Milling Quality as Affected by Brown Rice Temperature

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ABSTRACT

Three cultivars of long grain rice were used to evaluate the effects of cooling brown rice before milling on head rice yield (HRY) and degree of milling (DOM). Brown rice at initial temperatures (Tᵢ) ranging from 0 to 25°C was milled for 15, 30, 45, or 60 sec in a McGill No. 2 laboratory mill. The HRY versus Tᵢ and the HRY versus DOM relationships were inversely linear. The three cultivars showed HRY increases of 1.4–1.8 percentage points for Tᵢ reduction from 25 to 0°C at the standard 30-sec milling time (MT). However, when HRYs were adjusted to equivalent DOMs using a commercial milling meter, there was no significant improvement in HRY due to cooling the brown rice.

MATERIALS AND METHODS

Three long grain rice cultivars (Adair, Alan, and Newbonnet) were used. The rough rice was cleaned and dried to 14% mc (wb) immediately after harvest. It was then bagged in paper sacks and placed in storage at 1°C for 10 months until being removed for milling. Moisture content for each of the cultivars was measured by drying in an oven at 130°C for 24 hr. At the time of milling, the Adair, Alan, and Newbonnet lots had 13.1, 13.6, and 14.0% mc (wb), respectively.

Experimental Procedure

After being removed from cold storage, rough rice from each cultivar was allowed to remain at 22°C in plastic bags for at least 24 hr. The bulk rice was separated into samples of ~150 g using a Boerner divider. These samples were hulled with a Seedboro sheller-huller at a rate of ~500 g/min (USDA 1984) to yield a brown rice sample of at least 123 g. Each brown rice sample was placed in doubled, sealable plastic bags to prevent any change in moisture content. Twelve samples for each Tᵢ to be tested within each cultivar were held at temperatures ranging from ~10 to 25°C. The lower temperatures of ~10 and 5°C were achieved by placing samples in a walk-in freezer and walk-in cooler, respectively. Other temperatures were obtained using an air-relative humidity-temperature control unit. Samples were held in the respective temperature conditions for at least 24 hr to allow all kernels to come to a uniform temperature. Samples were removed from their respective temperature conditions just before milling and placed in an insulated cup. The Tᵢ was measured using a thermocouple. The mean temperature of the 12 samples taken from a set condition was reported as the Tᵢ; for those samples. Standard deviations ranged from 0.95 to 0.06°C, with the average standard deviation being 0.50°C.

McGill No. 2 Milling Procedure

A McGill No. 2 mill was instrumented with thermocouples on the outside and inside of the mill chamber. These temperatures, as well as the laboratory temperature, were continuously monitored during milling. The mill was warmed by milling ~120 g of brown rice until the external mill temperature reached at least 28.5°C. Milling of each of the subsequent samples began when the external mill temperature cooled to 28.5°C. This was done to reduce variability that might occur due to mill temperature. Brown rice samples of 123.0 g were milled for 15, 30, 45, or 60 sec in the McGill No. 2 laboratory mill, which was equipped with an automatic timer. A 1,500-g mass was placed on the mill lever arm, 15 cm from the center of the milling chamber. Immedi-
ately after milling, the rice was placed in an insulated cup and the final milled rice temperature ($T_f$) was measured using a thermocouple. The mill was thoroughly cleaned between each milling. Milled rice mass was measured. Head rice was separated from broken rice (sized) using a Seedboro shaker-sizer. Three milling replicates were made at each of the four milling times (MT) for each $T_i$.

DOM Determination
DOM of the sized white rice was measured using a Satake milling meter, model MM-1B. The milling meter displays DOM as a value from 0 (brown rice) to 199 (pure white rice). Therefore, the larger the DOM number, the more well-milled the sample. DOM levels of 85–95 are target levels for most commercial rice mills. Three DOM readings were taken on a subsample of ~25 g. The meter displayed the average DOM value for the subsample. This procedure was repeated for two additional subsamples, and the mean of the three average DOM readings was reported as the DOM for the sample.

RESULTS AND DISCUSSION

HRY vs. Initial Temperature
Regression analyses were performed on the milling data using the general linear models procedure PROC GLM (SAS 1989). The regression that related HRY to $T_i$ for Adair, Alan, and Newbonnet showed HRY increases of 1.4, 1.6, and 1.8 percentage points, respectively, for $T_i$ reduction from 25 to 0°C. Figure 1 shows the relationship of milled rice yield (MRY) and HRY to $T_i$ for the three cultivars for the standard 30 sec MT. MRY and HRY were linearly correlated with brown rice $T_i$. The $R^2$ values for HRY versus $T_i$ at the 30-sec milling time were 0.67, 0.51, and 0.45 for Adair, Alan, and Newbonnet, respectively.

$$MRY(T_i) = a_{MRY} + b_{MRY} \times DOM$$

$$HRY(T_i) = a_{HRY} + b_{HRY} \times DOM$$

where $a$ and $b$ are regression coefficients. Values for $a$ and $b$ are given in Table 1. The relationship between HRY and DOM was linear for each $T_i$, with most $R^2$ values being >0.93. If all $T_i$ were grouped together within each cultivar, the $R^2$ values were 0.91, 0.89, and 0.85 for Adair, Alan, and Newbonnet, respectively. These high $R^2$ values indicate that the relationship between HRY and DOM was independent of $T_i$.

DOM vs. MT
The relationship of DOM to MT at measured $T_i$ for the three cultivars is depicted in Figure 2. The graphs of DOM versus MT for different $T_i$s show that HRY for a given MT should not be directly compared from one $T_i$ level to another because of differences in DOM between the $T_i$ levels. HRY for the various $T_i$ levels needed to be adjusted to equivalent DOM before comparisons could be made. For a given MT, a sample with a lower $T_i$ tended to mill to a lesser DOM. As MT increased, the disparity in DOM between warmer and cooler $T_i$ samples decreased.

HRY vs. DOM

The regressions shown in Figure 1 do not include an adjustment for DOM. A wide range of DOM and associated HRY was created by the various MT. These data were used to regress MRY and HRY against DOM. The HRY versus DOM trend for Adair can be seen in Figure 3. For clarity, data points are shown for only three $T_i$ for Adair. However, the regression line shown was developed from the data from all nine $T_i$. Model equations that correlated MRY and HRY (at a given $T_i$) to DOM were:

$$MRY(T_i) = a_{MRY} + b_{MRY} \times DOM$$

$$HRY(T_i) = a_{HRY} + b_{HRY} \times DOM$$

Fig. 1. Milled rice (MRY) and head rice yields (HRY) vs. initial brown rice temperature for 30-sec milling times for the three cultivars tested. Regression lines were generated from Equations 1 and 2. Data does not include an adjustment for degree of milling.

Fig. 2. Degree of milling (DOM) versus milling time for the cultivar Alan at the indicated initial brown rice temperature.

Fig. 3. Head rice yield (HRY) vs. degree of milling (DOM) for the cultivar Adair at the indicated initial brown rice temperature. Regression line fitting data from all initial brown rice temperatures across all milling times is shown.
The model equation was:

\[ \text{DOM} = c + d \times \text{MT} \]

where \( c \) and \( d \) are regression coefficients. Values for \( c \) and \( d \) and estimated times required to reach a given DOM for each \( T_i \) are given in Table III. \( R^2 \) values were >0.90 for 15 out of 18 regressions. The trend was that the lower the \( T_i \), the longer the sample had to be milled to reach a desired DOM level. For example, Alan rice at a \( T_i \) of 23.2°C reached a DOM of 90 in 31 sec, whereas 44 sec of milling was required to reach a DOM of 90 for a \( T_i \) of 1.7°C.

**Final Milled Rice Temperature vs. MT**

The relationship between final milled rice temperature (\( T_f \)) and MT was examined. As MT increased, the range in \( T_f \) from the coldest to warmest \( T_i \) lessened. Figure 4 shows this trend for Adair. The initial temperature difference of 24°C between the 24.4 and 0.4°C samples became reduced to only 5°C at the 60-sec MT. Greater heat transfer from the mill during the longer MT would explain this trend.
viscous and more difficult to remove from the kernel than it is when it is at a warmer, less viscous state. It is speculated that the bran must reach a high enough temperature before it can be readily removed from the kernel. Brown rice at lower $T_i$s requires more energy input from the mill to reach the proper temperature range for bran removal than does rice at a higher $T_i$, and therefore must be milled longer to reach an equivalent DOM.

**CONCLUSIONS**

MRY and HRY were affected by brown rice $T_i$. This apparent effect was due primarily, if not totally, to resulting DOM of the samples. HRY versus DOM curves were obtained for each $T_i$, and these curves were used to adjust for DOM differences between samples. After adjustment to given DOM levels, there was no change in MRY and HRY due to milling at different $T_i$. Thus, no practical improvement in HRY was obtained by cooling brown rice before milling when DOM was considered. Brown rice that had been cooled had a lower DOM after being milled for the same length of time as a sample that had not been cooled. Bran properties were apparently affected by kernel temperature, as there was a strong correlation between $T_f$ and DOM. It is speculated that bran is not removed by the milling process until it reaches a sufficiently high temperature.

**LITERATURE CITED**


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**TABLE IV**

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<tr>
<th>Cultivar</th>
<th>$T_i$ ($^\circ$C)</th>
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<th>$f$</th>
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<th>90</th>
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$^a$ $T_{fl} = e + f \times$ DOM relating final milled rice temperature ($T_f$) to degree of milling (DOM) for Adair, Alan, and Newbonnet. $T_f$ at DOM of 80, 90, and 100 are given. All = coefficients of regression and estimates when all $T_i$ are grouped together in the regression analysis. $^b$ Relative rankings are shown for $T_f$ from low to high required $T_f$ at the given DOM within each cultivar.

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**Fig. 4.** Final rice temperature vs. milling time for the cultivar Adair at the indicated initial brown rice temperature.

**Fig. 5.** Final rice temperature vs. degree of milling (DOM) for the cultivar Newbonnet at the indicated initial brown rice temperature. For clarity, only data points for a high, medium, and low initial brown rice temperature are shown.