A MECHANICAL METHOD TO DETERMINE FISSURES IN MILLED RICE KERNELS

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ABSTRACT. *A device was developed and tested for determining the extent of fissuring in milled rice samples. The device consisted of a roller mechanism that applied compressive pressure to each individual kernel, which resulted in breakage of the weaker, fissured kernels. After a sample was passed through the roller mechanism, the broken kernels were separated from the whole, unbroken kernels. In this manner, comparisons between experimental treatments causing kernels to fissure could be made without visual inspection of each individual kernel. Data taken from tests of the roller mechanism showed acceptably high precision, especially in tests of samples having a high percentage of fissured kernels. A second, identical mechanism was constructed to demonstrate the variability in performance among mechanisms. Statistical analysis of the data showed that there was not a significant (α = 0.05) difference between the two roller mechanisms.* ***Keywords.*** *Rice, Grain processing, Fissures, Rice quality.*

Rice is a hygroscopic grain that will readily gain or lose water when it is exposed to a moisture adsorbing or desorbing environment. This moisture transfer can simultaneously induce tensile and compressive stresses within the kernel and often leads to fissure development (Kunze and Hall, 1965; Kunze and Choudhary, 1972). Fissured kernels typically result in broken kernels during handling, packaging, and subsequent processing. Since one of the primary quality indices in the rice industry is the percentage of whole kernels, the consequences of fissuring are of foremost concern to processors.

The degree to which physical damage is incurred by a kernel during moisture sorption is related to the number and extent of fissures created in the kernel. Henderson (1954) indicated that fissured kernels do not necessarily break when milled. Thus, the presence of a fissure in a kernel is not a true measure of strength reduction.

Fissures can be "counted" by illuminating the kernel with a focused light source. Stermer (1968) employed this technique in developing an equation for rate of stress-crack damage as a function of a change in equilibrium moisture content (due to changes in air temperature and relative humidity) of milled rice kernels. This visual inspection of kernels is a slow, tedious process that lends itself to errors such as unseen fissures due to their small size or due to the kernel being oriented such that the light source does not illuminate the fissure.

A rapid and precise method of assessing the amount of damage incurred by experimental treatments that cause fissures is needed. The objective of this research was to develop a mechanical method to quantify the extent of fissure damage incurred by milled rice kernels resulting from rapid moisture transfer treatments.

MECHANISM DESIGN AND OPERATION

A 'roller' mechanism was developed and used to quantify fissure damage incurred by milled rice after exposure to moisture adsorbing and desorbing environments. A schematic of the device is shown in figure 1. A single kernel feed mechanism (not shown in fig. 1), similar to the notched disk feed mechanism used on a Shizouka Seiki CTR-800 (Shizouka Seiki Co., Ltd., Japan) single kernel moisture tester, was mounted just above the rollers and was used to meter rice kernels individually into the clearance between the rollers. The

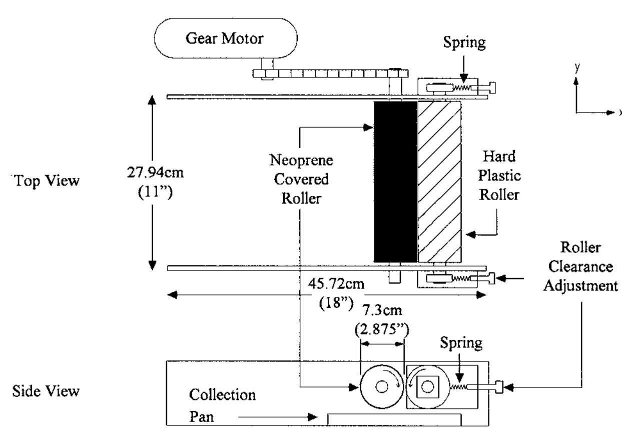

Figure 1–Roller mechanism used to measure the extent of fissured kernels in milled rice.

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individual kernels were passed between the rollers by rotating one of the rollers using a gear motor. The compression force applied to each individual kernel while passing between the rollers resulted in breakage of the weak, fissured kernels.

The main components of the mechanism are two cylindrical rollers, each being 250 mm (9-7/8 in.) in length and 48.3 mm (2-7/8 in.) in diameter. The driven roller was covered with a layer of neoprene rubber, 3.2 mm (1/8 in.) in thickness, with a durometer reading of 60. This covering provided a surface that would "grip" the kernels and pull them between the two rollers. The second roller was composed of hard plastic.

Both roller axles were mounted to a frame. The bearing housing of the neoprene-covered roller axle was rigidly mounted to the frame. This roller was driven at 2.8 rpm by a 0.05 kW (1/15 hp) electric gear motor. The hard plastic roller axle was attached to slides that allowed it to move freely along the x-axis, as denoted in figure 1. At each end of this roller, a spring was placed against the bearing housing that secured the roller axle to the slide. Using a spring scale, each side of the "sliding" roller was adjusted (using spring compression) so that a 8.9 N (2 lb_f) force was required to displace the roller axle 0.635 mm (0.025 in.) along the x-axis. This force level was selected based on initial observations indicating that at least a 2 lb_f tension was required to grip the kernel, but greater tensions would break non-fissured kernels. The deflection of 0.635 mm (0.025 in.) was chosen because trial run measurements indicated that this was a typical roller deflection when passing long-grain rice kernels between the rollers. The typical thickness of a long-grain kernel ranges from 1.524 to 2.032 mm (0.06 to 0.08 in.) (Helms et al., 1995); however, kernels form a depression in the neoprene roller covering as they pass between the rollers.

Operation of the mechanism was as follows:

1. Up to 15 g of milled rice were loaded into the feed reservoir.
2. Power to the rollers and the kernel feed mechanism was turned on.
3. Kernels were fed individually between the rollers at a rate of approximately 100 kernels/min.
4. After the entire sample was passed through the rollers, head rice, those kernels three-fourths or more of the original kernel length, was removed from brokens with a Seedburo shaker-sizer.
5. The brokens percentage was calculated as the mass percentage of broken kernels of the total sample mass.

Evaluation and Testing

Preliminary Testing

To evaluate the use of the roller mechanism as a device for indicating the extent of fissured kernels in milled rice, both extensively fissured and non-damaged kernels were initially tested. Milled long-grain rice (Katy variety) with no visible fissures was split into two lots of approximately 120 g each; no treatment was applied to one of the lots, which represented non-damaged kernels, while the other lot was exposed to a severe moisture adsorbing environment (air at 90% RH, 30°C) that created visual fissures in all kernels inspected under a focused light source. Nine subsamples of approximately 12 g from each lot were tested in the roller mechanism.

For the samples with extensively fissured kernels, the average brokens percentage was 91.8% with a standard deviation of 1.47%. For the undamaged kernels, an average of 5.2% of the kernels broke with a standard deviation of 1.33%. The ideal situation would be one in which 100% of fissured kernels would be broken by the rollers, and none of the non-fissured kernels would break. Some fissured kernels may be able to withstand the force applied to them, which is supported by Henderson (1954), who indicated that fissured kernels do not necessarily break when milled. Additionally, a bulk of rice kernels typically has a range of kernel sizes (Sun and Siebenmorgen, 1993). Even though these kernels may not have internal fissures, exposure to forces such as those applied by the rollers could break some of the immature, thinner kernels. The difference of approximately 87 percentage points to distinguish fissured rice from "good" rice was deemed acceptable to carry on further testing.

Sample-to-Sample Repeatability Tests

The repeatability of the device was subsequently tested. Two long-grain varieties (Katy, a small-kernel variety, and Lemont, a large-kernel variety) were milled in a McGill No. 2 laboratory mill and then exposed to air conditions that caused various levels of fissuring in the kernels. The air conditions comprised a temperature of 30°C and six levels of relative humidity ranging from 29% to 55%. The samples (approximately 100 g) were spread in thin layers and exposed to one of the air conditions for 20 min. Four

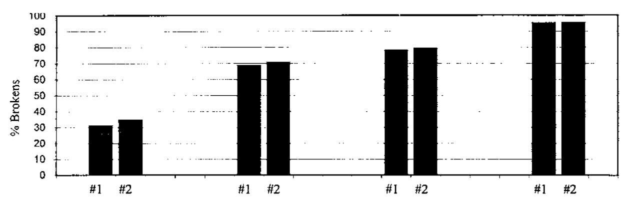

Figure 2–Repeatability test results of a roller mechanism using Katy variety long-grain milled rice at six levels of fissure damage. The top of each bar represents the mean brokens percentage of four subsamples. Cross-hatching indicates the standard deviation of the mean brokens percentage level.

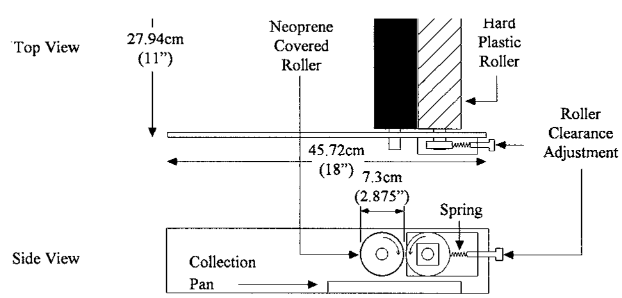

Figure 3–Repeatability test results of a roller mechanism using Lemont variety long-grain milled rice at six levels of fissure damage. The top of each bar represents the mean brokens percentage of four subsamples. Cross-hatching indicates the standard deviation of the mean brokens percentage level.

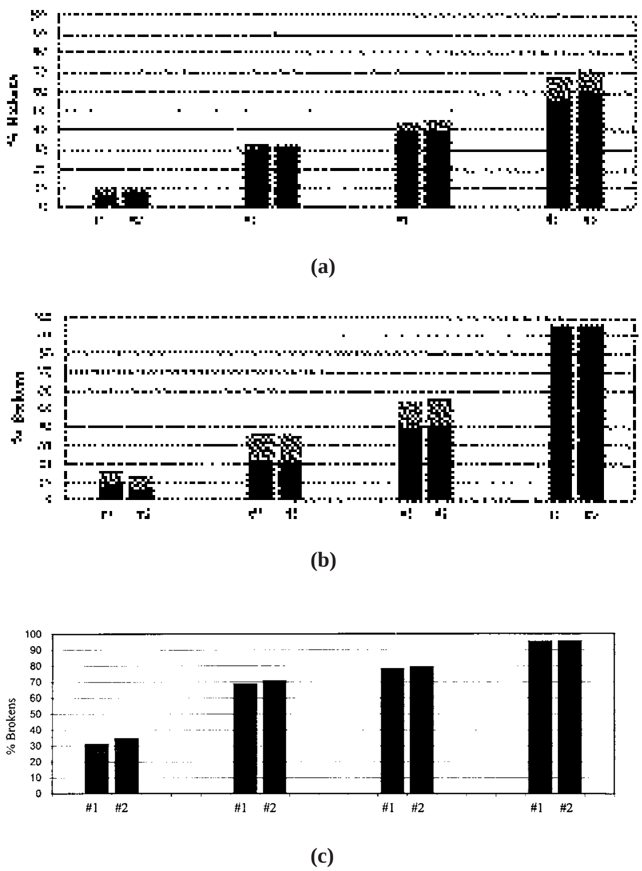

Figure 4–Test of repeatability between roller mechanisms (no. 1 and no. 2) using: (a) Newbonnet; (b) Cypress; and (c) Lemont varieties of long-grain rice. The top of each bar represents the mean brokens percentage of four subsamples. Cross-hatching indicates the standard deviation of the mean brokens percentage level.

samples from each level of exposure were tested in the roller mechanism.

Figures 2 and 3 show the percent brokens for each of the four samples at each level of exposure. For the Katy variety (fig. 2), the maximum difference in brokens percentage of each four-sample group ranged from 2.09 to 7.26 percentage points across the six levels of fissure damage; the corresponding maximum differences for Lemont ranged from 0.64 to 10.43 percentage points. Most of the values were well within five percentage points of each other in each of the four sample groups. No trend was observed to indicate that repeatability changed dramatically across fissuring damage level. However, under very high levels of fissured grains, as shown in figure 3, there was little variability in brokens percentage. This is postulated to be due to the fact that the extreme moisture desorption environment of 30°C and 29% RH caused extensive fissuring in most all of the kernels, rendering all kernels very weak.

Mechanism-to-Mechanism Comparison Tests

Uniformity of performance between mechanisms was determined by constructing an identical roller unit. Different levels of fissured kernels were produced in this instance by first gradually conditioning milled, long-grain samples of varieties Newbonnet, Cypress, and Lemont to four moisture contents of approximately 12%, 13%, 13.5%, and 14%. The samples were then exposed to a drying stream of air at 30°C and 25% RH for 20 min. After exposure, four subsamples from each variety of rice at each level of fissured kernels were tested in each of the two rollers, denoted as roller no. 1 and no. 2.

Figure 4 compares both roller mechanisms using the three varieties at each of the four fissuring levels. The top of each bar represents the average brokens percentage of the four subsamples at a given level of fissured kernels, as measured with each roller. As was the case in figures 2 and 3, the variability in brokens percentages was lowest when the extent of fissuring was very high, as indicated in figures 4b and 4c. A statistical analysis ($\alpha = 0.05$) performed on the data in figure 4 showed that there was no significant difference between the means of the two roller mechanisms in all 12 cases. Therefore, the roller mechanism appears to be reproducible.

Summary

The results of these experiments indicate that the roller mechanism described herein was satisfactorily precise in quantifying the extent of fissured kernels in milled rice. The data showed that the mechanism is precise, particularly when the level of fissured kernels is very high. A comparison of two identically-constructed roller mechanisms showed that reproductions of the unit performed similarly in measuring the level of fissured kernels.

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