PROJECT NO. RU-6

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

January 1, 2006– December 31, 2006

PROJECT TITLE: Improvement of Consistency and Accuracy of Rice Sample Milling
- Development of Standard Rice Sample Preparation Procedures

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

Objectives

1. Determine the effects of rough rice quality with known histories, such as harvest moisture and drying temperature, on appraised rice milling quality obtained by different milling procedures.
2. Quantify the effects of rice sample preparation procedures, such as storage time after drying, on rice milling quality appraisal.
3. Develop recommendations for establishing standard rice sample milling and preparation procedures.

Experimental Procedures

<u>Effect of rough rice quality on appraised milling quality by different milling procedures</u>

Materials and Milling Procedures

Californian M202 rice sample with harvest moisture content of 24.8% (w.b.) obtained from Farmers' Rice Cooperative was used in this study. To create rough rice with different milling quality, the rice sample was split into three large samples. The two of them were laid on the concrete floor to be gradually dried to 22.7% and 20.2% moisture at the Food Processing Laboratory in the Department of Biological and Agricultural Engineering, UC Davis. The three moisture contents are called original moisture contents then all three rice samples were dried with air at four different temperatures, 23, 36, 43 and 53°C to 18% from the original moisture (MC). Then the rice was further dried to 14% using air at 23°C. The air at 23°C is ambient air of the laboratory without heat.

The samples (1000g each) were milled with the McGill No. 3 laboratory mill (Fig. 1) at California Agri Inspection Co. Ltd (CAICL). The rice samples were milled with three different procedures (methods); standard Western Milling Procedures with and without cooling (referred as Low temperature milling (LM) and Normal Milling (NM) in this report) and standard Southern Milling Procedures (SMP) of Grain Inspection Packers and Stockyards Administration (GIPSA). The standard Western Milling Procedures uses a 10 pound weight for milling and a 2 pound weight for polishing, but the standard Southern Milling Procedures uses a 7 pound weight or milling and 0 pound weight for polishing.

The current milling practice at CAICL is to cool the cutter bar to an initial temperature of 48-54°C (115 -130°F) using a fan before a new rice sample is milled using the standard Western Milling Procedures. The initial temperature was also used in the Normal Milling and Southern Milling Procedures in this study.

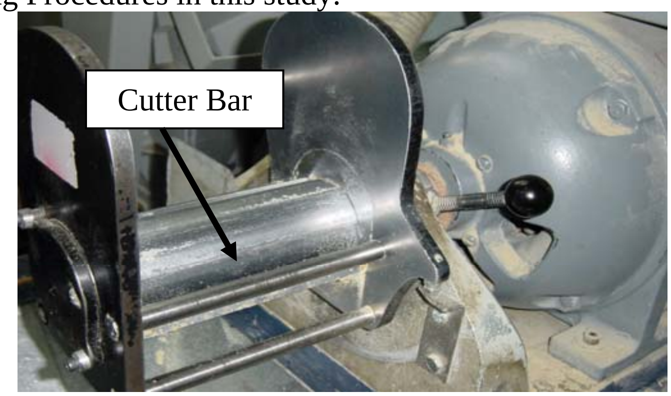


Fig. 1 McGill No.3 rice sample mill and location of cutter bar temperature measurement

To reduce the milling temperature (including rice and equipment temperatures) during milling, two external and internal cooling devices developed in the previous year were used. They were named as saddle and cutter bar heat exchangers, respectively. The cooling medium (ice water) was pumped through the heat exchangers during the milling process. The experimental set up of the cooling tests is shown in Fig 2. The initial cutter bar temperature was 34-38°F. 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 current standard Western Milling Procedures at CAICL. The milling procedure is called low temperature milling in this study. The temperature of milled rice was also measured after milling. The experimental design is shown in Table 1.

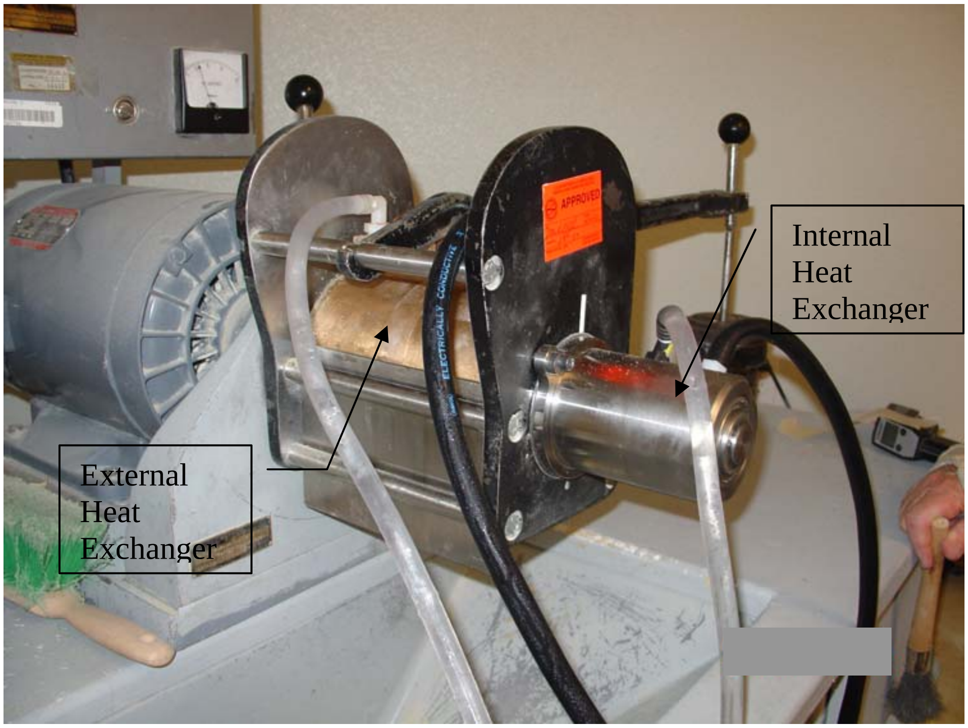


Fig. 2 Set-up of internal and external heat exchangers

Table 1. Experimental design for studying effects of rice history and milling procedures on milling quality

Rice		Southern milling procedure (SMP)	Western milling procedure (NM)	Western milling procedure with cooling (LM)
Original MC (%)	Drying Temperature (°C)			
24.8%	23	X	X	X
	36	X	X	X
	43	X	X	X
	53	X	X	X
22.7%	23	X	X	X
	36	X	X	X
	43	X	X	X
	53	X	X	X
20.2%	23	X	X	X
	36	X	X	X
	43	X	X	X

	53	X	X	X

Measurement of Milled Rice Quality

The evaluated quality indicators included total rice yield (TRY), head rice yield (HRY), Whiteness Index (WI) and lipid content (LC. The WI was used to evaluate the whiteness of milled rice determined with Whiteness Tester, C-300, (Kett Electronic Laboratory, Tokyo, Japan). A higher index number indicates whiter milled rice. The lipid content was measured with Foss NIR (Foss NIR Systems-5000, U.S.A).

Effect of rice sample preparation procedures on milling quality

A Californian M202 rice sample with harvest moisture of 25.1% (w.b.) was used to study the effect of rice sample preparation procedures on milling quality. To create rice sample with different original moisture contents, the rice sample was split into two large samples and one of them was dried to 20.5% with the procedures mentioned above. Both of the samples were used for this part of the study.

The rice samples were dried with three different drying procedures. One was the current drying practice in rice industry, which used 43°C air drying for 20 min followed by a 4 hr tempering at 43°C in a container with rice bed thickness of 12 cm. The second procedure used ambient air drying (about 23°C) to remove 2% moisture in each drying pass followed by 4 tempering at room temperature. The third drying procedure was to dry the rice samples from the original moisture contents to 14% by one single pass without tempering. The moisture removals and time used in each drying pass for different drying procedures were recorded and reported.

The rice samples were stored in Zip-lock plastic bags after drying. To determine the effect of storage time after drying, the moisture and milling quality of the rice samples were measured at 1, 4, 7, 14 and 28 days. To exam the accuracy of different moisture measurement methods, three moisture measurement methods were used; standard oven method (130°C, 24 hrs), Dickey-John (Auburn, Illinois, U.S.A) and single kernel moisture meter, PQ-510,(Kett Electronic Laboratory, Tokyo, Japan). The moisture contents of original samples and dried samples before milling were measured using all three methods. The samples were milled using the standard Western Rice Milling Procedures and measured milling quality included TRY, HRY, and Whiteness Index.

SUMMARY OF 2006 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVES:

Effect of rough rice quality on appraised milling quality by different milling procedures

Tables 2 to 4 show the milling quality results of rough rice with different drying history and milling methods. In general, rice with high original moisture content had a slightly low milling quality (TRY and HRY) compared to the rice with low original moisture content even though the difference may not be significant. The reason could be due to too much moisture removal (from original to 18%) for high moisture rice during a single drying step causing fissures.

A very clear quality reduction trend of milled rice was observed when the rice samples were dried at high temperature, especially at 53°C. But there was no significant difference in quality for rice obtained with 23 and 36°C drying temperatures. The results indicated that rice samples with different milling quality were created as we expected, which were used for identifying the effect of milling procedures on appraised milling quality.

The milling results showed that low temperature milling and normal milling had the highest and lowest TRY and HRY, respectively, for any sample milled with the three milling procedures. The milling quality (TRY and HRY) of Southern milling procedures was between the normal milling and low temperature milling. But differences in WI and LC of rice milled with the three procedures were not significantly different even though the rice milled with normal milling was slightly whiter than others.

Table 2. Milling quality of rice with different drying history and milling methods
(Original rough rice moisture = 24.8%)*

Drying air temperature (°C)	Milling procedures[a]	Quality of milled rice[b]			
		TRY	HRY	WI	LC
23	LM	66.74 a	63.52 a	41.80 a	0.35 a
	NM	65.49 a	60.95 bc	41.57 a	0.30 a
	SMP	65.78 a	61.92 b	41.77 a	0.34 a
36	LM	68.27 a	64.49 a	42.07 ab	0.35 a
	NM	66.74 c	61.54 b	42.53 a	0.43 a
	SMP	67.39 abc	63.21 a	41.87 ac	0.36 a
43	LM	68.77 a	60.15 a	42.20 ab	0.42 a
	NM	66.78 c	55.27 c	42.47 a	0.36 a
	SMP	67.74 abc	58.14 b	41.73 ac	0.36 a
53	LM	68.59 a	54.99 a	42.23 a	0.45 a
	NM	67.27 bc	50.85 b	42.57 a	0.31 a
	SMP	67.40 b	51.91 b	42.17 a	0.39 a

* Sample letter indicated no significant difference between different milling procedures at p<0.05
[a] LM = low temperature milling(ice water), NM = western milling procedure, SMP = southern milling procedure
[b] TRY = total rice yield, HRY = head rice yield, WI = whiteness index, and LC = lipids content

Table 3. Milling quality of rice with different drying history and milling methods
(Original rough rice moisture = 22.7%)

Drying air temperature (°C)	Milling procedures[a]	Quality of milled rice[b]			
		TRY	HRY	WI	LC
23	LM	68.35 a	65.14 a	41.1 a	0.29 a
	NM	66.46 c	61.63 c	41.3 a	0.24 a
	SMP	67.49 b	63.65 b	40.43 b	0.31a
36	LM	69.13 a	66.12 a	41.6 b	0.27 b

	NM	67.41 b	62.42 c	42.23 a	0.25 b
	SMP	68.71 a	64.38 b	41.2 b	0.43 a
43	LM	68.70 a	60.89 a	42.17 a	0.31 a
	NM	67.53 bc	57.70 c	42.37 a	0.28 a
	SMP	68.20 ab	59.41 b	41.77 a	0.39 a
53	LM	69.10 a	49.41 a	42.23 b	0.48 a
	NM	67.61 bc	45.05 c	43.10 a	0.33 a
	SMP	68.19 ab	47.83 b	42.47 b	0.38 a

* Sample letter indicated no significant difference between different milling procedures at $p<0.05$
[a] LM = low temperature milling(ice water), NM = western milling procedure, SMP = southern milling procedure
[b] TRY = total rice yield, HRY = head rice yield, WI = whiteness index, and LC = lipids content

Table 4. Milling quality of rice with different drying history and milling methods
(Original rough rice moisture = 20.2%)

Drying air temperature (^{o}C)	Milling procedures[a]	Quality of Milled Rice[b]			
		TRY	HRY	WI	LC
23	LM	68.95 a	65.59 a	42.27 c	0.45 a
	NM	67.05 b	62.91 c	43.10 a	0.41 a
	SMP	68.04 a	64.30 b	42.73 abc	0.43 a
36	LM	69.43 a	65.84 a	42.30 a	0.53 a
	NM	67.93 bc	63.67 c	42.77 a	0.42 a
	SMP	68.43 b	64.27 b	42.47 a	0.35 a
43	LM	68.79 a	64.32 a	42.37 b	0.43 a
	NM	67.40 c	61.31 c	43.07 a	0.31 a
	SMP	68.21 ab	62.68 b	42.27 b	0.39 a
53	LM	68.38 a	57.56 a	42.40 a	0.38 a
	NM	66.83 bc	54.14 c	43.00 a	0.32 a
	SMP	67.08 b	54.92 bc	42.47 a	0.33 a

* Sample letter indicated no significant difference between different milling procedures at $P<0.05$
[a] LM = low temperature milling(ice water), NM = western milling procedure, SMP = southern milling procedure
[b] TRY = total rice yield, HRY = head rice yield, WI = whiteness index, and LC = lipids content

To illustrate the improvement in milling quality by using low temperature milling, the difference in HRY and WI of milled rice using low temperature milling vs. normal milling procedures and Southern milling procedure vs. normal milling procedures were calculated and shown in Fig. 3 and 4. It is clear that low temperature milling and Southern milling procedures have significantly improved HRY from 3% to 4% and 1.5% to 2%, respectively, on average, but not much difference in color of the milled rice was detected. The results confirmed our previous findings that low temperature milling improved the milling quality. Also, from this study it has been observed that the improvement was more significant for low quality rice than the high quality rice. The reason caused the difference in appraised milling quality could be mainly due to the milling temperatures of different milling procedures. It is clear that low temperature milling had significant lower milled rice temperature than the normal milling and Southern Milling Procedures, which resulted in reduced breakage of milled rice (Fig. 5).

Based on all results about rice milling consistency and accuracy obtained in the last three year, it is recommend that milling procedures in the United States need to be standardized. Low temperatures or controlled milling temperatures in rice sample milling should be used if it is possible.

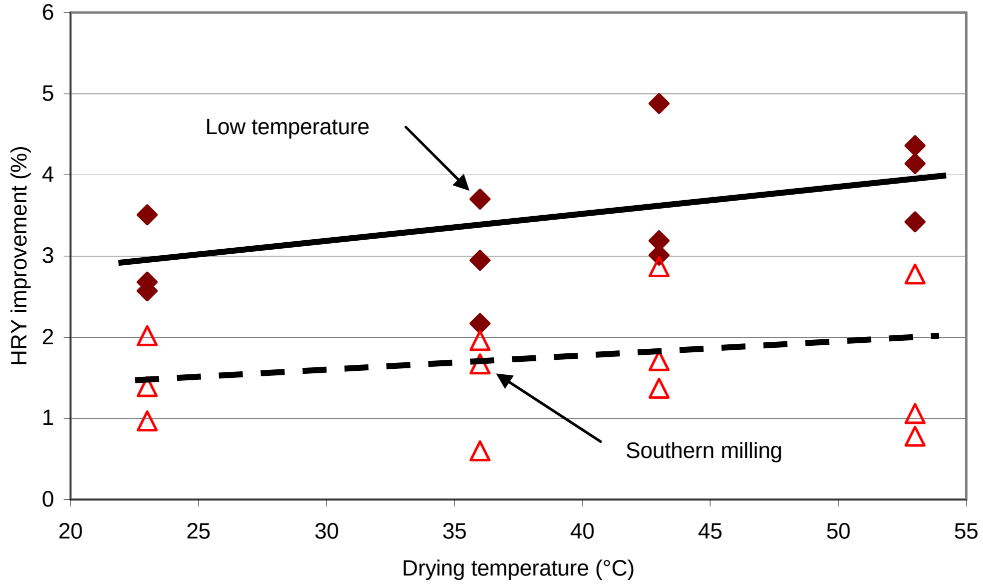


Fig 3. HRY improvement with low temperature and Southern milling procedures compared to Western milling procedures

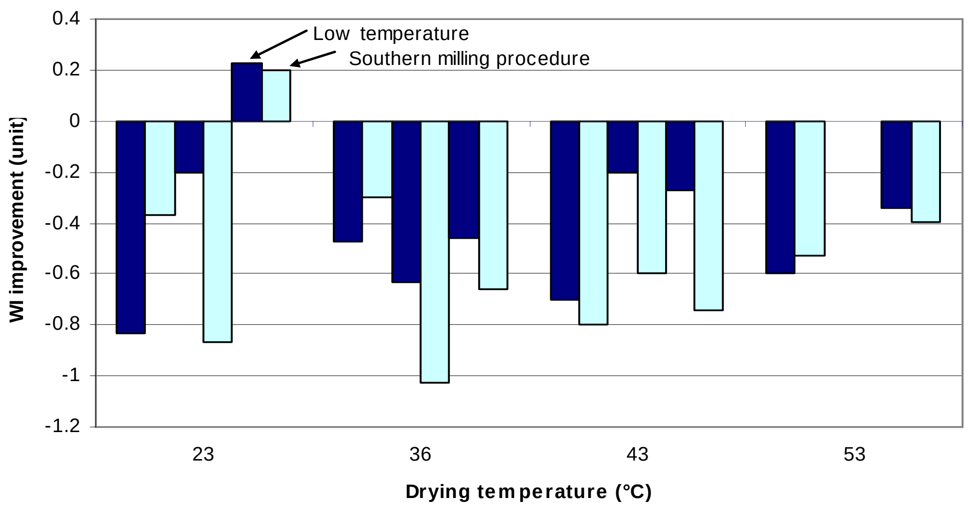


Fig 4. WI changes of rice milled with low temperature and Southern milling procedures compared to Western milling procedures

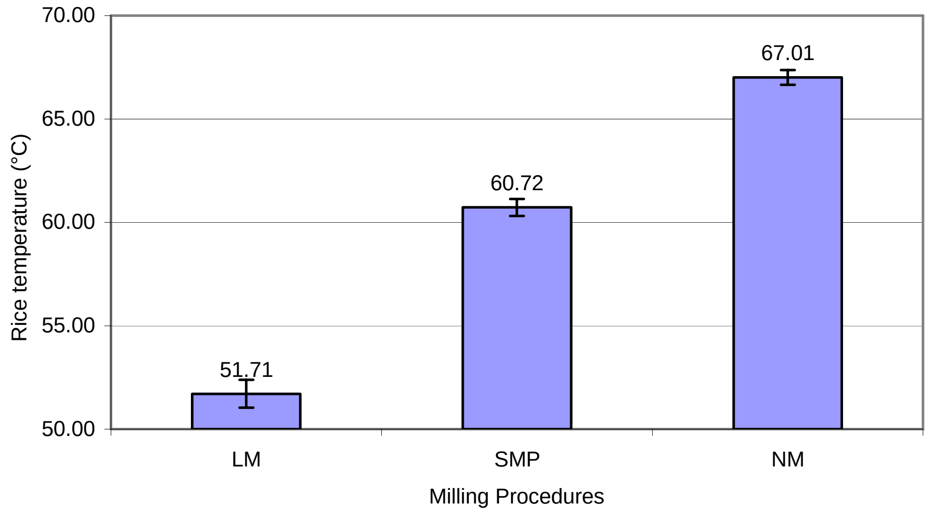


Fig. 5 Temperatures of milled rice with different milling procedures

Effect of rice sample preparation procedures on appraised milling quality

Moisture change with storage time

In general, the storage time and drying methods did not cause any significant change in measured moisture contents of rice samples during storage up to 28 days after drying (table 5). However, it is clearly observed that the moisture results measured with single kernel moisture meter was consistently higher than those measured with oven and Dicky-John methods. For example, the overall average moisture contents of rice samples with 25.1% original MC dried at 43°C were 13.64±0.12%, 13.08±0.04%, and 14.30±0.02% measured with the oven, DKJ and SKM methods, respectively. The average maximum difference among the three methods was less than 1.22%. DKJ had lowest MC value which was about 0.56% lower than the oven result. When these methods were used for measuring the moisture contents before drying, the results were 25.10±0.20%, 25.27±0.15%, and 25.07±0.15% for rice with MC level at about 25% and 20.50±0.19%, 20.3±0.1%, and 20.2±0.1% for rice with MC level at 20% measured with oven, DJK and SKM methods, respectively. This means that the DKJ and SKM need to be calibrated at the full moisture range to ensure accurate results of moisture measurement.

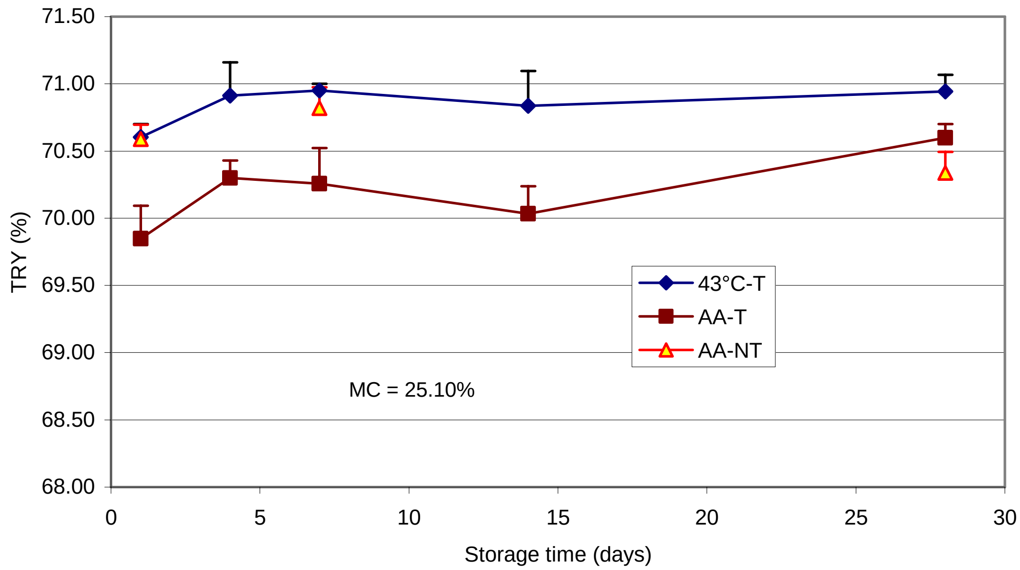
Table 5. Moisture contents of rice samples during storage after drying

Original MC (%)	Drying methods	MC measurement methods	Storage time (days)					
			1	4	7	14	28	AVE
25.1	43°C	Oven	12.38±0.17	12.61±0.15	12.63±0.15	12.57±0.11	12.85±0.06	12.61±0.04
		DKJ	12.40±0.14	12.50±0.12	12.53±0.05	12.43±0.13	12.43±0.10	12.46±0.04
		SKM	13.45±0.06	13.75±0.06	13.50±0.08	13.88±0.05	13.68±0.05	13.65±0.01
	AA-Temp	Oven	13.83±0.05	14.00±0.46	14.03±0.31	14.13±0.12	14.28±0.13	14.05±0.17
		DKJ	13.30±0.14	13.53±0.05	13.55±0.13	13.53±0.15	13.48±0.10	13.48±0.04
		SKM	14.43±0.10	14.60±0.14	14.43±0.10	14.85±0.06	14.68±0.05	14.60±0.04
	AA	Oven	14.02±0.45		14.17±0.33		14.2±0.09	14.13±0.18
		DKJ	13.05±0.13		13.45±0.06		13.30±0.08	13.27±0.04
		SKM	14.33±0.10		14.45±0.10		14.55±0.06	14.44±0.02
20.5	43°C	Oven	12.86±0.10	13.01±0.08	13.24±0.27	13.58±0.29	13.48±0.32	13.23±0.11
		DKJ	12.60±0.08	12.70±0.08	12.55±0.06	12.48±0.05	12.55±0.06	12.58±0.01
		SKM	13.88±0.05	14.15±0.06	14.23±0.05	13.78±0.10	13.75±0.06	13.96±0.02
	AA-Temp	Oven	13.12±0.09	13.41±0.35	13.42±0.36	13.70±0.20	13.90±0.30	13.51±0.12
		DKJ	12.80±0.08	12.98±0.15	13.00±0.08	13.05±0.10	13.08±0.05	12.98±0.04
		SKM	14.15±0.06	14.30±0.08	14.55±0.06	14.23±0.05	14.28±0.10	14.30±0.02
	AA	Oven	14.01±0.14		14.38±0.32		14.50±0.09	14.30±0.12
		DKJ	13.60±0.00		13.75±0.13		13.90±0.08	13.75±0.07
		SKM	14.73±0.10		14.88±0.05		15.05±0.06	14.88±0.02

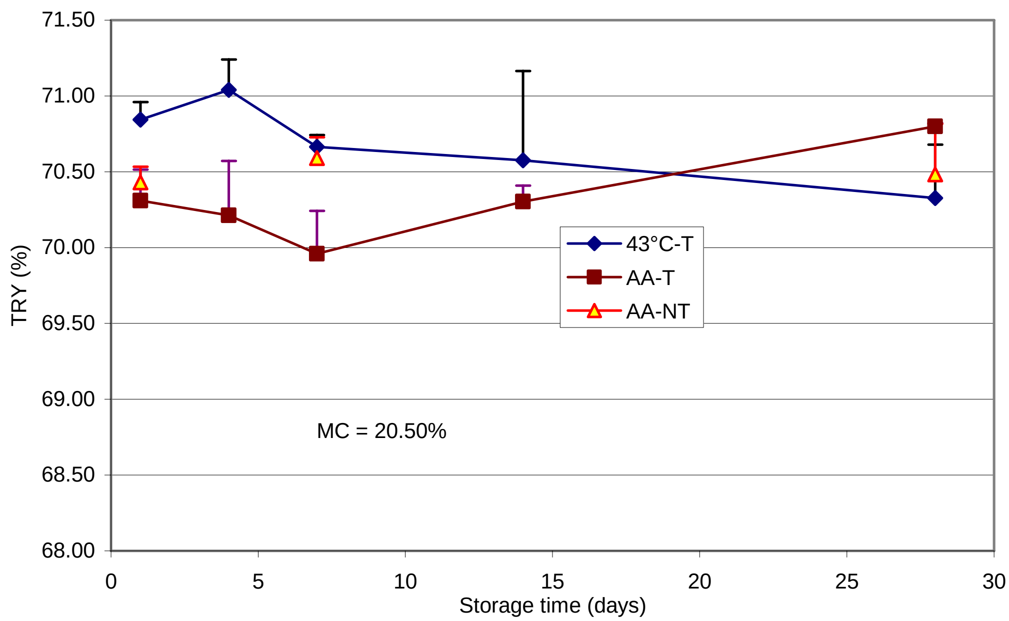
Milling quality change with storage time

The milling quality results of rice at different storage times are shown in Figs. 5-7. For TRY, the maximum variation (less than 1%) among the different treatments was considered not significant. However, the significant HRY variation has been observed. The trend of increased HRY after four day storage was very clear compared to the rice milled one day after drying, especially for the rice dried at 43°C. However, it is still unknown if the minimum required storage is less four days, which needs to be further studied. More importantly to notice, the difference in HRY between rice dried with ambient air and 43°C was about 8% and 2% when the original MC were 25.10% and 20.50%, respectively. The whiteness of 43°C dried rice was slightly lower than ambient air dried rice with original MC of 25.10%, but no difference was observed for rice with 20.50%. When the moisture removal at each drying step was examined, it was found that the moisture removal was less 2% (1.7%, 1.8%, 1.8%, 1.5%, 1.4%, 1.3%, 1.1%, 0.7%, and 0.7% for 25.10% MC rice and 1.3%, 1.3%, 1.3%, 1.0%, 1.0%, and 0.6% for 20.50% MC rice. It is unexpected that the rice dried with 43°C has so much HRY reduction compared to ambient air dried rice even the moisture removal was less than 2% in each step with tempering treatment for rice dried at 43°C. Normally, it has been believed that less than 2% MC removal in each drying pass should not cause HRY loss. The exact reason that caused the so significant loss, especially for the rice with 25.1% original MC, was not known, which it may be related to the tempering temperature. It is suggested to further study the effect of tempering temperature after drying on the appraised milling quality. It has also observed that it took 9 steps with current drying procedure to dry the rice from 25.10% to about 14%, which is time consuming. There is a need to develop high efficient rice sample drying method. When the HRY of rice dried with ambient air with and without tempering, the HRY were very similar.

All the results indicated that when the rice has high original MC, it needs to be handled carefully and appropriate sample preparation procedures are needed.

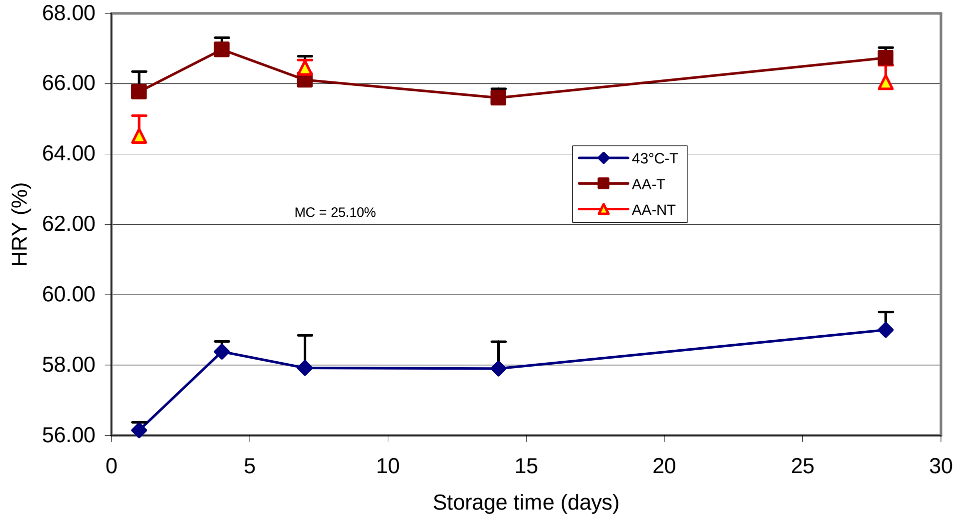


(a)

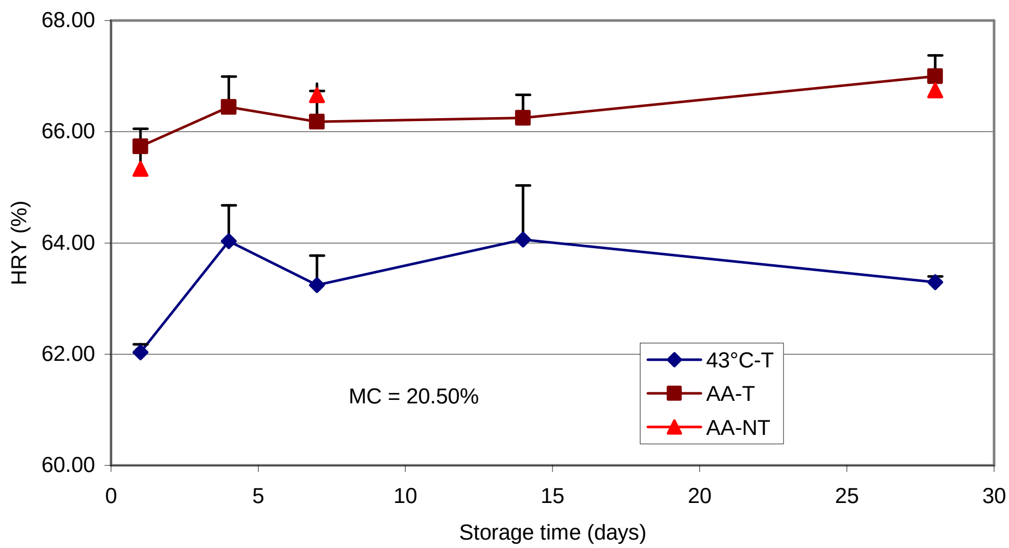


(b)

Fig. 5. Effect of storage on total rice yield
(a) MC = 25.10%; (b) MC = 20.50%

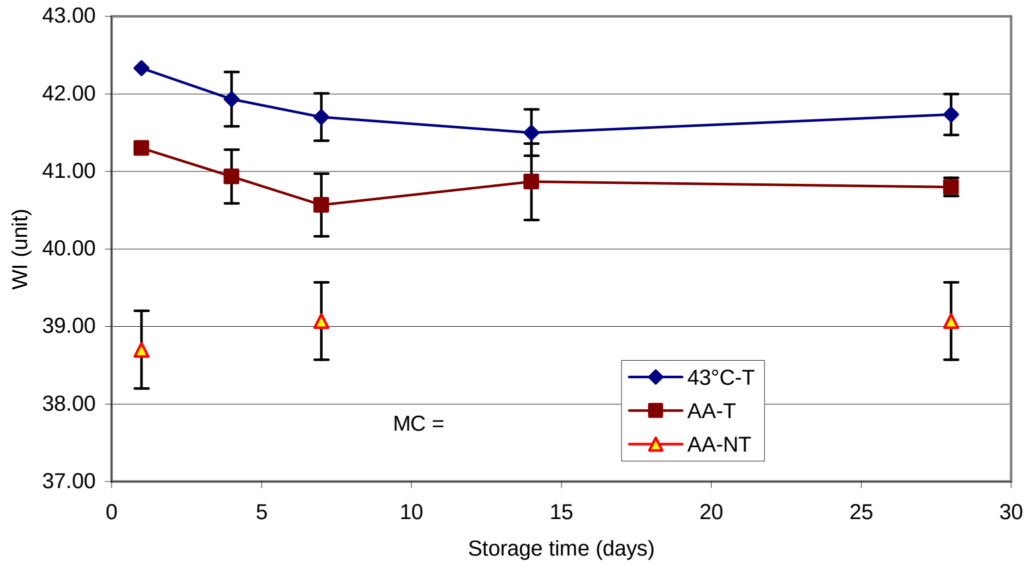


(a)

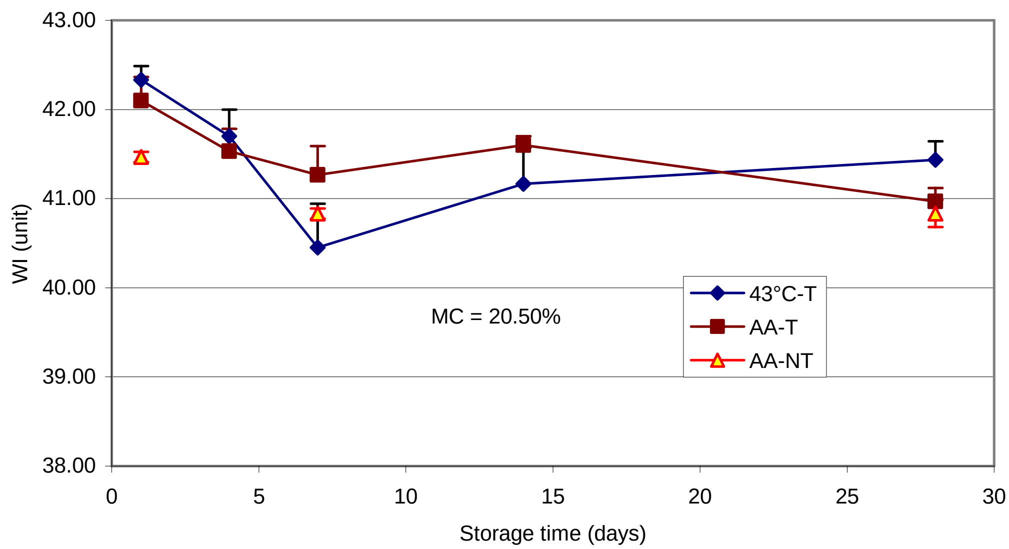


(b)

Fig. 6. Effect of storage on head rice yield
(a) MC = 25.10%; (b) MC = 20.50%



(a)



(b)

Fig. 7. Effect of storage on whiteness index
(a) MC = 25.10%; (b) MC = 20.50%

<u>Recommendations</u>

Based on all results about rice milling consistency and accuracy obtained last three year, it is recommend that milling procedures in the United States need to be standardized. Low temperature or controlled milling temperature in rice sample milling should be used if it is possible.

For rice sample preparation procedures, it is suggested that rice to be stored at least four days to avoid the negative effect of storage time on appraised milling quality. However, rice with high original MC had very low HRY when the samples were dried with 43°C heated air, which may related to the tempering procedures and need to be further studied.

PUBLICATIONS OR REPORTS

N/A

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

The research in this report period focused on two objectives. One was to study the effect of rough rice quality with known history on appraised milling quality by different milling procedures. Another one was to identify the effect of rice sample preparation procedures, such as drying temperature and storage time after drying, on appraised milling quality.

For achieving the first objective, three rice samples, originated from the same sample, with moisture contents of 24.8%, 22.7% and 20.2% were dried using four different temperatures, 23, 36, 43, and 53°C. When the samples were milled, they had significant differences in milling quality. The high drying temperatures resulted in a significantly lower milling quality than the low drying temperatures. When these samples were milled with three different milling procedures, Western Milling Procedures, Western Milling Procedures with cooling (low temperature milling) and Southern Milling Procedures, the low temperature milling and Southern Milling Procedures had 3% to 4% and 1.5% to 2% improvement, respectively, in head rice yield than the standard Western Milling Procedures. The results were similar to the finding we have obtained in the previous two years. More importantly, we have observed that low temperature milling improved appraised rice milling quality about 1% more on average for low quality rice than high quality rice. This indicates low temperature milling could be a viable approach for both sample milling and commercial rice milling. Based on all results about rice milling consistency and accuracy obtained from last three years, it is recommend that milling procedures in the United States need to be standardized. Low temperature or controlled milling temperature in rice sample milling should be used if it is possible.

To study the effect of rice sample preparation procedures on appraised milling quality, rice samples with two moisture contents, 25.1% and 20.5%, were dried with three different drying procedures. One was the current standard drying procedure of 43°C drying for 20 min followed by a 4 hr tempering for each drying pass. The rice also dried with ambient air (about 23°C) with and without tempering. The one with tempering removed 2% moisture in each drying pass followed by a 4 hr tempering. The one without tempering dried from the original moisture content to 14% in a single pass. The appraised milling quality results showed that the 43°C drying temperature has up to 8% lower head rice yield than the ambient air drying, which was unexpectedly high and needs to be further studied. When the dried rice was milled one day after drying had about 2% lower head rice yield compared to the samples had storage time more than 4 days. The moisture measurement results at different storage durations did not show any significant change, which were measured with three methods, oven method (130°C for 24 hours), Dicky-John moisture meter, and single kernel moisture meter. Therefore, for rice sample preparation procedures, it is suggested that rice should be stored at least four days to minimize the negative effect of storage time on appraised milling quality. However, rice with high original

MC had very low HRY when the samples were dried with 43°C heated air, which may be related to the tempering procedures and needs to be further studied.

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