Impacts of Thickness Grading on Milling Yields of Long-Grain Rice

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ABSTRACT

As variations in kernel uniformity can affect rice milling performance, limited thickness-grading to remove thin kernels was evaluated for effects on milling yields. Along with unfractioned (UNF) rice of four long-grain cultivars, rough rice was mechanically sieved, resulting in two thickness fractions, Thick (>0.079 inch) and Thin (<0.079 inch). Milled rice yield (MRY) and head rice yield (HRY) were determined for each cultivar/fraction. Thickness grading resulted in between 67% and 90% Thick kernels. Milled rice yield of Thick kernels was greater than that of Thin kernels, and were generally greater than UNF. Moreover, HRYs of Thick kernels were greater than both Thin and UNF. Thickness-grading improved milling-yield parameters, and showed a trend for reducing chalkiness of Thick kernels when compared to UNF. Although it would create an extra process operation and flow, benefits to milling yield could justify this procedure.

INTRODUCTION

Milling yield, either milled rice yield (MRY) or head rice yield (HRY), largely determines the economic value of rough rice. Milled rice yield represents the mass fraction of unprocessed, rough rice that remains as milled rice, which includes both head rice and broken kernels. Head rice yield represents the mass fraction of rough rice that remains as head rice, defined as the well-milled rice kernels three-fourths or more of the original kernel length. The goal of the milling operation is to maximize MRY and HRY while processing to a desired degree of milling.

Surface lipid content (SLC) of milled rice is an indicator of degree of milling (Hogan and Deobald 1961), with SLC declining as degree of milling increases. Elevated
SLC values negatively impact sensory properties of stored milled rice (Wadsworth, 1994). Therefore, it is important to carefully control degree of milling during processing (Wadsworth, 1994), and to monitor and adjust for lot-to-lot milling variability (Siebenmorgen et al., 2006).

Chen et al. (1998) showed that when rice was milled in bulk, and the milled rice subsequently thickness-fractioned, the thinner kernels tended to mill at a slower rate, thus having greater SLC than thicker kernels. As such, commercial milling operators tend to over-mill the thick kernels in a bulk lot in order to process the thin kernels to the desired degree of milling, thus reducing both MRY (Wadsworth, 1994) and HRY (Sun and Siebenmorgen, 1993). Size-exclusion techniques could reduce milling variability inherent within lots (Chen et al., 1998).

Thickness grading has been proposed as a means of improving kernel uniformity by removing thin, rough rice kernels, and designating the thin kernels for alternate use, such as parboiling (Matthews et al., 1982). Sun and Siebenmorgen (1993) showed greater HRYs for thicker kernels of rice when compared to bulk, unfractioned rice of three long-grain cultivars. Rohrer et al. (2004) reported that, when fractioned as rough rice prior to milling, thin kernels milled to a lower SLC and HRY compared to thicker kernels at the same milling duration. Thus, if size-fractioning were implemented, millers could potentially reduce over-milling of thicker kernels, while reducing the milling duration for the additional thin-kernel processing stream, and ultimately increasing overall MRY and HRY. As such, the goal of this research was to examine limited thickness-grading to increase MRY and HRY, in a manner potentially compatible with commercial-scale milling operations.

**PROCEDURES**

Four long-grain rice cultivars, two pure-lines (CL151 and Wells) and two hybrids (CLXL729 and CLXL745), were evaluated. Three of the cultivar lots (CL151, CLXL729, and CLXL745) were combine-harvested in 2011 from large-scale strip-trials near Jonesboro, Ark. The Wells lot from the University of Arkansas Rice Research and Extension Center, Stuttgart, Ark., was also combine-harvested. Lots were cleaned, conditioned to approximately 12.5% (wet basis) moisture content, and stored at 40 ± 2 °F prior to thickness grading. One day prior to thickness grading, bulk samples were removed from refrigerated storage and equilibrated to room temperature (72 ± 2 °F).

In addition to unfractioned (UNF) rice, a portion of each bulk rice lot was thickness graded using a dockage tester (Model XT4, Carter-Day, Minneapolis, Minn.) equipped with a No. 24 screen (0.079 × 0.47 inch slot) in the top-most, vertically-oscillating position. A No. 22 screen (0.059 × 0.47 inch slot) was used in the underlying, laterally-oscillating position, and was the final screen, allowing passage of only fines and unfilled kernels. Bulk rice was screened only once, and split into only two thickness fractions, Thick (> 0.079 inch) and Thin (< 0.079 inch) rough rice. This thickness-grading procedure was designed to approximate what could potentially occur at a milling facility with high rough rice throughput.
Four replicate 150-g samples of rough rice of each cultivar/fraction were prepared. The samples were dehulled in a laboratory sheller (THU 35B, Satake, Hiroshima, Japan) with a clearance of 0.019 inch between the rollers, and milled for 30 s using a laboratory mill (McGill No. 2 mill, RAPSCO, Brookshire, Texas) equipped with a 1.5-kg weight on the lever arm, situated 6 inches from the milling chamber centerline. Milled rice yield was determined, and then head rice was separated from brokens to determine HRY. As an indicator of degree of milling, SLC was quantified for head rice kernels of each cultivar/fraction sample using a lipid extraction system (Avanti 2055, Foss North America, Eden Prairie, Minn.).

Analysis of variance (ANOVA, $\alpha = 0.05$), and means separation using Fisher’s least significant difference procedure (LSD) at a significance level of 0.05 were conducted using statistical software (JMP release 9.0, SAS Institute, Inc., Cary, N.C.).

**RESULTS AND DISCUSSION**

Thickness-grading of rough rice resulted in Thick fractions ranging from 67% to 90% of the bulk rice on a mass basis (Fig. 1). Clearfield 151, CLXL729, and CLXL745 had 85% or greater Thick kernels, while the Wells cultivar, had only 67% Thick kernels. Thickness grading of commonly produced, long-grain rice cultivars in the mid 1970s (Matthews and Spadaro, 1976) resulted in only 2% to 54% kernels equivalent to the Thick-kernel fraction herein. Sun and Siebenmorgen (1993) report between 20% and 70% Thick kernels for three long-grain rice cultivars. In contrast, the range of 67% to 90% Thick kernels from this current study was narrower, and approached or exceeded the maximum proportion of Thick kernels of cultivars reported previously. Thus, there appears to be a shift toward greater kernel thickness with current long-grain rice cultivars produced in the mid-South region of the United States. As a result, the simplified thickness-grading approach presented here should provide for a minimal thin-fraction processing stream.

The 30-s milling duration resulted in a degree of milling close to the target 0.4% SLC for UNF and Thick rice of all cultivars. Thickness grading resulted in a trend of greater MRY of Thick kernels when compared to UNF rice, with the exception of Wells (Fig. 2). In the case of both CL151 and CLXL729, MRY for Thick kernels was significantly greater than that of UNF rice. The MRY for Thick kernels of CLXL745 followed the same trend as the CL151 and CLXL729 cultivars, but the difference from UNF rice was not significant. The MRYs for both Thick kernels and UNF rice were significantly greater than that of Thin kernels at the 30-s milling duration for all cultivars (Fig. 2). Although significant, the difference in MRYs of Thick and Thin kernels for the Wells lot was less than that observed for the other three cultivars.

Also at this 30-s milling duration, HRY of the Thick kernels was significantly greater than that of UNF rice for all cultivars (Fig. 2). As observed for MRY, HRYs of the Thin kernels were significantly lower than either Thick or UNF rice for all cultivars (Fig. 2). With the exception of Wells, this was partially the result of greater degree of milling (lower SLC) of the Thin kernels relative to Thick kernels and UNF rice (Fig. 3).
Rohrer et al. (2004) also reported a similar trend, where thin kernels milled faster than thick kernels when milled separately. However, Thin kernels of all cultivars, including Wells, had significantly lower MRY and HRY than Thick kernels or UNF rice (Fig. 2). Thus, the reduced MRY and HRY of Thin kernels were attributed primarily to greater breakage of Thin kernels during the milling process. Because of the relative proportions of Thin kernels generated from thickness-grading the selected bulk samples, there were insufficient Thin kernels to allow additional, shorter milling durations to achieve the target 0.4% SLC, which would have invariably increased both MRY and HRY for the Thin fraction.

**SIGNIFICANCE OF FINDINGS**

The procedure presented here for single-pass, thickness grading generally resulted in greater MRY, and always resulted in significantly greater HRY, of Thick kernels when compared to UNF rice. Moreover, these four cultivars currently popular in the mid-South United States have a sufficiently large fraction of Thick kernels to minimize the secondary process flow of Thin kernels. While thickness-grading would create a secondary process flow, improved milling yields and greater kernel uniformity could justify this procedure.

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**LITERATURE CITED**


Fig. 1. Mass fractions resulting from thickness-grading of rough rice of four long-grain cultivars using a dockage tester (Model XT4, Carter-Day, Minneapolis, Minn.) equipped with a No. 24 screen (0.079 × 0.47 inch slot) in the top-most, vertically-oscillating position. Fractions comprise thickness >0.079 inch (Thick) and <0.079 inch (Thin).
Fig. 2. Rice yield [milled rice yield (MRY) or head rice yield (HRY); milling duration of 30 s] of thickness fractions, in response to thickness-grading of rough rice of four long-grain cultivars. Fractions comprise Thick (>0.079 inch), Thin (<0.079 inch), and unfractioned (UNF) rice. Solid bars indicate MRY and inset, crosshatched bars indicate HRY. Letters inset within each bar facilitate the comparison of means within a cultivar; uppercase letters are associated with MRY, and lowercase letters with HRY; means with the same letter were not significantly different ($P > 0.05$).

Fig. 3. Surface lipid contents of head rice (milled kernels; milling duration of 30 s) in response to thickness-grading of rough rice of four long-grain cultivars. Fractions comprise Thick (>0.079 inch), Thin (<0.079 inch), and unfractioned (UNF) rice. Letters inset within each bar facilitate comparison within a cultivar; means with the same letter were not significantly different ($P > 0.05$).