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A Comparative Study Between the McGill #2 Laboratory Mill and Commercial Milling Systems

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ABSTRACT

The degree of similarity between rice milled in a McGill #2 laboratory mill and commercial milling processes was evaluated using eight physical, physicochemical, and end-use properties. There was no statistical difference between the two milling systems with respect to color parameters L^* and a^*, final viscosity, texture, and end-use cooking properties ($\alpha = 0.05$). Overall, the kernel dimensions of length, width, and thickness were less in the McGill #2 laboratory-milled rice than the same rice milled commercially. The incidence of bran streaks and peak viscosity values were each higher when the rice sample was milled commercially in 27, and 28, respectively, of the 29 samples by means comparison. The decrease in kernel dimensions and incidence of bran streaks were attributed to the more aggressive nature of the single-pass, batch milling system of the McGill #2 laboratory mill as compared with multipass, continuous milling systems that are used commercially. Finally, as surface lipid content (SLC) decreased, L^* increased and a^*, b^*, and the incidence of bran streaks decreased for both milling systems.

The goal of rice milling is to remove the germ and bran layers from the exterior of the rice kernel caryopsis while maximizing head rice yield (HRY), the main quality indicator of rice. Head rice yield is the mass percentage of rough rice that remains as three-fourths or more of a whole kernel after milling (USDA 2005). The extent to which the bran layers are removed from the caryopsis influences the quality and processing characteristics of rice. Large-scale commercial mills process several tons of rice per hour and remove the bran layers by friction, or abrasion forces, sometimes with the aid of a water mist. Rice processing research, however, is usually conducted using small, representative samples that are typically milled using laboratory mills. One such mill, the McGill #2 laboratory mill, is commonly used by research facilities and the laboratories of commercial milling operations, and primarily removes bran layers by frictional forces. There is a lack of evidence that laboratory milling produces rice of the same physicochemical profile as that of commercial milling processes, thereby posing questions as to the representativeness of laboratory milling.

The degree to which bran layers are removed from the caryopsis can be measured and categorized as the degree of milling (DOM). The Federal Grain Inspection Service (FGIS) separates DOM into three categories: reasonably well-milled, well-milled, and hard-milled (USDA 2005). Qualification is made predominantly on the basis of color; rice will lighten as DOM increases (Chen and Siebenmorgen 1997; Mohapatra and Bal 2005; and Saleh and Meullenet 2007). Because the majority of extractable rice kernel lipids are in the bran layers and germ (Matsler and Siebenmorgen 2005), the surface lipid content (SLC) is another way to measure milled rice DOM. The analysis of milled rice using the SLC method is more quantifiable compared with the FGIS DOM qualification system and has been used for comparative studies in rice processing (Perdon et al 2001; Siebenmorgen et al 2006; Saleh and Meullenet 2007).

The SLC, as a measurement of DOM, affects the physical, physicochemical, and end-use properties of rice. First, HRY decreases as milling duration increases, and SLC correspondingly decreases (Bennett et al 1993; Reid et al 1998; Saleh and Meullenet 2007). Furthermore, HRY decreased, on average, 9.4 percentage points for every one percentage point decrease in SLC when milling was accomplished with a McGill #2 laboratory mill (Cooper and Siebenmorgen 2007). As above, the color of rice will normally whiten as DOM increases and SLC decreases. Mea surements of color parameters using the International Commission on Illumination (CIE) $L^* a^* b^*$ color system show that as the outer bran layers are removed, yellow and red pigments decrease to a point of equilibrium (Lamberts et al 2005). The prevalence of bran streaks, the linear mark on the dorsal edge of milled rice kernels, decreases as the SLC decreases (Bhattacharya and Sowbhagya 1976). Viscosity increases as SLC decreases (Dautant et al 2005). Perdon et al (2001) reported that peak viscosities increased with greater DOM, whereas final viscosities did not consistently increase or decrease. Lastly, Saleh and Meullenet (2007) concluded that as SLC decreases, rice firmness decreases, and water uptake and rice stickiness increase.

The McGill #3 laboratory mill, a larger version of the McGill #2, has been designated as "an approved device" to determine milling yields by the FGIS (USDA 2005). The approved procedure involving the McGill #3 laboratory mill entails starting with 1 kg of rough rice, a greater amount than is typically available for many research studies. The McGill #2 mill is a friction-based, batch mill that typically processes 150 g of rough rice per batch (Andrews et al 1992) and has been used extensively for research with smaller samples. Andrews et al (1992) and Bennett et al (1993) established milling quality trends, in terms of HRY and SLC, respectively, when using a McGill #2 laboratory mill under various operational conditions. Moisture content (MC) of the rough rice was the most significant attribute affecting SLC and HRY, while milling duration, mill chamber pressure, and sample size affected SLC and HRY to a lesser degree. Surface lipid content values decreased when MC, milling duration, or chamber pressure increased.

Milling a small amount of rice in laboratory mills is assumed to represent commercial milling processes. Though, commercial mills are continuous, multibreak, sequential systems that can mill several tons of rice per hour. Chen et al (1998) concluded that a multibreak abrasion and friction commercial milling system produced fewer broken kernels than a commercial single-break friction system. That same study also stated that for commercially milled (CM) rice with a low DOM level, corresponding to a high SLC, the bran content was greater on thinner kernel fractions than thicker fractions.

Beneficial results from research using laboratory mills have been slow to be adopted, in part due to the lack of evidence that laboratory mills adequately represent commercial milling processes. The objective of this study was to quantify the degree of similarity between CM and McGill #2 laboratory-milled rice

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across four physical variables: head rice percentage, color, particle size distribution, and bran streaks; two physicochemical variables: viscosity and texture; and two end-use properties: water uptake and volumetric expansion.

METHODS AND MATERIALS

Sample Procurement

Twenty-nine samples, comprising two medium-grain samples and 27 long-grain samples, with each sample comprising rough and milled rice subsamples, were gathered from four rice processors, totaling seven commercial milling sites with locations in Arkansas (3), California (1), Louisiana (1), Mississippi (1), and Missouri (1). Twenty-eight of the 29 CM subsamples were processed using various sequences of the following commercial mill models: VTA, VBF, and KB-40 (Satake, Hiroshima, Japan). Collection of the milled rice subsamples was timed to match the milling completion of the respectively collected rough rice subsamples (Fig. 1). Therefore, the rough rice subsample was representative of the same rice that yielded the milled rice sub-sample. This timing was used to control for other rice processing variations such as rice cultivar and MC that could have caused milling performance variation and thereby inhibited a reliable commercial mill to laboratory mill comparison.

The 29 samples chosen were selected to have a wide range of milled rice subsample DOM levels. Samples were collected over a five-month period from June 20th, 2006 to October 4th, 2006, during which rice from the 2005 growing season was being milled. Once collected, the samples were stored at 4°C for 5–12 months before testing.

Experimental Design

Because the SLC, as a quantifiable measurement of DOM, affects the physicochemical and end-use properties compared in this study, it was necessary to mill samples in the McGill #2 laboratory mill to the same SLC values as those of the CM rice samples. To match the SLC of the McGill #2 laboratory-milled samples to the CM rice samples, milling curves were produced for each of the 29 rough rice subsamples using a McGill #2 laboratory mill. Milling curves were built by first dehulling the rough rice subsamples using a laboratory huller (THU-35, Satake). The resulting brown rice samples were then milled in a McGill #2 mill for durations of 20, 40, and 60 sec. The SLC of the head rice was then determined, as described in the SLC section below, for each milling duration. These three SLC values were plotted versus the three durations to establish a milling curve for each of the 29 rough rice subsamples milled using the McGill #2 mill (Fig. 2). The SLC values of the CM rice subsamples were measured as described below and subsequently used to calculate the milling duration required to achieve the same SLC using the McGill #2 mill by applying the appropriate polynomial milling curve equation (Fig. 2). After milling the 29 rough rice subsamples in the McGill #2 mill for this calculated duration, the SLC was determined using the lipid extraction method.

The 29 CM rice samples and the corresponding 29 McGill #2 laboratory-milled samples were each tested in duplicate, totaling four samples for each of the dependant variables. Statistical analyses were performed with JMP software (v.7, SAS Institute, Cary, NC) using $\alpha = 0.05$ for all eight variable comparisons.

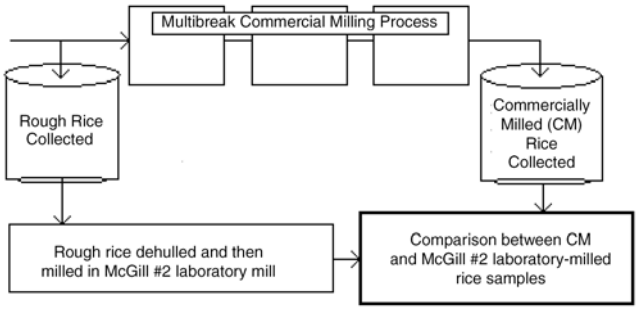

Fig. 1. Sample procurement schematic showing collection and comparison of commercially milled (CM) and McGill #2 laboratory-milled rice subsamples.

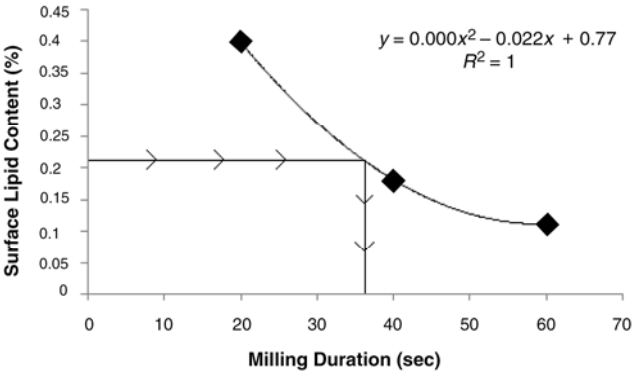

Fig. 2. Sample milling curve used to calculate milling duration to achieve the same surface lipid content (SLC) for McGill #2 laboratory-milled samples as those milled commercially (SLC 0.21% for this example).

Moisture Content, Rice Milling, and Head Rice Yield Determination

The rough rice had been dried in commercial dryers before the rough and milled rice subsample collection to 11.0–14.1% (wb).

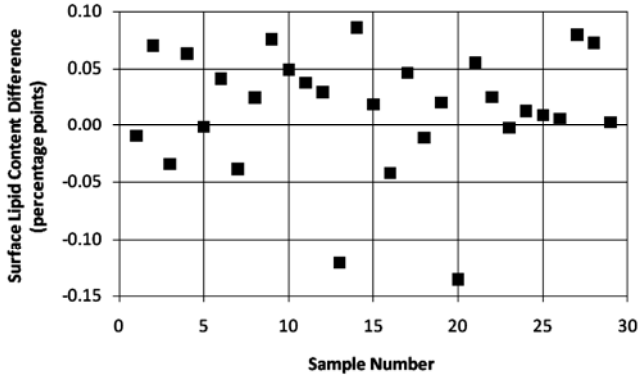

Fig. 3. Difference of surface lipid content (SLC) between 29 samples calculated as mean SLC value for commercially milled rice minus mean SLC value for McGill #2 laboratory-milled rice. Each data point is average of two measurements.

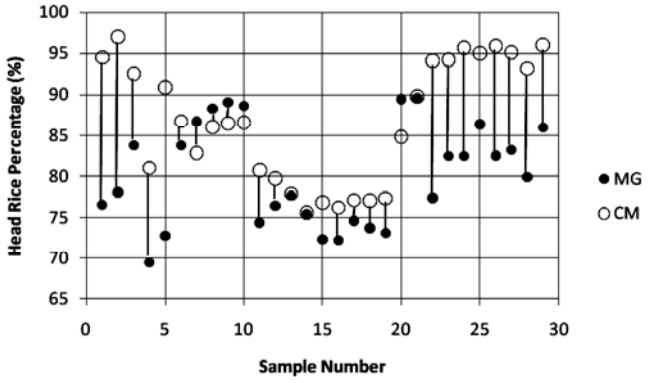

Fig. 4. Mean values of head rice percentage for commercially milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point is average of two measurements.

Moisture content of each of the 29 rough rice lots was determined by drying 15 g of rough rice in duplicate for 24 hr at 130°C in a convection oven and calculated on a wet-weight basis. Rough rice, 150 g as determined by Andrews et al (1992), was weighed in duplicate and then dehulled in a laboratory huller (THU-35, Satake). The resulting brown rice was milled with a McGill #2 laboratory mill (RAPSCO, Brookshire, TX). The milling duration for each of the 29 samples was that determined from each respective milling curve to yield a SLC equal to the CM rice as described above. The milled rice mass was then measured and the samples separated into head rice and broken rice using a shaker table (model 61-117-01, Grainman Machinery). Approximately 100 g of each CM rice sample was separated into head rice and broken rice in the same manner. The head rice masses of the CM and McGill #2 laboratory-milled samples were expressed as a percentage of milled rice mass not the rough rice mass because the exact mass of the corresponding rough rice from the CM subsample was unknown. These head rice mass percentages were subsequently used for comparison between the CM and McGill #2 laboratory-milled samples.

Surface Lipid Content

The milled rice SLC values were determined using a Soxtec lipid extractor (Avanti 2055, Foss North America, Eden Prairie, MN) for each CM and McGill #2 laboratory-milled sample using the method developed by Matsler and Siebenmorgen (2005) from Approved Method 30-20 (AACC International 2000). Head rice (5 g) for each duplicate was dried in a cellulose extraction thimble (Foss North America) for 1 hr at 100°C. The thimbles with the rice samples inside were placed into the lipid extractor. Preweighed aluminum extraction cups were placed under the thimbles in the lipid extractor. The thimbles were boiled in 70 mL of petroleum ether (boiling point 35–60°C) for 20 min and then rinsed for 30 min in petroleum ether condensate. After most of the solvent had evaporated from the extraction cups ≈3min later, the cups containing the extracted lipids were placed in a convection oven for 30 min at 100°C to evaporate any remaining petroleum ether and moisture. The cups were cooled in a desiccator for 30 min and the mass of the extraction cups and lipids was then measured. The SLC was expressed as a percentage of the original 5-g head rice sample using the equation

$$SLC = [(Cup_{final} - Cup_{initial})/R_{initial}] \times 100 \quad (1)$$

where Cup_{final} is the mass of the extraction cup and extracted lipids, $Cup_{initial}$ is the mass of the cup before the extraction process, and $R_{initial}$ is the mass of the head rice sample (≈5 g).

Color

Color was quantified using the CIE L^* a^* b^* system and a color meter (ColorFlex, Hunter Associates Laboratory, Reston, VA). The instrument was calibrated before testing once a day using manufacturer-supplied white and black calibration tiles. One 50-g sample from each duplicate of the CM and McGill #2 laboratory-milled samples was poured into the instrument sample dish. A color reading was taken and then the sample was rotated ≈120° to obtain two color readings for every 50 g. Each duplicate was homogenized and poured five times for a total of 10 L^* a^* b^* measurements. The 10 values were averaged for each duplicate.

Particle Size Distribution

The length, width, and thickness of 200 head rice kernels from each duplicate of the CM and McGill #2 laboratory-milled samples were taken using a dual CCD camera optical image analyzer and feeder (rice image analyzer [RIA 1A], Satake). Rice kernels were individually fed onto a viewing platform where one camera acquired an image for length and width, and the second camera

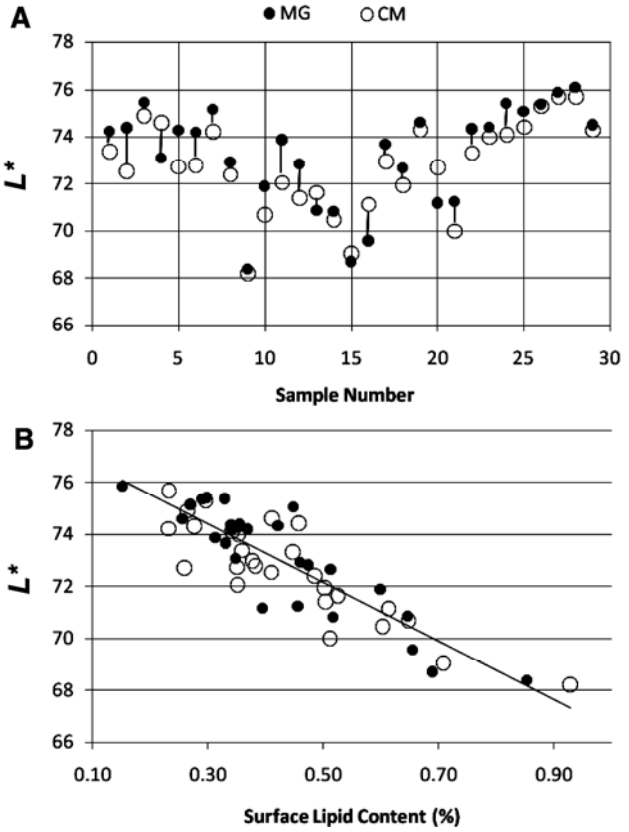

Fig. 5. Values for L^* by sample number (**A**) and surface lipid content (**B**) for commercially milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point is average of two measurements.

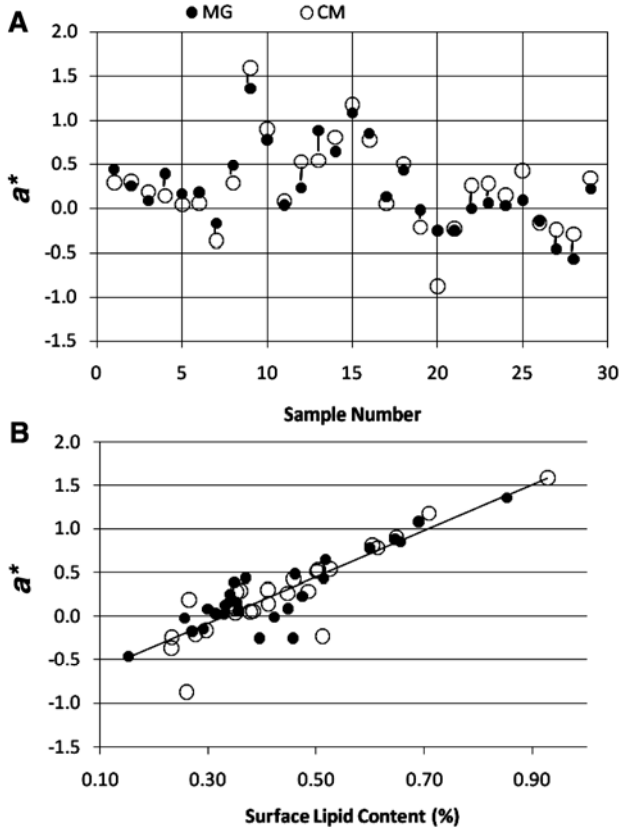

Fig. 6. Values for a^* by sample number (**A**) and surface lipid content (**B**) for commercially milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point is average of two measurements.

acquired an image for thickness. The dimensions were quantified using the system software and saved as a text file.

Bran Streaks

The number of bran streaks was quantified using the method of Bhattacharya and Sowbhagya (1976) by staining 100 head rice kernels from each duplicate of CM and McGill #2 laboratory-milled samples. A single layer of kernels was immersed in 10 mL of a 3:1 mixture of ethyl alcohol to 2% potassium hydroxide for 15 min inside a plastic 60 × 15 mm petri dish. After immersion, the stained kernels were drained and air-dried for 5 min. A kernel was counted with a bran streak when ≥50% of the bran was present on the dorsal rim of the kernel.

Viscosity

Peak and final viscosities were taken with a viscometer (RVA-4 Rapid Visco Analyzer, Foss North America, Eden Prairie, MN) following Approved Method 61-02 (AACC International 2000) as described in Perdon et al (2001). Head rice (15 g) from each duplicate of the CM and McGill #2 laboratory-milled samples were ground into flour and the MC was measured. To eliminate viscosity variability resulting from different rice flour MC values, a flour-in-water slurry was made using ratios provided in Approved Method 61-02 to equalize the MC of the different samples. The viscosity was measured using a temperature profile with a range of 50–95°C provided by the system software (Thermocline for Windows, v.2.0, Foss North America). Continuous data acquisition yielded a viscosity curve from which the peak and final viscosities were obtained.

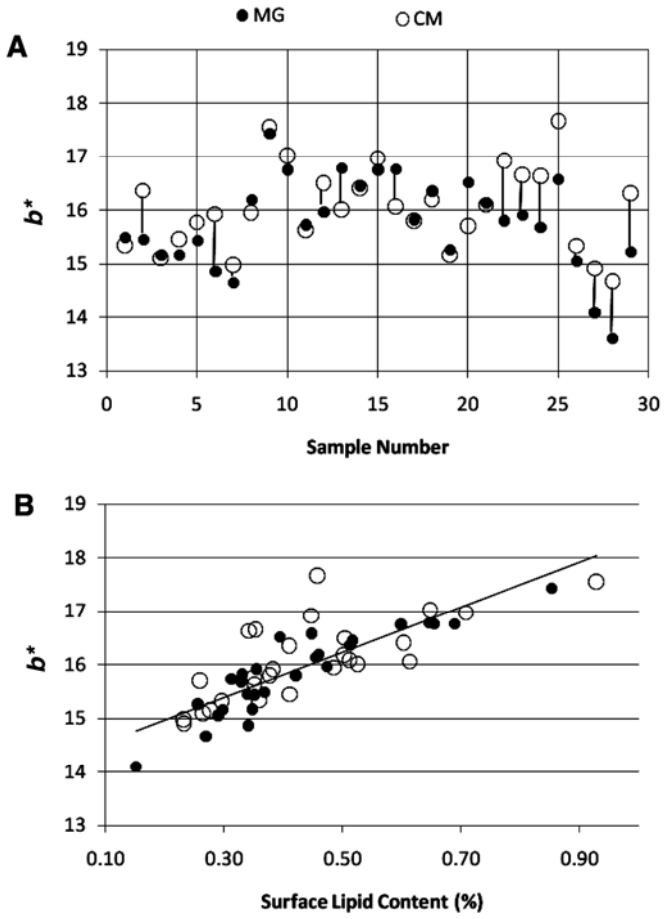

Fig. 7. Values for *b** by sample number (**A**) and surface lipid content (**B**) for commercially milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point is average of two measurements.

Texture

The methods for measuring the textural analysis traits of firmness and stickiness were those used by Saleh and Meullenet (2007). A 2:1 distilled water to head rice mix (20 mL of distilled water to 10 g of head rice) was cooked for 20 min and tempered for 5 min. The mix was cooked in a glass, spherical-bottom flask with a thermocouple-fitted glass cover using a heating mantle (TM 102, Glas-Col, Terre Haute, IN) and temperature controller (89000-10, Eutech Instruments, Singapore). Five repetitions of 10 cooked kernels, 50 total kernels, from each duplicate were subjected to a single compression analysis with a texture analyzer (TA-XT2i Plus, Texture Technologies, Scarsdale, NY). Each set of 10 kernels was placed on an aluminum plate and compressed

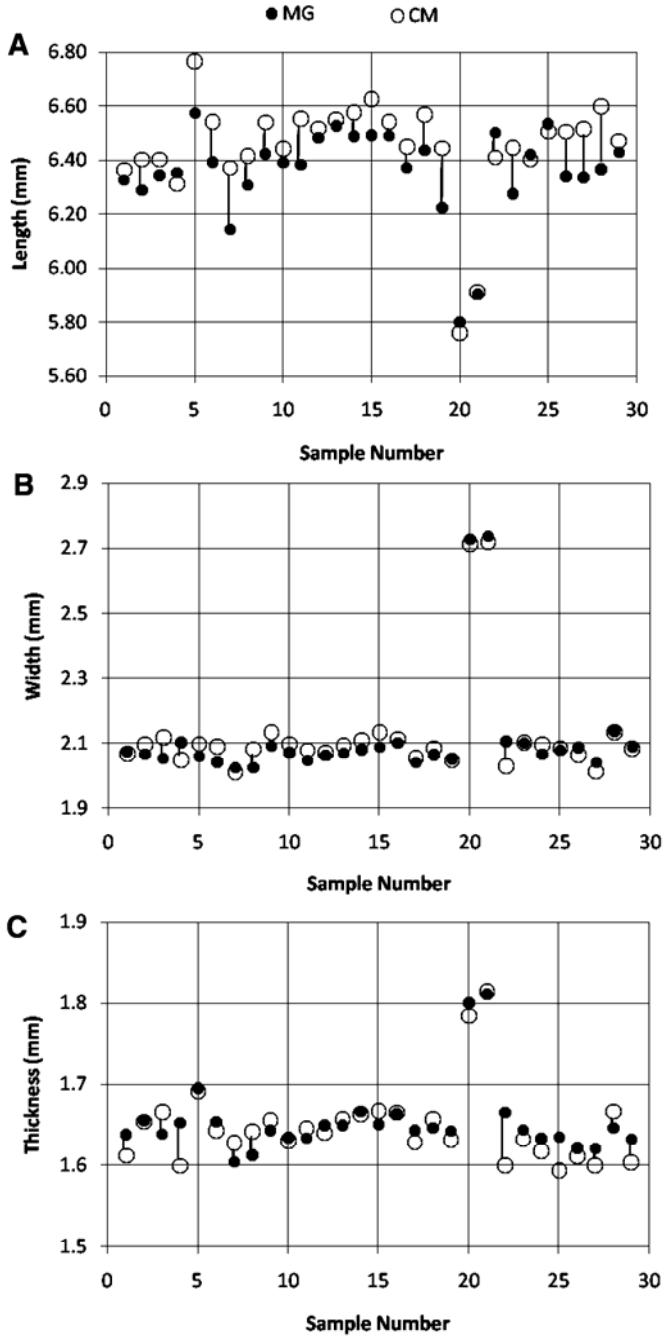

Fig. 8. Particle size distributions of length (**A**), width (**B**), and thickness (**C**) by sample number for commercially milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point is average of two measurements.

with a matching aluminum plate that was top-loaded by a 50-kg load cell at a rate of 5 mm/sec until the distance between the two aluminum plates was 0.3 mm. After holding a distance of 0.3 mm for 5 sec, the load cell ascended at a rate of 0.5 mm/sec. Firmness was calculated by the software (Stable Microsystems, v.1.0.0.92, Surrey, England) as the maximum force required to compress the kernels. Stickiness was quantified as the adhesion energy required to ascend the aluminum plate and load cell from the cooked rice; adhesion energy was measured as the total area under the force – duration curve (N·sec).

Water Uptake and Volumetric Change

Head rice (5 g) from each duplicate were cooked in 100 g of boiling water for 20 min in the cooking apparatus described for textural analysis. A separate 5-g sample was measured for initial volume by volumetric displacement using 10 mL of hexane in a 100-mL graduated cylinder. After cooking, the rice was drained of free water, weighed, and the volume measured by volumetric displacement in 20 mL of hexane in the same 100-mL graduated cylinder. Volumetric change and water uptake were calculated on a wet-weight basis with the equations

$$\text{Volumetric change} = [(V_{final} - V_{initial})/(V_{initial})] \quad (2)$$

$$\text{Water uptake} = [(M_{final} - M_{initial})/(M_{initial})] \quad (3)$$

where V_{final} and $V_{initial}$ are the volumes of the cooked rice and uncooked rice, respectively. M_{final} and $M_{initial}$ are the masses of the cooked rice and uncooked rice, respectively.

RESULTS AND DISCUSSION

Surface lipid content measured as the mass percentage of lipid remaining on rice kernels after milling had a range of 0.23–0.93% (average 0.43%) for the CM rice and 0.15–0.85% (average 0.42%) for the McGill #2 laboratory-milled rice samples. The difference in mean SLC between CM and McGill #2 laboratory-milled samples had a range of –0.140–0.086 percentage points (average 0.015 percentage points) (Fig. 3).

As explained above, head rice percentage, calculated as a percentage of milled rice mass, was used as an indicator of HRY in this study because the CM rough rice subsample mass was unknown. The mean head rice percentage averaged across the 29 lots was statistically different between the CM and McGill #2 laboratory-milled samples. The head rice percentage range was 75.6–97.0% (average 86.8%) for the CM rice samples and 69.5–89.6% (average 80.2%) for the McGill #2 laboratory-milled samples.

The McGill #2 laboratory mill is a batch milling system that removes the bran layers in one pass compared with the multipass, sequential commercial systems used in this study. Single-break and batch milling systems produced more broken kernels and consequently lessen the percentage of head rice within a lot than multibreak systems used commercially (Chen et al 1998). Therefore, it was expected that the CM rice would yield greater head rice percentages. In this study, the magnitude of the difference in head rice percentages between the CM and McGill #2 laboratory-milled samples was determined in part by the rice processor. Two of the four rice processors contributed CM rice subsamples that

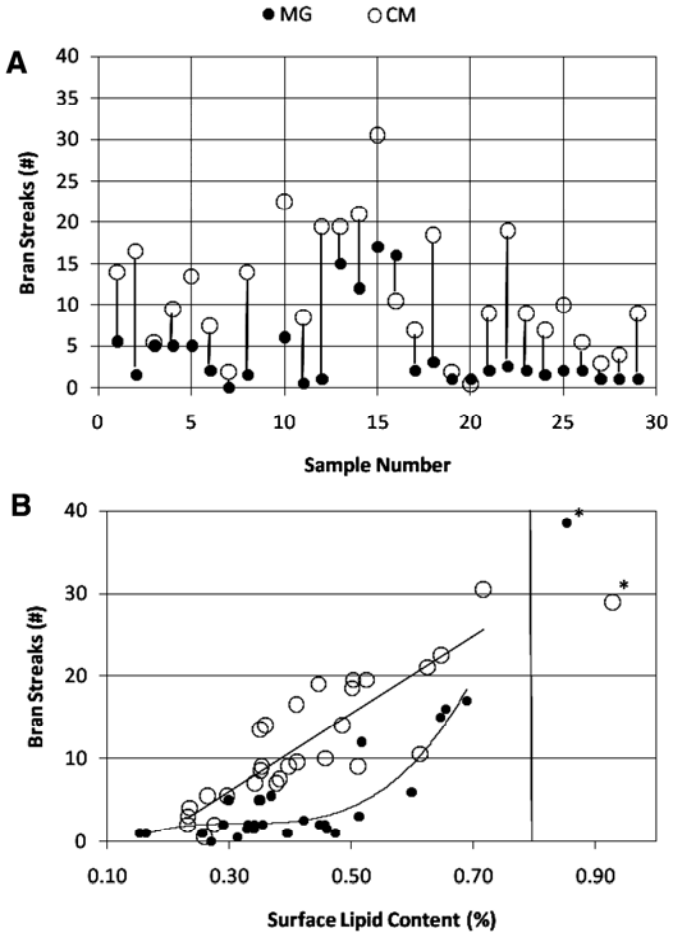

Fig. 9. Number of bran streaks by sample number (**A**) and surface lipid content (**B**) for commercially milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point is average of two measurements. Samples with SLC < 0.8 were not used in analysis.

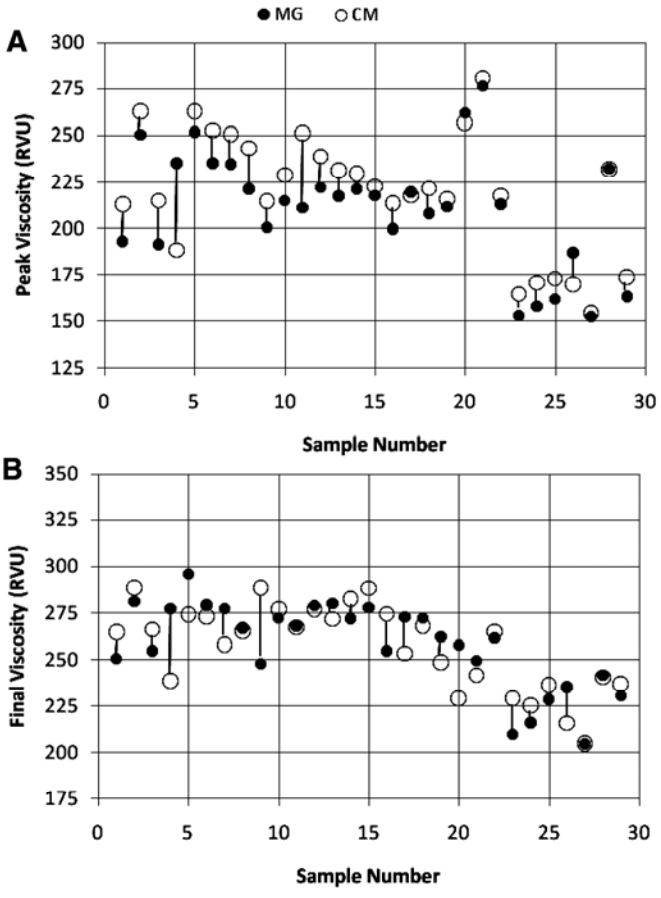

Fig. 10. Graphs depicting peak viscosity (**A**) and final viscosity (**B**) by sample number for commercially milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point is average of two measurements.

were 8.8–19.0 percentage points greater than the rough rice subsample milled in the McGill #2 laboratory mill. The CM rice subsamples contributed by the other two processors were 6.3 percentage points more to 4.6 percentage points less head rice percentage than McGill #2 laboratory-milled counterpart (Fig. 4).

Color quality using the CIE L^* a^* b^* color system was not statistically different between the CM and McGill #2 laboratory-milled samples within the L^* and a^* values but was statistically different for the b^* value (Figs. 5, 6, 7). The CM samples had L^* a^* b^* values of 68.2–75.7 (average 72.8), –0.88–1.60 (average 0.25), and 14.7–17.7 (average 16.0), respectively. The McGill #2 laboratory-milled samples had L^* a^* b^* values were 68.4–76.1 (average 73.3), –0.57–1.36 (average 0.24), and 13.6–17.4 (average 15.8), respectively. As expected, the L^* values linearly increased, indicating the rice became more white as the milling duration increased and the SLC correspondingly decreased for both milling systems (Fig. 5). Concurrently, the a^* and b^* values linearly decreased as milling duration increased indicating less red and yellow was observed, respectively, for samples milled in both systems (Figs. 6, and 7). The rates of linear decrease of L^* and increase of a^* and b^* were not statistically different between the CM and McGill #2 laboratory-milled rice samples. For both milling systems, SLC explained 77, 78, and 66% of variation in L^*, a^*, and b^*, respectively (Figs. 5, 6, 7).

Particle size distributions developed from the length, width, and thickness of kernels were determined using an image analyzer. Overall, the CM rice samples were of statistically equal or greater size by length, width, and thickness than those milled in the McGill #2 laboratory mill (Fig. 8) based on a means comparison of each of the 29 sample lot dimensions. The smaller kernel dimensions of the rice milled in the McGill #2 laboratory mill are attributed to the more aggressive, single-pass nature of the mill relative to that of the commercial mills, as mentioned above. The ranges for the lengths of the 27 long grain samples were 6.3–6.8 mm (average 6.5 mm) for the CM rice and 6.1–6.6 mm (average 6.4 mm) for the McGill #2 laboratory-milled samples. The ranges for the widths and thicknesses of the 27 long grain samples were 2.0–2.1 mm (average 2.1 mm) and 1.6–1.7 mm (average 1.6 mm), respectively, for both the CM and McGill #2 laboratory-milled samples. The two medium grain samples ranged in length from 5.8–5.9 mm (average 5.9 mm) and had mean width and thickness dimensions of 2.7 mm, and 1.8 mm, respectively, for both the CM and McGill #2 laboratory-milled samples. The dataset originally comprising the 200 length, width, and thickness values was reduced to include only those measurements within three standard deviations above and below the mean to eliminate values from no kernel and double kernel measurement outliers. The dimensions of the milled rice samples are consistent with those milled using a McGill #2 laboratory mill by Webb et al (1986), which showed length, width, and thickness values of 5.2–7.8, 1.9–3.0, and 1.5–2.0 mm, respectively.

The CM rice samples had a statistically greater number of bran streaks than the McGill #2 milled counterparts in 27 of the 29 samples using a means comparison (Fig. 9). The number of bran streaks for the CM samples were 1–31 (average 12) per 100 kernels, whereas the McGill #2 laboratory-milled samples were 0–39 (average 5) per 100 kernels. The incidence of bran streaks increased as the SLC increased for both the CM and McGill #2 laboratory-milled samples (Fig. 9). Though, bran streak incidence generally linearly increased with SLC for the CM rice, whereas the McGill #2 laboratory-milled samples had five or fewer bran streaks up to a SLC of 0.47, after which the number of bran streaks increased dramatically with SLC. The more aggressive nature of the McGill #2 laboratory mill mentioned above is believed to have caused this difference in response to SLC.

There was statistical difference in the peak viscosity between the CM and McGill #2 laboratory-milled samples. Of the 29 samples, 17 had statistically equal, and 11 had statistically greater peak viscosity values in the CM subsample than the corresponding McGill #2 laboratory-milled sample by means comparison (Fig. 10). There was no statistical difference in the final viscosity between the CM and McGill #2 laboratory-milled samples. The CM rice samples had a peak viscosity range of 154–281 RVU (average 220 RVU) and a final viscosity range of 205–288 RVU (average 257 RVU). The McGill #2 laboratory-milled samples had a peak viscosity range of 152–276 RVU (average 211 RVU) and a final viscosity range of 205–296 RVU (average 258 RVU).

There was no statistical difference in the firmness or stickiness between the CM and McGill #2 laboratory-milled samples. The firmness of the CM rice samples had a range of 79.6–123.8 N (average 95.8 N), whereas the McGill #2 laboratory-milled samples had a range of 80.0–122.5 N (average 94.9 N). Stickiness ranged from 1.1–6.0 N·s (average 2.8 N·s) for CM rice samples and 1.1–6.1 N·s (average 2.9 N·s) for the McGill #2 laboratory-milled rice samples. The large range of firmness and stickiness values among both sets of milled rice samples was likely due to difference in cultivars of the rice samples.

The end-use cooking parameters of volumetric expansion and water uptake were not statistically different between the CM and McGill #2 laboratory-milled samples. Volumetric expansion, measured as percent change by volume precook to postcook, had a range of 268–356% (average 316%) for the CM rice and 265–346% (average 314%) for the McGill #2 laboratory-milled rice (Fig. 11). Water uptake, measured as a percent change by mass,

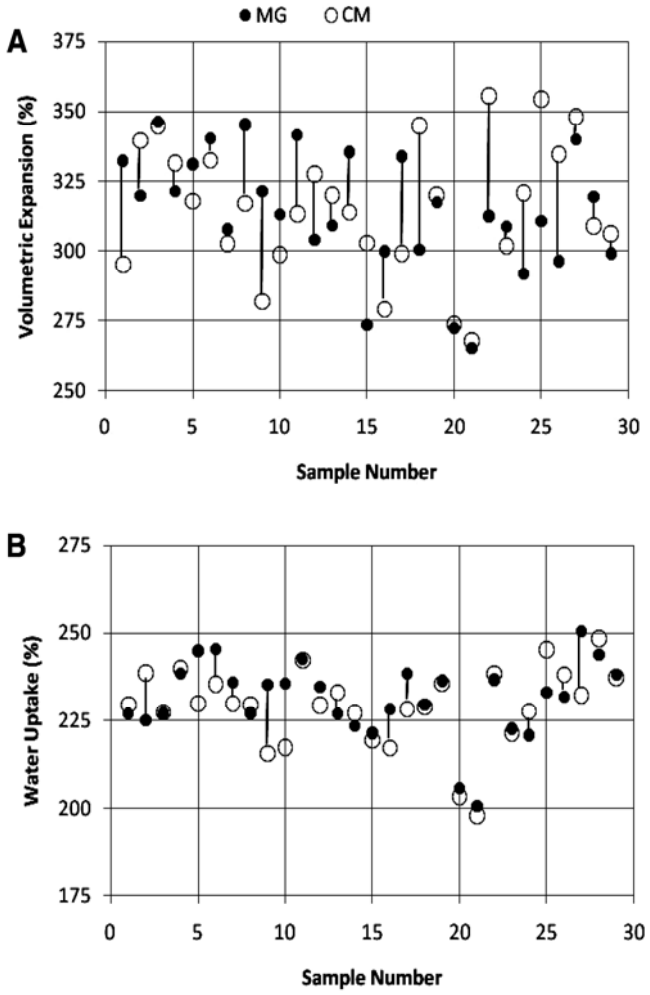

Fig. 11. Volumetric expansion (**A**) and water uptake (B) by sample number for commercially-milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point is average of two measurements.

ranged from 198–249% (average 229%) for the CM rice, and 201–251% (average 231%) for rice milled in the McGill #2 laboratory mill.

CONCLUSIONS

The results of this study indicate a degree of similarity between rice milled in a McGill #2 laboratory mill and commercial milling processes with respect to color parameters L^* and a^*, kernel thickness, final viscosity, texture, and end-use cooking properties. However, there were differences in head rice percentage, the color parameter b^*, kernel length and thickness, bran streaks, and peak viscosity between rice milled in the two systems. Furthermore, the similarity of the regression analysis of the L^* a^* b^* color parameters between the CM and McGill #2 laboratory mill extends previous research conducted in a McGill #2 laboratory mill. The aggressive nature of the McGill #2 milling process is evident in the decrease in kernel dimensions and the incidence of bran streaks compared with the CM rice samples.

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