ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
Jan. 1, 2001 to Dec. 31, 2001

PROJECT TITLE: Maintaining rice quality after harvest

PROJECT LEADERS:
Randall Mutters, Farm Advisor UCCE Butte Co.
James Thompson, Extension Specialist Biological & Agricultural Engineering, UCD

PRINCIPAL INVESTIGATORS:
Elaine Champagne, Scientist, USDA-ARS, SRRL, New Orleans, LA
Casey Grimm, Scientist, USDA-ARS, SRRL, New Orleans, LA
Eunice Tan, Graduate Student, Biological & Agricultural Engineering, UCD
David Slaughter, Professor, Biological & Agricultural Engineering, UCD
ZhongLi Pan, Adjunct Professor, Biological & Agricultural Engineering, UCD
Jerry Knutson, Development Engineer, Biological & Agricultural Engrg, UCD
James Eckert, Postgraduate researcher, UCCE/UCD

COOPERATORS:
Dave Jones, Farmer's Rice Cooperative, Sacramento, CA
Dale Rice, CDFA, West Sacramento, CA

LEVEL OF 2000 FUNDING:
$23,807

OBJECTIVES AND EXPERIMENTS:

Effect of holding time and rice moisture content and development of off-odor

We repeated the laboratory incubation tests conducted last season, to verify the effects of variety, holding time and grain moisture on quality loss of temporarily stored, field moisture rice.

In the laboratory, 500 pound batches of freshly harvested rice were held in insulated metal boxes for 48 hrs. Twelve batches of Akitakomachi and nine batches of M202 with moistures ranging from 20 to 28% were tested. During the test we measured grain temperature and carbon dioxide as indicators of general microbial activity. Previous research indicated that off-odors in high-moisture grain were caused by a range of microbes including bacteria, yeasts, fungi, and actinomycetes. A hand-held sensor was used to detect ethanol and we assumed that this volatile organic compound (VOC) is an indicator of the presence of other VOCs that cause off-odor. We also collected and dried grain samples for identification of VOCs by gas chromatography mass spectrometry and collected larger samples for a taste panel evaluation. Dr. Elaine Champagne, USDA-ARS, New Orleans is conducting these analyses and the data are not completed at the time of this report.

Results from the incubation studies were similar for Akita Komachi and M-202. Therefore the data from both varieties were combined in Figs. 2 and 3. Typical patterns of carbon dioxide and ethanol concentration over time are graphed in Fig.1. Carbon dioxide level tended to plateau after about 24 hours while ethanol concentration showed a continuous, straight-line rise over the test period. Therefore, we used maximum CO_2 and rate of ethanol rise as descriptors of these two measurements. When these are plotted against rice moisture, Fig. 2 and 3, a threshold can be seen at about 22% to 24% moisture below which microbial activity and the potential of off-odor development are very low. At moistures less than 18% ethanol does not increase in the rice. At 20% ethanol rises at a rate of about 0.001 mg/l per hour, but at 27% its rate of increase is 100 times greater. Based on using ethanol as an indicator microbial activity, rice at moistures above 24% is very susceptible to high rates of microbial activity. Drying should start as soon as possible after harvest.

These observations apply only to freshly harvested rice. As rice is dried below about 17% field micro-organisms become inactive. Spoilage under storage conditions is associated with a different group of organisms than those found in the field. Microbes found in storage bins may behave differently than organisms that are associated with the field environment.

At this time we are not able to make any conclusions about safe holding times for wet rice as it relates to aspects of quality. We will understand more about this after the volatile organic and taste panel tests are completed.

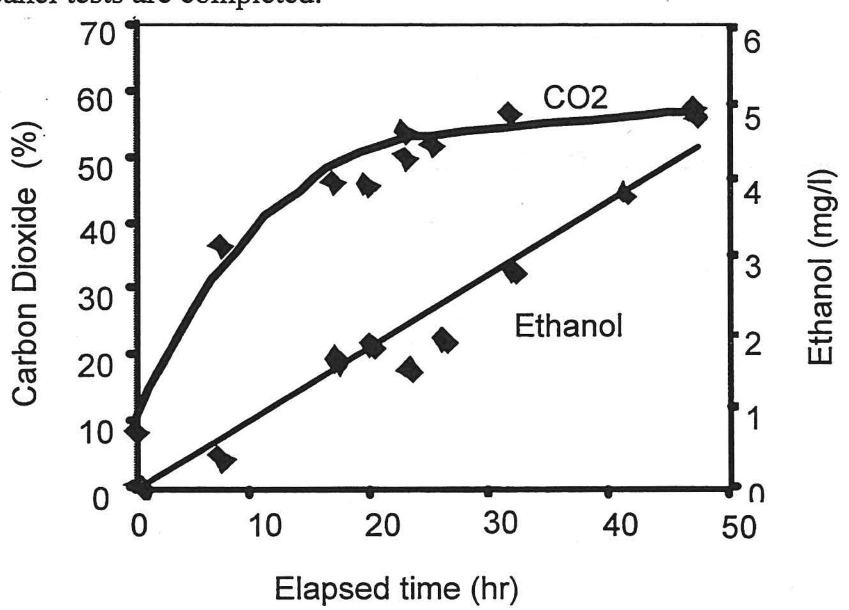

Figure 1. Typical carbon dioxide and ethanol; concentrations in laboratory test. Data from a lot of Akitakomachi rice at 26.9% moisture.

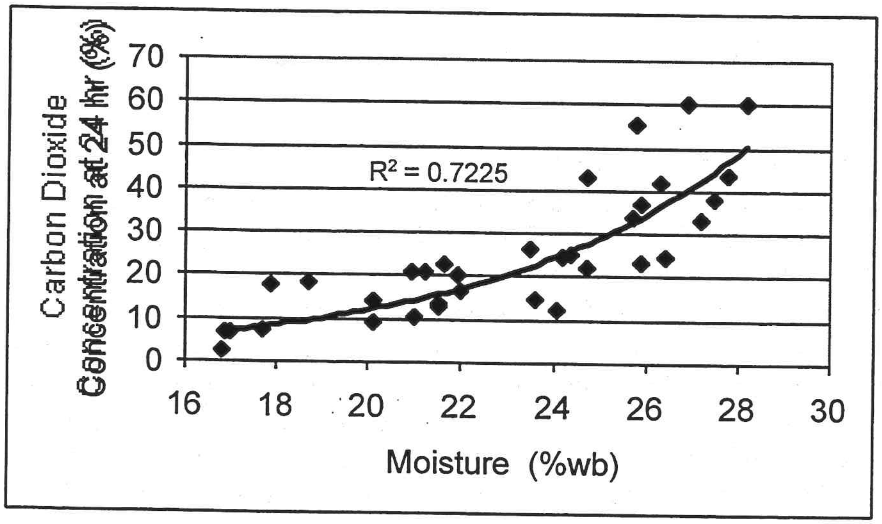

Figure 2. Carbon dioxide concentration in a mass of rice after 24hrs in an insulated metal box. Graph includes data for Akitakomachi and M202 varieties from the 2000 and 2001 tests

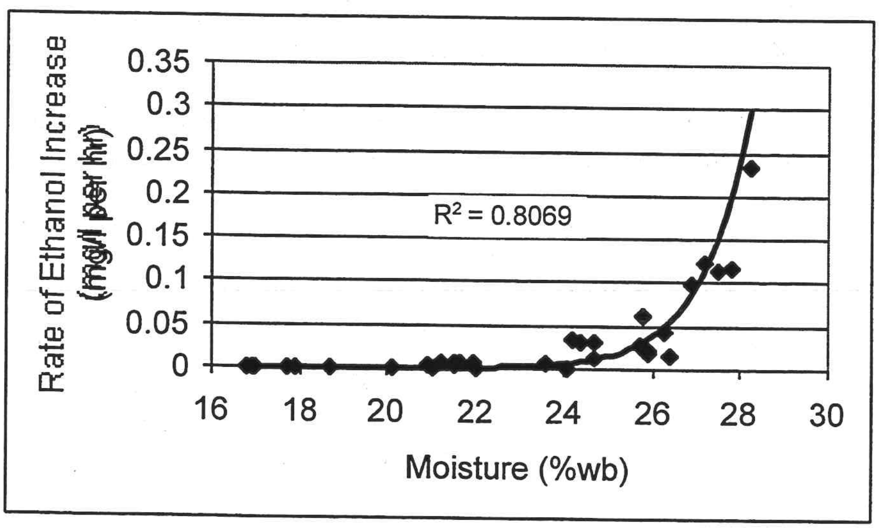

Figure 3. Rate of increase in ethanol concentration in a mass of rice held in an insulated metal box. Graph includes data for Akitakomachi and M202 varieties from the 2000 and 2001 tests

Moisture content and development of off-odor – truck sampling.

The laboratory incubation tests showed that ethanol and carbon dioxide concentrations in a mass of rice are indicators of microbial activity and potential off-odor development. We used battery-operated, hand-held detectors to measure carbon dioxide (Bacarach) and ethanol (Intoximeters, Inc.) concentrations in truckloads arriving at a rice drying facility in West Sacramento. We also collected a moisture sample with a hand probe and measured grain temperature. All measurements were taken near the center of the trailer, about 3' down from the top surface of the load.

On each day a group of trucks arrived from about 7:30 to 10:00 in the morning. These were presumably filled with rice that had been harvested at the end of the previous day and held over night before transport to the dryer. The afternoon trucks were sampled beginning about 2:00 PM and were filled with rice harvested that day. All of the trucks arrived with a fabric cover over the load. Nearly all of the morning loads had elevated ethanol concentrations, Table 1. The second sampling day had particularly highly high levels in the morning compared with the afternoon. This may have been due to the high grain temperatures. It was not associated with higher rice moisture because rice was an average 2 percentage points drier on the second day than the first. On both days, all of the afternoon loads had no measurable ethanol in the rice.

This work illustrates the quality advantage of shipping rice during the day of harvest. However, we detected a noticeable odor in only one of the morning loads. It is possible that most of the morning loads arrived quickly enough to have no odor problems. However, the rice was destined for a holding bin before drying began and could have yet sustained damage before drying actually began.

Table 1. Truck sampling data for loads of undried rice arriving at a West Sacramento drying facility. Average conditions of truckloads of rice at receiving.

Date & Time		Number of loads sampled	Ethanol Conc. (mg/l)	CO_2 Conc. (%)	Load Temp. (°F)	Moisture (% wb)
19 Sept.	AM	7	0.07	6.8	81	22.8
	PM	8	0.0	7.8	88	26.3
2 Oct.	AM	12	0.41	18.1	93	20.8
	PM	11	0.0	1.3	95	20.3

The lab tests showed that ethanol concentration increases steadily during holding, with the rate controlled by grain moisture content. Without information on the total time in the trailer and possible air exchange during highway transport, it would be impossible to associate ethanol levels with rice moisture in the trailer environment.

First pass drying.

The objective of this laboratory study was to determine the amount of moisture that can be removed from rice without causing head rice loss. Drying to below 18% to 20% in a single pass would allow the rice to be stored for short times without being subject to off-odor development. Samples of M202 rice were harvested at different times with four different moisture contents ranging from 17.3% to 26.3%. The rough rice was first dried with heated air (110°F or 122°C\F). The moisture content reduction with heated air ranged from 2% to 10%, but the final moisture content after drying with heated air was not less than 13%. Then the samples were tempered for 2 hours before they were dried with room air to about 13% moisture. Each treatment was replicated three times. The samples were milled at the CDFA laboratory in West Sacramento.

At harvest moistures of 20.9% and greater, 4 points of moisture can be removed without affecting head rice, Table 2. For the high moisture rice, head rice tended to decrease with the higher drying temperature when the moisture removal was greater than 4% with a single pass.

Table 2. Effect of initial rice moisture and amount of removed moisture on head rice quality in single pass drying. All tests were done with M202 rice. Boxed cells represent significant head rice loss.

Initial moisture (%)	Drying air temperature (°F)	Percentage points of moisture removed					
		0	2	4	6	8	10
26.3	110	64.0		64.7	63.3	59.7	55.0
26.3	122	64.0		64.5	62.5	57.5	45.5
22.7	110	51.7	53.0	51.7	50.0		
20.9	110	64.0	63.7	63.7	57.7		
17.3	110	51.0	52.3	48.7			

A similar test was conducted at a farm-scale column dryer (Farm Fans, Inc.). The unit had two temperature sections with the top section at the higher temperature. The dryer was filled with a fresh batch of rice and both the heated air and discharge roll were turned on. Samples of exiting rice were collected every three minutes for about one hour. No head rice quality was lost in the first test, although a maximum of only 1.5 points of moisture were removed, Table 3. The second batch was drier, at 20.5% moisture, and showed head rice loss when more than two points of moisture were removed.

Table 3. Effect of initial rice moisture and amount of removed moisture on head rice quality in single pass drying of M202 rice in a commercial dryer.

Initial moisture (%)	Drying air temperature (°F)	Percentage points of moisture removed						
		0	0.5	1.0	1.5	2.0	2.5	3.0
22.1	120/100	64. 5	64.5	64.5	64.5			
20.5	120/100	49.5	49.5	49.5	49.5	49.0	48.5	45.5

Together the lab and field data indicate that high moisture rice can be subjected to quite high amounts of moisture loss during the first pass. It appears that four percentage points of moisture can be safely removed at moistures above about 23%. However, the field tests demonstrated that drying times become quite long when large amounts of moisture are removed in a single pass. For example the first 0.5% moisture was lost in 6 min, while moisture loss from 2.5% to 3.0% required 24 min. Daily drying capacity may be too greatly reduced by attempting to remove large amounts of moisture from the rice. At typical harvest moistures, removing four percentage points of moisture is adequate to prevent off-odor development.

Effect of harvest moisture on head rice and grower return.

Rice moisture at harvest has a demonstrated effect on rice quality. Low moisture is associated with low head yield and high moisture allows more immature kernels and slightly lower total rice levels. General recommendations are to harvest medium grain rice at about 24% moisture for optimum head yield. But previous studies have not included the effect of drying and handling costs on optimum harvest moisture. These costs typically range from about $0.55 to $1.00 per hundredweight and of course, high moisture rice is charged more for drying than low moisture rice.

Five years of receiving data for California medium grain rice were analyzed to determine the optimum harvest moisture. The previous harvest moisture recommendation of about 24% proved to be true if the grower's goal is to optimize head yield, Table 4. For example harvesting at 18% moisture reduced head yield by 6 percentage points compared with harvesting at 24% moisture.

However, total yield increased slightly at lower moistures and drying costs were lower for drier rice. If net grower return (USDA loan value minus handling and receiving charges) was considered rather than head yield, then the optimum harvest moisture was 21%. The table also shows that harvest return is not very sensitive to moisture content. Harvesting at moistures ranging from 18% to 24% does not cause more than a 5 cent per hundredweight variation in return.

Table 4. Five year (1996 – 2000) summary of the quality and value of California medium grain rice

Harvest Moisture (%)	Head Yield (%)	Total Yield (%)	Drying Charge ($/cwt- dry)	Net Return ($/cwt-dry)	Net Return 1.5xdry cost ($/cwt-dry)
16	50.8	68.9	0.62	5.27	5.17
18	54.6	68.8	0.68	5.36	5.21
20	57.5	68.5	0.74	5.41	5.22
22	59.5	68.2	0.82	5.41	5.19
24	60.6	67.8	0.90	5.38	5.12
26	60.8	67.4	0.98	5.31	5.02

A closer look at the data shows that there is a great deal of variation in the quality and return values. The data from 1996 is typical of an average harvest and shows this variation, Figure 4. Head yields can be 5 to 10 points higher or lower than the average line. This means that lots with moisture below 16% can sometimes have head yields of 60%. On the other hand, lots in the recommended moisture range can have head yields below 45%. Obviously there are factors other than average harvest moisture that influence rice quality. Weather at harvest time (particularly rain), late tillering, rice variety, and soil moisture at harvest may contribute quality variation.

Net return data based on 1996 receiving data, Figure 5, show that harvest moisture has very little effect on crop value. Certainly between 18% and 24% there is little effect of harvest moisture on returns especially considering the variation in the quality data. The risk of poor returns begins to increase below 18%. We do not recommend harvesting above 24% because research indicates that there is an increasing risk of off-odor development for rice harvested above 24%.

An analysis of premium medium grain (M401) data shows that there is a financial advantage to harvesting at higher moistures with this variety, Table 5. M401 has highest head yields at higher moistures than regular medium grain varieties and maximum return is obtained at 24% harvest moisture. Grower return when harvesting at 18% moisture is $0.34/cwt less than harvesting at 24%.

Table 5. Five year (1996 – 2000) summary of the quality and value of M401 variety rice

Harvest Moisture (%)	Head Yield (%)	Net Return ($/cwt-dry)
16	43.2	6.26
18	47.5	6.50
20	50.8	6.68
22	53.3	6.79
24	55.2	6.84
26	56.3	6.82

Rising energy costs may cause dryer operators to increase drying fees. If drying charges were increased by 50%, the maximum return is obtained at 20% moisture and drops off rapidly above 22%. High energy costs will encourage growers to allow their crop to dry to low moistures before they harvest. In previous years, the average medium grain harvest moisture was 20% to 21%, which is in the range of the optimum return to the grower. If drying costs increase by 50% and growers aim for the optimum return, the industry average harvest moisture may drop by one or two points. Industry-wide, this could result in a slight increase in total yield and an average head rice loss of 2 to 3 points for California medium grain rice.

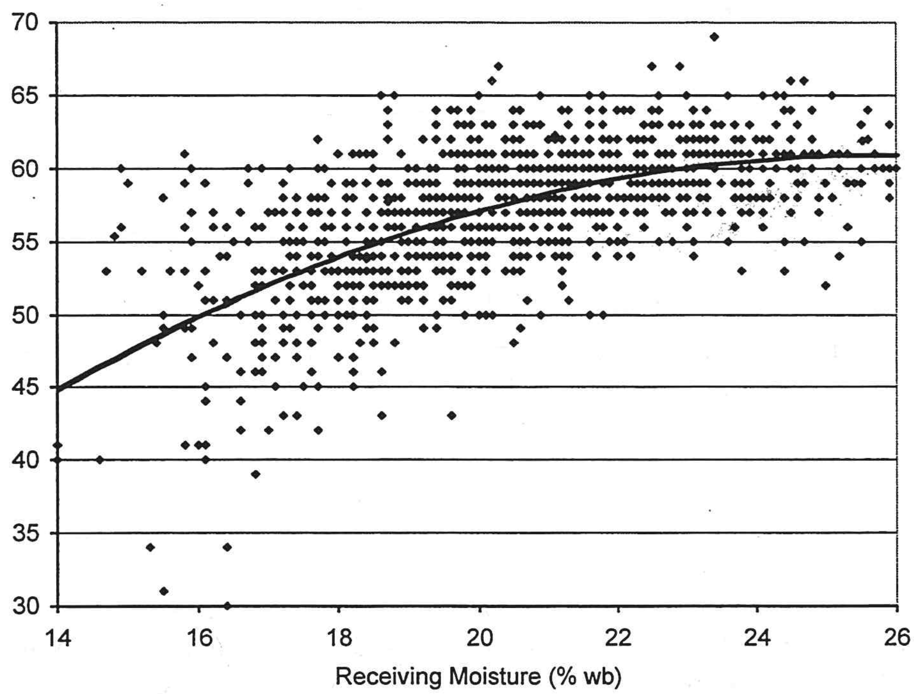

Figure 4. Effect of harvest moisture on head rice yields of California medium grain varieties for the 1996 season.

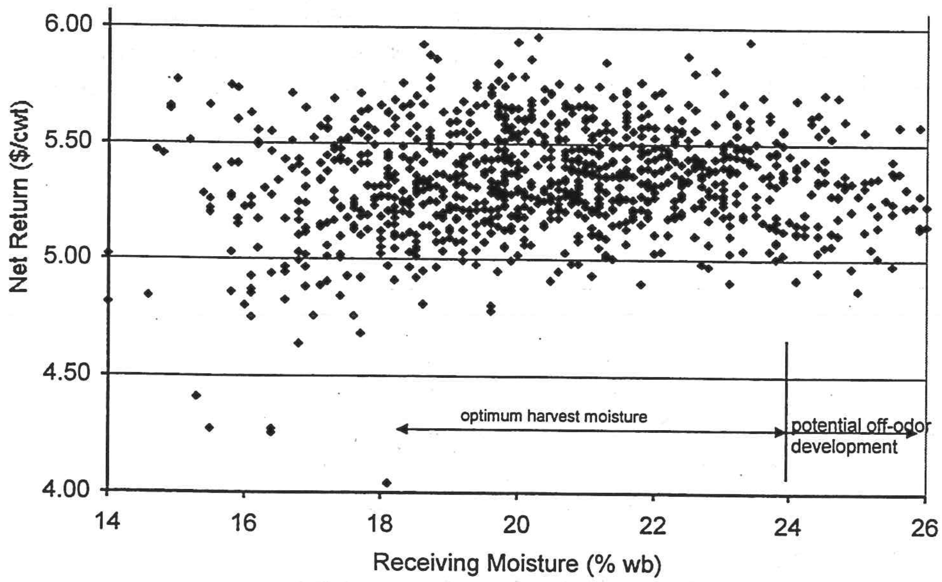

Figure 5. Effect of harvest moisture on net grower return of California medium grain varieties for the 1996 season.

Moisture meter calibration.

During the truck sampling we collected moisture samples that were evaluated with a GAC II meter at the receiving facility, several GAC 2100 machines at CDFA , a Kett single grain meter. These readings were compared against a standard gravimetric air oven procedure, 72 hours at 103°C. Each oven sample was replicated three times.

Figures 6, 7 and 8 show the comparisons between the three meters and the air oven standard. Each graph has a line that represents an accurate correlation between the air oven standard and the machine measurement techniques. The meters appear to be reasonably well correlated to the standard up to about 24%, the limit of our data. The GAC 2100 meters show a trend to read slightly high. The correlations however do show that there is a significant spread in the data. This variation is high enough that any individual reading may be ±2 percentage points of moisture different than the air oven standard.

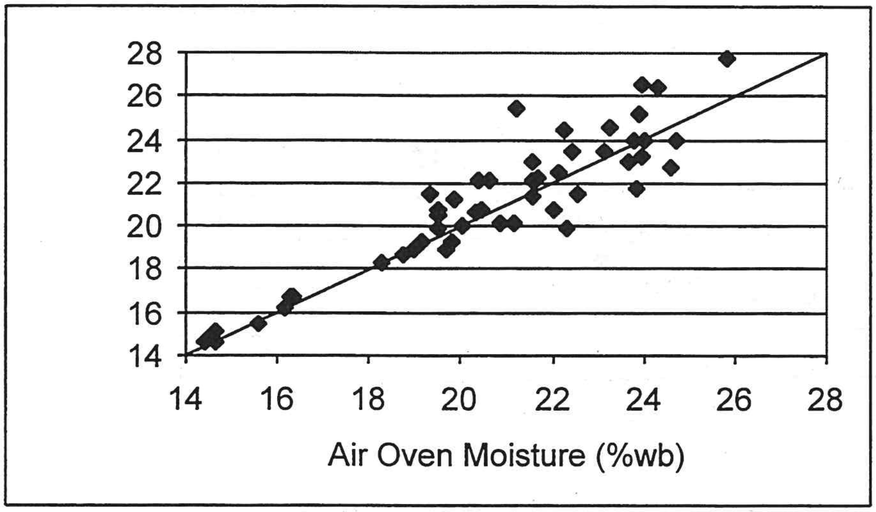

Figure 6. Correlation between GAC II moisture meter and the air oven standard.

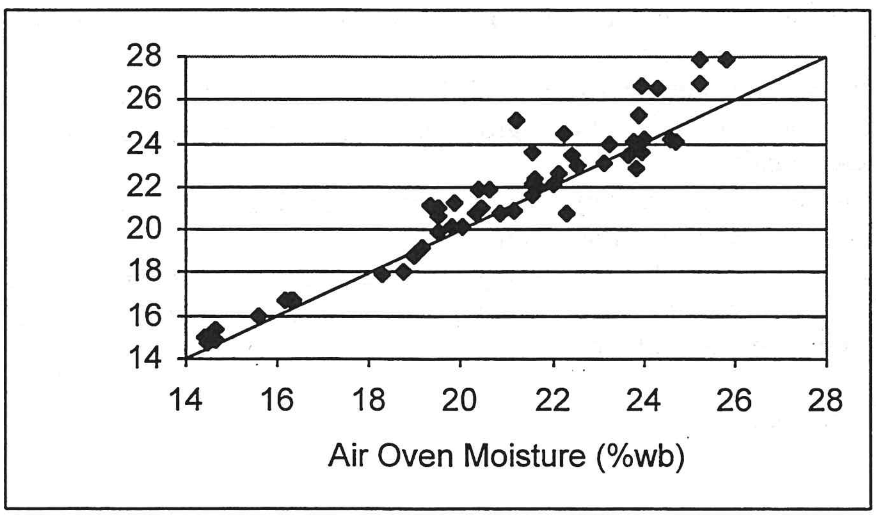

Figure 7. Correlation between GAC 2100 moisture meter and the air oven standard.

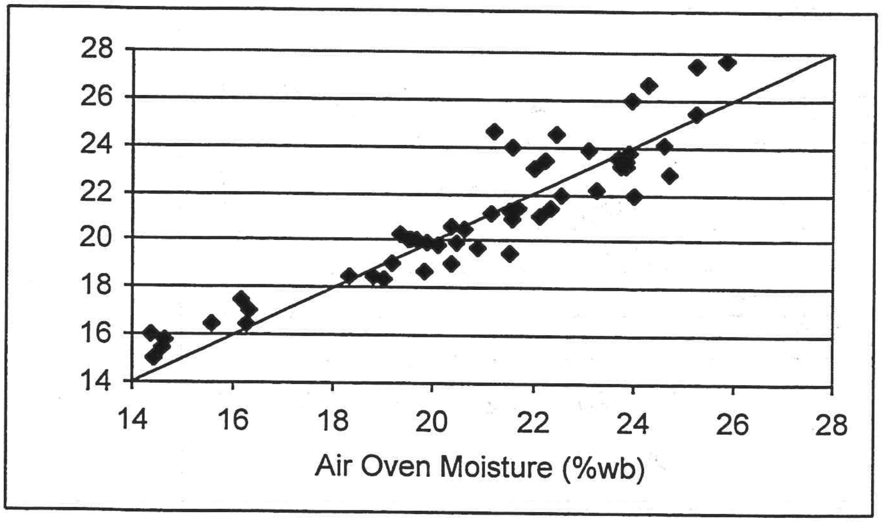

Figure 8. Correlation between GAC Kett single grain moisture meter and the air oven standard.

SUMMARY OF 1999 RESEARCH BY OBJECTIVE:

1. Based on ethanol development, it appears that rice above 24% moisture should begin drying quickly to prevent off-odor development.
2. First pass drying of wet rice can remove about 4 percentage points of moisture to ensure off-odors do not develop in tempering.
3. Grower return for M202 is not significantly different when rice is harvested between about 18% to 24% moisture. This allows growers to harvest at moistures below 24% without a financial penalty.
4. Grower return for M401 is affected by harvest moisture and it should be harvested at about 22 to 24% moisture for maximum returns.
5. A limited set of data indicates that the Dickey-john electronic moisture meters are fairly well calibrated. However an individual reading may be ±2 percentage points different than an air oven determination of moisture.

PUBLICATIONS AND REPORTS:

None

CONCISE GENERAL SUMARY OF CURRENT YEAR'S RESULTS:

Preliminary results based on ethanol production indicate that rice above 24% moisture is very susceptible to off-odor development. It should begin the drying process as soon as possible after harvest. High moisture rice can be dried in a single pass to safe moistures for temporary storage in tempering bins. California medium grain (M202) rice can be harvested at moistures as low as 18% with little effect on grower returns. This allows growers to safely start harvest at the beginning of the season at moistures below 24% and avoid off-odor development. Grower return for M401 is more sensitive to harvest moisture and maximum returns are achieved at 22% - 24% moisture. A limited set of data indicates the Dickey-john moisture meters correlated reasonably well to air oven standard moisture, although readings can be quite variable.