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LONG-TERM STORAGE OF ROUGH RICE AT TEMPERATURES BELOW ICE POINT

by

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Summary: We investigated the freezing temperatures and extents of freezing injury of rice samples with various levels of moisture content, and we also investigated the effects of a temperature below ice point during long-term storage on the physiological properties of rice. Rice with a moisture content of less than 17.8% did not freeze even at a temperature of –80°C. There is therefore no need for concern about freezing of rice stored at temperatures below ice point in farm silos during winter. Low temperature and low moisture content minimized the physiological activities in rice and hence the deterioration of rice quality.

Keywords: Rice, Storage, Freezing temperature, Freezing injury, Germination rate, Free fat acidity

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INTRODUCTION

The temperature and moisture content of rice grain greatly affect its quality during storage. In Japan, the moisture content of rough rice during storage is maintained at a level below 16.5%. There are two commercial rice storage systems in Japan: an environment-temperature storage system, in which the grain temperature during storage is not controlled; and a low-temperature storage system, in which the grain temperature is maintained below 15°C during storage. About five million tons of brown rice, which is about half of the total amount of brown rice produced in Japan, is stored in the low-temperature storage system.

It is possible that if rice were to be stored at a temperature below ice point, the physiological activity of the grains would be minimized and a high quality of rice, almost the same as that of freshly harvested rice, could be maintained. However, there have been no attempts to store rice at a temperature below ice point because it is thought that rice stored at such a low temperature would be frozen. The aims of the present study were therefore to determine the freezing temperature and the extent of freezing injury of rice and the effects of temperature below ice point on the physiological properties of rice during long-term storage.

MATERIALS AND METHODS

FREEZING TEMPERATURE

The rice samples used to determine the freezing temperature were Kirara 397 and Hoshinoyume, which are commercial Japonica non-waxy varieties. Rough rice samples were collected at six moisture content levels during the drying process: 26.5%, 24.2%, 23.1%, 22.1%, 20.8% and 19.5%. Moisture content was determined by the standard method of the Japanese Society of Agricultural Machinery: about 10 g of a whole-grain rice sample was placed in a forced-air oven at 135°C for 24 h, and the moisture content was computed on a wet basis.

A differential scanning calorimeter (DSC 3100 S, Mac Science Co., Tokyo, Japan) was used to measure the freezing temperature of rough rice. The cooling rate was controlled at 2°C/min and the temperature was decreased to –55°C. One grain of rough rice was used for each scan, and five to six grains at each moisture content level were used to measure the freezing temperature.

FREEZING INJURY

The rice used to determine freezing injury was Kirara 397 variety. Rough rice samples were collected at seven moisture content levels during the drying process: 26.5%, 23.1%, 20.8%, 19.5%, 17.8%, 16.8% and 15.7%. Freezing injury of grain seed such as rice is usually determined by the germination rate. Grains that suffer freezing injury do not germinate.

Rice samples (about 50 g per sample) were stored in refrigerators controlled at 2°C, –10°C,

–20°C, –30°C, –40°C or –80°C for 11 days. The samples were then dried to about 16% moisture content (m.c.) in a forced-air oven at 40°C - 45°C and hulled. Germination rate was determined according to the standard method of the Japan Food Agency: three hundred sound brown rice grains were soaked in a hydrogen peroxide solution (1% [w/w] concentration) and placed in an incubator at 20°C. The germination rate was calculated by counting the number of grains that had germinated within a period of seven days.

Rice Storage Experiment

The rice used for the rice storage experiment was Hoshinoyume variety. Rough rice samples were controlled at two moisture content levels after the drying process: 16.2% and 14.2%. About 15 kg of rough rice was stored in a polyethylene container with a screw lid and the containers were stored in incubators or refrigerators, controlled at +25°C, +15°C, +5°C, –5°C, –20°C or –50°C, from the beginning of October 1998. The storage experiment will be continued until October 2002.

To determine the physiological properties of the rice samples, free fat acidity and germination rate were determined. Some grains were periodically taken from the rough rice samples and hulled. Free fat acidity was determined by the rapid method of the American Association of Cereal Chemists (AACC, method 02-02): free fat acid was extracted from ground brown rice in a benzene solution, and the extracted solution was then titrated with potassium hydroxide solution. Germination rate was determined according to the standard method of the Japan Food Agency. Grains that have lost their physiological activity (dead seeds) do not germinate.

Results and Discussion

Freezing Temperature

Figure 1 shows the relationship between moisture content and freezing temperature of rice.

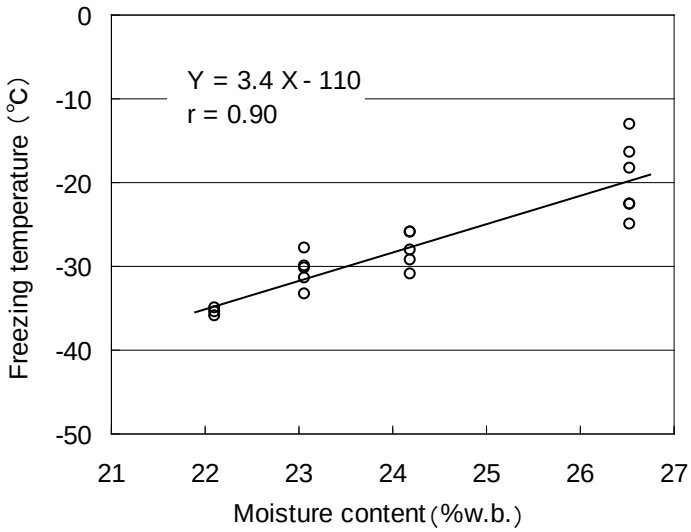

Figure 1 - Relationship between moisture content and freezing temperature of rice.

Rice of 26.5% m.c. froze at temperatures in the range of –13°C to –25°C. The moisture content of each sample was measured using 10 g of rough rice. There were about 350 grains in 10 g of rough rice. Although each grain had various moisture contents, the average value of 350 grains (26.5%) was used for analysis. The freezing temperature was measured using one grain for each scan. The freezing temperatures of the rice of 26.5% m.c. were therefore distributed in the range of –13°C to –25°C. Rice of 22.1% m.c. froze at about –35°C. Rice samples of 20.8% m.c. and 19.5% m.c. did not freeze even at a temperature of –55°C.

FREEZING INJURY

Figure 2 shows the germination rates of rice samples of seven different moisture content levels stored at six temperature levels for 11 days. Freezing injury did not occur in any of the rice grains stored at 2°C because the germination rate of these rice grains was almost 100%, while freezing injury occurred in all of the rice grains of 26.5% m.c. stored at the temperatures below –20°C because the germination rates were 0%. There was no freezing injury in 64% of the rice grains of 23.1% m.c. stored at –20°C. Rice grains with a moisture content of less than 17.8% germinated after being stored at –80°C. Thus, no grain with a moisture content of less than 17.8% froze even at a temperature of –80°C.

In Japan, rice for long-term storage is always dried until the moisture content is less than 16.5%. Thus, there is no need for concern about the freezing of rice stored in farm silos at temperatures below ice point.

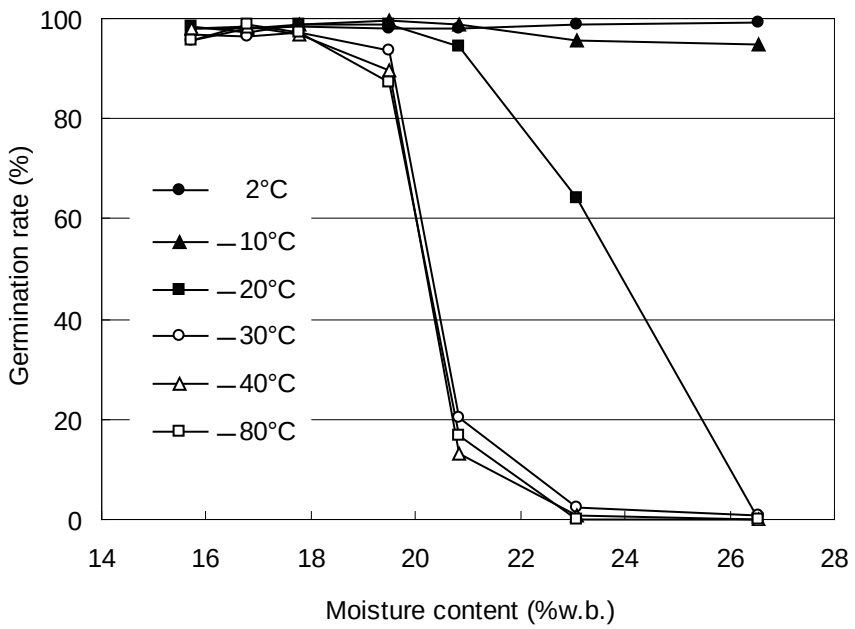

Figure 2 - Germination rate of rice of seven moisture content levels stored at six temperature levels for 11 days.

RICE STORAGE EXPERIMENT

Lipase hydrolyzes fat in rice grains to fatty acid. When the activity of lipase in rice is high, free fat acidity increases during storage. This increase in free fat acidity causes deterioration of the quality of rice during storage. Figures 3 and 4 show changes in the free fat acidity of rice of 16.2% m.c. and 14.2% m.c. stored at six temperature levels for 19 months. The free fat acidity of rice stored at temperatures below +5°C was almost the same as that at the beginning of storage. However, the free fat acidity of rice of 16.2% m.c. stored at +25°C dramatically increased during storage. These results indicate that low temperature and low moisture content minimize lipase activity in rice and hence deterioration of the quality of rice.

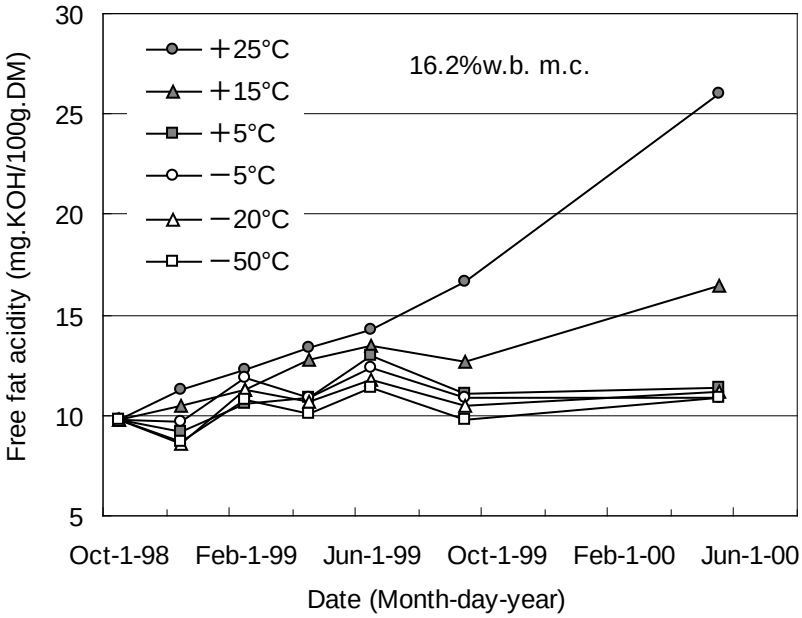

Figure 3 - Changes in free fat acidity of rice of 16.2% m.c. stored at six temperature levels.

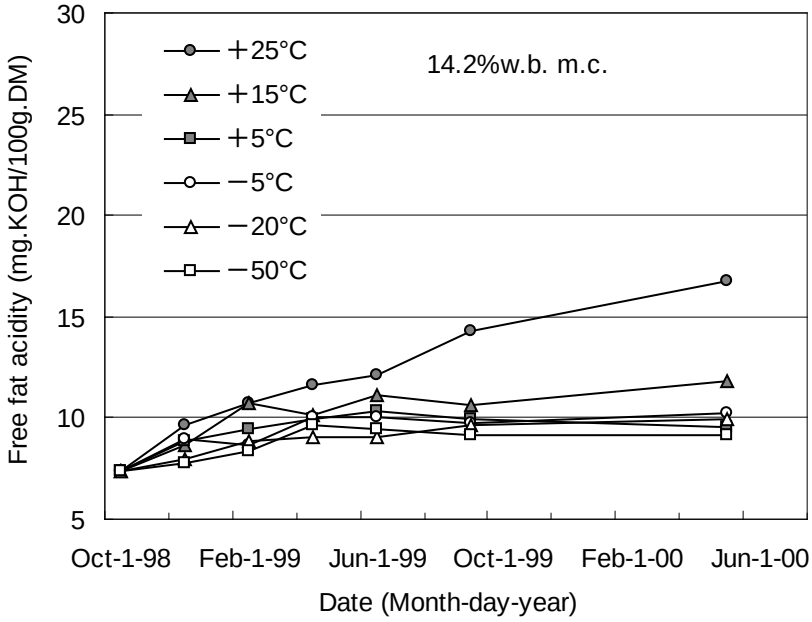

Figure 4 - Changes in free fat acidity of rice of 14.2% m.c. stored at six temperature levels.

Figures 5 and 6 show changes in the germination rate of rice of 16.2% m.c. and 14.2% m.c. stored at six temperature levels for 19 months. Grains that do not germinate do not have any physiological activities as rice seeds. The germination rate of rice of 16.2% m.c. stored at +25°C had decreased to 0% after 1 year of storage. On the other hand, the germination rate of rice stored at temperatures below +15°C was almost 100%. This rice storage experiment will be continued until the harvest season in 2002. It is expected that there will be a greater effect of low temperature on the physiological properties of rice after such long-term storage.

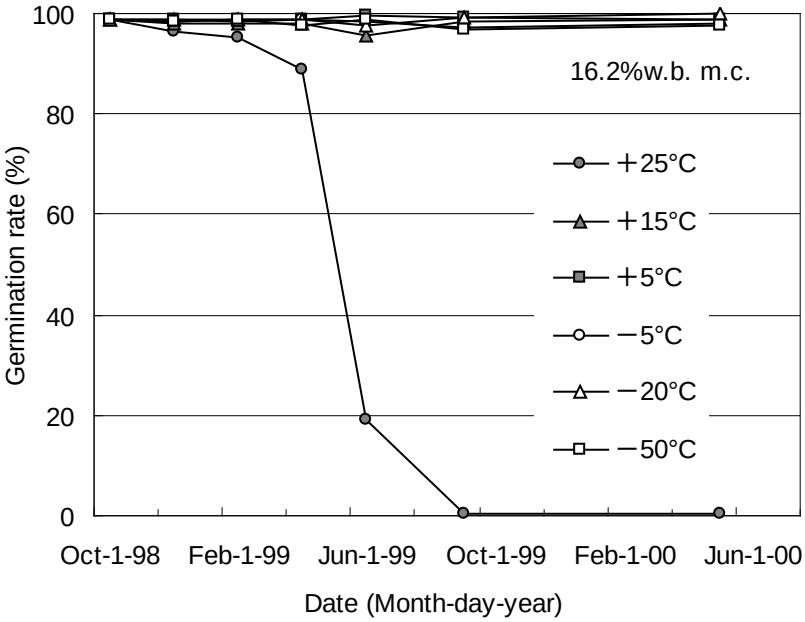

Figure 5 - Changes in germination rate of rice of 16.2% m.c. stored at six temperature levels.

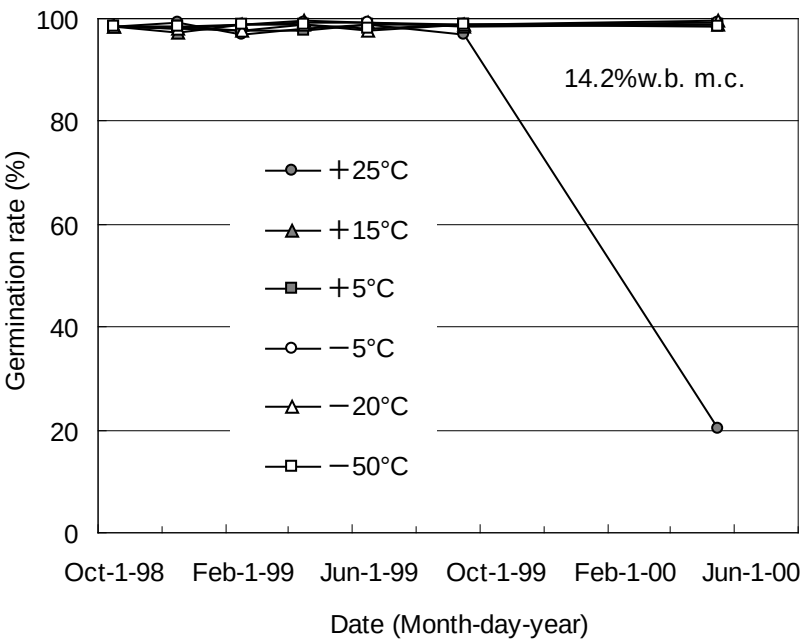

Figure 6 - Changes in germination rate of rice of 14.2% m.c. stored at six temperature levels.

We have developed a unique technique for storing rice at a temperature below ice point using natural coldness in winter. The use of natural coldness in winter to store rice at temperatures below ice point could be used as a new technique for preserving rice quality without the need for a cooling facility and electricity. This technique has been used in the northern part of Japan. It is predicted that the total amount of rough rice stored in farm silos at temperatures below ice point in Hokkaido, the northernmost island of Japan, in the year 2000 will be about 60 thousand tons.

CONCLUSIONS

Rice with a moisture content of less than 17.8% did not freeze even at a temperature of –80°C. There is therefore no need for concern about the freezing of rice stored at temperatures below ice point in farm silos during winter. Low temperature and low moisture content minimized the physiological activities in rice and hence the deterioration of rice quality.

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