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# Milling Characteristics of High and Low Quality Rice

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# Milling Characteristics of High and Low Quality Rice

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## ABSTRACT

Harvest moisture contents (HMCs) have been proven to play a role in rice quality, especially affecting head rice yield (HRY) due to fissuring or immature kernels. Differences in milling characteristics between samples having high and low level milling quality were studied in this experiment. Two hybrid, long-grain cultivars (CL XL729 and CL XL745) and two pureline, long-grain cultivars (CL 181 and Wells) were harvested at near optimal and low HMCs, representing high and low milling quality, respectively. Lots were dried to approximately 12.5 ± 0.5% and milled in triplicate for durations of 10, 20, 30, and 40 s. Results showed that low quality rice achieved a greater degree of milling (DOM) than high quality rice when milled for the same duration. Low quality rice also reached a given surface lipid content (SLC) at a faster rate as supported by greater SLC reduction rates. As DOM increased, milled rice yield (MRY) of low quality rice decreased at a statistically greater rate than that of high quality rice. The rate at which HRY decreased, however, was not greatly impacted by milling quality as a function of HMC.

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## MEET THE STUDENT-AUTHOR

*Alexandria Huck*

I grew up in Tontitown, Arkansas and graduated from Har-Ber High School in 2009. I then found myself studying at the University of Arkansas, majoring in Food Science with a minor in Spanish. After taking a year of classes, I became very interested in nutrition and decided to also major in Food, Human Nutrition, and Hospitality with a concentration in Dietetics. I have worked in the University of Arkansas Rice Processing Program for the past three years and am very grateful for the opportunity. I am also a member and president of the University of Arkansas Water Ski Club where we travel and compete against other competitive college teams from around the nation. I am also a member of the Food Science club.

After graduating, I plan to complete a dietetic internship, becoming a registered dietician. I then plan on pursuing a job in product development or as a clinical dietician. I would like to thank Terry Siebenmorgen, Sarah Lanning, and the rest of Rice Processing Program team for the great opportunity and continued support.

## INTRODUCTION

Rice is a cereal grain that supplies approximately 23% of the world's human calories (Kahlon and Smith, 2004). Rough rice, comprised of an endosperm, germ, bran layers, and hull, is processed by first removing the outermost layer, the hull, resulting in brown rice. The bran layers and germ are then removed from the endosperm, or the starchy, innermost portion of the rice kernel, during the milling process. Milled rice is comprised of both head rice (HR) [milled rice kernels at least three-quarters of their original length (USDA, 2009)] and broken rice. Milled rice yield (MRY) and head rice yield (HRY) can be calculated as the mass percentage of milled rice or head rice that remains from the original rough rice, respectively. Rice bran, comprised of bran layers and germ, is approximately 20% lipids (Lloyd, et al., 2000); therefore, milling rice results in the removal of lipids. The degree to which bran has been removed can be expressed as the degree of milling (DOM), which is measured as a function of surface lipid content (SLC), or the mass fraction of lipid that remains on the outer surface of milled rice kernels. A reduction in SLC results in an increased DOM; therefore, the more lipids removed, the greater the DOM.

Degree of milling can affect rice milling and end-use quality (Cooper and Siebenmorgen, 2007). While both MRY and HRY are used to assess milling quality, HRY is often a primary measure of milling quality; the greater the HRY, the better the milling quality. While both MRY and HRY determine the economic value of each lot of rice, HRY is especially critical since broken kernels are worth only approximately 60% of head rice (Siebenmorgen et al., 2011). As SLC (the determining factor of DOM) decreases with longer milling durations, HRY also decreases as a result of greater bran and inadvertent endosperm removal (Reid et al., 1998).

Degree of milling can be affected by several factors. Sun and Siebenmorgen (1993) concluded that kernel thickness and milling durations greatly affected DOM and HRY. Degree of milling may also be affected by the pre-drying and drying conditions of rice (Daniels et al., 1998). Siebenmorgen et al. (2006) concluded that DOM and SLC are also dependent on cultivar differences; some cultivars mill at a faster rate than others, indicating that the required milling duration needed to reach a desired DOM varies between cultivars. A recent study by Lanning and Siebenmorgen (2011) found that hybrid cultivars reached a target SLC much faster than pureline cultivars.

Harvest moisture content (HMC) also plays a role in rice quality. The optimum HMC, determined by the peak HRY, was found to be 19%-22% for long-grain cultivars in a study done by Siebenmorgen et al. (2007). It was also determined that rice harvested below the optimum HMC had a reduced HRY due to fissuring, or cracking, of low-moisture content (MC) kernels that had rapidly adsorbed moisture, while rice harvested above the optimum HMC had a reduced HRY due to the greater percentage of immature kernels. However, the difference in milling characteristics between high quality rice harvested at a near optimal HMC and lower quality rice harvested at a low MC has not been directly researched, which is the focus of this experiment. The objective of this study was to measure the milling characteristics of high and low quality rice, as initially estimated by HMC. The milling characteristics measured included the rate at which bran was removed and the overall impact on MRY and HRY.

## MATERIALS AND METHODS

*Sample Procurement and Conditioning*. Two hybrid, long-grain cultivars (CL XL729 and CL XL745) and two pureline, long-grain cultivars (CL 181 and Wells) were harvested near Keiser, Arkansas in 2010. Each cultivar was harvested at two MCs, representing high and low milling quality. High HMCs for CL XL729, CL XL745, CL 181, and Wells were 16.6%[1], 17.9%, 23.0%, and 17.2%, respectively, and the low HMCs were 12.0%, 12.7%, 11.8%, and 11.8%, respectively. Rough rice MC for each sample was measured in duplicate in a convection oven (1370FM, Sheldon Manufacturing, Inc., Cornelius, Oreg.) held at 130 °C for 24 h as described by Jindal and Siebenmorgen (1987). Rough rice from each lot was cleaned (Carter-Day Dockage Tester, Carter-Day Co., Minneapolis, Minn.) and high HMC lots were dried to MCs of approximately 12.5 ± 0.5% in an air chamber held at a constant 21 °C and 62% relative humidity (RH), which is associated with a rough rice equilibrium MC of approximately 12.5% (ASABE Standards, 2007), with a temperature and RH controller (AA5582, Parameter Generation & Control, Inc., Black Mountain, N.C.). Low-HMC lots had no additional drying. All rice was stored at refrigeration temperature (4 °C) until further analysis.

*Sample Milling*. In this study, the objective of milling was to obtain variant degrees of milling for each cultivar-HMC lot. Four 150-g sub-samples of each rough rice lot were milled for 10, 20, 30, or 40 s. This procedure was replicated three times, resulting in 12 rough rice samples per cultivar-HMC lot or 96 samples in total (four cultivars × two HMCs × four milling durations × three replications). Each rough rice sample was taken out of refrigerated storage and equilibrated to room temperature in plastic bags for a minimum of 12 h before milling. Samples were then de-hulled using a laboratory de-huller (THU, Satake, Tokyo, Japan) with a 0.048-cm (0.019-in) clearance between the rollers, resulting in brown rice. To attain a range of DOM, the de-hulled, brown rice samples were then milled for 10, 20, 30, or 40 s in a laboratory mill (McGill No. 2, RAPSCO, Brookshire, Tex.) with a 1.5-kg weight placed 15 cm from the milling chamber centerline on the mill lever arm. The mill was cleaned between each milling run. The resulting milled rice was weighed and head rice was then separated from broken rice using a double-tray sizing machine (Seedburo Equipment Co., Chicago, Ill.). Milled rice yield and HRY were calculated as the mass percentage of milled or head rice, respectively, remaining from the original 150 g of rough rice.

*Surface Lipid Content*. The SLCs of head rice samples were determined using a solvent extractor (Soxtec Avanti 2055, Foss North America, Eden Prairie, Minn.) using AACC method 30-20 (AACC International, 2000), with modifications to the petroleum ether washing duration, as described by Matsler and Siebenmorgen (2005). Surface lipid content was measured for each cultivar-HMC milling replicate and was expressed as the mass percentage of extracted lipid from the original head rice.

*Total Lipid Content*. Samples of brown rice from each cultivar-HMC combination were used to determine total lipid content (TLC). Brown rice was first ground into flour in a cyclone sample mill (3010-30, Udy, Fort Collins, Colo.) fixed with a 100-mesh sieve (0.5 mm). Total lipid content was then measured by the lipid extraction procedure described above. Total lipid content was measured in duplicate for each cultivar-HMC, brown rice lot and was expressed as the mass percentage of extracted lipid to the original brown rice.

*Statistical Analysis*. Plots of SLC vs. milling duration and MRY and HRY vs. SLC were developed using statistical software (JMP release 9.0, SAS Institute, Cary, N.C.). Analysis of variance (ANOVA) was performed using least significant difference (LSD) at a level of 5% probability to determine the significance of the differences observed between MRY and HRY vs. SLC slopes.

## RESULTS AND DISCUSSION

*Milling Characteristics*. When comparing the milling rate of high- and low-milling quality samples (Fig. 1), low-milling quality lots, represented by the low-HMC samples, consistently had lesser SLCs at the shorter milling durations among all cultivars tested. High-milling quality lots of Wells and CL XL729, harvested at greater MCs, did eventually reach a common DOM with the low HMC rice after 30-40 s of milling (Fig. 1). The trends for CL XL745 and CL 181 (Fig. 1) suggest that the SLCs for high HMC and low HMC rice may equalize at milling durations greater than 40 s; however, they did not come to an equal DOM within tested milling durations. It is noted that the milling moisture content (MMC), or the MC at which

[1] All MCs are expressed on a percentage wet basis (w.b.) unless otherwise noted.

the samples were milled, likely had no effect on the rate at which SLC decreased, as all MMCs were at or near 12.5% (data not shown). This point is significant due to the findings of Lanning and Siebenmorgen (2011), who showed that at MMCs greater than 12.5%, the rate at which SLC decreases is significantly greater than that of MMCs less than 12.5%.

As suggested above, Fig. 1 shows that low HMC rice reached a given SLC sooner than did high HMC rice. Previous studies have indicated that the greater rate of reduction in SLC may be due to differences in TLC of brown rice (Bergman et al., 2004). To account for any initial differences in TLC (Table 1), the rate of SLC reduction was calculated for each milling duration and is shown in Fig. 2. Across all cultivars, low HMC lots had significantly greater percent reductions ($\alpha = 0.05$) from 0 to 10 s (Fig. 2). At a 20 s milling duration, SLCs of high and low HMC lots among Wells, CL XL745, and CL 181 (Fig. 2) were statistically different. However, the percent reduction of SLC among the high and low HMC lots of CL XL729 (Fig. 2) were not statistically different. At a milling duration of 30 s, differences among the percent reduction of high and low HMCs for CL XL745 and CL 181 were still found to be statistically significant, with the low HMC rice exhibiting a greater percent reduction. Differences among Wells and CL XL729 were not statistically different as the percent reductions began to equalize. Similar trends were observed at a milling duration of 40 s. These findings support those of Lanning and Siebenmorgen (2011), which suggest that attaining a desired DOM is not solely a function of initial lipid content, but also the rate at which lipids are removed during milling. However, unique to this study is the trend that the rate of bran removal appears to be related to the overall milling quality of the sample. The low-HMC lots, representing low-milling quality rice (Fig. 1), may have reached given SLC levels faster due to the presence of more broken kernels that apparently aided in bran removal.

*Milling Quality*. Figure 3 displays the change in MRY as a function of SLC. Low HMC lots exhibited a MRY range of approximately 61-70% within the narrow range of about 0.1-0.5% SLC. This narrow range can be attributed to the large reduction in SLC during the first 10 s of milling with the low-milling quality lots. High HMC lots exhibited a slightly greater MRY (about 65-75%) over a greater range in SLC (about 0.1-1.0%) (Fig. 3). Overall, low HMC lots exhibited lesser MRYs than did high HMC lots. For example, at an SLC of 0.3%, low HMC Wells had a MRY of approximately 64% while high HMC Wells had a MRY of approximately 69%; low HMC CL XL745 had a MRY of approximately 65% whereas high HMC CL XL745 had a MRY of 68%. Figure 3 shows that as DOM increased, MRYs of low HMC lots decreased at a dramatically greater rate than that of high HMC lots for all cultivars tested. Slopes indicating the rates at which MRY decreased in relation to SLC are shown in Table 1.

Figure 4 displays the change in HRY as a function of SLC. Low HMC lots exhibited a HRY range of approximately 8-30% over a SLC range of about 0.1-0.5%. High HMC lots exhibited a greater range of HRYs; approximately 46-63% over a SLC range of about 0.05-1.1%. This range was expected due to harvesting each cultivar at the high and low HMCs. For specific examples, at a SLC of 0.3%, low HMC Wells had a HRY of approximately 9% while high HMC Wells had a HRY of 49%. Low HMC CL XL745 had a HRY of approximately 22% and high HMC CL XL745 had a HRY of approximately 53% at a SLC of 0.3%.

While low HMC lots exhibited greater rates of reduction in MRY vs. HR SLC, the rate at which HRY decreased was not dramatically impacted by HMC, as shown in Fig. 4. Interestingly, though the slopes were generally not statistically significant (Table 1), trends show that the rate at which HRYs of the low HMC lots decreased was more gradual than that of the high HMC, opposite the trends observed for MRY vs. HR SLC. Though HRYs for high and low HMC lots decreased with SLC at about the same rate (Table 1), it is made fairly obvious by Fig. 4 that at any given SLC, the low HMC rice had extremely low HRYs. For example, the low HMC lot for Wells (Fig. 4) never exceeded a HRY of 10.3%, whereas the high HMC lot had HRYs ranging from 46.5-57.9%. Low HMCs for the other cultivars (Fig. 4) produced HRYs ranging from approximately 20-30%, whereas the high HMC HRYs for these cultivars ranged from approximately 52-63%. Figure 5 further illustrates the poor milling quality of the low HMC lots as compared to that of the high HMC lots, at a comparable DOM of 0.4% SLC.

While the dramatic differences in high and low milling quality lots were due in large part to the differences in the MC at which the lots were harvested, which indicates the amount of moisture-adsorption fissuring that was incurred (Siebenmorgen et al., 2007), overall low HRY values were invariably due to chalkiness resulting from the very high nighttime air temperatures experienced in 2010, as reported by Lanning et al., 2011. Ambardekar et al. (2011) showed the relationship of nighttime air temperature increases with increased chalk and reduced milling quality.

The authors hypothesize that since fissured and/or chalky kernels break easily and quickly during milling, the presence of broken kernels in the mill may actually facilitate bran removal from other kernels as part of the abrasive action occurring during milling. This would lead to more rapidly increasing the DOM achieved, but simultaneously lead to reduced MRYs and HRYs.

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**Table 1. Total lipid contents (TLCs) and slopes relating milled rice yield (MRY) and head rice yield (HRY) to head rice (HR) surface lipid content (SLC) for high and low milling quality lots, produced by harvesting at high and low harvest moisture contents (HMC), respectively, of tested rice cultivars.**

| Cultivar | HMC | TLC | MRY vs. HR SLC Slope | HRY vs. HR SLC Slope |
|---|---|---|---|---|
| Wells | High | 2.5 | 6.3b | 13.0a |
| | Low | 2.6 | 29.1a | 5.0b |
| CL 181 | High | 3.0 | 8.2b | 9.2a |
| | Low | 3.1 | 17.4a | 10.4a |
| CL XL745 | High | 2.7 | 7.0b | 11.9a |
| | Low | 2.5 | 19.6a | 5.4a |
| CL XL729 | High | 2.8 | 10.2b | 10.4a |
| | Low | 2.6 | 27.1a | 4.7a |

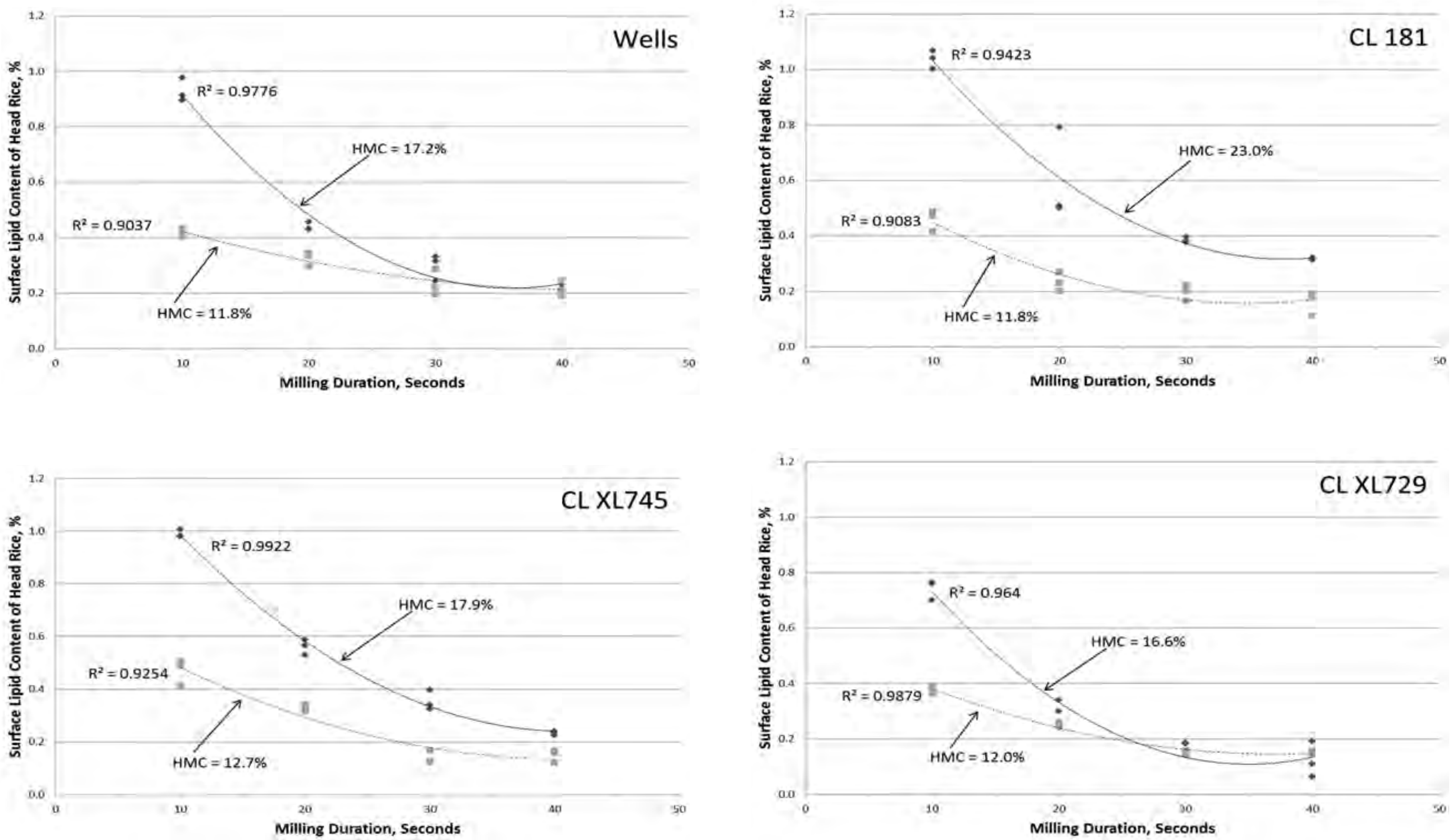


**Fig. 1.** Head rice surface lipid contents corresponding to milling durations of 10, 20, 30, and 40 s for the indicated cultivars, each harvested at near-optimal and low-moisture contents (HMC, % w.b.) to produce high- and low-milling quality lots, respectively.

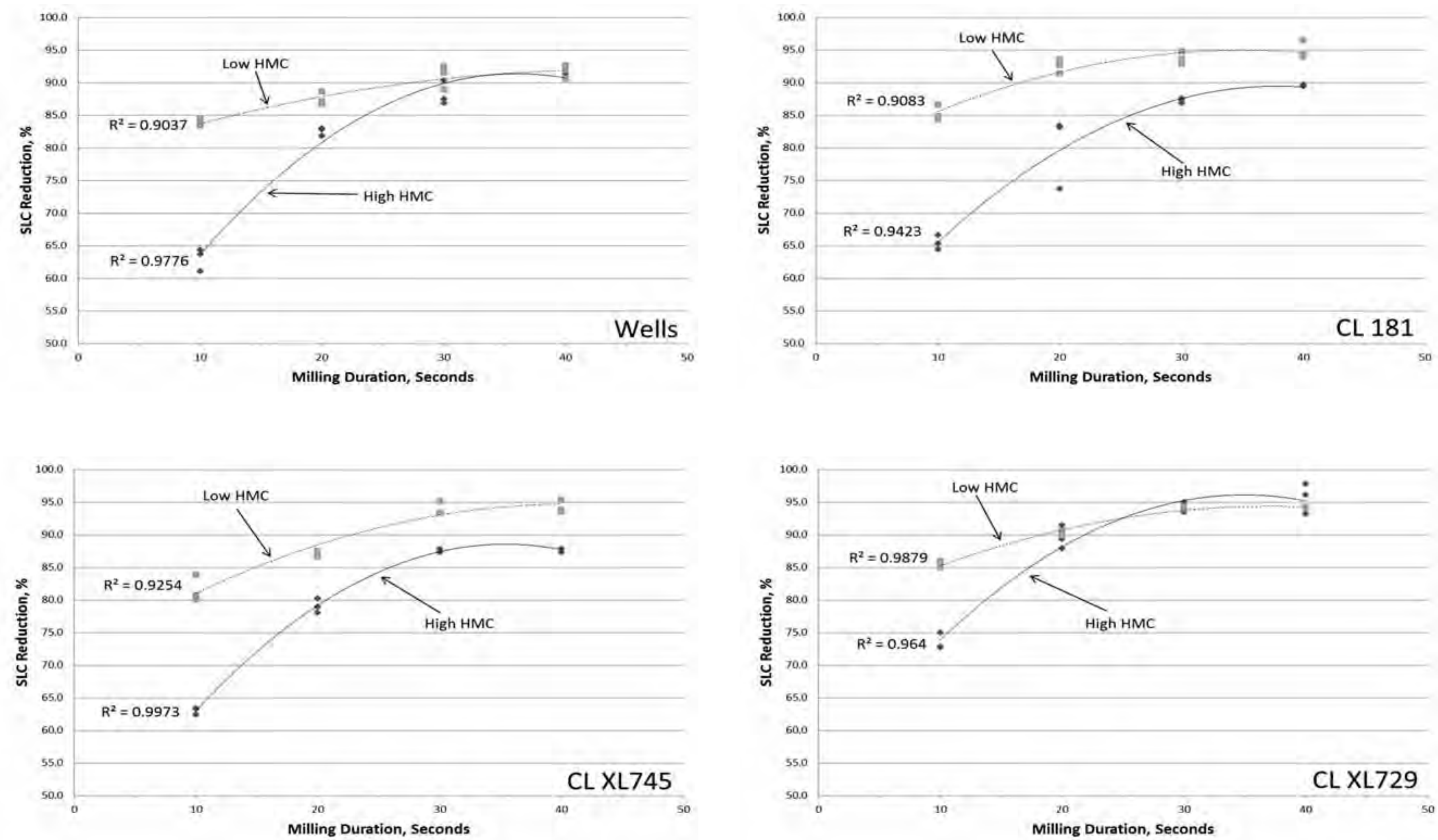


**Fig. 2.** Percent reduction in head rice surface lipid content (SLC) corresponding to milling durations of 10, 20, 30, and 40 s for the indicated cultivars, each harvested at near-optimal and low-moisture contents (HMC) to produce high- and low-milling quality lots, respectively.

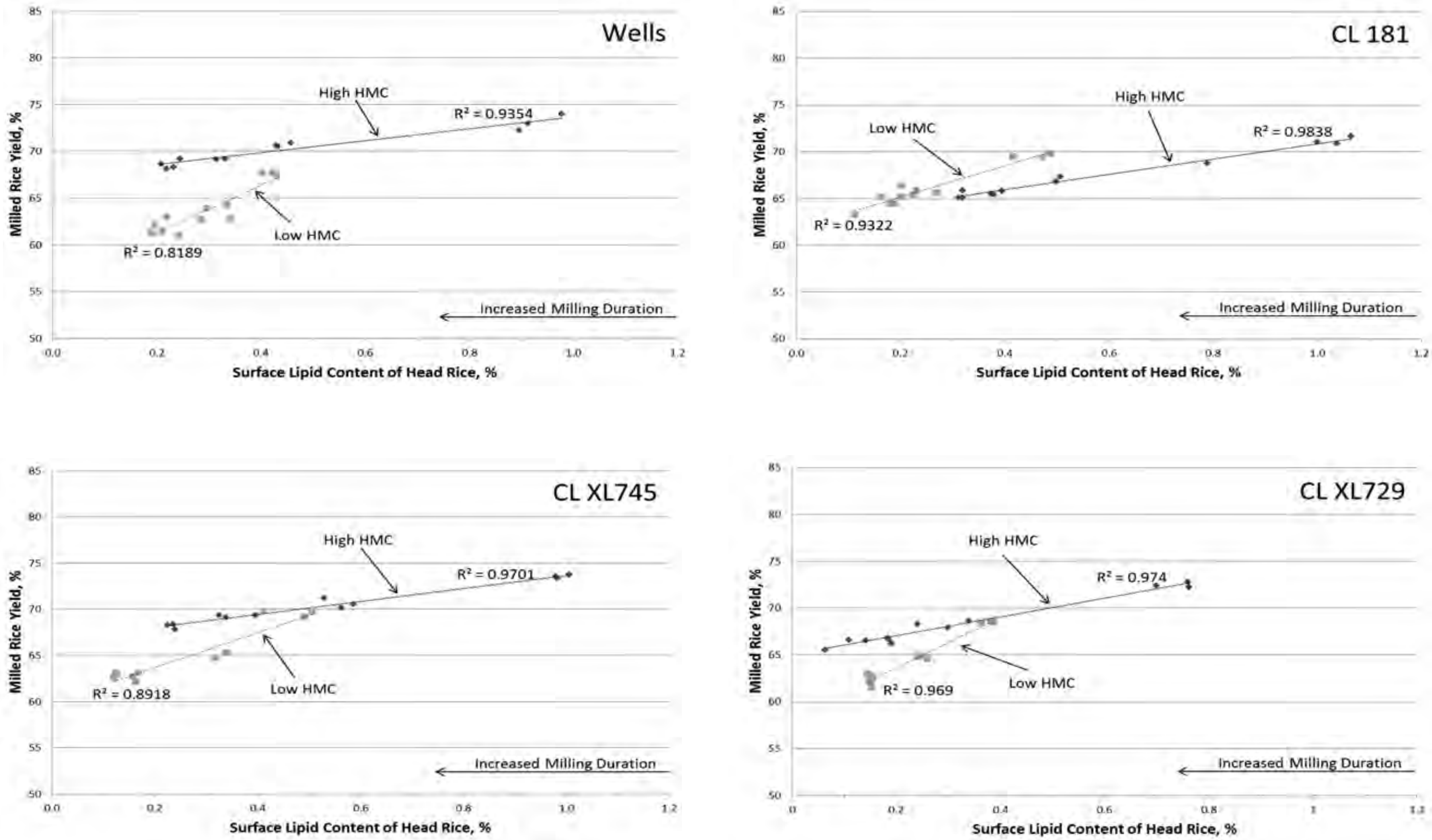


**Fig. 3.** Milled rice yields at various head rice surface lipid contents for the indicated cultivars, each harvested at near-optimal and low-moisture contents (HMC) to produce high- and low-milling quality lots, respectively.

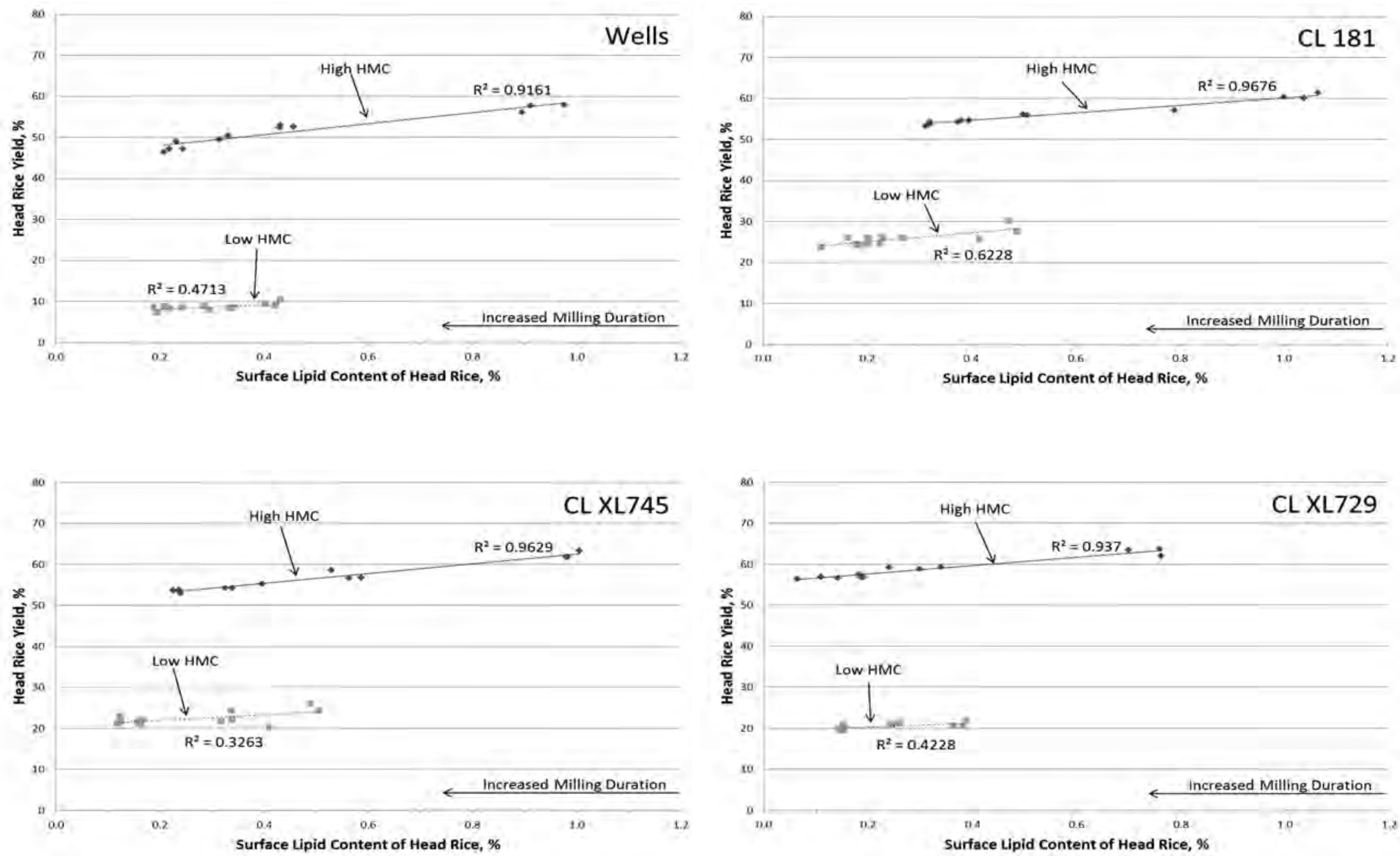


**Fig. 4.** Head rice yields at various head rice surface lipid contents for the indicated cultivars, each harvested at near-optimal and low-moisture contents (HMC) to produce high- and low-milling quality lots, respectively.

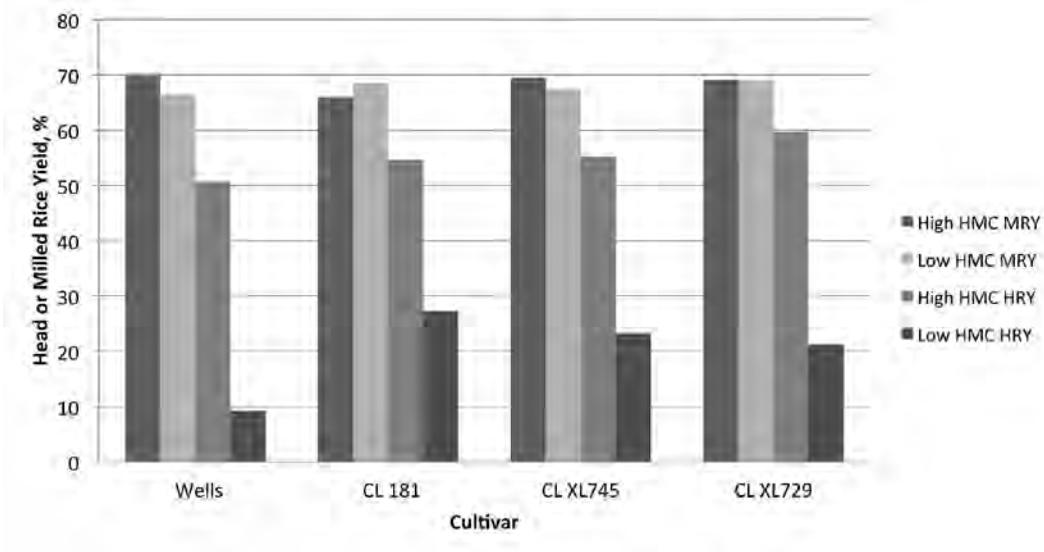


**Fig. 5.** Milled rice yield (MRY) and head rice yield (HRY) as measured at a surface lipid content of 0.4% for the indicated cultivars, each harvested at near-optimal and low-moisture contents (HMC) to produce high- and low-milling quality lots, respectively.