NOTE

Effects of Rough Rice Moisture Content at Harvest on Peak Viscosity

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During rice kernel development, kernel size and chemical composition change with maturation, and the kernel moisture content progressively decreases (Del Rosario et al 1968; Lee and Chang 1985). Therefore, kernel moisture content is an important indicator of rice kernel development. Lee and Chang (1985) found that when starch and protein synthesis were nearly completed, the rice kernel moisture content was ≈27–29% (wb). The composition of rice kernels harvested after this point reportedly did not change dramatically, although the starch content increased slightly, causing a proportional decrease in protein content in the kernel (Del Rosario et al 1968; Kim et al 2001).

Rice kernel-to-kernel development on panicles is nonuniform, which in turn produces a range of kernel moisture contents within a bulk at harvest (Chau and Kunze 1982; Kocher et al 1990; Siebenmorgen et al 1992). As such, physical properties such as bulk density and milling quality change with harvest moisture content (HMC). The grade of rice typically improved and the bulk density increased as HMC decreased (Morse et al 1967; Fan et al 1998). The number of fissured kernels increased dramatically when the HMC decreased from 19 to 13% and was especially severe when kernel moisture content decreased rapidly in a short time (Jodari and Linscombe 1996). Reports of optimum HMC for maximum head rice yield (HRY) ranges from 18 to 26% based on growing location, harvest date, and cultivar (Kester et al 1963; Huey 1977; Lu et al 1988, 1992; Siebenmorgen et al 1992; Jongkaewwattana et al 1993a; Ntanos et al 1996; Bautista and Siebenmorgen 2000).

Limited research has been conducted to determine the effect of the HMC on functional characteristics of rice. Kester et al (1963) reported that the peak viscosity (PV) of short-grain rice first decreased and then increased with maturation. It was explained that amylases were responsible for these changes. Kim et al (2001) also noted differences in PV of medium-grain rice with HMC, however, the trends did not follow consistent patterns. The study reported herein was designed to quantify the effects of rough rice HMC on PV of popular several rice cultivars grown in the mid-South rice producing region of the United States.

MATERIALS AND METHODS

One medium-grain cultivar (Bengal) and nine long-grain cultivars (1093, Ahrent, Cocodrie, Cypress, Drew, Francis, Wells, XL7, and XL8) were plot combine-harvested from Alvin, TX, and Stuttgart and Keiser, AR, between July 30 and August 30, August 21 and September 23, and October 1 and October 31, respectively, in 2002. All samples of a given cultivar were harvested from the same field. Rainfall information during the 2002 harvest period at Keiser, AR, was provided by the Northeast Research and Extension Center of the University of Arkansas.

Shortly after harvest, the rough rice HMC was measured using an individual kernel moisture meter (Shizuoka Seiki CTR 800E, Japan) which measures moisture content of individual rough rice kernels by correlating the electrical resistance measured across a kernel while it is crushed between two steel rolls. The samples were cleaned using a grain cleaner (MCI Kicker Grain Tester, Mid-Continent Industries, Newton, KS) and dried on screened trays in a chamber held at ≈22°C and 65% rh to ≈12.5% (wb) moisture content. Duplicate samples were hulled with a paddy husker (Satake Engineering, Tokyo, Japan) and milled for 30 sec in a laboratory mill (McGill No. 2, Rapsco, Brookshire, TX). The head rice was separated from brokens using a sizing device (Seedburo, Chicago, IL), and the HRY was calculated. Head rice from the milled samples was ground into flour using a cyclone sample mill (Udy Corp., Fort Collins, CO) equipped with a 0.5-mm screen. Duplicate PV values of the rice flour samples were determined on a paste of 3 g of rice flour in 25 mL of distilled water with a Rapid Visco Analyser (RVA-4 Series, Newport Scientific Pty, Ltd, Warriewood, NSW, Australia) following Approved Method 61-02 (AACC 2000). The flour paste was held at 50°C for 1.5 min, heated to 95°C at 12.2°C/min, held at 95°C for 2.5 min, and cooled to 50°C at 12.2°C/min.

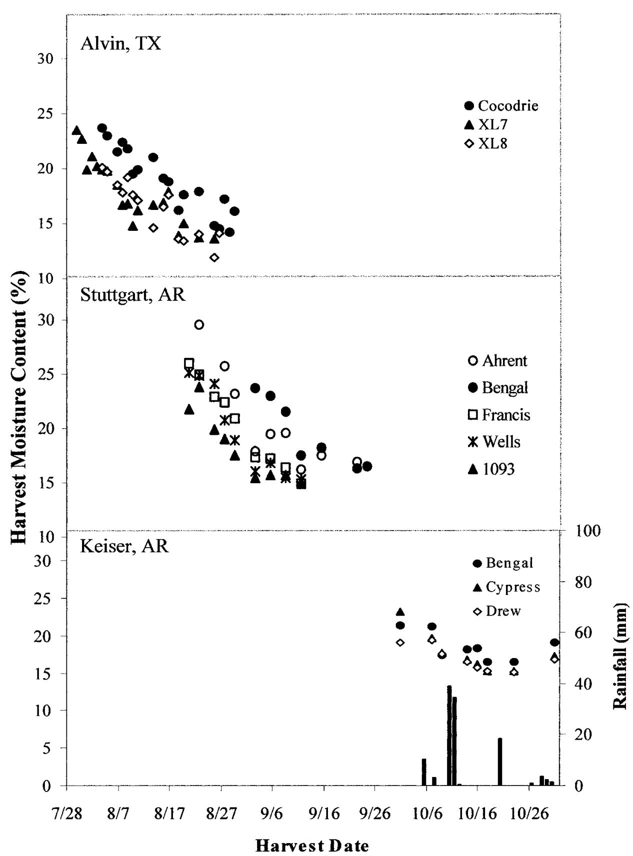

Fig. 1. Harvest moisture content (wb) vs. harvest date for rice cultivars from Alvin, TX, and Stuttgart and Keiser, AR, and rainfall at Keiser, AR, in 2002.

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Preliminary data was collected in 1997 from the medium-grain cultivar (Bengal) and the two long-grain cultivars (Cypress and Kaybonnet) from Stuttgart, AR, were used for comparison. The PV was determined using an amylograph (Viskograph-E, C. W. Brabender Instruments, South Hackensack, NJ) as in Approved Method 61-01 (AACC 2000). Experimental data were analyzed using the general linear models procedure of SAS for Windows (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

The HMC ranges of rough rice samples from Alvin, Stuttgart, and Keiser were 11.9–23.5%, 14.9–29.6%, and 15.1–23.2%, respectively (Fig. 1). Varietal differences in HMC at given harvest dates were observed that might reflect management practices such as planting date. Within a given cultivar from a given location, the HMC generally declined linearly with harvest date. Many studies have shown this general trend in HMC with maturation (Del Rosario et al 1968; Paul and Mukherji 1971; Lee and Chang 1985; Kocher et al 1990; Siebenmorgen et al 1992). However, rainfall temporarily increases the HMC, especially at late harvest dates when the HMC is low (Siebenmorgen et al 1992; Lu and Siebenmorgen 1994). An example of this phenomenon in this study is shown in Fig. 1, where the HMC of rough rice samples harvested on October 31 at Keiser, AR, increased from 15.1–16.4% to 16.8–19.0% due to the 7.4 mm of rainfall between October 28 and October 30. Jodari and Linscombe (1996) reported that the HMC could increase one percentage point with a 5-mm rainfall, and could increase by as much as four percentage points with several days of continuous rainfall. Head rice yields varied with HMC and location. HRY from Keiser increased steadily from 63% at 21.3% HMC to 68% at 15.2% HMC. HRY values from Alvin and Stuttgart, however, displayed parabolic relationships with the highest HRY values found at HMC (18 and 20%, respectively).

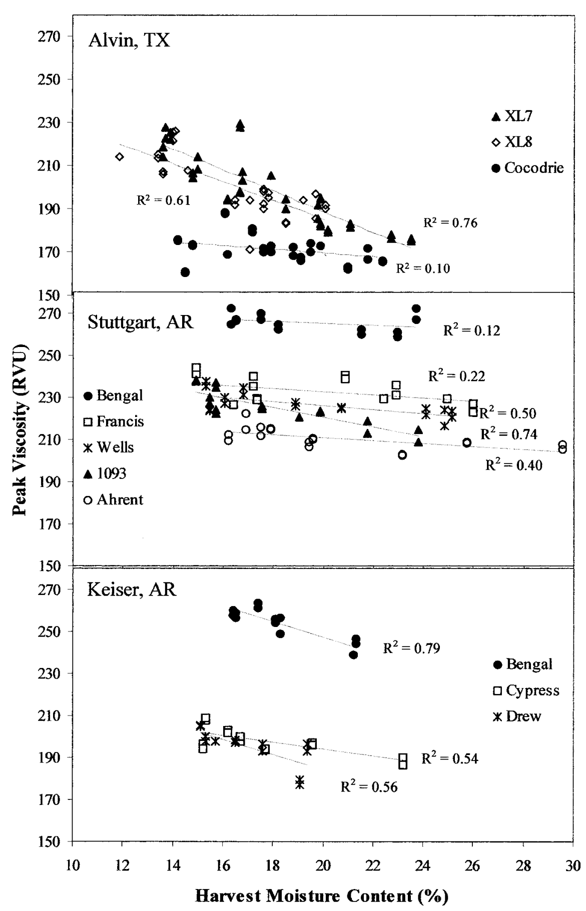

Fig. 2. Effects of harvest moisture content (wb) on peak viscosity of rice cultivars from Alvin, TX, and Stuttgart and Keiser, AR, in 2002.

The effect of HMC on PV is shown in Fig. 2. The medium-grain cultivar Bengal from Stuttgart and Keiser, AR, had significantly greater PV values than those of the long-grain cultivars. Medium-grain cultivars typically have lower amylose contents than long-grain cultivars. Generally, rice flours with low amylose content tend to have higher PV values (Tan and Corke 2002; Vandeputte et al 2003).

The PV of rice flour within a given cultivar was generally inversely correlated with HMC (Fig. 2). However, the rate of increase in PV as HMC decreased varied with the cultivar and location (Table I). The correlation coefficients between PV and HMC were greater for cultivars XL7 and XL8 from Alvin, 1098, Ahrent, and Wells from Stuttgart, and all cultivars from Keiser (the analysis does not include the last harvest date at Keiser because of the increase of HMC by rainfall). The trendlines of PV vs. HMC of rice flours from Stuttgart were flatter, except for 1093 than those from Alvin and Keiser. This could indicate that conditions at Stuttgart in 2002 favored a more rapid maturation than at the other locations.

The cause for increases in PV as HMC decreased was not determined. Kester et al (1963) noted variations of rice flour PV with rice maturation. These variations were postulated to be due to changes in amylase activity and starch and protein molecular structure during maturation. Amylase activity, which is related to starch synthesis, was maximized at 14 days after flowering and then decreased gradually (Baun et al 1970). Chrastil (1993) found that the average starch molecular weight increased steadily, while the number of rice protein disulfide bonds increased slightly, as the kernel matured. Because rice kernels develop nonuniformly on a panicle, kernels on the top portion of panicles matured as much as 10–15 days earlier than those on the bottom portion (Jongkaewwattana et al 1993b). A greater HMC vs. PV trendline slope may suggest greater proportions of immature kernels in samples. More immature kernels in samples may cause reductions in PV due to a greater amylase activity and protein content compared with those with more mature kernels.

The trends in the data collected in 1997 agreed with those determined from the 2002 samples. The PV of Bengal, Cypress, and Kaybonnet linearly increased as HMC decreased, particularly those of Bengal and Kaybonnet, which increased from 341 and 310 BU to 478 and 445 BU, respectively, as HMC decreased from 22 to 18%. The increase in PV of Cypress was more modest, from 294 to 302 BU over the same HMC range. The results may indicate that some of the Bengal and Kaybonnet were still maturing during the HMC change, but most of the Cypress was already mature. The rate of increase in PV with HMC for the 1997 samples was greater than that of the 2002 samples, which may be due to the fact

TABLE I
Correlations and Trendline Slopes of Peak Viscosity vs. Harvest Moisture Content Relationships (Fig. 2)

Growing Location	Rice Cultivar	Correlation Coefficient	Trendline Slope
Alvin, TX	Cocodrie	–0.32	–0.84
	XL7	–0.87**[a]	–4.84
	XL8	–0.78**	–4.26
Stuttgart, AR	1093	–0.86**	–2.37
	Ahrent	–0.63**	–0.71
	Bengal	–0.34	–0.48
	Francis	–0.47*	–0.74
	Wells	–0.71**	–0.95
Keiser, AR	Bengal	–0.89**	–3.70
	Cypress	–0.73**	–1.66
	Drew	–0.75**	–3.55

[a] *,** Significant at $P < 0.01$ and $P < 0.001$, respectively.

that an amylograph was used for the 1997 PV tests, which may be more sensitive in distinguishing PV variations with HMC compared with the RVA.

CONCLUSIONS

Peak viscosity, which is often used as an indicator of rice functionality and performance in end-use product applications, increased as the rice harvest moisture content decreased, although the rate of increase varied with the rice cultivar and growing location. The dependence of PV on HMC could affect end-use processing operations. Because rough rice is typically not segregated based on HMC, some of the variability in processing performance that end-use processors have noted could possibly be due to HMC, particularly for rice grown in certain locations. The fundamental causes of the increases in PV as HMC decreased, especially why these relationships changed with cultivar and growing location, is currently being investigated.

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