EVALUATION OF TWO METHODS FOR SEPARATING HEAD RICE FROM BROKENS FOR HEAD RICE YIELD DETERMINATION

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ABSTRACT. Milled rice from a laboratory mill and a commercial-scale mill was evaluated for head rice yield using a shaker table and a machine-vision system called the GrainCheck. Comparisons were made for both medium- and long-grain rice varieties. For each variety, samples with different levels of broken kernels were analyzed to determine the performance of the two instruments over a range of head rice yields. Percentage head rice was also measured by the FGIS for commercially milled samples to compare the shaker table and the GrainCheck with an official measurement. Head rice yield values were found significantly different between the two instruments for all of the laboratory–milled samples but the mean head rice yield variation was equivalent for both instruments. Commercially milled rice showed that the FGIS and GrainCheck percentage whole kernel measurements were equivalent while the shaker table average was seven percentage points less. Similar trends were found for both varieties.

Keywords. Rice, Head rice yield, Milling, Shaker table, GrainCheck.

Head rice yield (HRY) is one of the primary factors that currently determine the official market grade of rice. Head rice, or the “whole” kernels in a well-milled rice sample, is defined by the USDA Federal Grain Inspection Service (1999) as, “Unbroken kernels of rice and broken kernels of rice, which are at least three-fourths of an unbroken kernel.” HRY is the weight percentage of a rough rice sample that remains as head rice after complete milling. Head rice is generally worth twice as much as the broken kernel classes of brewers, second heads, and screenings. Thus, HRY primarily determines the economic value of rice since it is an indicator of the milling quality of a rice lot. End-users of rice pay premium prices for head rice and typically specify maximum tolerances of percentage broken kernels for any given sale. Because of the importance of HRY as an indicator of rice quality, accurate HRY measurement by laboratory milling tests is essential. In addition to its importance in establishing commercial economic value, HRY is also used to quantify the effects of other processing operations, such as drying, tempering, and storage on milling quality. Therefore, a precise and accurate measurement of HRY is important to producers, processors, and end-users of rice.

Standards for test milling of rice are published by the USDA FGIS (1999). These standards specify the use of a McGill No. 3 mill. Many laboratories have opted for smaller, more convenient mills. However, for most laboratory methods, HRY determination consists of three operations: the laboratory shelling of the rough rice sample, the laboratory milling of the resulting brown rice, and the separation of the head rice from the broken kernels. The laboratory milling operation consists of milling an appropriate size sample of hulled rough rice in a McGill No. 2 or No. 3 test mill, or other equivalent rice mill at appropriate predetermined mill settings. These mill settings include sample amount, mill weight placement, and milling duration. Reid et al. (1998) and Andrews et al. (1992) presented thorough evaluations of the mill settings for the McGill No. 2 rice mill. The test sample must be milled equal to a degree of bran removal or better than the official degree of “well-milled” rice for proper HRY measurement (USDA FGIS, 1999).

After milling, the next operation of the HRY measurement consists of accurately separating head rice from broken kernels. Typically, this procedure is done by a mechanical sizing method or by hand picking. Both of these separating methods are operator dependent with operator subjectivity becoming a factor, especially in hand picking. Mechanical separating can utilize sieves, riddles, and indent cylinders. The most common laboratory method used is a device consisting of inclined indent plates developed by Smith (1955). However, this device has been shown to provide inaccurate and highly variable separation of milled rice kernels as noted by Sterner and Beerwinkle (1970). They compared 10 different sizers (also called shaker tables) and noted that factors such as stability of the supporting table and variations in vibration of the carriage table affected sizer performance. They concluded that acceptable precision among sizers was obtained by adjusting vibration frequency.
of the carriage table using a suitable variable-speed drive. The shaker table has also been noted as a time-consuming, requiring operator supervision to ensure adequate separation.

Previous researchers used other devices to separate the different fractions of long-grain rice. Mathewson et al. (1990) built a mechanical system to separate a milled rice sample into four fractions using sieves. The system required 30 to 40 min to separate 100 g of milled rice into fractions. They evaluated their sieving system using an image analysis system, placing five subsets of 45 to 60 kernels (or broken kernels) on a black velvet background. By capturing the projected area of the kernels, each piece was categorized as whole kernels or broken.

Image analysis has been used to successfully evaluate and/or separate other grain commodities in a fast and effective manner. Sapirstein et al. (1987) used a machine vision system to classify whole kernel samples of hard red spring wheat, barley, rye, and oats based on physical features such as kernel length, width, and area. Gunasekaran et al. (1988) used a machine vision system to evaluate the quality of corn and soybeans. Majumdar et al. (1997) used an automated machine vision system to classify kernels of Canada Western red spring wheat, Canada Western Amber Durum wheat, barley, oats, and rye. Talsma et al. (1989) developed a machine vision system to classify broken, whole, and fissured rice kernels. They developed two image processing techniques that were reported to be 77 and 92.4% effective compared to USDA inspected samples.

Although the above work was important for image processing of grains, most of the work was done only with prototype systems. These systems have not been commercially marketed or implemented in the grain industry or in grain inspection stations due to slow operational speeds, cost, or other factors.

A new commercially available analytical instrument called the “GrainCheck” has been designed to incorporate the non-subjectivity of image analysis with recent advances in image processing speed to evaluate quality of milled rice and other grains. The GrainCheck uses a CCD camera, an image processing system, and a material handling system to automatically measure HRY and other important factors in grading rice such as chalky kernels or foreign seeds. The GrainCheck is being used by some rice processors to replace the shaker table for determination of HRY or to measure the percentage of whole kernels in a milled rice sample. The purpose of this project was to evaluate the GrainCheck analysis system versus the conventional shaker table method in measuring HRY for long-grain and medium-grain milled rice samples.

**Materials and Methods**

**Separation Equipment**

The shaker table used for this experiment was a Grainman Model 61-115–60 (Grain Machinery Mfg. Corp., Miami, Fla.). The original single speed motor was replaced by a variable-speed DC motor to allow adjustment of the shaker carriage vibration frequency for optimum separation of broken from head rice. Vibrating frequency was approximately 60 Hz (600 cpm) with an amplitude of 3 mm.

The screens used in the shaker device were two No. 10 screens for separation of the medium-grain variety and two No. 12 screens for the long-grain variety. The hole size in the screens was 3.97 mm for the No. 10 screens and 4.76 mm for the No. 12 screens.

A GrainCheck model 310 system (Foss North America, Eden Prairie, Minn.) was used to simultaneously separate head rice from broken kernels and measure HRY. The GrainCheck system uses pre-calibrated Artificial Neural Networks (ANN) software. The ANN software is trained to identify broken kernels using a consensus of experts. Therefore, the decisions made by the GrainCheck should be equivalent to the decisions made by experienced inspectors. However, the variance between inspectors is eliminated when using the GrainCheck because every GrainCheck instrument uses the same software.

A schematic of the GrainCheck 310 is shown in figure 1. A 40- to 60-g sample of milled rice was loaded into the machine to a feeder conveyor belt. The kernels were then automatically distributed onto an analysis conveyor belt moving in a step-wise manner. The analysis belt was illuminated by a fluorescent lamp encircling a CCD camera, which took a static image of several kernels per frame as they passed. The image was then digitized and segmented to split the image into individual kernels. The individual kernels were identified as either whole or broken by a PC with the pre-calibrated ANN software. A pixel weight (g/pixel) was determined by calculating the ratio of the total sample mass as determined by an internal electronic balance, over the total number of pixels using the sum of the projected area of all the kernels present in the sample. The mass (and percentage) of both head rice and broken kernels was internally calculated by multiplying the total number of pixels of each fraction by the pixel weight. A windows-based display software allowed user interface for the UNIX control system of the GrainCheck. The computer displayed various outputs such as mass and percentage of each fraction with an option to display images of each kernel along with various other kernel dimensions. The head rice percentage given by the GrainCheck was multiplied by the sample’s milled rice yield (sum of head rice and broken kernels) of the McGill No. 2 mill to obtain a HRY measurement. This value then corresponded to the HRY measurement from the shaker table method for equivalent comparison. Analysis time for the GrainCheck was approximately 5 to 7 min for a sample size of 40 to 60 g of milled rice.

**Procedure for Experiment 1:**

**Laboratory Milled Samples**

Two rice varieties were used, Cypress, a long-grain variety, and Bengal, a medium-grain variety. Both varieties were grown and harvested at the University of Arkansas Rice Research and Extension Center at Stuttgart, Arkansas. The moisture content at harvest was approximately 18 to 20% (unless otherwise stated; all moisture content values are expressed on a wet basis). Both varieties were dried using air at 60°C and 17% relative humidity for different durations to produce three distinct levels of HRY noted as low, medium, and high. Drying durations were chosen that would result in HRY levels around 55, 60, and 65%, respectively. Detailed explanation of the drying procedures is found in Cnossen and Siebenmorgen (2000). The final equilibrium moisture content of all of the samples was 12.5%, which is the typical moisture content of rice for milling in the United States. Six samples (150 g) of each variety and drying condition combinations
(36 samples total) were then hulled in a Satake laboratory huller (model APS30 CXM, Satake, Houston, Tex.) to produce brown rice. Each brown rice sample was then milled in a McGill No. 2 laboratory rice mill (Rapsco, Brookshire, Tex.) for 30 s to produce a well-milled white rice sample comprised of head rice and broken kernels. The degree of milling (DOM) of the samples was measured with a Satake MM–1B milling meter (Satake, Houston, Tex.) corresponding to a DOM of 80 to 90. The white rice produced from the 150-g samples was approximately 90 to 100 g. The entire milled rice sample was loaded onto the shaker table for separation and only one person operated the shaker table for measurement uniformity. As mentioned earlier, the GrainCheck required about one-half of the milled rice sample. A Boerner divider was used to split each milled sample, and then approximately 45 to 55 g was loaded into the GrainCheck for separation of head rice and brokens.

The HRY of each of the 36 milled rice samples was determined by performing five measurements with the shaker table method and five measurements using the GrainCheck image analyzer. The five replicate measurements were averaged and the average of the six replicate samples of each drying condition and separation method combination are reported in Figure 2 for Cypress and Figure 3 for Bengal. Analysis of variance was performed for all the data using the GLM procedure in SAS (1998) for a 3 factor nested factorial design for the 12 treatment combinations.

**Procedure for Experiment 2:**
**Commercially milled samples**

A second experiment was performed to compare the shaker table and the GrainCheck's ability to separate and measure the head rice percentage for commercially milled rice. The HRY could not be calculated because the initial rough rice weight was unknown. This experiment was incorporated into the study because commercially milled rice is generally cleaner with less dust and other small particulate matter found in a laboratory test sample, due to efficient aspiration equipment found in commercial mills. An accurate and precise percentage head rice measurement is important to commercial rice millers in order to check milling and grading process parameters.

Two medium-grain and two long-grain milled rice of approximately 900 g each were obtained from Riceland Foods (Stuttgart, Ark.) These samples contained varying levels of head rice and brokens because they originated from separate, individual commercial rice lots with different post-harvest backgrounds. These samples had been commercially aspirated to remove most of the dust from the bran and hulls. Each of the four individual lots was divided into six sub-samples and was measured for percentage of head rice with the shaker table and the GrainCheck. After all measurements using the shaker table and the GrainCheck are completed, the HRY was calculated for each sample and the average of the six HRY values determined for each drying condition and separation method combination.

![Figure 2. Comparison of shaker table and GrainCheck methods for separation and determination of HRY of Cypress long-grain rice for three kernel breakage levels produced by three drying durations. Each HRY value represents the mean of six samples measured five times. Error bars represent two standard deviations of each sample mean.](image-url)
Figure 3. Comparison of shaker table and GrainCheck methods for separation and determination of HRY of Bengal medium-grain rice for three drying conditions incurring three kernel breakage levels. Each HRY value represents the mean of six samples measured five times. Error bars represent two standard deviations of each sample mean.

were made, the sub-samples from each of the four original lots were recombined, then split again into six sub-samples using a Seedburo Boerner divider. These 24 sub-samples were then sent to the USDA FGIS grading station in Stuttgart, Arkansas, for official head rice percentage determination by hand picking.

RESULTS AND DISCUSSION
LABORATORY MILLED SAMPLES

As seen in figure 2, HRY measurements for long-grain Cypress rice were significantly (α < 0.05) different within each of the three HRY levels for the two separation methods. For each of the three HRY levels, the HRYs measured with the shaker table were lower than those with the GrainCheck. These results indicated that the shaker table and the GrainCheck system produced different HRY measurements for the same long-grain milled rice samples. One observation was that the shaker table often retained some head rice wedged in the outer edges of the frames of the indent screens, which was consequently classified as broken.

Table 1 shows the standard deviations of each of the mean values for each drying duration, separation method, and variety. An associated F-test for equivalence of standard deviation showed that none of the standard deviations were significantly different for each drying duration/separation

<table>
<thead>
<tr>
<th>Variety</th>
<th>Drying Duration</th>
<th>p-Value for Equivalence of Mean HRY</th>
<th>Standard Deviation of the Sample Mean</th>
<th>Difference in HRY between each Measurement Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cypress</td>
<td>Low</td>
<td>0.0001</td>
<td>0.88973</td>
<td>0.88560</td>
</tr>
<tr>
<td>Cypress</td>
<td>Medium</td>
<td>0.0001</td>
<td>0.74790</td>
<td>0.66897</td>
</tr>
<tr>
<td>Cypress</td>
<td>High</td>
<td>0.0001</td>
<td>0.70154</td>
<td>0.48336</td>
</tr>
<tr>
<td>Bengal</td>
<td>Low</td>
<td>0.0001</td>
<td>0.81148</td>
<td>0.50184</td>
</tr>
<tr>
<td>Bengal</td>
<td>Medium</td>
<td>0.2636[a]</td>
<td>0.30754</td>
<td>0.63396</td>
</tr>
<tr>
<td>Bengal</td>
<td>High</td>
<td>0.0010</td>
<td>0.87884</td>
<td>0.80623</td>
</tr>
</tbody>
</table>

[a] No significant difference (α > 0.05) in mean HRY.

method treatment combination. This result indicated that both the shaker table and the GrainCheck had equivalent measurement variation for the same set of long-grain lab-milled samples.

Figure 3 gives the results for the medium-grain Bengal rice. The HRY measurements for each separation method were significantly (α < 0.05) different for the low and high drying duration between each separation method. However, for the medium drying duration, HRY measurements for the shaker table and the GrainCheck were not significantly (α < 0.05) different. This occurrence was the only case when the GrainCheck and the shaker table produced equivalent HRY measurements for the lab-milled samples.

While the GrainCheck system produced HRY measurements close to the shaker table, the mean HRY measurements were consistently higher than the shaker table (figs. 1 and 2). Therefore a statistical estimate of the actual difference between the mean HRY of both separation methods for each drying duration and variety was tested for equivalence (SAS, 1998). Table 2 gives these differences across the drying durations to determine if a significant equivalence occurred between the subtraction of mean HRY separation methods across the drying durations.

For both Cypress and Bengal, the estimated differences in separation methods at high HRY level and low HRY level were significantly different. This finding showed that the GrainCheck gave a higher HRY value, but the difference was not constant across these HRY levels. Comparing the low and medium HRY levels, both varieties had high p-values of 0.1123 and 0.2261 indicating that the differences in these cases were equivalent. Finally, when comparing the medium and high HRY levels, an equivalent difference existed for Cypress. These comparisons illustrated that a simple proportionality constant subtracted from the GrainCheck's HRY measurement to match the shaker table would need to be specific for each HRY level and each variety.

A pooled sample variance was calculated for both separation methods for both varieties and drying conditions. The reported standard deviations of the pooled data are presented in table 1. Like the individual standard deviations, these pooled deviations were not significantly different.
between the GrainCheck and the shaker table. This comparison showed that for laboratory-milled samples, both methods had equal variation across a range of HRY levels for laboratory milled long- and medium-grain rice.

COMMERCIAL MILLED SAMPLES

Figure 4 shows the results for the commercially milled long-grain rice lots. For lot no. 1, which had the highest percentage of broken kernels, all three separation methods produced significantly different percentages of head rice. The shaker table and FGIS measurements differed by more than 7 percentage points. This difference could result in high HRY discrepancies for such a wide margin in percentage head rice. Comparison of the standard deviations of lot no. 1 for each method (table 3) revealed that the GrainCheck and FGIS variation were not significantly different. However, the shaker table had a standard deviation that was approximately three times larger than those by the other two methods.

For lot no. 2, the GrainCheck and FGIS mean head rice values were not significantly different. This result could be explained by the fact that the GrainCheck was calibrated using samples with a high percentage of head rice (>80% head rice) from the FGIS. Thus, equivalent measurements were anticipated and usually observed for the samples of the commercially milled lots with higher head rice percentages. The shaker table head rice mean was approximately 7 percentage points less than the FGIS. When comparing standard deviations for lot no. 2, no significant difference was found among the three methods. The higher shaker table standard deviation was attributed to an increased likelihood of each method identifying and removing the broken kernels because the sample contained a smaller population of broken kernels. A fewer number of broken kernels would allow the shaker table screens to capture more of them because less indents would be filled.

Figure 5 shows almost identical results for medium-grain commercially milled rice as those found for the long-grain rice. For the low HRY sample (lot no. 3), each method produced a significantly different head rice mean value. Again, the shaker table mean was approximately 7 percentage points lower than the FGIS value. The standard deviations for the three methods were not significantly different for lot no. 3. For the higher head rice lot no. 4, the GrainCheck and the FGIS head rice means were not significantly different. The shaker table again produced the lowest head rice percentage value. The standard deviation was not significantly different for the GrainCheck and the FGIS methods. The shaker table, however, had a standard deviation over five times larger than those by the other two methods.

It was speculated that the higher shaker table variation could be partially attributed to slight misalignment of the indent screens when they were secured to the shaker table carriage after they were taken off to remove the broken kernels. This problem would cause the kernels to migrate to one side of the indent plate minimizing the effect of the indent holes to retain the broken kernels.

A pooled variance for each method was also calculated from the entire commercially milled data set using all four lots. These pooled variances gave an indication of the measurement error for each method over the range of all commercially milled rice lots used in this study. Table 3 shows the magnitude of the pooled standard deviations. The shaker table had a pooled standard deviation approximately twice as large as the FGIS method. The GrainCheck had a pooled standard deviation not significantly different than that by the FGIS method indicating that the GrainCheck's overall measurement variance for two varieties at two head rice levels was nearing that of hand picking by experienced FGIS personnel.

![Milled Rice Separation Method](image)

**Figure 4.** Comparison of the shaker table, GrainCheck, and FGIS methods for determination of percentage head rice in two long-grain rice lots milled in a commercial milling system. Data represents the mean of six measurements with error bars representing two standard deviations. Like letters indicate that the mean head rice measurements within a lot were not significantly different.

![Milled Rice Separation Method](image)

**Figure 5.** Comparison of the shaker table, GrainCheck, and FGIS methods for determination of percentage head rice in two medium-grain white rice lots milled in a commercial milling system. Data represents the mean of six measurements with error bars representing two standard deviations. Like letters indicate that mean head rice measurements within a lot are not significantly different.
The GrainCheck system performed better with fewer cleanings required between samples for the commercially milled rice than that of lab–milled rice. A 5–min cleaning procedure was necessary approximately every 10 samples for the lab–milled rice. This cleaning load was lessened with the commercially milled samples. These samples had less bran dust and other foreign material that could alter pattern recognition as well as coat the camera lens with excessive dust, causing possible deviations.

CONCLUSIONS

Head rice yield for laboratory milled long– and medium–grain rice was measured for samples obtained from three drying conditions using a shaker table and a GrainCheck system. HRY values were significantly different between methods for all three HRY levels and both varieties. The GrainCheck measured slightly higher HRYs in every case, and the differences in separation methods were equivalent for only a few HRY level and variety combinations. The variation in mean HRY was equivalent for both the shaker table and the GrainCheck for all treatment combinations for the laboratory milled samples.

Commercially milled rice samples also proved that the shaker table and the GrainCheck provided significantly different HRY measurements. At low head rice levels, the shaker table, the GrainCheck, and official hand picking by the FGIS provided significantly different head rice percentage determinations for both long– and medium–grain rice. At higher head rice levels, the shaker table gave measurement of percentage head rice about 7 percentage points lower than the other two methods. The GrainCheck and FGIS values were not significantly different for the high head rice samples for long– or medium–grain milled rice. The GrainCheck proved to be an effective instrument in measuring percentage head rice for milled rice, especially for clean, commercially milled samples. For these samples, the GrainCheck measured equivalent head rice percentages to the FGIS but higher than the conventional shaker table head rice percentage measurements.

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REFERENCES


