Engineering in Agriculture, Environment and Food 7 (2014) 40–45

Contents lists available at ScienceDirect

Engineering in Agriculture, Environment and Food

journal homepage: http://mama.agr.okayama-u.ac.jp/AABEA/

Research paper

Long-term storability of rough rice and brown rice under different storage conditions☆

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ARTICLE INFO

Article history:
Received 15 July 2013
Received in revised form
9 December 2013
Accepted 11 December 2013
Available online 27 December 2013

Keywords:
Super-low temperature storage
Low temperature storage
Room temperature storage
Rough rice
Brown rice
Free fatty acid content
Germination rate
Cooked rice overall flavor

ABSTRACT

Two storage tests (4 years for Kirara 397 and 3 years for Yumepirika) were carried out to investigate long-term storability of rough rice and brown rice under three storage conditions. Super-low temperature storage (below ice point) maintained physiological properties and eating quality of rough rice and brown rice at levels similar to those of raw materials after 2 years of storage. Low temperature storage (below 15 °C) minimized the rate of quality deterioration for Kirara 397 but not the rate of quality deterioration for Yumepirika. The results indicated that rice variety also affects the storability of rice. Seed vitality of rough rice and brown rice in room temperature storage showed only minor changes for a period of 10 months.

1. Introduction

Rice is the major source of dietary energy and protein due to daily consumption and it serves as the staple food for 80% of the population in Southeast Asia (Yadav and Jindal, 2001). However, with the heavy population pressure, many Asian countries are expected to become net importer of rice over the next 10–20 years (Zhou et al., 2002). To maintain a stable supply, it is necessary to increase rice productivity and to reduce rice losses during post-harvest processes. Storage is an important post-harvest process that should be controlled carefully, since numerous physicochemical and physiological changes that greatly affect rice end-use quality occur during storage (Noomhorm et al., 1997; Sodhi et al., 2003).

Rice storability is the ability of rice to maintain quality properties during storage that are indispensable to consumers. Rough rice storage, brown rice storage and milled rice storage are popular in many countries. In Japan, brown rice storage has been a popular practice, and the storage capability of rough rice has gradually been increasing in recent years. Three storage systems have been available for brown rice and rough rice: environment temperature storage, in which the temperature is not controlled; low temperature storage, in which the temperature is kept below 15 °C; and super-low temperature storage, in which the temperature is kept below ice point. Previous studies (Fukai et al., 2003; Genkawa et al., 2008; Rehman, 2006) indicated that insect activities and mold growth are minimized in low temperature storage and that an even lower temperature is desirable for maintaining rice storability at a high level. Kawamura et al. (2004, 2005) reported that rough rice with moisture content of less than 17.8% did not freeze even at a temperature of −80 °C, and super-low temperature storage technology has thus been established.

Perdon et al. (1997) and Yanai et al. (1979) showed that storage temperature and duration, moisture content and relative humidity of the raw material play important roles in maintenance of rice storability. It has been shown that there is an initial increase in peak viscosity during the first 6 months of storage and a steady decrease during the subsequent 3 years for rough rice (Indudhara Swamy et al., 1978). Milled rice stored at a higher temperature (37 °C) showed increases in peak temperature and conclusion temperature compared to those of milled rice stored at a lower temperature (4 °C) (Zhou et al., 2010).

Storage durations in research range from short term to intermediate term (several months) (Park et al., 2012; Yu et al., 2010),

☆ Partly presented at the 70th Annual Meeting of the JSAM in September, 2011 in Hirosaki University.

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1881-8366/$ – see front matter
http://dx.doi.org/10.1016/j.eaef.2013.12.007

and newly harvested rice is stored for several months during distribution to consumers. On the other hand, long-term storage for more than one year is needed to ensure a stable supply in the case of sharp reduction of rice yield caused by natural disasters such as tsunami, flooding and cold weather in summer. According to the official policy of the Japanese Ministry of Agriculture, Forestry and Fisheries, brown rice harvested each year should be stored for 5 years in governmental storehouses, and a total of 0.95 million tons had been stored until June of 2012 (brown rice harvested from 2006 to 2011). There is little information on changes in rice quality properties during storage for such a long period, and a clear understanding of the changes in quality properties is therefore of great value both theoretically and practically.

In this research project, we investigated the effects of super-low temperature, low temperature and room temperature storage condition on the long-term storability (4 years and 3 years) of rough rice and brown rice.

2. Materials and methods

2.1. Design of storage tests

Two Japonica varieties were prepared for long-term storage tests. Kirara 397 produced in Asahikawa was collected in December of 2008. Kirara 397 is a variety with a cultivation history of more than 20 years in Hokkaido, Japan.

In November of 2009, Yumepirika produced in Uryu was collected for a repeated storage test. Yumepirika is a new variety released in 2009, and it has been shown to have superior sensory quality since it is a variety with low amylose content.

Raw materials of rough rice and brown rice were stored in a rice low-temperature storehouse, and were also stored at room temperature (no temperature control) and at a super-low temperature (below ice point). Under each storage condition, raw materials were placed in paper bags that were each coved with three plastic bags to minimize changes in moisture content of stored rice during storage.

Low-temperature storage and room temperature storage are shown in Figs. 1 and 2, respectively. The storage test for Kirara 397 started on Dec 16, 2008 and the storage test for Yumepirika started on Nov 7, 2009. Both tests were continued until Dec 14, 2012. Stored Kirara 397 samples were collected after 3, 6, 8, 10, 12, 15, 19, 22, 24, 29, 36, 42 and 48 months of storage, and stored Yumepirika samples were collected after 1, 4, 8, 11, 13, 18, 25, 32 and 38 months of storage.

Variation in rice temperature and relative humidity were recorded by sensors (Espec, Thermo recorder RS-11, Osaka, Japan) placed in the stored rice under each storage condition.

Fig. 1. Low temperature storage in a commecial rice storehouse.

Fig. 2. Room temperature storage in a laboratory room.

2.2. Measurements of quality properties during storage

Moisture content was measured according by the air-oven method (135 °C for 24 h) as specified by the Japanese Society of Agricultural Machinery (JSAM) and moisture content was derived on the wet basis.

Free fatty acid content was determined by using the rapid method of the American Association of Cereal Chemists (AACC, 02-02): free fatty acid was extracted from ground brown rice in a benzene solution, and the extracted solution was titrated with potassium hydroxide.

According to the standard method of the Japan Food Agency, germination rate was determined by counting the number of rice kernels that germinated within a period of 7 days.

2.3. Sensory tests for stored rice samples

Okabe (1979) pointed out that cooked rice texture governed acceptance when consumed, and it has been defined as a multidimensional characteristic that only humans can perceive, define and measure. A sensory test is thus critical, though instrumental measurement of texture is also a common practice.

Sensory tests were carried out after 2 years of storage using the Japanese rice taste testing method standardized by the Japan Food Agency. Sensory test items were appearance, aroma, hardness, stickiness and overall flavor. A rough rice sample in super-low temperature storage was chosen as a reference sample that had the same sensory qualities as those of the raw material. There were 58 and 43 panelists who took part in the sensory tests for Kirara 397 stored samples and Yumepirika stored samples, respectively. The ratios of weight of cooking water and weight of milled rice were 1.30 and 1.25 for Kirara 397 and Yumepirika, respectively.

3. Results and discussion

3.1. Variations in rice temperature and relative humidity during storage under different storage conditions

Variations in rice temperature and relative humidity (Kirara 397) during the 4-year storage periods are shown in Fig. 3 and Fig. 4, respectively. Temperature of rice in room temperature storage varied seasonally with the outside environment. The mean temperature was 21.2 °C and the standard deviation was 3.5 °C. Temperature of rice in low temperature storage was maintained below 15 °C. The mean temperature was 10.5 °C and the standard deviation was 2.8 °C. In the low temperature storehouse, brown rice was cooled using an electric cooling system in summer, and