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# Factors Affecting Rice Milling Quality

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## Overview of Rice Milling

Rice is harvested in the Mid-South at moisture contents (MCs) typically ranging from 13% to 22% (wet basis). Because these MCs are greater than those safe for long-term storage, rice is dried within a fairly short period after harvest to 12% to 13% MC before being placed in storage. Once dried, "processing" of rough rice into milled rice takes place throughout the year and consists of several operations.

After cleaning to remove foreign material, rough rice is hulled to produce brown rice. The hull represents approximately 20% of the mass of a rough rice kernel. Brown rice is usually milled immediately after hulling, removing the bran layers and germ by frictional and/or abrasive action. The bran represents approximately 10% of the original rough rice mass.

The remaining milled or "white" rice comprises head rice, defined as those kernels retaining three-fourths or more of their original length, and broken kernels (brokens). The *milled rice yield* (MRY) represents the mass of milled rice expressed as a percentage of the original dried rough rice mass. Typical MRYs range from 68% to 72%. Upon removal of brokens, only head rice remains. The mass of head rice, expressed as a percentage of the original rough rice mass, is defined as the *head rice yield* (HRY). Head rice yields can vary from 0 (all kernels are broken) to a theoretical maximum of approximately 70% (no kernels are broken). Milling quality is often expressed as a ratio of the HRY to the MRY, e.g., a 58/70 value would indicate an HRY of 58%, MRY of 70% and brokens yield of 12%, the difference between the two values.

Broken kernels reduce milling yield. Brokens produced during milling are generally the result of immature, chalky, or fissured kernels, all of which are weak and typically break during milling due to the substantial forces imparted to kernels in order to remove bran. Since brokens are only worth approximately 60% of the value of head rice, HRY directly determines the economic value of a rice lot, e.g., if the value of head rice is $0.20/lb and brokens $0.13/lb, the discount for HRY reduction would be $0.07 for every percentage point change in HRY for each 100 lbs of rough rice. Thus, if HRY decreases by 10 percentage points, e.g., from 60% to 50%, the price decrease would be $0.70 for every 100 lbs of rough rice, or $0.32 per bushel.

The degree to which rice is milled, or the *degree of milling*, is determined by the amount of bran remaining on milled kernels. Whiteness, as measured with a color meter, is sometimes used to indicate degree of milling. However, a more common method of quantifying degree of milling is measuring the amount of lipids, or oil, on the surface of milled kernels. Since bran is approximately 20% lipids, the surface lipid content of milled rice is directly related to the amount of bran remaining on milled kernels. As milling progresses and the degree of milling increases, the whiteness of milled rice increases, the surface lipid content decreases, and both MRY and HRY decrease. While there is currently no accepted standard for measuring degree of milling, most commercially milled rice must meet some form of degree of milling specification.

## Production Factors Affecting Milling Quality

Several factors during rice production can affect milling quality. Such factors are generally manifested as individual kernel strength reduction, which ultimately determines the ability of the kernel to withstand the rigors of hulling and bran removal without breaking apart. Diseases such as rice blast or sheath blight can cause milling quality reductions (Candole et al., 2000). In addition, kernel smut disease reduces milling quality and can sufficiently discolor rough rice to create problems during parboiling (R. Cartwright, personal communication). Additionally, field insects can have detrimental effects on rice quality. Most notable is the stink bug, which bores into the kernel during development, resulting in a black spot on the kernel known as "peck."

## Factors at Harvest

Head rice yield typically varies with the MC at which rice is harvested. The harvest MC at which HRY is maximum, under Arkansas weather conditions, is approximately 19% to 21% for long-grain cultivars and 22% to 24% for medium-grains (Siebenmorgen et al., 2007). Harvesting at MCs greater than or less than optimal can result in decreased HRY, as illustrated in Figure 1; the causes are explained as follows.

As rice matures, kernels on a panicle will exist at very different MCs, representing various maturity and kernel strength levels (Bautista and Siebenmorgen, 2005). An example of this is illustrated in Figure 2, which shows that when the average bulk MC is 22.7%, a large spread in individual kernel MCs exists. Distributions of individual kernel MCs change with the bulk MC of the sample, e.g., individual kernel MC distributions usually have multiple "peaks" when rice is harvested at 16% MC or greater. These distributions transition to single peaks at lower MCs, yet there is still a large range in kernel-to-kernel MCs, as is shown in Figure 2 for rice at a bulk MC of 14.3%. At any given point in time, some kernels on a panicle may be at much different MC than others and thus will respond differently to ambient air changes.

Individual kernel MC distributions can be used to explain milling quality levels in that the distributions quantify the percentage of immature or "green" kernels, often considered as those kernels with MCs greater than 22%, as well as the percentage of "dry" kernels, often taken as those kernels with MCs less than 14%. Immature kernels, illustrated in Figure 3, can be a source of milling quality reduction because these kernels are typically weak in structure and often break during milling (Siebenmorgen et al., 2006). Rapid rewetting of low-MC kernels, such as would occur through exposure to rain or ambient air relative humidities greater than approximately 85%, cause dry kernels to expand rapidly at the kernel surface. However, because an extended time is required for the moisture to migrate inward, the kernel center cannot immediately expand, creating stress differences inside the kernel that ultimately result in material failure and fissure formation. Fissured kernels, as illustrated in Figure 4, typically break apart during milling, drastically reducing HRY.

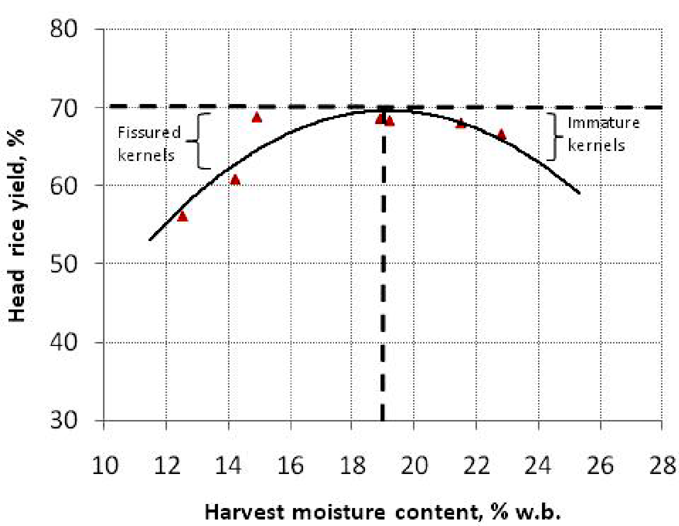


**FIGURE 1. Parabolic relationship between head rice yield and harvest moisture content of long-grain cultivar Cypress sampled over a range of harvest moisture contents from Keiser, Arkansas.**

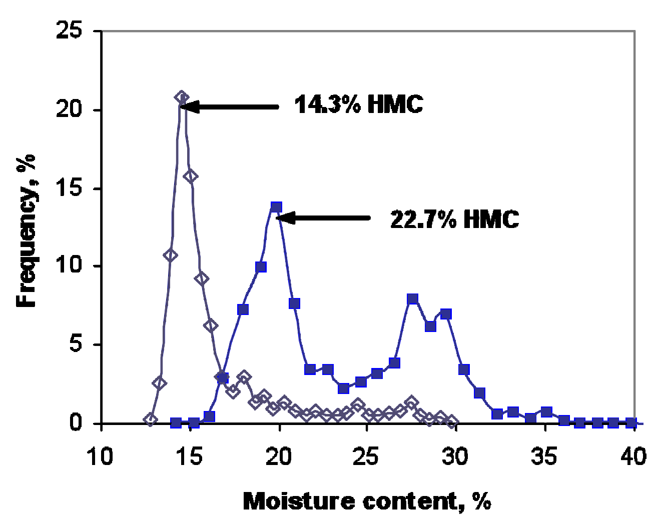


**FIGURE 2. Individual kernel moisture content distributions within panicles (composite of kernels from five panicles) of Bengal rice at average harvest moisture contents (HMCs) of 22.7% and 14.3% from Stuttgart, Arkansas.** *(Taken from Bautista and Siebenmorgen, 2005)*

**FIGURE 3. Immature kernels on a panicle (above) and after harvest and hulling (left), which are generally weak in structure and prone to breaking.**

**FIGURE 4. Fissured kernel due to rapid moisture adsorption.**

Figure 5 shows how the percentage of fissured kernels in a sample increases as the MC at which rice is harvested decreases. The percentage of fissured kernels increases approximately exponentially as the grain dries in the field, thus exposing increasing numbers of dry kernels to rapid moisture adsorption conditions. The propensity for kernels to fissure due to moisture adsorption increases as the kernel MC decreases. It is to be noted that the rate of fissured kernel percentage increase is not always perfectly correlated to the percentage of low MC kernels, since fissuring by moisture adsorption is dependent on moisture being supplied by the environment in some manner, such as precipitation or high relative humidity.

An example of the relationship between HRY and individual kernel MC distributions is given in Figure 6. The HRY versus harvest MC curve of Figure 6 indicates a peak HRY at approximately 20% MC. The decline in HRY at low harvest MCs corresponds to the increasing percentage of kernels with MCs less than 14%; these kernels likely fissure due to rapid moisture adsorption. The longer rice is left in the field at low MCs, the greater the potential for fissured kernels.

Figure 6 also shows that HRYs decline at harvest MCs greater than the peak of 20%, likely due to the increasing presence of thin, immature kernels (Siebenmorgen et al., 2006). Figure 6 illustrates this increasing presence of immature kernels by the curve depicting the percentage of kernels with MCs greater than 22%. Siebenmorgen et al., 2006 showed that these thin kernels often break during milling. Trends in HRY across harvest MCs over a five-year period for multiple cultivars and locations in Arkansas are given by Siebenmorgen et al., 2007.

Based strictly on maximizing HRY, it is generally recommended to harvest rice at the optimal MCs indicated above. However, when considering that drying costs generally increase dramatically with harvest MC, the *economic optimum* harvest MC may be slightly less than the optimal MC for maximizing HRY, depending on drying charges and the relative value of head rice to brokens, as presented by Siebenmorgen et al., 2008; *see the manuscript for general recommendations*.

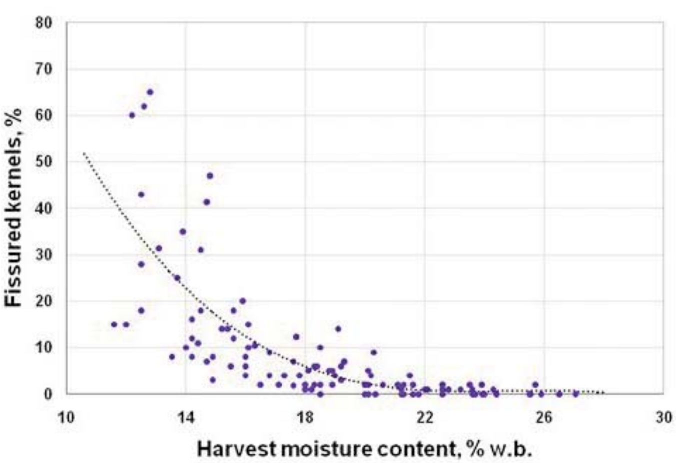


**FIGURE 5. Fissured kernel percentages as a function of harvest moisture content.** *(Taken from Bautista et al., 2009)*

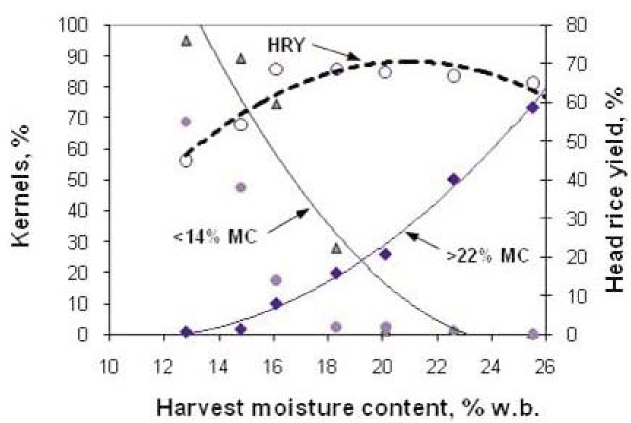


**FIGURE 6. Relationships of percentages of kernels at moisture contents (MCs) >22% or <14% and head rice yields (HRYs) to harvest MCs for long-grain cultivar Drew harvested at Keiser, Arkansas.** *(Taken from Bautista et al., 2009)*

## Nighttime Air Temperature Effects

Another production factor that can impact rice quality is ambient temperature during kernel development. Previous research conducted in controlled-air chambers has shown that increasing nighttime air temperatures during certain kernel reproductive stages will dramatically increase chalkiness and reduce HRYs in several cultivars (Cooper et al., 2008). Chalkiness, illustrated in Figure 7, reduces kernel strength and thus directly relates to milling quality reduction. Recent field research has confirmed and extended these findings. This research shows that increasing levels of nighttime air temperatures during grain filling stages are strongly correlated to increasing levels of chalkiness and reduced HRYs. The most dramatic impact on milling quality is that peak HRYs, obtained by harvesting at optimal MC levels, will be reduced substantially when high nighttime air temperatures occur during kernel filling. Figure 8 provides such an example. Peak HRYs of the Wells cultivar, grown in two Arkansas locations, Pine Tree and Stuttgart, during 2008 were as much as four percentage points different. This difference is attributed to the effects of high nighttime air temperatures.

Figure 9 illustrates how nighttime air temperatures (defined as those occurring between 8 p.m. and 6 a.m.) during the R-8 reproductive stage (Counce et al., 2000) impact chalkiness and peak HRYs, with data collected from six cultivars grown in 2007 through 2010 at locations from northern to southern Arkansas. The 95th percentile of nighttime air temperatures was used to represent the temperature below which 95% of nighttime air temperatures occurred during a reproductive stage. Figures 9a and 9b show that, in general, as nighttime air temperatures during R-8 increase, chalk values increase and corresponding peak HRYs decrease, particularly in some cultivars. *It is especially noted that the data from 2010 generally represented extreme nighttime air temperatures as well as drastically high chalk levels and low HRYs, with peak HRYs often being below 50%.*

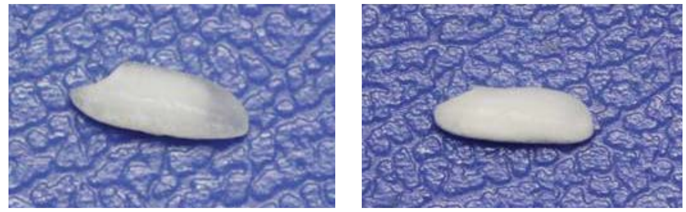

**FIGURE 7. Chalky kernels – chalk appears opaque white and may affect a particular region of a kernel (left) or the entire kernel (right).**

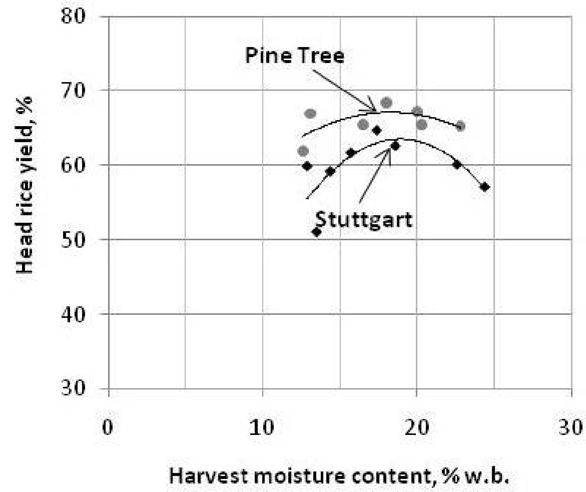


**FIGURE 8. Head rice yields of long-grain cultivar Wells harvested over a range of moisture contents at northern (Pine Tree) and southern (Stuttgart) locations in Arkansas during 2008. The difference in peak head rice yields between the two lots is attributed to elevated nighttime air temperatures that were observed in Stuttgart during the grain-filling stages.**

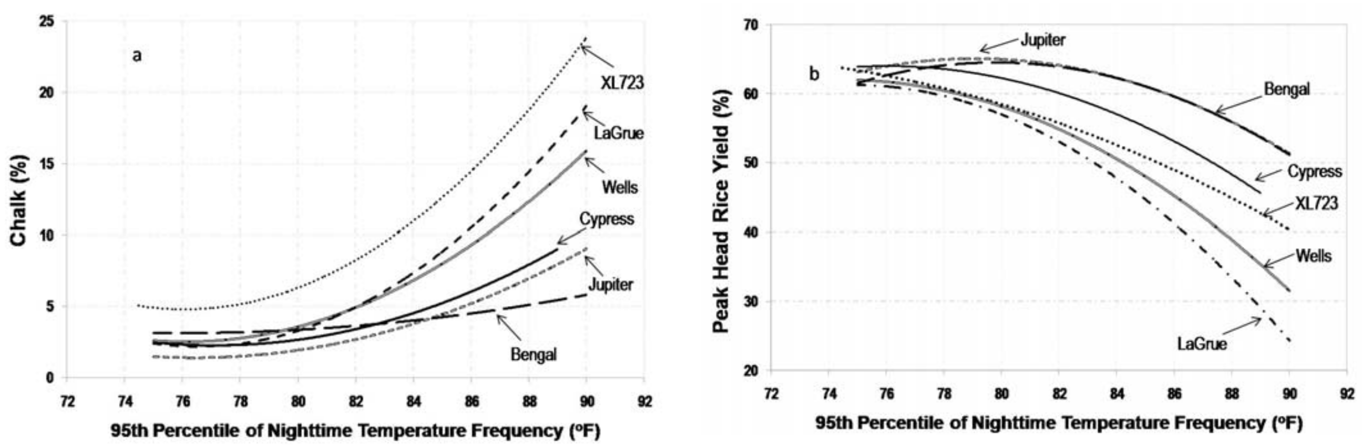


**FIGURE 9. Relationships of chalk (a) and peak head rice yields (b) and the 95th percentiles of nighttime air temperature frequencies during the R8 stages of the indicated cultivars grown during 2007, 2008, 2009 and 2010.**

This recent research has shown at both lab and field levels that peak HRY is inversely affected by nighttime air temperatures during the kernel filling stages of reproductive growth. The research has also shown that the effects of nighttime air temperatures are cultivar-dependent; some cultivars are very susceptible to the negative impacts of high nighttime air temperatures while others are somewhat resistant.

## Summary

In summary, any factor that causes a reduction in the strength of kernels, and the resultant ability of kernels to withstand the forces imparted during hulling and milling, will impact milling quality. These factors include those incurred during production, such as fungal diseases and insects, and as recently documented, high nighttime air temperatures during kernel filling. Additionally, the MC at which rice is harvested can have a dramatic impact on milling quality, with HRY reductions occurring by harvesting at greater MCs (reductions due to increasing numbers of immature kernels) or lesser MCs (reductions due to moisture adsorption fissuring) than optimal.

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