Milling Characteristics of Rice Cultivars and Hybrids

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ABSTRACT

Many rice cultivars and hybrids have unique physical characteristics that affect milling performance. The purpose of this study was to quantify the rate of bran removal during milling for several rice cultivars and hybrids common to the southern United States, and compare the quantity of lipids remaining on the kernel surface to that located throughout the kernel. This was accomplished by analyzing two sample sets. The first comprised cultivars Cocodrie, Cypress, and Lemont, and hybrids XL7 and XL8, which were milled for 0 (brown rice), 20, 30, 40, 50, 60, and 70 sec in a laboratory mill. In the second set, cultivars Cocodrie, Cypress, and Wells, and hybrids XL7 and XL8 were milled for 0, 20, 40, and 60 sec. The surface lipid content (SLC) and color of head rice samples were measured as indications of the degree of milling (DOM). The total lipid content (TLC) of ground head rice was also measured to determine the total amount of lipids present throughout the entire kernel. Results showed that at a given milling duration, SLC and color varied across cultivars and hybrids. In particular, the SLC levels of hybrids were lower than those of cultivars, particularly for Cocodrie, for all milling durations. This research indicated that it may be necessary to mill different cultivars and hybrids for varying durations to attain comparable DOM levels. Milling to a consistent DOM level is necessary to ensure equitable head rice yield comparisons across cultivars and hybrids.

Rice cultivars are inherently different in many physical characteristics including kernel size and shape, kernel hardness, and surface topography (Bhashyam and Srinivas 1984; Pomeranz and Webb 1985). All of these characteristics can affect rice quality, particularly milling quality. Milling quality is quantified in large part by the head rice yield (HRY), defined as the mass percentage of rough rice that remains as head rice after milling; head rice comprises milled kernels that are at least three-fourths the length of a whole, milled kernel (USDA 1997). Rice kernel characteristics are influenced by the environmental conditions under which the rice was grown (Webb 1980) and by the genetics of the rice.

Rice kernel characteristics affect the relative ease and thereby the rate at which bran and inadvertent chips of endosperm are removed during milling. This rate determines the milling duration required to attain a given degree of milling (DOM) and is thus a determinant of HRY. The DOM of rice refers to the extent to which the germ and bran layers of brown rice kernels have been removed during the milling process. Head rice yield is inversely and generally linearly related to DOM. There are specific DOM grades established for rice by the U.S. Department of Agriculture (USDA) that range from “under-milled” to “hard-milled” (USDA 1997). The USDA DOM measurement method is based on visual comparison to line samples. Milled rice end-users often set more specific DOM specifications that rice mills must meet (Webb 1980).

Several rice kernel characteristics have been studied in regard to impact on milling performance. Pomeranz and Webb (1985) and Webb (1980) state that cultivars with thicker kernel sizes require more milling pressure due to a thicker aleurone layer within the bran morphology. Kernels with deeper surface grooves also require more milling pressure or longer milling durations to smooth the surface of the kernel to remove an adequate amount of bran to achieve a desired DOM (Pomeranz and Webb 1985). Increased milling pressure or longer milling durations result in greater amounts of bran or endosperm being removed and transferred to the bran stream, thereby reducing HRY (Reid et al 1998). Because rice cultivars have different overall kernel sizes and surface topographies, this project was conducted to quantify the milling response of selected rice cultivars and hybrids to various milling durations, as determined by surface lipid content (SLC) and color measurements.

Additionally, because there have been ongoing discussions in the rice industry as to the distribution of lipids within kernels from various cultivars and hybrids, and how this distribution changes during milling, the total lipid content (TLC) of milled rice samples was also measured. In measuring SLC, intact head rice was used in an extraction procedure; this procedure assumes that only lipids at the surface of kernels are removed during extraction. The extraction procedure for measuring TLC was the same as that for SLC, except that head rice was ground into flour before the extraction was performed. Thus, TLC is a measure of the amount of lipid throughout the entire milled kernel. The SLC and TLC levels were compared in an effort to address lipid distribution changes during milling.

MATERIALS AND METHODS

Sample Procurement and Preparation

The first sample set comprised cultivars Cypress and Lemont, and hybrids XL7 and XL8 grown near Stuttgart, AR; cultivar Cocodrie was also included in the first set, but was grown near Alvin, TX. All first-set samples were grown in 2001 in strip trials (each strip was ≈15 m × 300–400 m) as part of the RiceTec, Inc. (Alvin, TX) field-scale variety testing program. After harvest, samples were dried to ≈12% using forced-air driers with air temperatures from 40 to 43°C. The samples were then stored in paper bags in a cooler at ≈17°C. The milling procedure consisted of removing samples from storage and allowing the samples to equilibrate in the bags in a laboratory at 21°C for at least a day. After equilibration and immediately before milling, rough rice moisture contents (MC) were measured using a convection oven procedure that involved drying 15-g samples at 130°C for 24 hr; MC values ranged from 10.5 to 11.5%. Rough rice samples (150 g) from each cultivar/hybrid lot were then dehulled in a laboratory sheller (THU, Satake, Tokyo, Japan). The resultant brown rice was milled for 0, 20, 30, 40, 50, 60, and 70 sec in a laboratory mill (McGill #2, RAPSCO, Brookshire, TX). Head rice (milled kernels ≥75% of the original milled rice kernel length) was separated from brokens with a sizing device (Seedburo Equipment Co., Chicago, IL). To obtain ground rice used for TLC determination, head rice samples were ground into flour with a laboratory mill (cyclone sample mill, Udy Corp., Ft. Collins, CO) equipped with a 0.5-mm screen.

Based on results from the 2001 samples, an additional sample set was obtained and milled for comparison purposes. For the second

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set, cultivars Cocodrie, Cypress, and Wells, and hybrids XL7 and XL8 grown in 2002 near Alvin, TX, from RiceTec strip trials, were harvested, dried, and stored in the same manner as the 2001 set. Samples were likewise milled, except for durations of 0, 20, 40, and 60 sec, based on the 2001 sample observations.

SLC and TLC Measurement

The SLC levels of replicate head rice subsamples and the TLC levels of replicate ground rice samples from each cultivar or hybrid/milling duration/sample set combination were measured using a lipid extraction system (Soxtec Avanti 2055, Foss North America, Eden Prairie, MN) following the procedure of Matsler and Siebenmorgen (2005). In summary, this method utilized 4–5 g of head rice or ground rice weighed into cellulose thimbles (33 mm, i.d. × 80 mm external length) (Foss North America, Eden Prairie, MN). Thimbles containing rice samples were predried for 1 hr in an oven maintained at 100°C. Lipid was extracted from the sample utilizing 70 mL of petroleum ether (boiling point 35–60°C; VWR, Suwanee, GA). The hot plate below the extraction cups was heated to 135°C. The extraction cycle consisted of immersing the thimbles in the extraction cup solvent for a boiling duration of 20 min, then raising the thimbles above the solvent, and rinsing the samples with petroleum ether condensate for 30 min. After the rinsing duration, the extraction cups were removed from the Soxtec unit and placed into an oven maintained at 100°C for 30 min. After removal from the oven, samples were placed in a desiccator to cool to room temperature for ≈30 min. After cooling, the extraction cups containing the extracted lipids were removed from the desiccator and weighed. The difference between the mass of the cups containing the extracted lipid and the original mass of the cups was then calculated to obtain the mass of the extracted lipid. The mass of surface lipid or total lipid extracted was divided by the original head rice sample mass and expressed as a percentage to obtain SLC or TLC, respectively.

Color Measurement

The color of milled rice can also be used as an indication of DOM. As such, the color of replicate samples from the 2001 sample set was measured by scanning replicate 50-g head rice subsamples with a color meter (Hunter Colorflex, Hunterlab, Reston, VA) equipped with Universal software (v. 5.3, Hunterlab) using the $L^*a^*b^*$ scale. These $L^*a^*b^*$ values were then converted to the more descriptive values of hue angle and chroma by the software. Hue angle represents the actual color of the sample, while chroma represents the intensity of the color (McLellan et al 1995).

Statistical Analysis

A students t-test ($\alpha = 0.05$) was performed using JMP software (v. 5.0.1.2, SAS Institute, Cary, NC) to compare the mean values of cultivar or hybrid/sample set/milling duration SLC, TLC, hue angles, and chroma values.

RESULTS AND DISCUSSION

Surface Lipid Content

Surface lipid contents of brown rice (0 sec milling duration) were lower than those of samples that had been milled for even brief durations (Figs. 1 and 2), particularly for the 2001 samples (Fig. 1A). This is thought to be due to the waxy seed coat or cuticle on the periphery of the caryopsis (Champagne et al 2004),

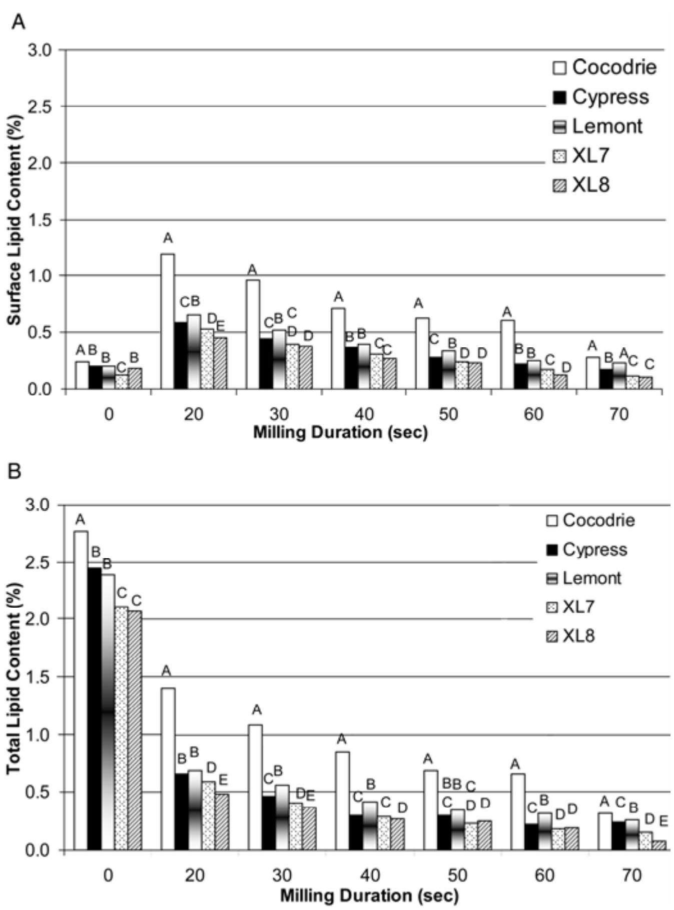

Fig. 1. Surface lipid contents (**A**) and total lipid contents (**B**) of three cultivars and two hybrids harvested in 2001. Each point represents the average of two subsample extractions. Columns within a milling duration set with different letters are significantly different at $P > 0.05$.

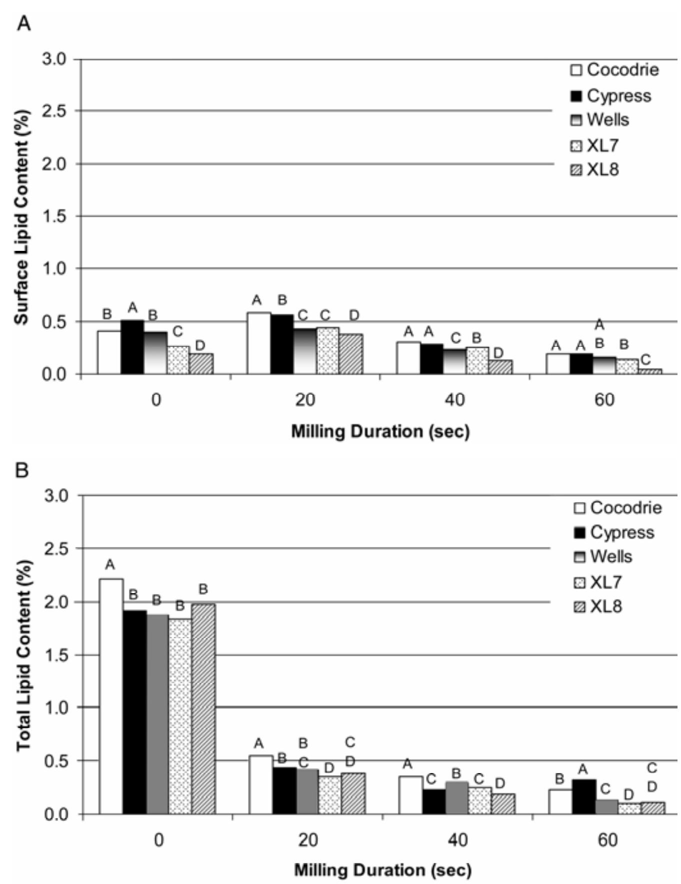

Fig. 2. Surface lipid contents (**A**) and total lipid contents (**B**) of three cultivars and two hybrids harvested in 2002. Each point represents the average of two subsample extractions. Columns within a milling duration set with different letters are significantly different at $P > 0.05$.

which may prevent the penetration of petroleum ether to extract lipid. In general, SLC decreased as milling duration increased for all cultivars and hybrids from both sample sets (Figs. 1 and 2). This was due to more bran being removed from the kernel surface as milling progressed.

Figures 1 and 2 show the general trend that hybrids reached a certain SLC faster than cultivars, that is, hybrids had a greater "millability" than cultivars. Cultivars Cocodrie, Cypress, and Lemont from the 2001 samples, and cultivars Cocodrie and Cypress from the 2002 samples, had significantly greater ($P < 0.05$) SLC levels than hybrids XL7 and XL8 for each milling duration (Figs. 1 and 2). In the 2002 samples, cultivar Wells milled similarly to hybrid XL7 at each milling duration ($P < 0.05$) (Fig. 2A). XL8 had the lowest SLC for all milling durations in both sample sets.

A striking difference in Cocodrie SLC between the two sample sets was observed (Figs. 1 and 2). Cocodrie had significantly greater SLC levels than the other cultivars and hybrids from the 2001 samples ($P < 0.05$) for all milling durations except the 70 sec duration, at which SLC of Cocodrie and Lemont were not statistically different. This observation is supported by anecdotal information from milling industry personnel that Cocodrie requires greater milling to achieve specified DOM levels. The greater Cocodrie SLC levels are attributed to inherently greater lipid levels on the Cocodrie kernels, as indicated by the brown rice TLC levels (Figs. 1 and 2). However, the Cocodrie SLC from the 2002 samples were much closer to the levels of other cultivars and hybrids. Cocodrie and Cypress or Wells SLC levels were not statistically different at the 40- and 60-sec milling durations (Fig. 2A).

Total Lipid Content

Total lipid content is considered to represent the extractable lipid present throughout an entire milled rice kernel. For all cultivars and hybrids from both sample sets, TLC decreased as milling duration increased (Figs. 1 and 2). The TLC trends were similar to the SLC trends in that the cultivar samples had greater TLC levels than hybrid samples at all milling durations. It is noted that the inherent lipid levels in the various cultivars and hybrids were not the same, as indicated by the brown rice TLC. Figure 1A shows that in the 2001 samples, Cocodrie had ≈2.7% brown rice TLC, while the hybrid XL8 brown rice sample contained only 2.1% lipid.

The difference in the TLC of the samples could be part of the reason that the cultivars and hybrids responded differently to the milling process. If a sample contained more lipid to begin with (brown rice), it would logically take a longer milling duration to achieve a comparable DOM relative to samples that have a lower brown rice TLC.

As was seen with the SLC, there was a difference in the TLC of Cocodrie from the 2001 and 2002 samples (Fig. 2). In the 2001 samples, Cocodrie brown rice contained ≈2.7% total lipid, while in the 2002 set it contained only 2.2%. An even larger difference was observed in the TLC of Cocodrie samples after 20 sec of milling. In the 2001 samples, Cocodrie head rice contained ≈1.4% total lipid, while the 2002 Cocodrie sample had slightly over 0.5% lipid. The large difference in Cocodrie TLC values between the two sample sets is indicative of the inherent range in lipid levels, as well as the response to milling, of Cocodrie kernels procured from different sources. This range could be due to production environment.

Total vs. Surface Lipid Content

An ongoing discussion within the AACC International Rice Technical Committee concerns the question of determining at what point a rice kernel is "adequately" milled. This is a critical issue as the DOM affects HRY (Sun and Siebenmorgen 1993; Reid et al 1998) and many end-use, postmilling properties (Perdon et al 2001). One point of interest apparent from the data of this research is the milling duration at which the SLC and TLC curves converge; that is, the duration at which the SLC equals the TLC (Fig. 3). This duration represents the point at which the amount of lipid remain-ing on the surface of head rice kernels equals that of ground head rice kernels.

This duration may be deemed the point at which a sample can be considered adequately milled. The rationale for this is that at short milling durations, in which the TLC is greater than the SLC, portions of intact bran layers remaining on the surface of kernels impede petroleum ether extraction of lipid at those locations, as was the case when extracting lipid from brown rice (0 sec milling duration). As such, for these kernels, the TLC would be greater than the SLC. Subsequent milling to remove these remaining bran areas to the point that petroleum ether can extract lipid across the entire kernel surface would yield a situation in which the TLC equals the SLC.

For the 2001 Cocodrie samples, the SLC and TLC curves converged after ≈50 sec of milling (Fig. 3). For the Cypress samples harvested in 2001, however, the SLC and TLC curves converged after only ≈20–25 sec of milling. Interestingly, the 2002 Cocodrie samples did not respond in the same manner as the 2001 Cocodrie samples in that the SLC and TLC curves converged after only 20 sec of milling, similar to the 2001 Cypress SLC/TLC responses (Fig. 3). The SLC/TLC trends shown for the 2001 Cypress samples were representative of those for the other cultivars tested (data not shown).

Color

Figure 4 illustrates the changes in milled rice hue angle as milling duration increased. Lower hue angle values indicate darker rice, which could correspond to more bran remaining on the surface of kernels or to inherently darker kernels. The data showed a general trend of lighter color rice as milling duration increased,

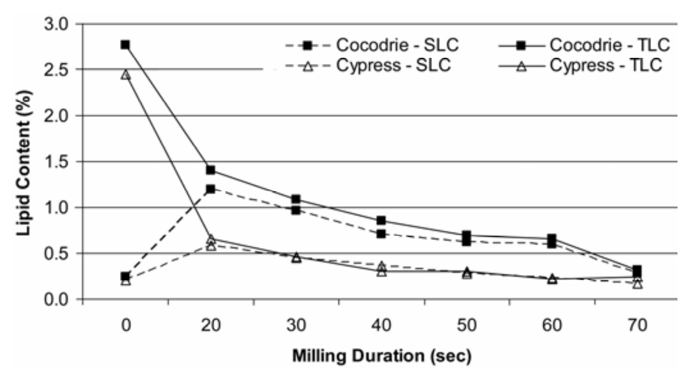

Fig. 3. Surface lipid contents (SLC) and total lipid contents (TLC) of rice from the indicated cultivars harvested in 2001. Each data point is the average of two extractions.

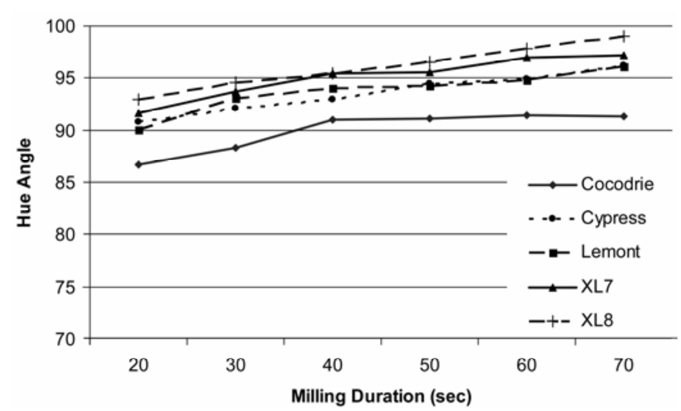

Fig. 4. Hue angles for head rice of three cultivars and two hybrids harvested in 2001. Each data point represents the average of two subsample color measurements.

corresponding to less bran remaining on the kernels. Figure 4 also shows that the 2001 Cocodrie head rice samples had statistically lower hue angle values than the other 2001 samples ($P < 0.05$) for all milling durations. XL8 head rice had greater hue angle values than the other 2001 cultivars/hybrids except for at the 40-sec milling duration.

SUMMARY

This study indicates that some cultivars and hybrids mill more easily than others, that is, the milling duration required to attain a certain SLC, and thereby a specified DOM level, is shorter when milling some cultivars and hybrids than others. For example, if a typical SLC of 0.3% is chosen as a desired DOM level, Fig. 1 indicates that XL8 would require a milling duration of ≈25 sec, while Cocodrie would require 65 sec. This would have implications in HRY measurement in that if all samples were milled for a set duration (typically 30–40 sec), some samples would be over milled relative to others, causing an inequitable HRY comparison.

This research also showed that the milling duration at which the SLC and TLC curves converged varied depending on the cultivar or hybrid being analyzed. This duration varied from 20 to 50 sec, although most cultivar and hybrid sample curves converged near the 20-sec duration. The point at which the head rice SLC and TLC levels become equal may be a good indication of the duration required to achieve an adequately milled sample. The importance of SLC and TLC comparison is the topic of continuing research.

LITERATURE CITED

Bhashyam, M. K., and Srinivas, T. 1984. Varietal difference in the topography of rice grain and its influence on milling quality. J. Food Sci. 49:393-401.

Champagne, E. T., Wood, D. F., Juliano, B. O. and Bechtel, D. B. 2004. The rice grain and its gross composition. Pages 77-107 in: Rice Chemistry and Technology. E. T. Champagne, ed. AACC International: St. Paul, MN.

Matsler, A. L., and Siebenmorgen, T. J. 2005. Evaluation of Soxtec system operating conditions for surface lipid extraction from rice. Cereal Chem. 82:282-286.

McLellan, M. R., Lind, L. R., and Kime, R. W. 1995. Hue angle determinations and statistical analysis for multiquadrant Hunter *L,a,b* data. J. Food Qual. 18:235-240.

Perdon, A. A., Siebenmorgen, T. J., Mauromoustakos, A., Griffin, V. K., and Johnson, E. R. 2001. Degree of milling effects on rice pasting properties. Cereal Chem. 78:205-209.

Pomeranz, Y., and Webb, B. D. 1985. Rice hardness and functional properties. Cereal Foods World 30:784-788.

Reid, J. D., Siebenmorgen, T. J., and Mauromoustakos, A. 1998. Factors affecting the slope of head rice yield vs. degree of milling. Cereal Chem. 75:738-741.

Sun, H., and Siebenmorgen, T. J. 1993. Milling characteristics of various rough rice kernel thickness fractions. Cereal Chem. 70:727-733.

USDA. 1997. Inspection handbook for the sampling, inspection, grading, and certification of rice. HB 918-11, section 5.41. USDA Agricultural Marketing Service: Washington, DC.

Webb, B. D. 1980. Rice quality and grades. Pages 543-565 in: Rice: Production and Utilization. B. S. Luh, ed. AVI Publishing: Westport, CT.

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