out the effectiveness of the H/H ratio as an indicator of the palatability of the stored rice and that of Otahara et al. (1995) who showed that the aging of rice is evaluated by the H/H ratio.

As mentioned above, we confirmed that the content of the free fatty acids in the polished rice and the H/H ratio of the cooked rice are effective indicators of the palatability deterioration after storage.

2. Correlation of the content of free fatty acids and the H/H ratio in the old rice with those in the rice stored in the STC for various periods

Table 4 and Fig. 3 show the correlation coefficient of the content of free fatty acids in the old rice, whose palatability correlated with the content of free fatty acids, for that in the rice stored in the STC for various periods (10, 20, 30 and 60 d) in 18 cultivars. The correlation coefficient of the content of free fatty acids in the old rice in 1999 was the highest for that in the rice stored in the STC for 30 d (r=0.837). The correlation coefficient in 2000 was also significant at the 5% level (r=0.571), suggesting that the content of free fatty acids in the old rice is estimated from that in the rice stored in the STC for 30 d. On the other hand, the content of free fatty acids in the rice stored in the STC for 60 d did not correlate with that in the old rice (Fig. 4). For instance, in cultivar Nankai 151, the content of free fatty acids in...
the old rice was the lowest (7.8 mg KOH/100 g) among the cultivars, but that in the rice stored in the STC for 60 d was very high (42.5 mg KOH/100 g). On the contrary, in Nankai 137 and Tsukushiwase, the content of free fatty acids in the old rice was high, 15.0 and 14.6 mg KOH/100 g, respectively, but that in the rice stored in the STC for 60 d was not so high (only 34.5 and 27.1 mg KOH/100 g, respectively).

Table 5 and Fig. 5 show the correlation coefficients of the H/-H ratio of the old rice, whose palatability correlated with the H/-H ratio, for that of the rice stored in the STC for various d in 18 cultivars. In 1999, the correlation coefficient of the H/-H ratio in the old rice was the highest for that in the rice stored in the STC for 30 d (r=0.903). Even if the dot-circled value in Fig. 5 was excluded, the correlation coefficient was 0.675 showing a positive correlation. In 2000 also, the H/-H ratio of the old rice significantly correlated with that of the rice stored in the STC for 30 d (at 1% level, r=0.675). The correlation between the H/-H ratios of the old rice and the rice stored in the STC for 60 d was significant but with a low correlation coefficient. Furthermore, the brown rice stored in the STC for 60 d was brittle, and in such rice many broken particles are produced during milling, causing many troubles in preparing the samples and measuring the H/-H ratio.

As mentioned above, the content of free fatty acids and the H/-H ratio in the rice stored in the STC for 30 d correlated most closely with those in the old rice, and can be used to estimate these values in the old rice within a short period after harvesting.

3. Correlation of the palatability of the old rice with the content of free fatty acids and the H/-H ratio in the rice stored in the STC for 30 d

In Fig. 6 and 7, the palatability (evaluation value as a whole) of the old rice was plotted against the content of the free fatty acids (Fig. 6) and the H/-H ratio (Fig. 7) in the rice stored in the STC for 30 d. The content of free fatty acids significantly correlated with the palatability of
The content of free fatty acids in the old rice is an effective indicator of the palatability deterioration, but that in the rice stored in the STC for 30 d is not. For the selection of strains based on the absolute value of the H/–H ratio, we recommend the use of the value for cultivar Koshihikari, whose palatability deterioration is slight (Matsue et al., 1991), as the standard cultivar.

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*In Japanese.

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