Effects of Harvest Location and Moisture Content on Kernel-To-Kernel Breaking Force Distributions

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ABSTRACT

One medium-grain rice variety, six long-grain varieties, and two long-grain hybrids, harvested from 13.4 to 26.0% moisture content (MC) from Keiser, Ark., Stuttgart, Ark., and Alvin, Texas, were used to determine the influence of harvest location and MC on kernel-to-kernel breaking force distributions (BFDs). Harvest MC affected BFDs, however, a greater influence was imposed by the growing location. Head rice yield (HRY) was plotted against the percentage of kernels in a sample having breaking forces greater than 20 N, which was used to define “strong” kernels. The strongest correlations between HRY and the percentage of strong kernels were found for variety/growing location lots having low to mid-level HRY levels; little to no correlation was observed for samples having high HRYs.

INTRODUCTION

Rice MC at harvest is one of the most important factors influencing milling quality and overall economic value of rice. Calderwood et al. (1980) and Lu et al. (1992) found that HRY reached a maximum at an intermediate harvest date, and then declined. Lu et al. (1995) demonstrated that HMC affected the field yield, drying charges, and milling quality; HMC thus has a dramatic impact on the final gross income to a producer.

Since rice kernels on a panicle mature unevenly, the MC and resultant mechanical properties of individual kernels at harvest varies (Chau and Kunze, 1982). Freshly harvested rice kernels exhibit a wide range of MCs, particularly during the early
stages of the harvest season (Kocher et al., 1990; Siebenmorgen et al., 1992). The production of fissures due to rapid moisture adsorption by low MC kernels (Kunze and Prasad, 1978; Siebenmorgen and Jindal, 1986) is the primary reason for HRY reductions at low HMCs. Siebenmorgen et al. (1998) showed that the percentage of kernels with MCs less than critical levels before moisture adsorption was related to the HRY reduction incurred.

While it is known that harvest MC influences kernel MC variability, information relating kernel-to-kernel mechanical strength to harvest MC is not available. This information would lend a more direct understanding as to why harvest MC affects HRY. Further, differences in kernel strength distributions across growing locations could possibly explain HRY variability due to growing location. The objectives of this research were to determine: (1) the influence of HMC and growing location on the kernel-to-kernel BFDs of rice lots; and (2) the relationships between BFDs and milling quality.

**PROCEDURE**

Rough rice lots of ‘Bengal’ (8 harvest MCs), ‘Cypress’ (8 harvest MCs), and ‘Drew’ (8 harvest MCs) were plot combine-harvested from the Northeast Research and Extension Center at Keiser, Ark., from 1 October to 31 October 2002. Lots of ‘1093’ (9 HMCs), ‘Francis’ (9 HMCs), and ‘Wells’ (8 HMCs) were harvested from the Rice Research and Extension Center at Stuttgart, Ark., from 21 August to 12 September 2002. RiceTec Inc. at Alvin, Texas, similarly harvested ‘Cocodrie’ (14 HMCs), ‘XL7’ (17 HMCs), and ‘XL8’ (15 HMCs) samples from 30 July to 30 August 2002. After harvest, samples were cleaned using a dockage tester (Carter-Day Co., Minneapolis, Minn.). Two kg samples of each lot were dried slowly in a chamber maintained at approximately 21°C and 65% RH (rice equilibrium MC of 12.5%). The samples were stored in plastic bags at 2°C until testing.

Two hundred kernels were randomly selected from each location/variety/HMC lot and hulled by hand. Three-point bending tests were conducted on each kernel using a texture analyzer (TA.XT2i, Texture Technologies Corp., Scarsdale, N.Y.) with a flat-faced loading head (Fig. 1). The deformation rate was set at 0.5 mm/s. After placing a kernel across the supporting span, the bending test was initiated and the maximum force attained before the kernel failed was recorded as the breaking force. Two 150 g subsamples from each location/variety/HMC lot were milled with a McGill No. 2 mill. Head rice yield was determined from the percentage head rice in each milled sample, which was determined using an image analyzer (Graincheck 2312, Foss North America, Minneapolis, Minn.).
RESULTS AND DISCUSSION

Breaking Force Distribution Trends

Figure 2 shows the BFDs for samples with high, medium, and low harvest MCs from Keiser. In general, the BFDs became more uniformly distributed as harvest MC decreased, although a slight bi-modal distribution was apparent for all harvest MCs. The BFD patterns for lots from Stuttgart (Fig. 3) were much different than those from Keiser in that the Stuttgart distributions showed a major secondary mode at low breaking force levels. Associated with this pattern was an increased variation in breaking force as is indicated by greater standard deviation values for Stuttgart relative to Keiser. This difference in BFDs could have ramifications in milling quality as it is hypothesized that kernels with low breaking forces, resulting from either being thin due to immaturity or fissured due to moisture adsorption, will be prone to breaking during milling. Figure 5 indicates generally lower HRYs for Stuttgart samples relative to those from Keiser.

Figure 4 shows the BFDs for selected samples from Alvin. The Alvin BFDs more closely resembled those from Stuttgart than Keiser. The Alvin distributions tended to be heavily skewed to low breaking forces, with most all distributions having a large secondary mode. In general, samples with harvest MCs greater than 20% produced a bi-modal and in some cases a tri-modal BFD. As harvest MC decreased, the distributions became more uniform. The “shifting” from multi- to single-modal distributions was not consistent, which could have been due to in-field variability. Additionally, the occurrence of moisture adsorption fissuring could also have played a role in this inconsistency. The distributions for XL7 in Fig. 4, in particular, indicate that moisture adsorption could have been a likely factor, as the BFD for the sample harvested at 13.6% MC produced a primary mode at a much lower breaking force than samples at higher harvest MCs. This trend was more apparent in the Alvin samples than those from either Keiser or Stuttgart. Finally, another potentially important influence on the BFD may be the temperatures experienced by kernels during grain filling (Clements et al., 2003).

Head Rice Yield versus Breaking Force Distribution

Siebenmorgen and Qin (unpublished) showed a strong relationship between HRY and the percentage of “strong” kernels, defined as those kernels that withstood a breaking force in bending greater than 20 N, for three long-grain varieties. Using this criterion, the percentage of strong kernels for each sample was calculated. Figure 5 indicates the relationships between HRY and the percentage of strong kernels for each variety/location lot. The Keiser varieties showed no relationship between HRY and percentage of strong kernels; all of the samples from Keiser had very high HRYs, even though the percentage of strong kernels varied. However, a potential reason for this lack of correlation is due to the choice of force level used to define a strong kernel. The frequency distributions in Fig. 2 indicate that the force level
separating the two breaking force modes was approximately 12 to 13 N. Thus, using the previously defined level of 20 N would classify some strong kernels as being weak.

Head rice yields were more strongly correlated with the strong kernel percentages at Stuttgart and Alvin than Keiser. The distributions for Stuttgart in Fig. 3 indicate that 20 N was a reasonable estimate of the force level separating the breaking force modes, although the BFDs from Stuttgart did not reveal a definitive mode separation. As such, some of the kernels classified as weak could have indeed survived milling intact and contributed to HRY. Figure 5 shows that the HRY vs strong kernel trends for the Alvin samples were similar to those at Stuttgart. Similar to Fig. 2 for Keiser, Fig. 4 indicates that 20 N may not be the optimal value to use for defining a strong kernel.

## SIGNIFICANCE OF FINDINGS

The BFDs from each location were characteristic for that location, and varied greatly across locations. While it is stressed that the data presented represents only one year’s testing, this finding is considered to be very important, as the breaking force of a kernel ultimately determines its ability to survive the milling process. Thus the finding represents a possible explanation for why HRYs vary across locations; further work is needed to elucidate the cause of the varying BFDs across locations.

The BFDs in Figs. 2 to 4 indicate that the goal of predicting HRY by the “strong kernel percentage” might be difficult to attain in that there is not always a clear distinction between weak and strong kernels, and that the force level that would be used to separate weak from strong kernels is not consistently obvious. Incorporating the cross-sectional area of the kernel, from which a failure stress level could be calculated, into the procedure used to define strong kernels could improve HRY prediction.

## ACKNOWLEDGMENTS

The authors wish to thank the Arkansas Rice Research and Promotion Board and the corporate sponsors of the University of Arkansas Rice Processing Program for the financial support of this research.

## LITERATURE CITED


Fig. 1. Schematic of the three-point bending test device. The loading head was 1.48 mm thick and 9.9 mm wide with a flat surface.
Fig. 2. Kernel breaking force frequency distributions at selected harvest moisture contents in 2002 for ‘Bengal’, ‘Cypress’, and ‘Drew’ from Keiser, Ark.
Each curve was generated from a 200-kernel brown rice sample.
Fig. 3. Kernel breaking force frequency distributions at selected harvest moisture contents in 2002 for ‘1093’, ‘Francis’, and ‘Wells’ from Stuttgart, Ark. Each curve was generated from a 200-kernel brown rice sample.
Fig. 4. Kernel breaking force frequency distributions at selected harvest moisture contents in 2002 for ‘XL7’, ‘XL8’, and ‘Cocodrie’ from Alvin, Texas. Each curve was generated from a 200-kernel brown rice sample.
Fig. 5. Correlation of head rice yield to percentage of strong kernels for samples harvested in 2002 from Keiser, Ark., Stuttgart, Ark., and Alvin, Texas. Each point was generated from a 200-kernel brown rice sample. “Strong” kernels are defined as those kernels that withstood more than a 20-N force in a bending test.