Tracing changes of garlic bulbs stored at low temperature by MRI

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ABSTRACT

A serious problem of storing garlic at low temperature is concavity formation on the surface of scales (Fig. 1). Cavity formation seems related to the curing process and storage temperature [1-3], but the mechanism of the defect is not clear, nor are the proper drying conditions and storage temperature. In this study, we trace the changes of a garlic bulb during drying and storage using MRI. Concavity formation of garlic during low-temperature storage significantly depends on the post-harvest curing (drying) conditions. The curing process and concavity formation during storage was traced by MRI and an MR microscope. Images indicated that garlic changed with storing time, and garlic bulbs with concavity formation could be seen as differing from images of normal bulbs.

Keywords: garlic; MRI; drying; storage; low temperature

INTRODUCTION

Garlic is one of the most popular spices in the world. It is harvested in early summer and stored in Japan. An agricultural chemical was previously used to prevent garlic bulbs from sprouting and rooting during storage at room temperature, but garlic is now stored at low temperature to prevent it from sprouting and rooting because use of the chemical has been prohibited since 2002. A serious problem of storing garlic at low temperature is concavity formation on the surface of scales (Fig. 1). Cavity formation seems related to the curing process and storage temperature [1-3], but the mechanism of the defect is not clear, nor are the proper drying conditions and storage temperature. In this study, we trace the changes of a garlic bulb during drying and storage using MRI, a powerful tool for studying plant physiology [4-6].

Figure 1. Crosssection of a garlic clove (left) and cloves with concavity surface (right).
MATERIALS & METHODS

Garlic: Garlic bulbs were harvested at the beginning of July in Aomori Prefecture (northern part of Honshu Island) in Japan and dried for four weeks under two different conditions, 33 degrees (centigrade) and 33 degrees only during the daytime with cooling allowed at night. Dried garlic bulbs were stored at two different temperatures, 0 degrees and -1.8 degrees.

MRI measurement: MR images of drying garlic were obtained using a compact MRI system (MR Technology, Japan) with a permanent magnet (0.2T; 8MHz for 1H) and 11cm diameter detector. The spin-echo method was used to obtain images. Detailed MR images of stored garlic cloves were obtained using a Bruker DRX300WB NMR spectrometer (300 MHz for 1H) equipped with a micro-imaging system. A garlic clove was set in a 25mm-diameter detector and inserted into the magnet. The spin-echo method was used to obtain images. For relaxation times T1 and T2, images were constructed using the progressive saturation method and multi-echo images (tau = 5 ms). These images depict the distribution of T2 and T1 in the sample. T2 image represents T2 from 0 to 50 ms, and T1 image represents T1 from 0 to 1.0s.

Table 1 Number of concave cloves (%)

<table>
<thead>
<tr>
<th>Drying Temp.</th>
<th>Storing Temp.</th>
<th>Storing time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 m</td>
<td>2 m</td>
</tr>
<tr>
<td>a Only daytime</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>b All day</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c Only daytime</td>
<td>-1.8</td>
<td>0.0</td>
</tr>
<tr>
<td>d All day</td>
<td>-1.8</td>
<td>0.0</td>
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</tbody>
</table>

RESULTS & DISCUSSION

Table 1 presents concave cloves at different drying and storing conditions. When garlic was dried at a constant temperature (33 degrees), concave cloves appeared after four months of storage at both 0 and -1.8 degrees. In contrast, there was no concavity in cloves dried at 33 degree in the daytime and cooled at night (experiments b and d). This indicates that drying is important for maintaining good quality of garlic during low-temperature storage. We next traced the amount of water in garlic during drying and storage by MRI, which can non-invasively map the amount and mobility of water in the sample.

MR images of garlic acquired by a compact MRI during drying are presented in Fig. 2. Fresh and stored garlic bulbs had almost the same cross-sectional image because all garlic tissues had enough water (over...
65\%) to image each tissue by MRI. The outer skin and flower stalk disappeared after a few days of drying, and the image of the true stem gradually weakened. In dried samples, the image of the true stem disappeared, and only cloves consisting of the storage leaf, sprout leaf, and true stem were observed. Cloves retained 60\% of their water after being dried, which is almost the same water content as fresh samples (65\%). The images of cloves after one-month storage at low temperature did not become like images of dried cloves, and no difference could be detected between normal and concave cloves in longer storage.

To trace changes of the inner structure and amounts of water during low-temperature storage and concavity formation, detailed MR images of garlic cloves were obtained using a Bruker DRX300WB NMR spectrometer (Fig. 3).

Transverse MR images of garlic cloves just after drying exhibited homogeneity inside the cloves except for vascular bundles. Vascular tissues appeared as bright spots. In the T2 image, vascular bundles were observed as bright spots, suggesting that they had a long T2, although in the T1 image the bundles appeared as black spots (short T1). This pattern of three images (MR image, T2 image, and T1 image) was usually observed in fresh plants. After storage at low temperature, MR images of cloves change from homogeneous to inhomogeneous, and T2 and T1 images also changed. The inner part of a clove took on a rough appearance.
in MR images, and bright spots of vascular bundles in T2 images became unclear. However, the black spots of vascular bundles in T1 images became clear. After storage for four months, white spots of vascular tissues became clear at the inner part of the transverse image, although images of clove surfaces remained homogeneous. T2 images appeared opaque and dark, and vascular bundles in T1 images became clear and large. In this stage, some bulbs dried at 33 degrees and stored at -1.8 degrees exhibited slightly concave surfaces at the top of cloves, although bulbs dried and stored differently did not have such symptoms. MR images of a hollowed clove displayed a different image pattern from normal cloves not only around hollowed tissue but over the entire bulb (Fig. 3, four months at -1.8 degrees). This sample was slightly concave at the top of the clove (circled in Fig. 3). Concave tissue appeared dark in images. The dark area was not only superficial but also extended to the inner part of the clove from top to bottom. This may be along the vascular tissue. The concave cloves appeared bright and smooth (homogeneous) in transverse and horizontal MR images, indicating that the physiological condition of the clove differed from that of a normal clove, the detail of which is a future problem.

CONCLUSION
Concavity formation, a serious problem in low-temperature storage of garlic, was studied by MRI. We traced drying process of garlic by MRI and observed clear differences in drying of each part of the garlic. However, we could not discern any clear difference in water retention or mobility in garlic between two drying conditions. This must be studied in the future. Concavity formation during storage was detected by MR microscopy. Water retention and mobility in concave cloves differed from those of normal cloves. MRI is a good analytical method to trace drying process and changes in garlic bulbs during storage.

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REFERENCES