Drying Rough Rice with Infra-red Radiation

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SUMMARY

Preliminary experiments with drying rough rice with infra-red radiation from a gas-fired infra-red heater indicate possibilities for developing a faster method of drying rice and other agricultural products than conventional systems now in general use. Drying rates were obtained which ranged from 3.60 to 0.49 percent moisture removed per minute of exposure to infra-red. Yield of head rice was increased significantly over the yield from control samples air-dried at room temperature.

Rate of drying varied directly with radiation intensity, but was affected little by the maximum temperature to which the rice was heated.

Head yield varied directly with the total time rice was exposed to infra-red radiation and with the maximum temperature to which it was heated. It varied inversely with radiation intensity and with increasing rates of moisture removal.

Germination decreased as temperature and rate of moisture removal increased.

Small scale laboratory tests were conducted at College Station in August and September 1958 to determine the effects of infra-red radiation from a gas-fired "Schwank" infra-red 48,000 BTU heater on the drying of rough rice.

The experiments were designed to provide information on rates of drying, effects of this type of drying on milling yields and germination and to provide a basis for further experimentation to determine the possibilities for commercial application of the method for drying rice and other agricultural products.

EXPERIMENTAL PROCEDURE

The rice used in these experiments was obtained from the Rice-Pasture Experiment Station at Beaumont. The experimental long-grain selection used, is of very early maturity and has a low milling yield. The rice was harvested late in July at a moisture content of 24 to 25 percent and was transported immediately to College Station where it was stored in sealed containers, refrigerated at 45° F. until used in the drying experiments.

The basic procedures in the three experiments in this report were: (1) a quantity of green rice was mixed thoroughly; (2) split into samples of approximately 1 pint by volume with a Boerner Sampler; (3) the moisture content was determined for each sample; (4) the sample was sealed in pint mason jars until exposed to infra-red radiation; (5) the rice was spread on screen-bottomed trays in an approximately single kernel layer for drying; (6) when a laboratory thermometer at the level of the rice reached a predetermined temperature, the tray was removed from beneath the heater and the exposure time recorded; (7) intensity of radiation was varied by increasing or decreasing the distance between the rice and the heater; and (8) all moisture determinations were made with a CAE (Motomco) Moisture Meter.

In experiment 1, the trays were placed in front of a fan after irradiation until the rice cooled to room temperature and a moisture content determination was made. This procedure was repeated until the moisture content was reduced to approximately 14 percent. The samples were then sealed in their original containers and stored until they were milled.

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TEXAS AGRICULTURAL EXPERIMENT STATION

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TABLE 1. COMPARISON OF TREATMENTS AND THEIR EFFECTS ON MOISTURE REMOVAL IN EXPERIMENT 1 (NON-TEMPERED) AND EXPERIMENT 2 (TEMPERED)

Maximum temperature of rice, °C		50			55			60		
Distance from heater, inches		14	22	30	14	22	30	14	22	30
Number of exposures to infra-red	Non-temp.	10	10	10	7	7	8	6	7	8
	Tempered	5	5	5	5	5	5	5	5	5
Total exposure to infra-red, minutes	Non-temp.	3.93	8.63	14.05	3.93	7.35	12.63	4.37	9.42	19.30
	Tempered	2.42	4.42	8.15	3.38	6.45	12.78	3.98	8.43	17.69
Percent moisture removed during total exposure	Non-temp.	9.70	9.10	9.10	9.80	9.30	9.80	9.40	9.60	9.50
	Tempered	8.70	9.10	9.90	10.30	10.70	10.90	11.20	11.60	12.00
Percent moisture removed per minute of exposure	Non-temp.	2.47	1.24	.72	2.49	1.08	.70	2.15	1.04	.49
	Tempered	3.60	2.06	1.21	3.05	1.66	.85	2.81	1.38	.68

Experiment 2 duplicated the treatments of experiment 1 except that immediately after irradiation the samples were returned to their containers and allowed to stand at room temperature with tops removed for approximately 10 hours before a moisture determination was made. The containers were then sealed until the entire process could be repeated. In effect, there was a 24-hour or longer tempering period between exposures. The samples dried in experiment 2 were placed on screen-bottomed trays at room temperature for 4 days prior to milling. This was done in an attempt to bring all samples to the same moisture content so that any noted effects on head yield could be attributed to the infra-red drying treatments.

Experiment 3 was conducted with methods similar to those described for experiment 2. A different range of maximum temperatures and radiation were used and the samples were not air-dried after the last exposure to infra-red.

All treatments were replicated three times.

Control samples were air-dried at room temperature on screened trays; otherwise they were treated in an identical manner as the infra-red-dried samples.

Milled yields are based on 125-gram samples of rough rice, milled with a modified portable McGill Miller using two breaks at 15 and 5 pounds pressure, respectively, for 30 seconds each break.

RESULTS

The data compiled for experiments 1 and 2 are compared in Tables 1 and 2. Tempering between exposures appears to have increased the efficiency of moisture removal. As temperature was increased and radiation intensity decreased, the effect of tempering on the rate of moisture removal was not as great, Table 1. The most efficient moisture removal was obtained at the lowest temperature, 50° C., but at the highest radiation intensity, 14 inches from the heater. Radiation intensity appears to have a greater effect on removing moisture from rough rice than does the actual temperature to which the rice is heated; therefore, the faster the temperature of rice is raised the faster moisture is removed.

Heating the rice to 50° C. at high radiation intensity appears to be the most efficient treatment; however, the total moisture removed was not equal for all treatments since moisture removal is progressively slower at the rice becomes drier, Table 1. Further experimentation is necessary before the most efficient treatment can be ascertained.

The milling yields, Table 2, suggested that high temperatures and high radiation intensity increased milling yields. The lack of replication and failure to control the final moisture content accurately in these preliminary experiments prevent a close evaluation of the data, but a pattern is apparent in the results, which provide a basis for continued work.

TABLE 2. COMPARISON OF THE EFFECTS OF TREATMENTS ON QUALITY AS MEASURED BY YIELD OF HEAD RICE AND GERMINATION BETWEEN EXPERIMENT 1 (NON-TEMPERED) AND EXPERIMENT 2 (TEMPERED)

Maximum temperature of rice, °C		50			55			60			Control[1]
Distance from heater, inches		14	22	30	14	22	30	14	22	30	
Moisture content when milled, %	Non-temp.	14.7	14.6	14.3	15.3	14.9	14.3	15.2	14.9	14.7	13.5
	Tempered	12.7	11.8	11.3	12.2	12.0	11.3	12.3	12.0	11.0	11.3
Head rice in % of control, dry basis	Non-temp.	90.5	88.8	94.5	99.1	94.5	93.8	116.8	111.5	100.7	100.0
	Tempered	89.5	92.6	89.2	92.5	93.7	98.3	114.4	94.2	85.5	100.0
Percent germination	Non-temp.	10	64	65	0	7	20	1	0	25	50
	Tempered	51	84	91	3	46	84	0	8	53	90

[1]Air-dried at room temperature.

TABLE 3. RESULTS OF DRYING ROUGH RICE WITH INFRA-RED RADIATION AT THREE RADIATION INTENSITY LEVELS AND HEATING TO 2 MAXIMUM TEMPERATURES[1]

Maximum temperature of rice, °C	45			50			Control[2]
Distance from heater, inches	10	14	18	10	14	18	
Number of exposures to infra-red	15	15	15	13	13	13	0
Total exposure to infra-red, minutes	3.60	4.80	6.20	4.10	5.60	7.30	0
Percent moisture removed during total exposure	10.60	11.00	10.90	11.40	11.60	12.00	2.90[3]
Percent moisture removed per minute of exposure	2.94	2.29	1.76	2.78	2.07	1.64	
Moisture content when milled	13.70	13.50	13.30	11.50	11.90	11.40	13.40
Total yield milled rice in % of control, dry basis	101.60	100.10	100.90	103.50	102.70	104.70	100.00
Yield head rice in % of control, dry basis	94.00	94.30	100.90	114.50	122.00	123.20	100.00
Percent germination	39	69	82	5	26	65	72

[1]Average of three replications.
[2]Air-dried at room temperature.
[3]Moisture lost from open containers during the cooling period at room temperature.

Tests showed that germination decreases when the rice is dried rapidly at high temperature and the infra-red irradiation exposure period is increased.

Experiment 3 was planned and executed prior to obtaining the milling yields from experiments 1 and 2. The data in Table 3 are an average of three replications. The rate of moisture removal per minute of infra-red exposure followed the same pattern as observed in experiments 1 and 2; that is, increased radiation intensity and lower maximum temperature of the rice appearently increase the rate of moisture removal. To minimize the effects of final moisture content on the rate of moisture removal, the data are plotted in Figure 1 for rice dried at both temperatures at radiation intensity obtained 10 inches from the heater. The difference between drying rates is not significant. The data in Table 3 show a significant difference between drying rates when radiation intensity is decreased; hence the temperature to which the rice is heated apparently does not influence the rate of drying as much as does the intensity of the radiation. It, therefore, is assumed that rapid drying was achieved as a direct effect of infra-red radiation and not as a result of merely raising the temperature of the rice.

The head yield of infra-red-dried rice was increased over the head yield of the air-dried (room temperature) control in four of the six treatments in this experiment. Head yield tended to increase inversely with the rate of moisture removal following the trend observed in experi-

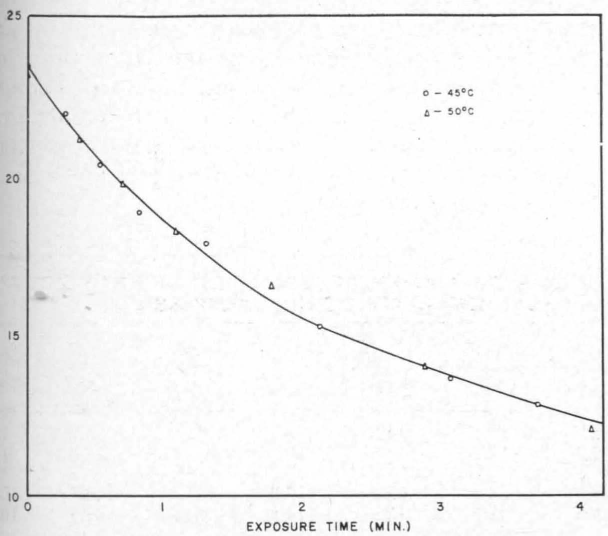

Figure 1. Rate of drying of rough rice exposed to infra-red radiation at a distance of 10 inches from the heater and heated to 45°C., compared with the rate of drying at the same intensity, but heated to 50°C.

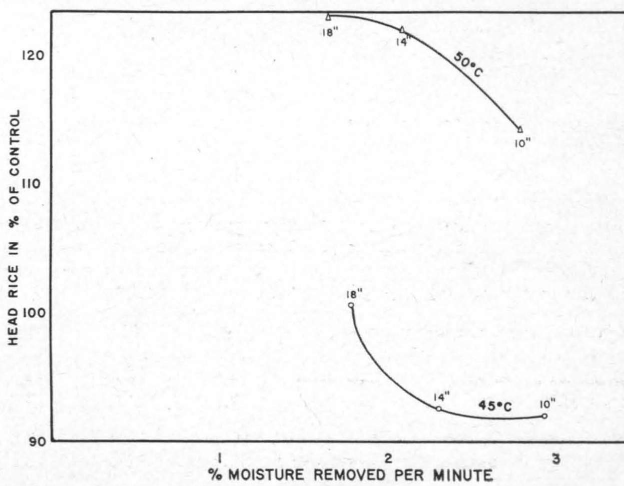

Figure 2. The relation of yield of head rice to drying rates for rice heated to maximum temperatures of 45°C. and 50°C., at distances of 10, 14 and 18 inches from the heater.

TABLE 4. ANALYSIS OF VARIANCE OF HEAD YIELD IN EXPERIMENT 3, DISREGARDING MOISTURE CONTENT OF RICE AT TIME OF MILLING

Source of variation	DF	SS	MS	F
Total	20	345.26		
Treatments	6	294.98	49.16	13.69[1]
Error	14	50.28	3.59	

[1]Significant at the 1% level.

ments 1 and 2. An analysis of variance of head yield in grams, disregarding the moisture content at the time of milling, is given in Table 4.

Using Duncan's range test of significance of variance of means for the 5 percent level, yields from all treatments heated to 50° C. were significantly greater than the head yield of the control. There was no significant difference between the control and any of the samples heated to 45° C.

Head yield was plotted in relation to the percentage of moisture removed per minute of exposure, Figure 2. Head yield decreased as the rate of drying increased for both temperatures. Figure 2 also shows that head yield decreases as infra-red radiation intensity increases.

ACKNOWLEDGMENT

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