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RICE MILLING

Effects of Milling Conditions on Breakage of Rice Grains

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Rice millers have felt for a long time that several variables in the processing of rice during milling have an effect upon the yield of head rice. The relationship of yield of head rice to the percentage of bran removal indicates that about 20% of the breakage occurs during the period in which 75% of the bran is removed. Breakage in milling was found to occur only in the stone sheller, the first- and second-break hullers, and the brush. Use of steam and abrasives increases yields for rice on which the bran is held tightly to the kernel and increases huller capacity by as much as 40%. For optimum yields the mill room atmosphere should be maintained at 70 to 80% relative humidity. Equally good results can be obtained by controlling the humidity of the atmosphere in the elevator, aspirator, trumble, and brush. The rough rice entering the mill should be at the temperature of the mill room. Careful attention to these details may reduce breakage losses by several millions of dollars per year.

Fifty-three million sacks of rough rice were produced in the United States in 1953. About 90% of the domestic rice crop is milled, yielding 40 to 60% of its weight as whole grains or head rice. Ten to 30% is broken during harvesting and processing (principally in milling) and the fragments are called second heads, screenings, and brewer's rice, depending on size. Nine per cent of the rough rice (unhulled) is recovered as bran and polish, and 21% as hulls and waste.

Millers continually strive to produce head rice in greater yield—that is, to minimize breakage—because head rice sells at a higher price than the broken grades. It has been estimated that if no breakage occurred during the milling operation, the value of the rice crop produced in a single year would be increased by about $15,000,000.

A few systematic studies have been made of the rice milling process (*3*, *8*). The literature on rice milling research and development is rather scanty and represents little over-all improvement or change in the rice milling procedure over many years. In order to provide the much-needed information on the rice milling procedure and to serve as a basis for any improvements thereon, the facilities of an existing experimental rice mill were used. The mill had been established in February, 1949 by the rice milling industry for research by the University of Arkansas Institute of Science and Technology. In this plant it was decided to make studies of the effect of premilling treatment and of atmospheric conditions on the efficiency of the milling process.

The rice milling process consists of four distinct operations: cleaning, hulling, scouring, and grading (*1*, *4–6*). Hulling and scouring largely determine the efficiency with which rice is processed, and hulling is conventionally performed with a burr-type stone sheller. Bran removal, or scouring, is accomplished in three steps with two scouring machines or hullers and a brush or polisher in series. The degree to which bran adheres to the rice endosperm varies greatly; thus a variation occurs in the amount and intensity of scouring necessary for barn removal. This variation of bran adhesion may be caused by conditions of drying and storage, culture and harvesting methods, and weather conditions. Variety is another important cause of difference in milling characteristics—for example, five to eight times more pressure may be required to mill Zenith rice than to mill Bluebonnet rice to the same degree.

Relative humidity and temperature are not controlled in the rice milling operation. There has been a general feeling that relative humidity is important in rice milling, but no systematic data on this subject have been available. Most rice mill superintendents agree that much better milling on comparable samples is done at night than during daylight hours. They are at a loss, however, to offer an explanation for their observations. In certain parts of Texas, mill rooms are situated at the point in the plant furthest from the dry north winds.

Smith and McCrea have shown that maximum yields of head rice are obtained when rice is milled for grading purposes in a laboratory mill conditioned

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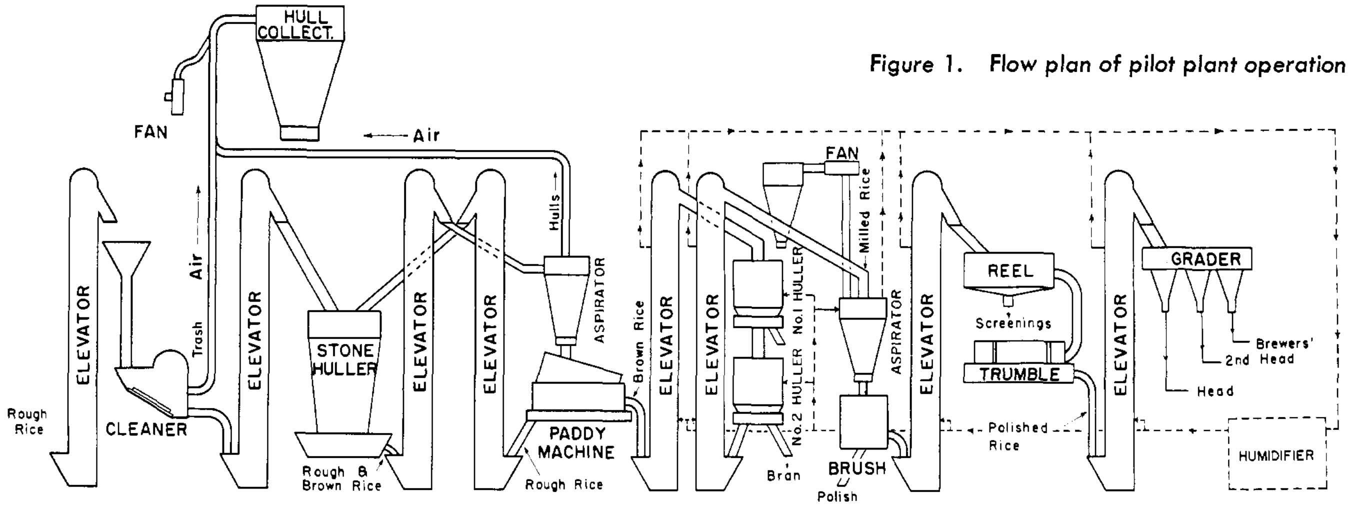


Figure 1. Flow plan of pilot plant operation

with air of 65 to 70% relative humidity (7).

Effect of Processing Variables

The first phase of this study was to relate the operation of the pilot plant with that of commercial mills, to determine the amount of breakage taking place at each part of the operation, to relate the amount of breakage to the degree of milling, and to determine the effect of premilling treatment by steam or abrasives on the milling properties of the rice.

Equipment and Methods The pilot plant consists of a rough rice cleaner, a stone sheller for removing hulls, a paddy machine for separating paddy from brown rice, first- and second-break hullers for scouring bran from rice, a brush for polishing milled rice, and a grader for separating broken from whole grain rice. Aspirators are located after the stone huller and the first- and second-break hullers. This plant has a milling capacity of approximately 75 pounds of rice per hour. Figure 1 presents a schematic plan of the operation.

The procedure used in milling the samples was standardized as nearly as possible. Milling samples of 225 to 250 pounds each were used, and 2 to 3 hours were spent in the processing of each. Runs of this duration were judged by the investigators to be sufficient to furnish reliable results. Controlled samples of approximately 2 pounds each were collected continuously during these runs and the general procedure followed in testing these samples in the laboratory was:

Mix or blend 2-pound composite samples to uniformity

Split 50-gram samples from the 2-pound samples to determine percentage breakage

Split 10-gram sample to determine fat content

Split 100-gram sample to determine moisture content

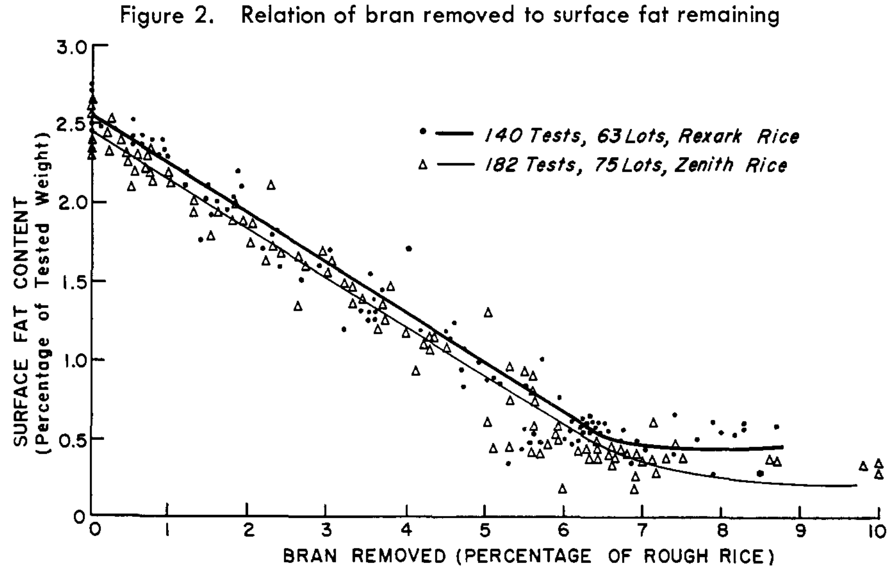
Samples were graded using the approved procedures of the U. S. Department of Agriculture and the percentage by weight of broken rice in the rough rice is reported. Moisture was determined by the use of a Brown-Duval moisture tester. *Milling* yields of the samples are percentages by weight of the quantity of head rice and of total milled rice that are produced from a unit of rough rice.

The degree of bran removal is estimated, in milling practice, by visual inspection. However, it was deemed necessary to use a more accurate and consistent means of measurement in order to obtain quantitative results. The bran layer, which is rather uniformly distributed over the surface of the kernel, contains a high percentage of the total fat content of the rice kernels. A total of 182 tests on the relationship of bran removed to fat extracted from the milled rice, was made on 75 lots of Zenith rice (medium grain). In addition, 140 tests were made on 63 lots of Rexark rice (long grain) grown in 1949, 1950, and 1951.

In conducting this investigation, bran, with the adhering polishing material, was weighed after it had been passed through an 18-mesh sieve to remove small chips of rice. The oil was extracted from the unground milled rice in a standard laboratory fat-extraction apparatus, using diethyl ether as the solvent. The excess ether was removed, the fat was heated and dried in an oven at 100° C. for at least 5 minutes, and the resulting product was weighed.

The percentages of bran removed (based on weight of rough rice) compared to the percentage of fat in the milled rice are plotted in Figure 2. They are related as a straight line from 0 to 6% removal of weight of rice, for both Zenith and Rexark varieties. The plot indicates that either all the bran has been removed when 6% weight loss has been achieved or the inner bran layer is extremely low in fat content. For any given variety, the relationship between the percentage of bran removed and the percentage of fat remaining on the milled rice is constant from year to year. These studies indicate that reliable and consistent results could be obtained by using the fat content of the milled rice as an index of degree of milling. This index is defined as the percentage of surface fat extracted from a sample of milled rice.

Figure 2. Relation of bran removed to surface fat remaining



The milled rice was extracted for 25 minutes to remove the surface oil. This method was suggested by K. K. Keneaster, Converted Rice, Inc., Houston, Tex. It is an approximate measure of the amount of inner bran layer left on the milled rice.

Correlation with Commercial Mills In order to allow proper interpretation of results in the pilot plant mill as they relate to commercial operations, it was necessary to correlate the performance of this mill with a commercial operation. For this purpose, rough rice samples of approximately 1000 pounds each were collected from three commercial mills during 4-hour milling runs. Whenever possible, the lots were sampled continuously. When this procedure was not feasible, samples were taken at 5-minute intervals throughout the milling period of the particular lot. The rate of collection was adjusted to obtain representative samples of the commercial lot. The 1000-pound mill samples were thoroughly mixed, divided into 250-pound lots, and stored in airtight containers preparatory to milling in the pilot plant. At the time the rough rice samples were taken, samples (totaling 2 pounds) were collected at 10-minute intervals from the stone sheller, the first-break huller, the second-break huller, the brush (when used), and the grader in each commercial mill. These samples were sealed in glass jars for use in laboratory tests to compare the product of each operation in the commercial mill with the corresponding product in the pilot plant.

Samples of the same lot of rice were processed over a range of milling with a degree-of-milling index above and below those achieved by the particular commercial mill. There is no accurate means of adjusting the scouring machines to obtain exactly the desired degree of milling. However, this factor can be controlled within satisfactory limits by comparing the color of the milled rice with the previously milled sample (from the same lot) of a known degree-of-milling index. The data thus obtained were treated graphically and correlation factors were determined. All experiments were conducted on medium-grain varieties and the ambient temperature and relative humidity of the commercial mill room and the pilot plant room were recorded.

The results of one of these correlation series are shown in Table I. A 1000-pound sample of Zenith rough rice with a moisture content of 14.5% (wet basis) was used to make these six runs. The pilot plant yielded 57% of head rice with a degree-of-milling index of 0.40% surface fat, compared to 53.8% yield with a like degree-of-milling index by commercial mill C. The relative efficiency of the pilot plant and the commercial mills can be expressed as a correlation factor by means of a ratio of head rice yields:

Table I. Relative Efficiency of Pilot Plant and Commercial Mill C in Yield of Head Rice

Run No.	Temp., °F.	Relative Humidity, %	Degree-of-Milling Index[a]	Yield, %
I	65	37	0.28	51.0
II	66	22	0.32	52.5
III	63	32	0.30	52.8
IV	63	33	0.40	56.5
V	66	37	0.45	60.7
VI	59	34	0.42	59.7
Commercial mill C	45	36	0.40	53.8

[a] Per cent surface fat of milled rice.

Correlation factor =

$$\frac{\text{yield, head rice (\%), commercial mill}}{\text{yield, head rice (\%), pilot plant}} = 0.94$$

The average of three pilot plant correlation factors, including the one mentioned above, was 0.95.

Breakage during Milling Continuous samples were taken during the milling of 167 samples of rough rice of the long-grain and medium-grain types. No appreciable amount of breakage occurred in the operations of the cleaner, the paddy machines, or the grader. Significant amounts of breakage occurred only in the stone sheller, the first-break huller, the second-break huller, and the brush. Representative results of these analyses, averaged for several determinations for each sample, are shown in Table II.

There is no consistent pattern of behavior in the rice milling operations. It is not possible, from examination of Table II, to point to any particular operation as being primarily responsible for breakage in the mill. Several points, however, are evident.

There is a wide variation in behavior of individual lots of rice.

A considerable amount of rice is broken prior to the milling operation.

With few exceptions, the greatest amount of breakage in the rice milling operation takes place in the first and second hullers.

Table II. Proportions of Rice Grains Broken in Shelling, Hulling, and Polishing Operations of Pilot Plant

Rice Grains Broken, %						
When received	In stone sheller	In first huller	In second huller	By brush[a]	Total in milling	Total Breakage, %
Medium Grain						
13.6	1.8	12.8	2.9	6.2	23.9	37.5
7.0	3.2	3.3	6.4	..	13.0	20.0
3.6	2.6	1.5	6.2	..	10.3	13.9
4.7	5.4	6.8	2.5	3.2	18.0	22.7
5.6	3.1	4.4	1.8	..	9.4	15.0
15.0	3.0	1.6	3.0	3.2	10.9	25.9
12.0	3.1	5.5	3.3	2.5	14.3	26.3
9.2	5.5	6.8	4.0	3.0	19.3	28.5
8.1	2.0	5.8	4.0	6.0	19.9	26.0
6.5	5.5	8.0	5.7	2.6	21.5	28.0
12.5	3.2	5.6	9.4	2.0	20.4	32.9
Long Grain						
9.4	4.0	14.5	8.8	..	27.4	36.8
8.3	2.0	1.4	7.9	..	11.3	19.6
6.0	1.8	3.3	5.7	..	10.8	16.8
8.4	4.2	3.5	2.2	..	10.0	18.4
15.7	16.7	3.3	4.1	3.6	27.8	43.5
10.4	9.6	2.9	2.5	5.8	20.9	31.3
13.7	5.6	3.9	6.3	..	15.8	29.5
2.6	2.4	4.8	9.8	..	17.0	19.6
1.9	1.9	4.6	4.1	..	10.6	12.5
7.4	1.4	2.8	1.6	0.8	6.6	14.0
7.5	10.3	5.2	9.7	4.2	29.5	37.0
9.5	8.2	7.1	5.5	1.4	22.2	31.7
14.4	9.0	3.2	3.9	3.0	19.1	33.5
16.2	9.5	0.8	0.8	0.7	12.8	28.0
..	3.5	4.2	4.5	2.3	14.5	14.5
5.0	3.5	3.7	2.6	2.4	12.2	17.2
10.0	5.1	6.3	4.1	..	15.5	25.5
6.5	7.4	4.6	3.7	..	15.7	22.2

[a] Blank spaces under this heading indicate that brush operation was not included in run.

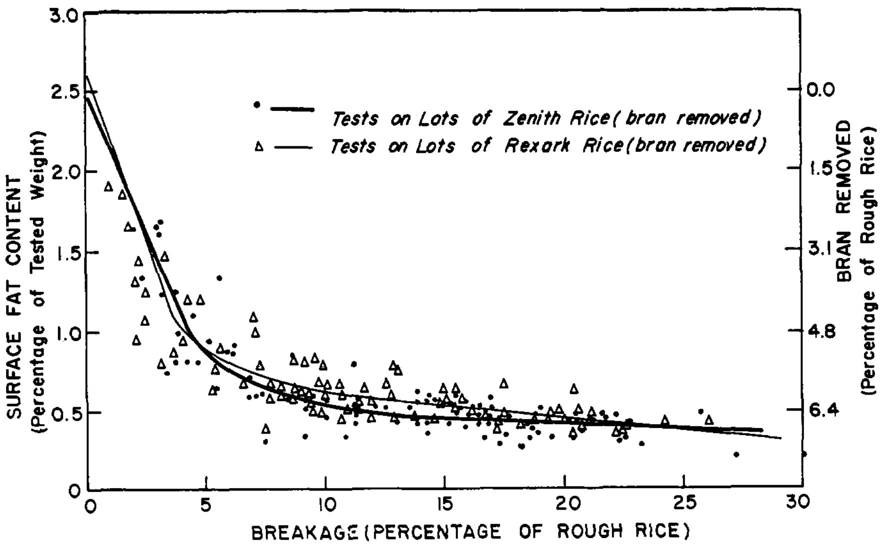


Figure 3. Relation of breakage to surface fat content

Relationship of Bran Removed to Breakage A total of 103 tests on the relationship of bran removed to breakage on 73 lots of Zenith rice and 105 tests on 63 lots of Rexark rice grown in 1949, 1950, and 1951 were made. The results are shown in Figure 3. There was no significant difference in the relationship of breakage to fat content from year to year.

Breakage was related to the amount of fat retained in the milled rice kernel. The outer bran is removed with relatively little breakage. However, as scouring proceeds, breakage increases and relatively little additional bran is removed. Only about one fifth of the total breakage occurs during the period in which 75% of the bran is removed. Thus, about four fifths of breakage takes place during the removal of the final 25% of the bran. Well milled Zenith rice contains 0.45% or less of fat; well milled Rexark contains 0.55% or less of fat.

Premilling of Brown Rice Steaming. The steaming of brown rice before the next step in milling has become a common procedure in commercial mills. Although it is recognized that steam assists removal of bran, no systematic study has been made previously of its effect upon bran adhesion or milling yields. In practice, different methods and types of equipment are used for steaming rice. In the pilot plant, steam was blown through a bed of moving rice in a screw conveyor, a method similar to that used in many commercial mills. It was found that droplets of water should not be allowed to come into contact with the rice and that the temperature of the rice should not be allowed to rise appreciably. When either of these conditions occurs, the result is a decrease in the yield of head rice. Optimum results are obtained when the rice comes from the steamed bath slightly damp and at a temperature near its entering temperature.

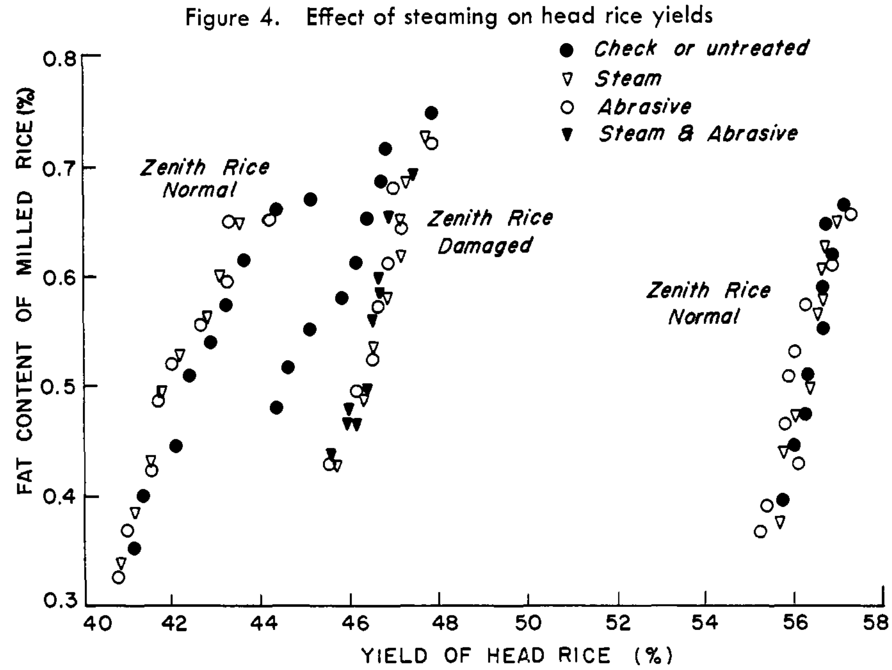
Experiments were made to determine the optimum steaming rate for three selected lots of Rexark rice using steam under a pressure of 20 pounds per square inch. Steaming rates are expressed as pounds of steam per 100 pounds of brown rice; yields as the pounds of whole rice obtained from 100 pounds of rough rice. The optimum steaming rate for Rexark rice was found to be 0.5 pound of steam per 100 pounds of brown rice. Zenith rice required 0.2 pound of steam per 100 pounds of brown rice. These steam rates were used in all subsequent tests.

Figure 4 presents graphically the effect of steaming on head rice yields of different surface fat content. On properly dried rice, lots 1 and 2, steaming had no significant effect upon yield. However, in lot 3, which was damaged severely in storage, resulting in greater adherence of the bran to the endosperm, the yield was increased greatly by steaming. As the intensity of milling was increased, the spread between steamed and unsteamed rice in the damaged lot was increased, showing the advantage of steaming on such types of rough rice. Similar results were obtained with Rexark samples. Figure 5 presents graphically the effect of steaming upon ease of milling. For the same throughput of rice, a higher degree of milling (as measured by surface fat) was achieved as a result of steaming the rice and the effect was more pronounced on damaged rice. This graph further demonstrates that steaming increases capacity of the pilot mill by about 0.2 pound per minute for the same degree of milling.

Effect of Abrasives. The addition of abrasives to rice before milling is a more common practice than steaming. Abrasives are mixed with rice to assist in scouring. A series of tests was made using the following abrasives: calcium carbonate, fine bauxite, coarse bauxite, and Attaclay (manufactured by Minerals and Chemicals Corp. of America, Philadelphia, Pa.). Calcium carbonate is the only abrasive commonly used for this purpose. The results of these tests on selected lots of Zenith and Rexark rice are shown in Figures 4 and 5. In all experiments, the mill was used at maximum capacity and the rate of application of abrasive was governed by the amount that would adhere to the brown rice. For each lot this was approximately 1.5 pounds of abrasives per 100 pounds of brown rice.

With properly dried and stored rice, abrasives had no significant effect upon yield. The yield was increased, however, on rice that had been heat damaged

Figure 4. Effect of steaming on head rice yields



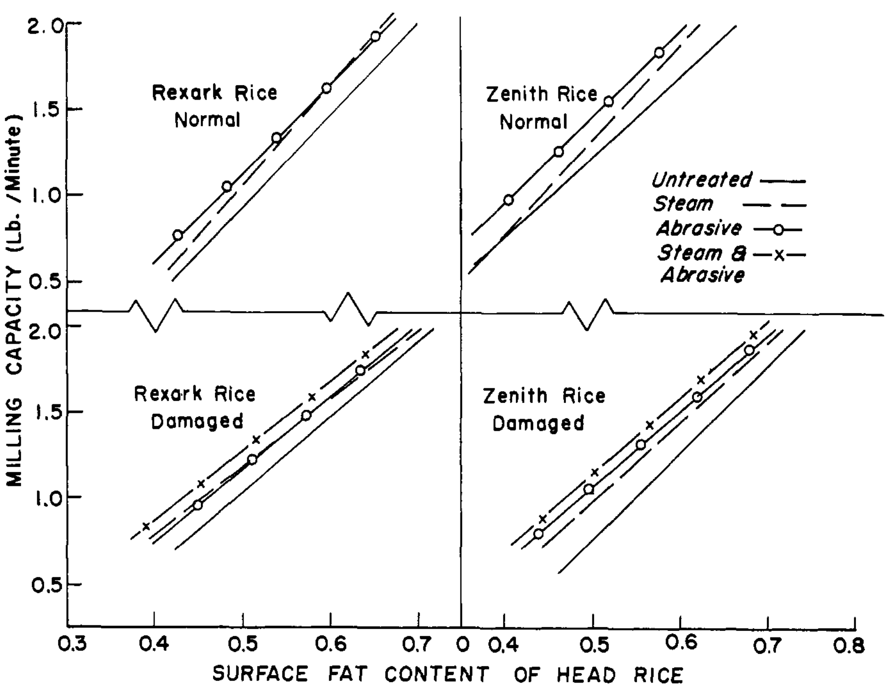


Figure 5. Effect of steam and abrasives on milling capacity

in storage and, in this respect, use of abrasives parallels use of steam in behavior. In every instance, the most efficient milling was obtained with calcium carbonate. The effect of abrasive on ease of milling is shown in Figure 5, where it is illustrated that the result is similar to that obtained when steam is utilized, particularly on the damaged lots. When both steam and calcium carbonate are used, there is greater improvement in mill capacity than when either is used alone (Figure 5).

Summary and Conclusions The milling efficiency of the pilot plant equipment was correlated with that of the commercial mills and the correlation factor (ratio of head rice yields in commercial mill to those in pilot mill) was 0.95. Thus, it is possible to compare the findings in this mill with commercial findings and to apply these to commercial practice.

Breakage during milling occurs in the stone sheller, first-break huller, second-break huller, and brush in significant amounts. Considerable amounts of broken grain were received.

There is a linear relation between the percentage of surface fat in the milled rice and the amount of bran removed until the weight loss of the rough rice exceeds 6%. One fifth of the total breakage occurs during the period in which 75% of the bran is removed.

Steaming and adding abrasives to rice decrease the amount and intensity of scouring required to remove the bran and increase the capacity of the mill. Yield, however, is not increased significantly, except for the samples of rice which had been damaged prior to milling and upon which the bran adhered more tightly to the endosperm than in the normal samples.

Effect of Atmospheric Variables

In the second phase of the study, the effect of atmospheric variables such as relative humidity and temperature in the mill room as well as in certain operations in the milling process was investigated.

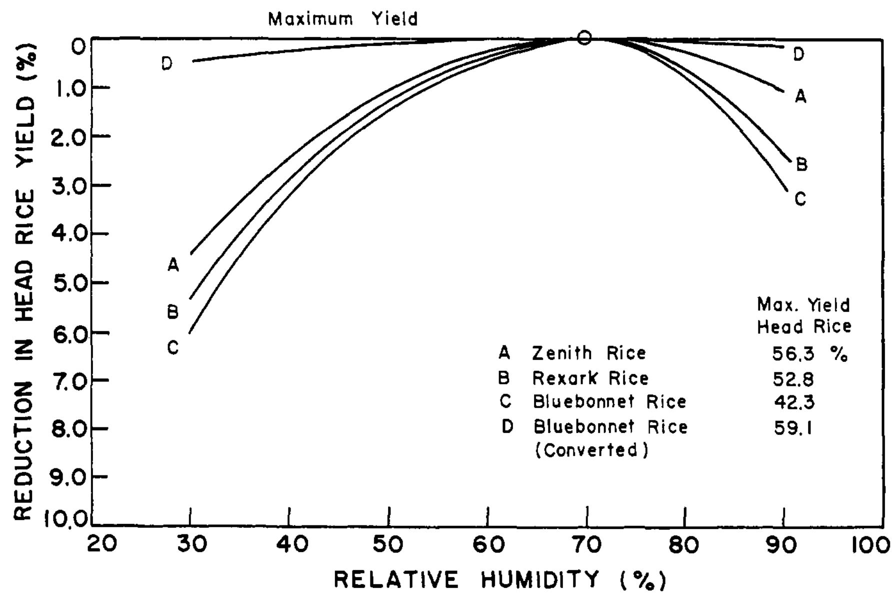
Equipment and Methods The pilot plant has been described. Figure 1 shows in dotted outline the plant modifications that were required to achieve localized relative humidity control.

The procedures described above were used in obtaining samples and in estimating the efficiency of milling. The operations of the pilot plant mill correlate well with commercial operation.

Effect of Relative Humidity **Experiments in Pilot Plant.** Experiments on the effect of relative humidity in the mill room at constant temperature were conducted on three varieties of rough rice and one sample of parboiled rice. Each lot of approximately 1200 pounds of rough rice was collected from representative lots being handled in commercial mills. The lot was thoroughly mixed, divided into six 200-pound sub lots, and stored in airtight containers for 1 to 3 weeks preparatory to milling. The mill room temperature was maintained at 85° ±2° F., and the mill machinery was adjusted to operate at maximum capacity (75 pounds of rice per hour) producing a well milled rice with a degree-of-milling index comparable to USDA Grade No. 1. For these investigations, the entire mill room was conditioned to control the relative humidity. The optimum relative humidity for processing the rice was found to be around 70%. The effect of humidity on yield was greatest for Bluebonnet (long grain) and lowest for Zenith rice (medium grain). For Bluebonnet the range in yield was from 39.1 to 42.3 (or 3.2%) over a range in humidity from 50 to 70%; for Zenith, from 52.8 to 54.6 (or 1.8%) over the same humidity range. There was little effect of relative humidity on the yields of parboiled rice. The average percentage deviation for maximum yield for all rice samples investigated is presented graphically in Figure 6.

Relative Humidity in Commercial Mills. The results obtained in the pilot plant were checked in commercial mills by selecting several days of differing

Figure 6. Average deviation from maximum yield with changes in humidity



relative humidity and comparing the milling yields of the same lot of rice on these days. Close agreement could be discerned by comparison of the data obtained in commercial mills. These results for three varieties of rice are shown in Table III. The humidity was not more than 76% any of the days on which the tests were made. Therefore, only the lower relative-humidity side of the curve of the type given in Figure 6 was obtained. It is clear, however, that there is a pronounced decrease in yield of head rice when the milling is done at low relative humidities. These results confirm the correlations between the mill operation and the pilot plant operation previously established and also serve to show that days exist during the milling season when the relative humidity is at a low level.

Table V. Effects of Controlled Relative Humidity upon Rice Milling Efficiency of Pilot Plant Equipment

Relative Humidity, %: In room	Relative Humidity, %: Conditioned air		Yield of Head Rice, %	Total Yield, %
		Zenith Rice (13.1% Moisture)		
30	30	All operations conditioned	47.7	70.5
30	30	All operations conditioned	47.5	70.5
70	70	All operations conditioned	52.7	70.5
70	70	All operations conditioned	53.0	70.5
70	70	All operations conditioned	52.8	70.5
30	70	All operations conditioned	52.8	70.5
30	70	All operations conditioned	52.9	70.5
30	70	Elevators and aspirators conditioned but	51.7	70.5
30	70	first- and second-break huller, brush,	51.6	70.5
30	70	trumble off	51.7	70.5
		Rexark Rice (12.8% Moisture)		
30	30	All operations conditioned	48.8	70.7
70	70	All operations conditioned	51.1	70.7
30	70	All operations conditioned	50.7	70.7
30	90	Elevators and aspirators conditioned but	49.7	70.7
30	70	first- and second-break huller, brush,	50.7	70.7
30	70	trumble off	50.3	70.7
		Elevators and aspirators conditioned but:		
30	70	First-break huller off	51.1	70.7
30	70	First- and second-break hullers off	51.0	70.7
		Arkrose Rice (11.1% Moisture)		
30	30	All operations conditioned	49.8	69.6
30	70	All operations conditioned	51.7	69.6
30	70	Elevator to first-break huller off	51.5	69.6

Table III. Effect of Humidity on Head Rice Yield in a Commercial Mill

Relative Humidity of Mill Room, %	Yield, %[a]: Head rice	Yield, %[a]: Total rice
Zenith		
Lot 1		
68	46.6	68.0
76	46.7	68.0
Lot 2		
32	37.4	68.0
45	39.4	68.0
58	41.0	68.0
60	41.2	68.0
Rexark		
Lot 1		
38	48.7	70.5
62	51.0	70.5
Lot 2		
50	50.5	70.0
55	50.7	70.0
60	51.7	70.0
66	53.0	70.0
Bluebonnet		
Lot 1		
48	40.4	69.0
65	44.0	69.0
75	44.2	69.0
Lot 2		
50	39.9	69.0
60	41.5	69.0
60	41.6	69.0

[a] Calculated from mill scale readings.

Isolation of Relative Humidity Effect

Effect of Cooling Rice in Closed Containers between Milling Operations. It has been demonstrated that relative humidity has a profound and economically important effect upon the yield of head rice. It remained to determine whether it was necessary to humidify or control the humidity in the entire milling room or only in portions of the operation. Such information would not only permit efficient utilization by the industry, but would provide a clue to the reason for this relative humidity effect. As the first step in this direction, the effect of cooling the rice in closed containers between operations was determined.

Rice was milled at 70° F. and 30% relative humidity, conditions designed to give a low yield. Zenith Rice of the same moisture content, 11.8% wet basis, was milled under conditions of 70° F. and 70% relative humidity, conditions presumed to give a high milling yield. There were three samples, in which rice was allowed to cool (1) in a closed container after passing through the first-break huller, (2) after passing through the second-break huller, and (3) after passing through both the first- and the second-break hullers. The results of these experiments are presented in Table IV. When the rice was allowed to cool in a closed container during the operation, particularly after the second-break hulling, practically the same yield of head rice was obtained as under the optimum conditions of processing.

Control of Humidity within Milling Equipment. In another series of experiments, the temperature of the equipment was controlled at 80° F. and the milling room was conditioned to 30% relative humidity to create conditions which would give poor yield. Then certain sections of the equipment were conditioned to 70% relative humidity, to determine whether such an operation would overcome the general deleterious effect of 30% relative humidity in the entire room. The results of these investigations are shown in Table V. When all the equipment was conditioned, the resulting yields were comparable to those obtained when the relative humidity of the entire room was controlled. It was possible to eliminate the conditioning of the elevator to the first-break huller, first- and second-break hullers—(collectively and individually), and the brush and trumble without materially influencing the yield of head rice. Only

Table IV. Effect of Cooling Rice between Milling Operations

Temperature of Rice, °F.: Out of 1st huller[a]	Into 2nd huller	Out of 2nd huller	Into brush	Yield of Head Rice, %
99[a]	87	144	107	50.5
103 cooled[b]	72	135 cooled	70	56.3
103[b]	94	147 cooled	72	55.5
103 cooled[b]	72	139	110	54.2
103[c]	93	145	108	56.3

[a] Rice entered mill at 70° F.
[b] Runs made at room conditions of 70° F. and 30% R. H.
[c] Run made at ideal conditions of 70° F. and 70% R. H.

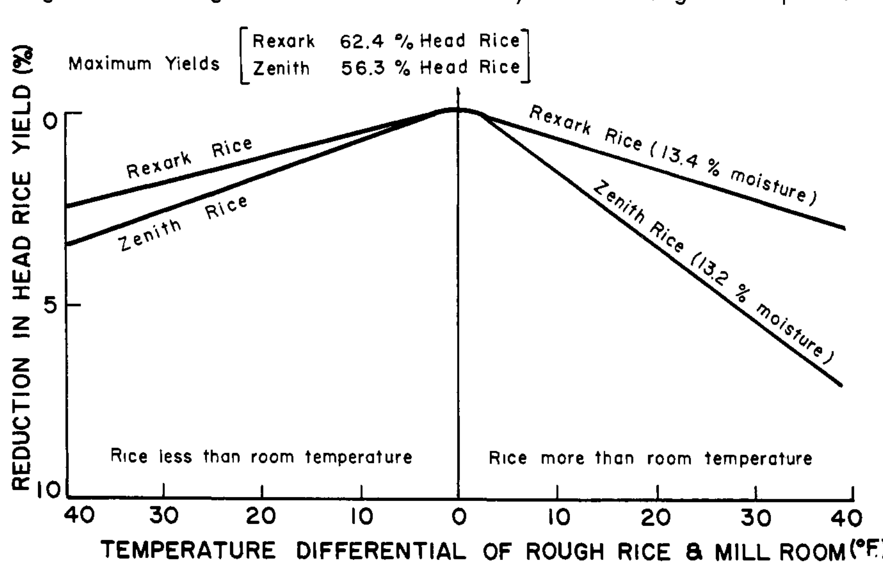
1% of the total yield was lost by not conditioning air to the first- and second-break hullers, the brush, and the trumble. These data demonstrate that the operations in which the rice comes into contact with large volumes of air, particularly in aspirators and elevators following the huller operations, are the critical points at which humidity affects yields of head rice. Thus, it should be possible to obtain the beneficial effect of humidifying an entire mill room by controlling the humidity in the elevators and the aspirators.

Effect of Temperature The relationship of mill room temperature to the temperature of the rice as it enters the mill is an important factor determining optimum yields, but it apparently is not as important as relative humidity under normal operating conditions. Only rarely does the temperature of the rice differ from the temperature of the mill room by as much as 20° F. In the southwest part of the United States, the temperature of stored rice usually equalizes with the average ambient temperature. Experiments were conducted to determine what effect, if any, would exist in the yield of head rice under conditions of great temperature differences between the stored rice and the milling room.

It was found that the absolute temperature of the mill room was not related to the optimum yield of head rice. However, the difference between the temperature of the rice entering the mill room and the temperature of the mill room itself could be correlated with yield. Experiments were conducted in which all adjustments of machinery were made so that the mill was operating at maximum capacity and producing a well milled rice with a degree of milling comparable to USDA Grade No. 1. Results are shown in Figure 7.

Optimum yields were obtained when there was no temperature differential between the rice and the mill room. Rexark rice was affected less by temperature differential than Zenith. There was a more significant decrease in yield when the temperature of the rice was greater than the temperature of the mill room. With the temperature differential of 10° F., Zenith rice showed an average deviation of 1.6% from optimum yields when the temperature of the rice was greater than that of the mill room. When the temperature of the rice was 10° F. lower than the temperature of the mill room, the average deviation was only 0.9%. Obviously an extreme differential in temperature is required to cause a great reduction in yield. If both temperature and relative humidity are reduced simultaneously, as easily could happen in winter, there would be a marked reduction in yield of head rice.

Figure 7. Average deviation from maximum yield with changes in temperature



Discussion

Breaking of rice during the milling process would seem to be associated with two processes: (1) development of strains and weak spots in the rice kernel, and (2) breakage of the kernel when subjected to mechanical stresses. It would seem that relative humidity has a profound effect on the occurrence of stresses in the rice kernel, and thereby makes breakage of the kernel possible when subjected to further mechanical strain. Examination of the lots of rice used in the experiments reported in this paper indicates that the majority fell between 13 and 14% moisture content (wet basis). On the basis of work by Karon and Adams (*2*) on the hygroscopic equilibrium of rice and rice fractions, all of the samples of rice that were milled were in equilibrium with air of relative humidity in the range of 60 to 80%, and most were in equilibrium with air of 70% relative humidity. Under these circumstances, there was less tendency for moisture to leave or enter the partially milled rice grain when the rice was in equilibrium with the surrounding air and, therefore, around 70% relative humidity.

The minimum amount of strain would be expected to occur in the rice under these conditions and the factors which contribute to breakage of the rice when subjected to further mechanical strain would be minimized. This seems to be a reasonable explanation of the effect of relative humidity on the rice milling operation and for the fact that when it is controlled to about 70%, optimum results are obtained.

When the rice is allowed to cool in a sealed container between milling operations, strain is minimized because moisture equilibrium with the interseed air is maintained. The fact that control of the points where large volumes of air come into contact with the rice gives the same effect as control of the entire milling room, is further substantiation of the fact that it is the strain of moisture loss that determines the susceptibility of rice to further breakage.

Presumably, temperature has a lesser effect on moisture transfer in rice than does relative humidity. Therefore, differences between temperature of the rice and temperature of the milling room have less effect on milling yield than when the rice and the surrounding air are not in hygroscopic equilibrium.

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