PROJECT NO. RD-1

COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE:

New Approaches and Energy Savings in Drying of California Smooth and Rough Hulled Rice Varieties.

PROJECT LEADER AND PRINCIPAL UC INVESTIGATORS:

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LEVEL OF 1981 FUNDING:

$21,667

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

Research was conducted at RGA rice drying plant, Willows, and at the Department of Agricultural Engineering, University of California, Davis.

SUMMARY OF 1981 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVES:

The major goal of research during 1981 has been to test the new computer model of rice drying at a commercial dryer location. The following provides a summary of experimental data collected from a column drier at RGA facilities, Willows. The computer model has been found to predict the dryer performance with high reliability.

The crossflow drier under study was one of the three commercial crossflow driers at the Rice Growers' Association (RGA) plant in Willows. Each of the two columns of the crossflow drier was 16.75 m high, 3.5 m wide and 0.3 m deep holding 11,775 kg of wet rice. Though the total height was 16.75 m, the effective height was considered to be 15.25 m because there was no perforated screen beyond 15.25 m height to allow the heated air to pass through. An airfoil fan (Aladdin Heating Corporation, type BB, size 730, single width) having an optimum capacity of delivering 56.6 m^3/sec at 0.62 kPa was being used. The fan was run by a 100 hp electric motor. The static pressure was measured in the plenum chamber with the help of a U-tube manometer. The average air velocity delivered by the fan was measured by a tachometer. To check the air distribution inside the drier, at three locations air velocities were measured across the entire width of the drier by hot wire manometers. At the same locations dry bulb and wet bulb temperatures of the exhaust air were measured by psychrometers having built-in fans to facilitate the measurement of wet bulb temperatures. A data logger was installed with thermocouples connected to it for recording the dry bulb temperatures of (i) ambient air, (ii) hot air inside the plenum chamber at three different heights, and (iii) exhaust air at three different heights. Rice temperatures were measured at the inlet and also at the outlet of the drier for each set of trials.

From the 8 sets of experimental results a statistical analysis was made to compute the 95% confidence intervals on the actual mean of the moisture contents and temperatures of the final product and temperatures, relative and absolute humidities of the exhaust air using 8 sets of predicted data. From the RGA's record on their natural gas consumption for the last one year and the amount of rice dried during that time, an estimation was made about the energy consumption per lb of water removed from the rice. The fossil fuel equivalence of electricity used as 1 kWh = 10.550 Btu to account for inefficiency of electric generation. The average energy consumption was obtained as 2,159 Btu/lb of water removed with a standard deviation of 285 Btu/lb of water removed.

With the crossflow drier being the nonmixing type, forcing heated air through one side of the rice bed, it was expected that there would be a moisture gradient across the rice column from the heated air into the exhaust air outside. In the commercial drier it was not possible to make any provision to take out samples from within the rice column to check the extent of the effect of uneven distribution of heat. In the laboratory a test was conducted with a 3 m column drier having a cross section of 0.3 m x 0.3 m. Heated air at 50°C was forced through rice initially at 32 percent dry basis moisture (24 percent wet basis) and rice samples were taken out at each 10-minute interval from two ports across the column for moisture measurements.

Moisture gradient across drier column as obtained by the laboratory experiment was found to be maximum after 30 minutes of drying which was about 6 percent. The layer away from the air entrance side dries at a much slower rate than the layer near the heated air side. The result identifies a serious problem in the use of crossflow driers since the grain is nonuniformly dried.

Static pressure inside the plenum chamber of the commercial crossflow drier varied from 0.145 to 0.20 kPa and the average air velocity delivered by the fan measured was 1320 cm/sec. From both manufacturer's manual and calculation by multiplying the air velocity by the inlet area of the fan using a fan efficiency of 80 percent, the delivering capacity of the fan while operating on the drier was found to be around 42.5 m^3/sec. Thus the fan was operating at 75 percent of its full capacity. The movement of the rice layer down the drier was calculated by timing a single grain displacement through a known distance and an average value obtained was 0.63 cm/sec. Thus the grains remain exposed to heated air for 40 minutes while traveling a height of 15.25 m.

Toward the top of the drier, exhaust air velocities were found to be a shade higher than those at the levels below, and at any height higher velocity concentration was observed within 2 m span around the center of the drier width. Though the fan delivers air at 42.5 m^3/sec, the average velocity was calculated to be 32 cm/sec with a standard deviation of 8. In the computer program an average velocity of 36 cm/sec was used as the input data. This indicates that about 15 percent of the air is escaping without passing through the rice. Some leaks in the system that create the path of least resistance for the air to escape can be held responsible for this loss.

Computer prediction of exhaust air temperatures were within acceptable limits. The actual mean temperature for 8 trials was within 95 percent confidence interval for the 8 predicted mean temperatures.

The moisture contents predicted are very close to the actual values. Except for trial IV and VII, the predicted moisture contents are within 1.5 percent of the actual values. This difference is mainly due to the fact that the initial moisture content in the drier was not uniform throughout. As observed from Table 1, the standard deviation on initial moisture content in some samples was as high as 2.3 percent. The second reason is that in the computer program the heated air temperature is kept constant whereas actually the temperature at the bottom is 2-3°C higher than that at 6 m from the bottom and above.

In addition to research on crossflow rice dryers, a new pilot-scale concurrent-flow rice dryer was fabricated during 1981. This drier is being tested now for its performance and energy saving potential. A commercial dryer based on concurrent flow principle was installed by DePue Warehouse Inc. in Williams. According to the dryer operator, the energy reductions with this new system amount to 20-40% of the typical crossflow driers. It is anticipated that the pilot-scale drier will be useful in the future to evaluate the performance of this new system for different California rice varieties and operating conditions. Computer-aided simulations of concurrent-flow rice driers have been developed that will be useful in scaling-up of pilot-plant drier results.

The research conducted during 1981 completes the first phase of our effort to develop a working model useful in simulating crossflow rice driers. The next phase involves use of the model in developing modifications of existing driers that would improve their energy efficiency. The model was tested on a commercial drier that used partial recycling of air. Energy savings of 10-20 percent were predicted and confirmed through field data (more details in the publication by Chandra et al., 1981).

PUBLICATIONS OR REPORTS:

Chandra, P. K., T. R. Rumsey, J. R. Thompson, R. P. Singh. 1981. Potential of air recycling in an industrial crossflow rice drier. ASAE Paper 81-6514.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

A computer-aided model to simulate crossflow rice drier was tested with field data obtained from a commercial rice drier. The agreement between the predicted and actual performance was excellent. Initial use of the computer model in partial recycling of exhaust air in crossflow drier shows a potential of 10-20 percent energy reductions. The computer-model will be a useful tool in developing energy-saving modifications of crossflow rice driers.

TABLE 1. Field and Predicted Data in a Nutshell

Part I

Data Collected		Trial I Actual	Trial I Predicted	Trial II Actual	Trial II Predicted	Trial III Actual	Trial III Predicted	Trial IV Actual	Trial IV Predicted
Inlet Moisture (%)	Average, w.b.	22.88		24.70		24.59		26.16	
	σ	1.476		0.69		0.248		*	
Final Moisture (%)	Average, w.b.	19.46	20.51	21.12	21.40	22.38	22.18	22.78	23.87
	σ	*		*		*		*	
Heated Air Temperatures (°F)	0' from bottom	116.6		116.6		116.6		113.0	
	18.5' from bottom	113.0		111.2		111.2		109.4	
	40' from bottom	113.0		111.2		111.2		109.4	
Ambient Air	Temperature (Average)	83.5		85.0		75.5		81.0	
	Humidity ratio (Average)	0.0110		0.0110		0.0108		0.0113	
Exhaust Air Humidity Ratio	0' from bottom	0.0176	0.0183	0.0193	0.0182	0.0185	0.0186	0.0183	0.0189
	σ	1.97×10^{-3}		5.6×10^{-4}		3.8×10^{-4}		5.5×10^{-4}	
	18.5' from bottom	0.0184	0.0186	0.0189	0.0185	0.0191	0.0189	0.0189	0.0191
	σ	4.0×10^{-4}		2.52×10^{-4}		2.07×10^{-4}		5.3×10^{-4}	
	40' from bottom	0.0177	0.0181	0.0180	0.0181	0.0184	0.0186	0.0179	0.0189
	σ	4.2×10^{-4}		1.15×10^{-4}		0.07×10^{-4}		*	

w.b. = Wet Basis
σ = Standard Deviation
* When number of observations is 2 or less.
⊙ Erroneous Data

TABLE 1. Field and Predicted Data in a Nutshell
Part II

Data Collected		Trial I		Trial II		Trial III		Trial IV	
		Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
Exhaust	0' from bottom	73.90	71.69	77.50	76.22	87.50	79.65	85.00	88.37
Air	σ	7.274		0.500		1.995		2.069	
Relative	18.5' from bottom	88.28	81.51	90.30	85.92	92.50	88.76	92.60	96.15
Humidity	σ	*		1.458		0.635		1.130	
(%)	40' from bottom	89.20	84.58	88.72	85.79	90.21	86.92	90.98	88.71
	σ	*		2.038		0.813		*	
Exhaust	0' from bottom	84.90	84.45	81.50	82.44	79.10	81.76	79.70	79.01
Air	σ	3.008		1.414		0.224		1.528	
Temper-	18.5' from bottom	78.00	81.08	78.50	79.27	78.20	78.87	78.00	76.71
atures	σ	0.219		0.820		0.205		0.812	
(°F)	40' from bottom	77.11	79.07	77.86	78.67	77.86	79.03	77.20	78.94
	σ	0.225		0.515		0.267		*	
Inlet Rice Temperature (°F)		85.0		85.0		86.0		83.0	
Outlet Rice Temperature (Average, °F)		95.0	97.7	95.0	95.4	95.0	95.2	94.0	92.2

w.b. = Wet Basis
σ = Standard Deviation
* When number of observations is 2 or less.
⊙ Erroneous Data

TABLE 1. Field and Predicted Data in a Nutshell

Part III

Data Collected		Trial V		Trial VI		Trial VII		Trial VIII	
		Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
Inlet Moisture (%)	Average, w.b.	23.71		23.32		19.55		20.95	
	σ	0.563		0.229		0.203		*	
Final Moisture (%)	Average, w.b.	21.37	21.64	20.95	21.26	16.44	17.89	18.00	19.08
	σ	*		*		0.882		0.194	
Heated Air Temper-atures (°F)	0' from bottom	109.4		111.2		107.6		107.6	
	18.5' from bottom	104.0		105.8		104.0		104.0	
	40' from bottom	104.0		105.8		104.0		104.0	
Ambient Air	Temperature (Average)	67.0		72.0		81.0		81.5	
	Humidity ratio (Average)	0.0091		0.0106		0.0108		0.0089	
Exhaust Air Humidity Ratio	0' from bottom	0.0185	0.0158	0.0191⊙	0.0173	0.0167	0.0163	0.0165	0.0151
	σ	1.26×10^{-4}		*		1.9×10^{-4}		1.15×10^{-4}	
	18.5' from bottom	0.0188	0.0160	0.0177	0.0176	0.0164	0.0165	0.0165	0.0154
	σ	2.5×10^{-4}		3.0×10^{-4}		1.9×10^{-4}		4.8×10^{-4}	
	40' from bottom	0.0175	0.0158	0.0168	0.0171	0.0155	0.0161	0.0152	0.0150
	σ	5.77×10^{-5}		3.3×10^{-4}		2.0×10^{-4}		2.6×10^{-4}	

w.b. = Wet Basis
σ = Standard Deviation
* When number of observations is 2 or less
⊙ Erroneous Data

TABLE 1. Field and Predicted Data in a Nutshell

Part IV

Data Collected		Trial V		Trial VI		Trial VII		Trail VIII	
		Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
Exhaust Air Relative Humidity (%)	0' from bottom	95.20⊙	76.77	94.60⊙	76.90	79.00	67.60	79.00	70.00
	σ	0.0854		1.224		1.615		0.774	
	18.5' from bottom	93.40	85.96	93.30	86.10	84.50	77.50	87.40	78.00
	σ	1.490		1.350		2.049		1.325	
	40' from bottom	91.40	84.89	91.50	86.61	85.20	77.91	85.20	77.15
	σ	1.305		0.404		1.183		1.144	
Exhaust Air Temper-atures (°F)	0' from bottom	78.00	77.9	77.3	80.60	78.80	82.70	78.40	79.50
	σ	*		0.447		0.434		1.294	
	18.5' from bottom	76.80	75.00	75.30	77.64	75.90	79.50	74.30	76.30
	σ	0.450		0.104		0.546		0.747	
	40' from bottom	75.70	74.92	74.40	76.67	74.30	78.05	73.90	76.20
	σ	0.270		0.390		0.322		0.351	
Inlet Rice Temperature (°F)		80.0		81.0		84.0		83.0	
Outlet Rice Temperature (Average, °F)		88.0	89.3	90.0	92.2	92.0	93.1	92.0	91.3

w.b. = Wet Basis
σ = Standard Deviation
* When number of observations is 2 or less.
⊙ Erroneous Data