Detection of Internal Hollows in Cooked Rice Using a Light Transmittance Method

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ABSTRACT

We previously reported that nuclear magnetic resonance (NMR) micro imaging detected the hollows in cooked rice but required a specialist to operate equipment. Convenient detection of hollows is useful in the characterization of cooked rice. X-ray imaging and light transmittance photography were studied as alternatives to NMR micro imaging. X-ray imaging detected about 50% of all hollows. Light transmittance photography detected almost all hollows in cooked rice (*Oryza sativa* cv. Koshihikari) effectively and rapidly, relatively quantifying hollow sizes and numbers.

Key Words: cooked rice, hollow, NMR micro imaging, transmitted X-ray, transmitted light

INTRODUCTION

MANY RICE CULTIVARS PROVIDE DIFFERent chemico-physical properties, such as appearance, flavor, and texture, with different degrees of palatability. Japanese prefer "Koshihikari" (*Oryza sativa* cv. Koshihikari), a kind of short-grain sticky rice, that comprised 30% of rice planted area in Japan in 1996. Rice palatability is mainly determined by its texture, and various parameters may be used to describe rice texture physically and chemically, including hardness, ratio of stickiness to hardness (Okabe, 1979), amylose content, and gelatinization temperature (Juliano et al., 1981).

In the study of water distribution in cooked rice by nuclear magnetic resonance micro imaging (MRI), we found that internal hollows formed within rice (*Oryza sativa* cv. Koshihikari) during cooking (Horigane et al., 1999). The number and size of such hollows could be an important factor determining rice texture, suggesting the advisability of clarifying any relationship between hollow conformation and rice palatability.

Since MRI requires both sophisticated instrumentation and operation, it would be inconvenient and unfeasible for routine observation and analysis. Alternative nondestructive analysis is needed to determine the internal hollows of cooked rice. Light transmittance has been used to detect cracks in wetting milled rice (Desikachar and Subrahmanyan, 1961) and hollow heart in potatoes (Birth, 1960), and X-ray transmittance has been used to detect lettuce and tomato maturity (Lenker and Adria, 1971; Brecht et al., 1991), apple bruising (Diener, 1970), and hollow heart in potatoes (Finney and Norris, 1978). Our objective was to use MRI, light, and X-ray, to detect the internal hollows in cooked rice and to compare their effectiveness and rapidity.

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MATERIALS & METHODS

BROWN RICE (*ORYZA SATIVA* CV. KOSHIhikari) grown in Ibaraki prefecture was harvested in September 1997 and stored for about 6 mo at 4 to 6 °C before our experiment. The grain was milled to about 90% before cooking. Water was added in an amount to equal a 1:1.5 ratio of rice to water by weight. Rice was presoaked for 30 min at room temperature (about 23 °C) and, then, cooked in a cooker-steamer (RCK-5ET, Toshiba Corp., Tokyo, Japan) with a capacity of 0.54 L. When the cook cycle was complete, the cooker automatically shifted to a "warm" setting. Rice was held an additional 10 to 15 min. Then, samples of 6 grains were randomly selected and placed on transparent plastic film (20 mm × 20 mm × 0.5 mm). Five sets of such samples were, thus, treated in 3 measurements as described below.

MRI experiment was performed on the Bruker DRX300WB spectrometer (Brucker, Rheistetten, Germany), equipped with a standard micro imaging accessory. The measurements were previously described in detail (Horigane et al., 1999). MRI of rice grains were obtained simultaneously, with a specially designed sample holder with a flat bed and polyvinylidene chloride (PVC) film (10 μm thick) as the cover to prevent dehydration. For projection and slice images, field of view was 20 × 20 mm with matrix dimension of 256 × 256 pixels. The thickness was 0.6 mm and 3 mm, respectively.

Samples were analyzed by X-ray transmittance, set on the sample stage with the cover off so that PVC film would not disturb images. The experiment was conducted with an X-ray analytical microscope (XGT-2000V, Horiba Ltd., Kyoto, Japan). It was equipped with an unfiltered Rh-target X-ray guide tube with an aperture set to analyze a spot –100 μm in dia. The voltage and current across the X-ray tube were 15 kV and 1.0 mA. Mapping images of 512 × 512 pixels were obtained under atmospheric pressure.

Samples were subjected to light transmittance, held on a copy stand (Type 3, Asahi Opt. Co., Tokyo, Japan). The light source of 5 10-W fluorescent lights (Neoline white FL10W, Toshiba Corp., Tokyo, Japan) was set evenly under samples, covered by 2 3-mm translucent plastic plates to irradiate samples evenly. Irradiation energy was 7.2×10^4 lux at the sample table, measured by an illuminometer (Photocell Illuminometer SPI-5, Toshiba Corp., Tokyo, Japan). The camera was a Nikon F-2 with 35-mm lens, assisted by an extension tube. Photographs of cooked rice were made on Provia ASA100 film (Fuji Photo Films Co. Ltd., Tokyo, Japan) and converted to digital data by an image scanner (Seiko Epson Corp., GT-9500, Tokyo, Japan).

In MRI, images showed high proton density as black and low as white. Digital photograph and X-ray data were image-processed by computer software (Adobe Systems Inc., Adobe Photoshop 5.0, San Jose, Calif., U.S.A.) to provide high contrast images. On MRI and photography, the length and width of hollows were measured on about 30 grains.

After the experiments were carried out, the scanning time and maximum grains of photography and X-ray imaging were determined. Size was measured for the hollow part of each image. The size data were plotted and the correlation coefficient calculated.

RESULTS & DISCUSSIONS

THE COMPARISON AMONG 3 METHODS were made for examples of easy detection (Fig. 1) and difficult detection (Fig. 2). The easy detection presents images of hollows in the same grain of cooked rice, taken by a projection image of MRI, a photograph of transmitted light, and X-ray image. The 3 hollows in MRI were white due to lack of proton signals in the hollow. Those in the X-ray, due to the intensity difference of X-ray transmittance, correlated with the low sample density. The photograph image of the hollow was black, because the light in-

Food Engineering and Physical Properties tensity through hollows was weaker than through the solid phase around the hollow. Similar phenomena were reported long ago by Birth (1960) in potato light transmittance. Light was reflected or refracted, decreasing light transmittance when it passed through a hollow, enabling the hollow to be detected. The thin depth of focus could distinguish between internal hollows and surface cracks by focusing the central plane on the cooked rice grain. It was clearly observed (Fig. 1) that each method gave similar results, detecting 3 horizontal hollows in the rice sample.

For grains with difficult detection (Fig. 2), the hollows were almost undetectable by X-ray transmittance, and unclear in the projection image of MRI. They were only demonstrable by slice image of MRI by slicing along the central plane of the rice grain. The 2 hollows were clearly detected by light transmittance, however, as horizontal shadows, showing the photograph to be an effective, low-cost alternative to MRI. Though X-ray imaging was low in sensitivity, the alternative methods, photography and X-ray imaging (instead of MRI) were also able to detect internal hollows in cooked rice.

Hollow size was quantified, using 30 randomly selected samples, and the photograph shows hollows rather clearly. Seventeen of 30 cooked rice grain samples had 1 hollow, and 11 samples had 2. Of the remaining 2 samples, 1 had no hollows, and the other 3 hollows. The hollows ranged from 0.37 to 2.3 mm on the long axis (length) and 0.10 to 0.38 mm on the short axis (width) in projection image of MRI; 0.11 to 2.3 mm on length and 0.12 to 0.47 mm on width in slice image of MRI; and 0.49 to 2.4 mm on length and 0.12 to 0.70 mm on width in the light photograph. X-ray imaging was less effective, detecting only about 50% of all hollows. Photography, thus, effectively detected the hollows. Hollow length and width obtained by both projection image of MRI and photograph were compared (Fig. 3). The length of photograph showed a significant correlation with that of MRI, but the width did not demonstrate correlation. Comparison of the 3 methods (Table 1) indicated MRI provides higher precision and three-dimensional imaging, quantifying hollow depths and volume. Photography was a viable alternative, providing effectiveness, rapidity, and availability that would prove very useful in routine analysis rice hollows.

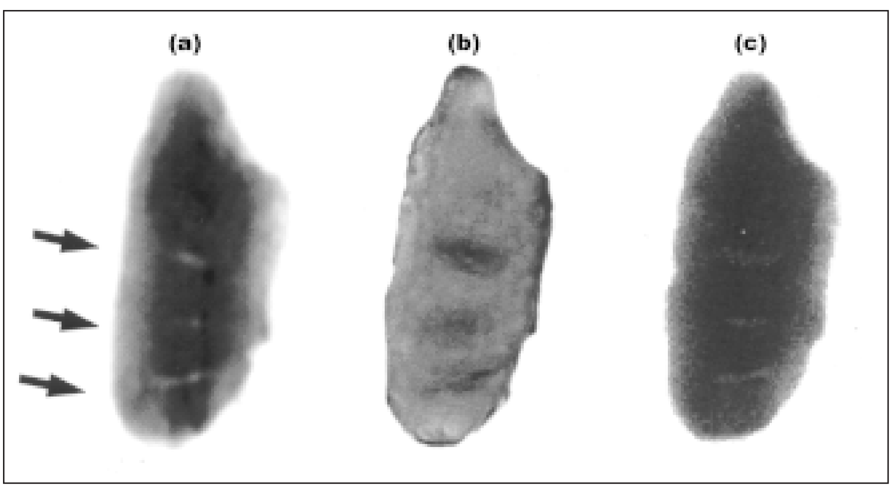

Figure 1—An example of easy hollow detection (a) projection image of MRI; (b) light transmittance; (c) X-ray image. Arrows indicate hollows.

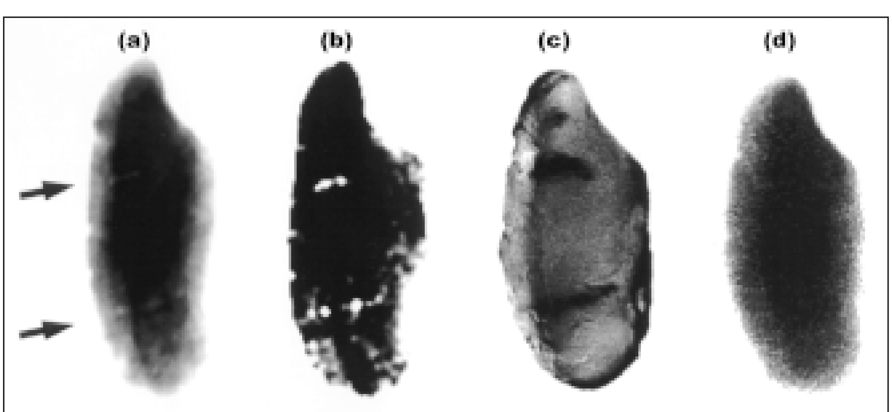

Figure 2. An example of difficult hollow detection (a) projection image of MRI; (b) slice image of MRI; (c) light transmittance; (d) X-ray image. Arrows indicate hollows.

Table 1—Relative comparison of three hollow detection methods

	MRI[a]	Light	X-ray
Instrument price	High	Low	Medium
Operation	Difficult	Easy	Medium
Analysis time (min)	30	5	40
Maximum grain number measured	10 grains	8 grains	32 grains
Effectiveness	High	High	Low
Size measurement	Easy	Easy	Difficult
3D Image	Possible	Not possible	Not possible

[a]One analysis for 2D-slice imaging.

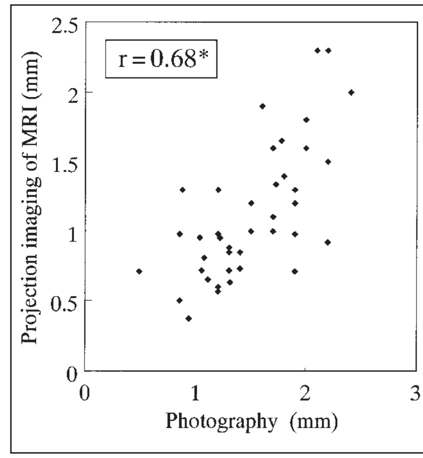

Figure 3. Length of the measured hollow parts of samples determined by projection image of MRI and by light photograph. * = significant at 1%.

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