PROJECT NO.__RU-6___

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2005 – December 31, 2005

PROJECT TITLE:

Improvement of Consistency and Accuracy of Rice Sample Milling
- Effect of Post-Milling Handling Procedures on Quality Appraisal

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LEVEL OF 2005 FUNDING: $24,900

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

Objectives

This research was a continuation of the previously funded project with an aim at developing new procedures/methods for improving the consistency and accuracy of rice sample quality appraisal. Our previous research results have shown that the rice milled with the McGill No. 3 had significant higher temperature than the rice from current commercial mills. The high temperature of milled rice in the rice sample milling needs to be cooled to room temperature before the quality evaluation is conducted. The cooling process may cause moisture loss and fissure of milled rice. The research of this year had three specific objectives:

1. Determine the effects of the temperature of milled rice on quality evaluation results, such as fissure and total and head rice yields.
2. Study the fissure rate and moisture loss of milled rice with different cooling procedures.
3. Develop recommendations for rice post-milling handling procedures.

Experimental Procedures

Materials and Milling Procedures

Medium grain rice, M202, with moisture content of 11.5±0.2% was used for this study. The rice samples were obtained from Pacific International Rice Mills, Inc. (Woodland, CA). The samples (1000g each) were milled with McGill No. 3 laboratory mill (Figs. 1 and 2) at CDFA Lab under four conditions following the standard Western milling procedures (10 pound weight for milling and 2 pound weight for polishing) of Federal Grain Inspection Service (FGIS). The four milling conditions included normal milling, milling at high temperature, milling with cooling using ice water and room temperature water as cooling media. The different milling methods were used to obtain different temperatures of milled rice.

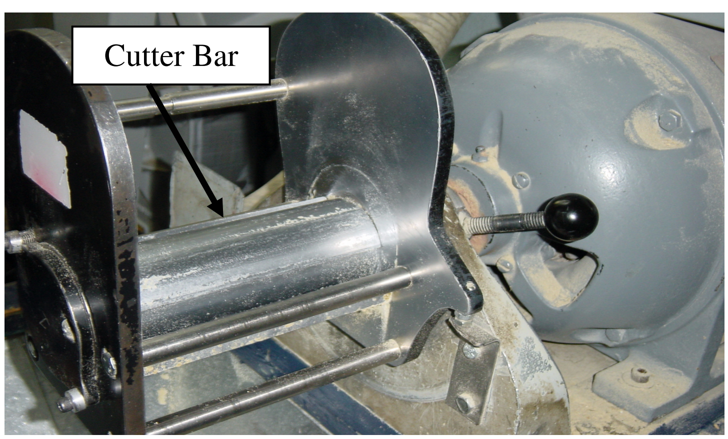

Fig. 1   McGill No.3 rice sample mill and location of cutter bar temperature measurement

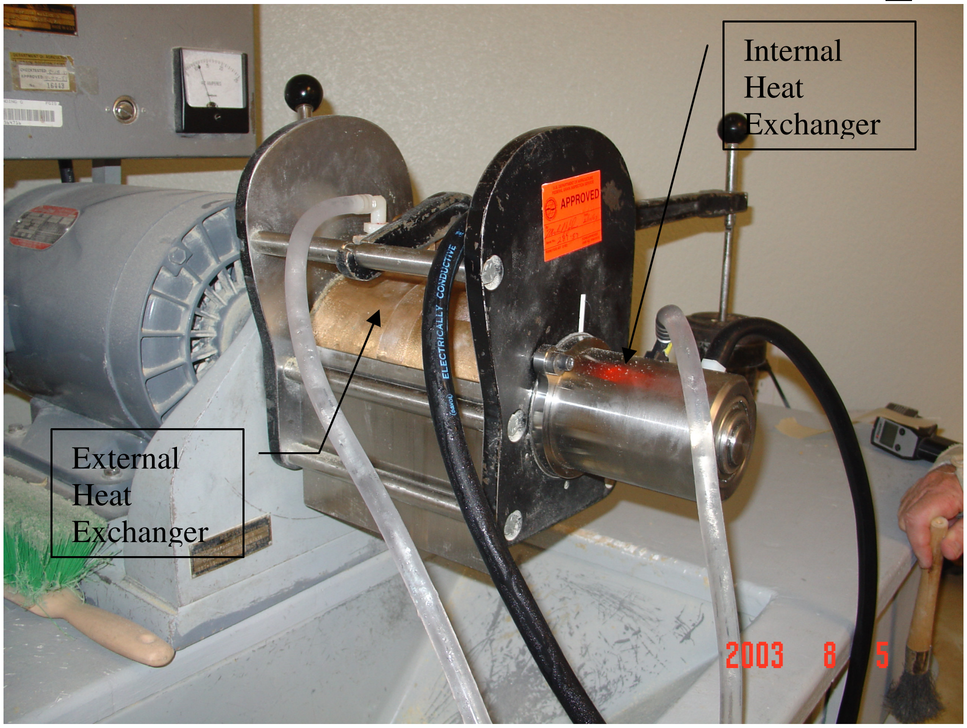

Fig. 2 Set-up of internal and external heat exchangers

Cooling Methods

The current milling practice at CDFA is to cool the cutter bar to 48-52°C (115 -130°F) using a fan before a new rice sample is milled. The temperature of cutter bar prior to the start of milling was named as initial cutter bar temperature in this study. After rice was milled and unloaded from the rice mill, the temperature of cutter bar was measured again and named as ending cutter bar temperature. Both initial and ending cutter bar temperatures were measured using an infrared temperature meter.

To reduce the milling temperature (including rice and equipment temperatures) during milling, two external and internal cooling devices were developed in the previous year. In this study, they were also called saddle and cutter bar heat exchangers, respectively. The cooling medium was pumped through the heat exchangers during the milling process. Both the external and internal cooling devices (heat exchangers) were used at the same time for the milling study. Ice water and water of ambient temperature were used as cooling media. The experimental set-up of milling with cooling is shown in Fig. 2.

When it was used, the external heat exchanger added additional weight to the milling chamber. Therefore, the weight load of mill was adjusted to keep the milling pressure to be the same as the pressure used in current standard milling practice at the CDFA lab.

Experimental Design of Milling and Post-Milling Cooling Tests

The effects of milling and post-milling cooling conditions on milling quality appraisal were studied following the experimental design shown in Table 1. The initial temperatures of the cutter bar were 13, 23, 49 and 70°C for ice water cooling, room temperature water cooling, normal milling, and high temperature milling. The initial and ending cutter bar temperatures and milled rice temperature were measured and reported under different milling conditions. The milled rice samples were cooled in closed plastic containers with three temperatures, 15, 23, and 35°C, which were used to simulate different cooling environmental temperatures (Fig. 3). The rice milled with the normal milling conditions were also cooled in open container and pan (Figs 3 and 4). The temperature changes under different post-milling conditions were measured using thermocouples and recorded. All tests were conducted in triplicates.

Table 1. Experimental design of milling and post-milling cooling conditions

Milling conditions	Post-milling cooling temperature	Container conditions
Ice water cooling	Low temp (15°C)	Closed
	Room temp (23°C)	Closed
	High temp (35°C)	Closed
Room temperature water cooling	Low temp (15°C)	Closed
	Room temp (23°C)	Closed
	High temp (35°C)	Closed
Normal milling	Low temp (15°C)	Closed
	Room temp (23°C)	Closed
		Open
		Open pan*
	High temp (35°C)	Closed
High temperature milling	Low temp (15°C)	Closed
	Room temp (23°C)	Closed
	High temp (35°C)	Closed

* Used blue pan for the cooling (Fig. 4)

Figure 3. Milled rice samples cooled in closed and open containers

Figure 4. Milled rice sample cooled in an open pan

Measurement of Milled Rice Quality

The evaluated quality indicators included total rice yield (TRY), head rice yield (HRY), Whiteness Index (WI), fissure rate, and fat content. The WI was used to evaluate the whiteness of milled rice determined with Whiteness Tester, C-300, (Kett Electronic Laboratory, Tokyo, Japan). High index number indicates whiter milled rice. The fissures of whole rice kernels were examined visually under light. The numbers of whole kernel rice with single fissure (one crack) or multiple fissures (more than one crack) were recorded. Three samples (100 kernels each) from each milling and cooling conditions were used. The numbers of kernels with fissures were reported as percentage of the total kernels. A NIR method with Infratech 1221 Grain Analyzer (Foss North America, Inc., Eden Praine, MN) was used for the total fat measurement performed at Pacific International Rice Mill, Inc. (Woodland, CA). The total fat contents are reported as percentages of sample weight on dry basis. The temperatures milled rice and bran were also measured using thermocouples after milling. The moisture contents of rough rice and different fractions were also measured using oven method (135°C, 24h) to determine the mass balance of the different fraction and moisture loss caused by the milling process.

SUMMARY OF 2005 RESEARCH (MAJOR ACCOMPLISMENTS) BY OBJECTIVES

Determine the effects of the temperature of milled rice on quality evaluation results

Temperature, TRY, HRY, WI, Fat Content of Milled Rice

The temperatures of ending cutter bar, milled rice and rice bran are shown in Figure 5. It is clearly seen that the temperatures are closely related to the milling methods. High initial cutter bar temperature was corresponded to the high milled rice temperature. The milled rice temperature with ice water cooling was 14.8°C lower than that with the current milling practice. When the rice was milled at high temperature (70°C of initial cutter bar temperature), the milled rice temperature was very high, 79.5°C. The high temperature milling also resulted in lower moisture contents in milled rice and rice bran due to water evaporation (Fig. 6). The fat contents of the milled rice were very similar even though the fat contents in the rice samples milled at high temperatures were slightly higher than the samples milled at low temperature.

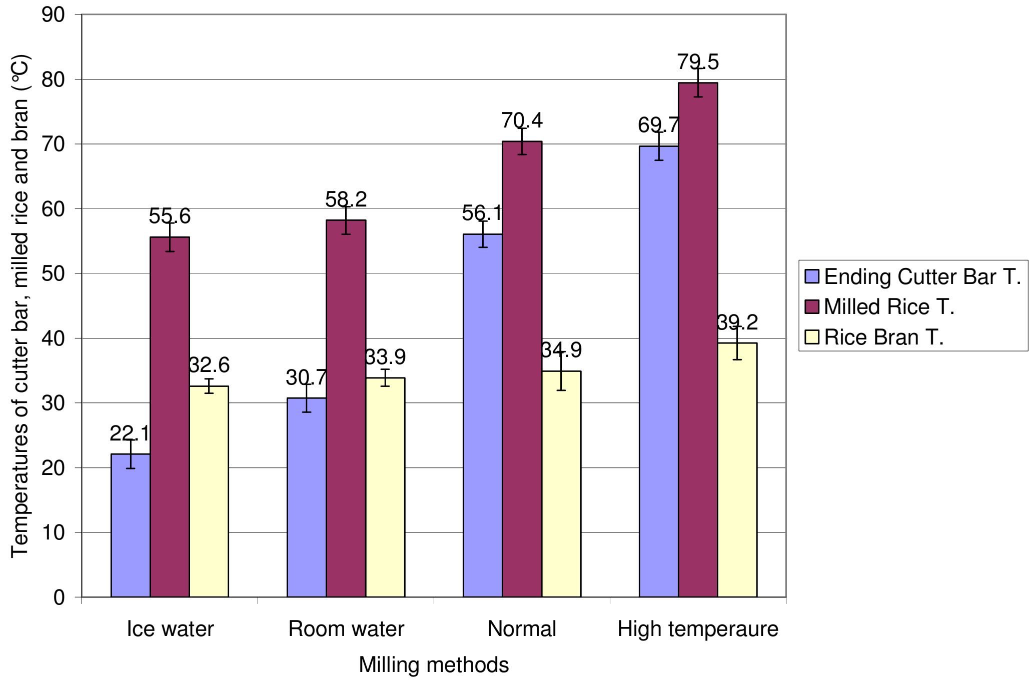

Figure 5. Temperatures of ending cutter bar, milled rice and rice barn under different milling conditions.

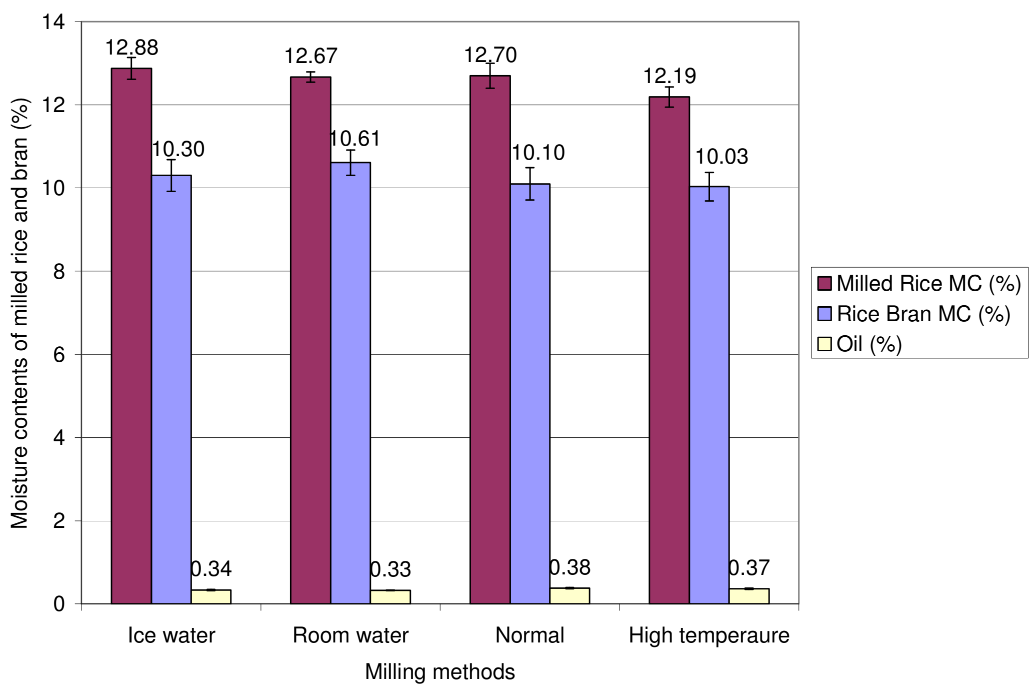

Figure 6. Moisture contents of milled rice and rice bran and fat contents of milled rice obtained with different milling conditions.

The total and head rice yields did not change much under different milling conditions, except for head rice yield obtained at high milling temperature (Fig 7 and Table 2). Such results were very different from what we have found in the past. In the previous research we had found that total and head rice yields reduced significantly with the increase of milling temperature. The degrees of the changes in the yields varied with rice quality. However, how the rough rice quality affects the milling quality at different temperatures is still not known. It is believed that the rough rice quality could be the major factor resulting in such results of milling yields, which did not change as much as expected. Therefore, it is necessary to study how the rough rice quality with known histories, such as drying temperature and harvest moisture content, is related to the milling quality under different milling temperatures.

From the mass balance data shown in Table 2, it is very important to observe that the average total moisture loss from rice bran and milled rice was 2.5% under the tested milling temperatures. The moisture loss should result in lower the head rice yield, which is calculated based on the weight of milled rice. Since the rice sample milling temperatures were significantly higher than the temperature in commercial mill, the head rice loss caused by the moisture evaporation in the rice sample milling could be higher than the commercial milling process. In order to determine if the moisture loss in the current rice sample milling was in the reasonable range of commercial milling practice, it will be very useful to know how much moisture loss occurs in commercial milling.

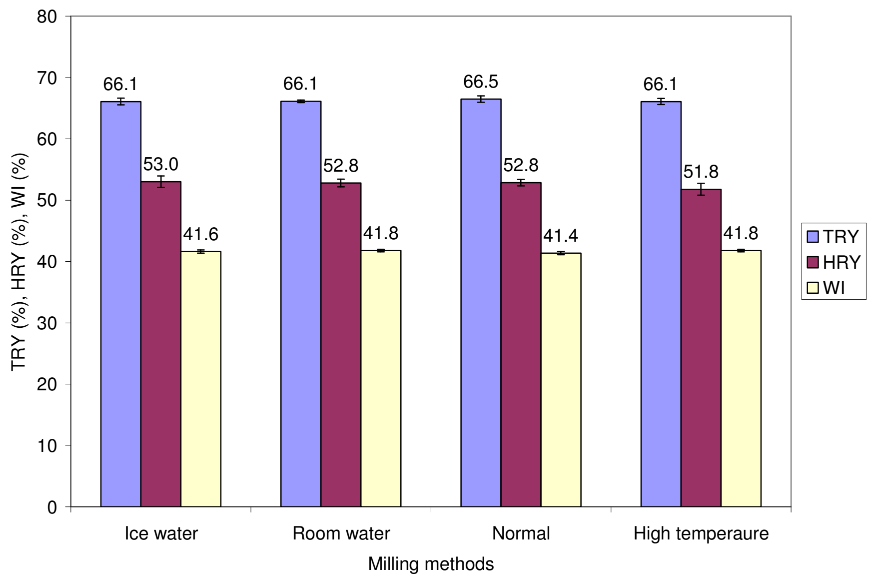

Figure 7. Total rice yield (TRY), Head rice yield (HRY) and whiteness index (WI) obtained under different milling conditions.

Table 2. Mass balance of rice milling under different milling conditions (g)

Milling conditions	Dockage	Rough rice	Hull	Brown rice	Milled rice	Bran	Moisture loss
Ice water	12.5	987.5	181.4	806.1	660.7	122.1	23.3
Room water	11.2	988.8	179.2	809.6	661.2	122.9	25.5
Normal	13.2	986.8	181.4	805.5	665.2	116.8	23.4
High temperature	11.2	988.8	178.9	809.9	660.9	119.5	29.4
Average (%)	1.2	98.8	18.0	80.8	66.2	12.0	2.5

Effects of Post-Milling Cooling Conditions

The cooling curves (Fig. 8) showed that the open pan cooling significantly reduced the required cooling time, due to the high cooling rate of the thin layer of rice in the pan (Fig. 9). As expected, the high post-milling cooling temperature reduced the cooling rate or increased the cooling time required to reach the room temperature. The low temperature and open container cooling methods did not improve the cooling much. However, the open container and open pan cooling methods resulted in slightly more moisture losses compared to closed container cooling. The total weights of milled rice cooled by open container and pan were about 5 g lower than the weight of the rice cooled in the closed container, which means about 0.5 percentage point reduction in total rice yield. The reduction could partially be due to the moisture loss that occurred during cooling. Therefore, open container and open pan cooling methods are not recommended.

In general, the high milling temperature led to higher single and multiple fissures in the milled rice (Figs. 11 and 12). Especially, it can be seen that normal and high temperature milling had significantly low percentages of non-fissure rice kernels. This shows the advantage of low temperature milling. However, it is difficult to see any trends between fissure rates and post-milling cooling methods.

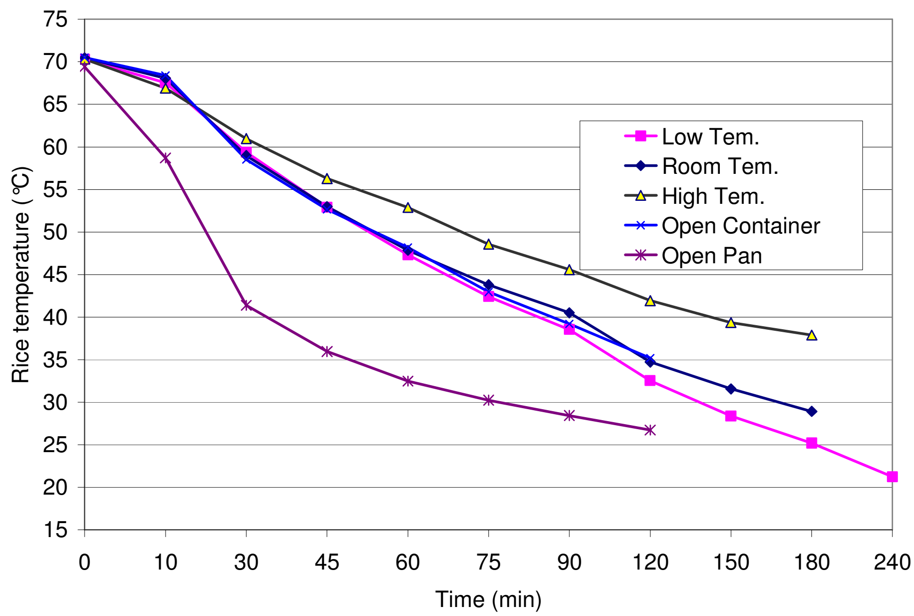

Figure 8. Cooling curves of milled rice milled under normal conditions

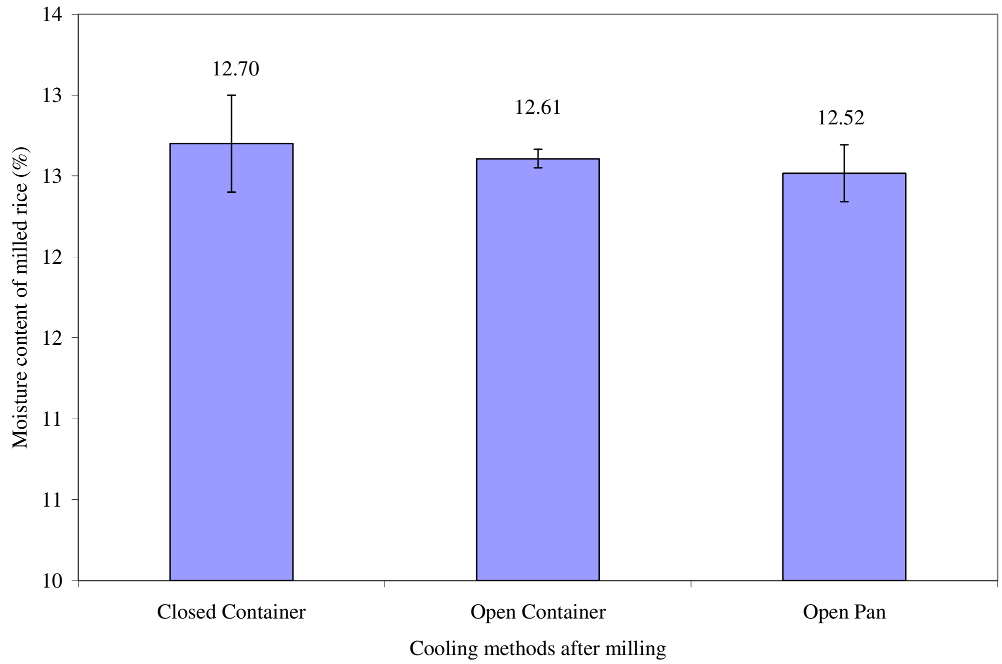

Figure 9. Moisture contents of milled rice with different cooling methods at room temperature.

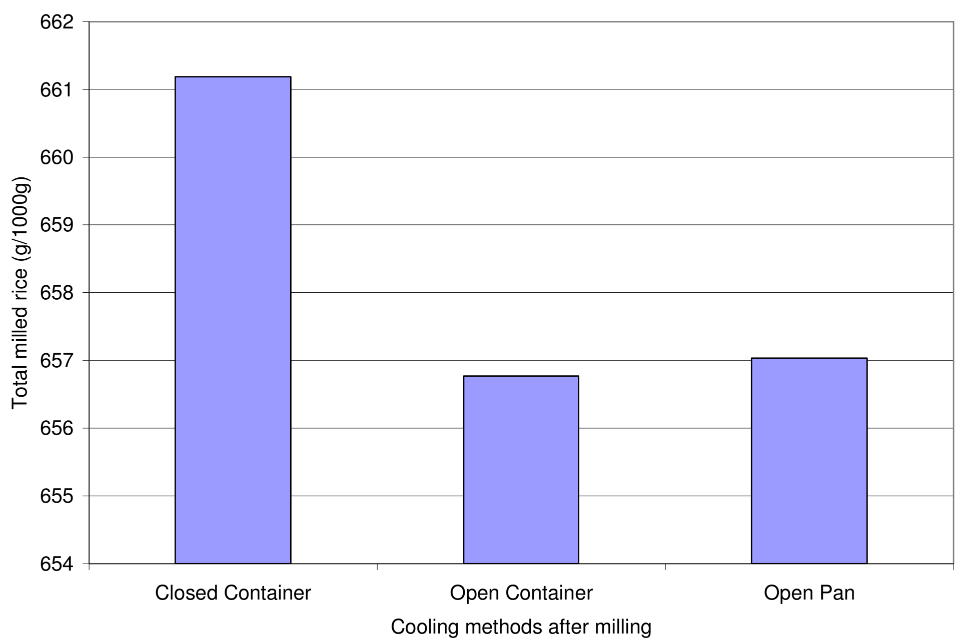

Figure 10. Total milled rice weights obtained with different cooling conditions

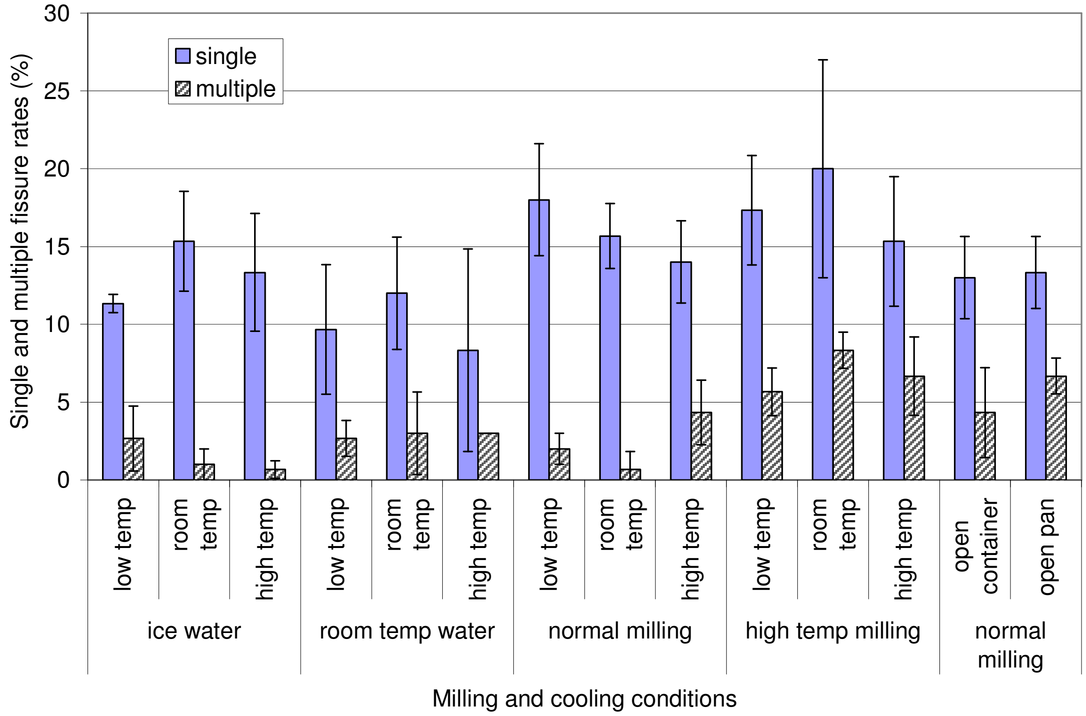

Figure 11. Fissure rates of milled rice with different milling and post-milling cooling conditions

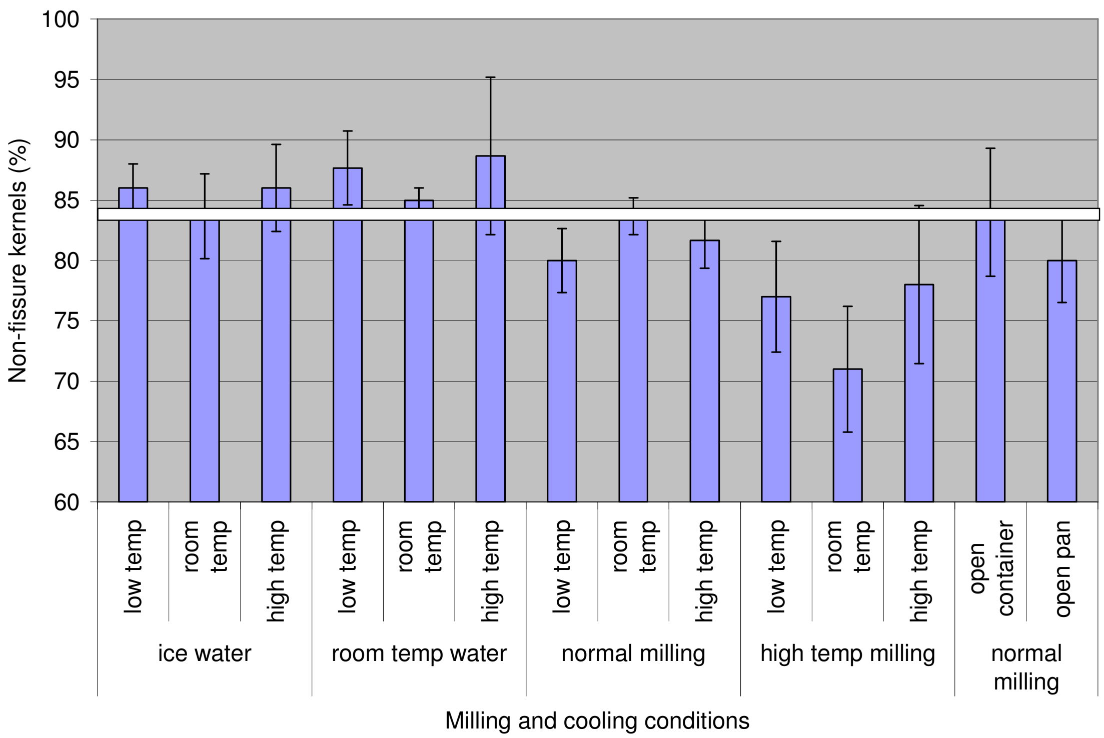

Figure 12. Non-fissure kernels of milled rice obtained with different milling and post-milling cooling conditions.

Recommendations for rice post-milling handling procedures

Based on the results obtained from this study, the current post-cooling procedures using closed containers are appropriate compared to the open container and open pan cooling methods used in other regions in the U.S. Different cooling temperatures may only affect the cooling rates, but not the quality results. Since the low milling temperature reduced the fissure rate in milled rice, it is recommended for use in rice sample milling.

Conclusions

The temperatures of milled rice samples obtained with different milling methods could directly be related to the fissure rates of whole rice kernels, especially at high temperatures. Using cooling to lower the milling temperature could reduce the fissure rate. Open container and pan cooling methods had more moisture losses and further resulted in lower appraised total rice yield than closed container cooling, and therefore, are not recommended. Post-milling cooling temperature did not show any significant effect on the fissure rate even though low temperature significantly reduced the cooling time. Based on mass balance of the rice sample milling process, it was found that about 2.5% of sample weight was lost during milling, which may primarily be due to moisture evaporation. The moisture evaporation could be reduced if the rice samples were milled at further reduced milling temperature than the temperatures that have been tested.

PUBLICATIONS OR REPORTS

N/A

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

Our previous research results have shown that the rice milled with the McGill No. 3 had significant higher temperature than the rice from current commercial mills. The milled rice of high temperature as a result of the rice sample milling need to be cooled to room temperature before the quality evaluation is conducted. The cooling process may affect the rice milling quality appraisal. The research for this year had three specific objectives: (1) determine the effects of the temperature of milled rice on quality evaluation results; (2) study the fissure rate and moisture loss of milled rice with different cooling procedures; and (3) develop recommendations for rice post-milling handling procedures.

Medium grain rice, M202, with moisture content of 11.5±0.2% was used for this study. The samples were milled with McGill No. 3 laboratory mill at CDFA Lab under four conditions following the standard Western milling procedures of Federal Grain Inspection Service (FGIS). The four milling conditions included normal milling, milling at high temperature, milling with cooling using ice water and room temperature water as cooling media. The different milling methods were used to obtain various temperatures of milled rice from 55.6 to 79.5°C. To determine the effect of post-milling cooling on appraised rice quality, the milled rice samples were cooled in closed plastic containers with three temperatures, 15, 23, and 35°C, which were used to simulate different cooling environmental temperatures. The rice milled samples with the normal milling condition were also cooled in open container and pan, which were used to simulate the cooling methods used in the other regions of the U.S.

The evaluated quality indicators of milled rice included total rice yield (TRY), head rice yield (HRY), Whiteness Index (WI), fissure rate, and fat content. The moisture contents of rough rice and different fractions were also measured to determine the mass balance of the different fractions and moisture loss caused by the milling and cooling processes. The results showed that the temperature of milled rice samples could directly be related to the fissure rates of whole rice kernels, especially at high temperatures. Using heat exchanger cooling to lower the milling temperature could significantly reduce the fissure rate. Open container and pan cooling methods had more moisture losses and further resulted in lowering appraised quality than closed container cooling. Therefore, they are not recommended. Post-milling cooling temperature did not show any significant effect on fissure rate even though the low temperature of the post-milling cooling reduced required cooling time significantly. Based on mass balance of the rice sample milling process, it was found that about 2.5% of rough rice sample weight was lost during milling, which may primarily be due to moisture evaporation. The moisture evaporation might be reduced if the rice samples were milled at further reduced milling temperature.

Based on the results obtained from this study, the current post-cooling procedures using closed containers are more appropriate compared to the open container and open pan cooling methods used in other regions of the U.S. Different cooling temperatures may only affect the cooling rates, but not the quality results. Since the low milling temperature reduced the fissure rate in milled rice, it is recommended to be used in rice sample milling.

Acknowledgement

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