BREAKAGE OF LONG-GRAIN RICE IN RELATION TO KERNEL THICKNESS[1]

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ABSTRACT

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Six lots of rough rice were separated into four fractions according to thickness of kernels. X-Ray photographs were used to determine the percentage distribution of cracked and broken rough rice in the fractions and in an unfractionated control sample of each lot. Percentage breakage after milling the various fractions (and control samples) demonstrated that breakage in the rough rice was related to that in the milled rice. The larger the percentage breakage in the milled unfractionated rice, the larger the breakage tended to be in all the milled fractions of a given lot. The distribution of rice among the four thickness fractions differed considerably in the various lots of rice. In general, breakage in the milled rice was greater for the thinner fractions.

Rice breakage is a serious economic problem for the rice industry because the value of broken rice is only one-half to two-thirds that of whole-grain rice. The efforts of rice breeders in developing new varieties, improvements in design of shelling and milling equipment, improvements in drying conditions, and treatments (parboiling, extractive milling) of the rice prior to or during milling have resulted in reduced breakage. However, further means for minimizing breakage would benefit rice millers and farmers.

Although a number of fundamental studies have been made on rice breakage (1,2,3, for example) and on factors affecting breakage such as moisture content at the time of harvest (4), milling at low moisture levels (5), and high temperatures during drying (6), a more complete understanding of the causes of the problem would help find possible ways to prevent breakage.

To explore the role of kernel thickness in breakage of rice, we determined the distribution of cracked and broken rough rice, the distribution of breakage after milling, and the distribution of rough rice among various thickness fractions in different lots of rice.

MATERIALS AND METHODS

Six lots of long-grain rice including Bluebelle, Bluebonnet-50, and Belle Patna varieties were examined. Moisture contents, determined with a Motomco Moisture Meter, ranged from 11.2 to 12.6%.

Each lot of rough rice was passed over the number 28 and 25 screens of the Carter Dockage Tester (7) to remove dockage, then passed over the number 000 riddle to remove broken brown rice. The aspirator of the Dockage Tester also removed material of low density such as sterile florets.

Each cleaned lot of rough rice was passed over slotted screens to separate it into kernels of different thicknesses. The thickest kernels were separated by passing the rice over the Carter No. 24 slotted screen placed in the top sieve

[1]Use of a company or product name by the U.S. Department of Agriculture does not imply approval or recommendation of the product to the exclusion of others that may also be suitable.

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position of the Dockage Tester; slots in the No. 24 screen are 0.078 in. wide. One pass over the screen removed most of the kernels thinner than 0.078 in. However, the kernels passing over the screen were passed an additional two times over the screen to ensure complete separation. The top sieve position of the Dockage Tester (which has an up-and-down motion) was used rather than the middle or bottom sieve positions (which have a side-to-side motion) because there was less tendency for the rice to stick in the slots of the screen.

In a fashion similar to the above, the rice which passed through the No. 24 screen was passed over the No. 23 screen (slot width 0.076 in.), rice passing through the No. 23 screen was passed over the No. 5 screen (slot width 0.070 in.), and rice passing through the No. 5 screen was passed over the No. 4 screen (slot width 0.064 in.). Since all the rice in the original cleaning process passed through the No. 25 screen (slot width 0.094 in.), these operations yielded five fractions of kernels differing in thickness. These were, in thickness, 0.078–0.094, 0.076–0.078, 0.070–0.076, 0.064–0.070 in., plus the kernels passing through the No. 4 screen which were less than 0.064 in. in thickness. Kernels passing through the No. 4 screen (0.064 in.) amounted to 4% or less of the total rice and were not analyzed further since they were very immature.

To serve as controls, several kilograms of each lot of rough rice were cleaned as above but not separated into thickness fractions except that the thinnest kernels, those passing through the No. 4 screen, were removed.

Fifty-gram samples of each of the rough rice fractions and controls were spread out in a monolayer under an X-ray film and exposed 1 min in a General Electric X-ray Grain Inspection Unit. The developed films were examined, and the total numbers of cracked kernels, broken kernels, and hulls containing part of a broken kernel were recorded. The total number of kernels in the 50.0-g samples was determined by counting the kernels in duplicate 5.0-g samples, multiplying the average by 10. The cracked and broken kernels may be expressed as a number percentage of the total number of kernels. Therefore, since the number percentage was determined on kernels of nearly the same thickness and on kernels of about the same weight, the percentage is expressed by weight in the data in order to facilitate comparisons. Also, for simplicity, cracked rough rice kernels are counted as broken in the data. Most cracked rough rice kernels break in the shelling and milling processes; but not all necessarily do so, as shown in previous publications (8,9) and by the data presented in this paper.

Two replicate samples were assayed in all determinations except for the determination of cracked and broken kernels in the rough rice as described above; averages of the replicates are reported.

A portion of each rough rice sample (about 1000 g) was shelled in a McGill Sheller according to directions in the Rice Inspection Manual. The standard clearance of 0.019 in. for long-grain rice was used between rollers of the sheller for all samples (7). No attempt was made to vary the clearance for each fraction since the unfractionated samples, which contain all the fractions, were shelled at one clearance; also, the varying of the clearance for each different fractionated sample would have introduced a variable that would have been difficult to control. In shelling the various lots, the thinnest fractions gave from 22 to 31% hulls in contrast to about 19% hulls from the three thicker fractions. Loss (material not accounted for) in shelling 1000.0 g of rouch rice was negligible, about 0.5 g. Samples (800 g) of the resulting brown rice were milled in the McGill Miller No. 3 according to directions in the Rice Inspection Manual. For a few samples of small size, 100.0-g samples of brown rice were milled in a McGill Mill No. 1 using hand pressure; these samples are indicated in the data. Experimental observations on one lot of rice showed that samples milled in the No. 1 did not greatly differ in percentage breakage from samples milled in the McGill No. 3.

Broken rice from both the shelling and milling operations was determined with the sizing device recommended in the Rice Inspection Manual, but no hand adjustment of head rice was made. Samples of about 200 g were used for sizing. A Boerner Sample Divider was used to obtain representative small samples. Broken brown rice is expressed as a percentage of the total brown rice and broken milled rice as a percentage of the total milled rice by weight.

Chips (small pieces of broken rice) were separated from the bran by aspiration and sieving, and then weighed.

The percentage of kernels with green-colored bran (immature kernels) was determined by hand-separating the green from the brown kernels in duplicate 25- to 50-g samples of shelled rice and weighing the two fractions.

RESULTS AND DISCUSSION

The results are presented in Table I. The first column shows the thicknesses of the four fractions and the unfractionated control of the rough rice of each lot. The six lots of rice are arranged from top to bottom in order of increasing percentage breakage in the milled rice of the control sample (seventh column of Table I).

Data in the second column of Table I show that the distribution of rice among the four thickness fractions differed considerably among the lots of rice. The percentage of rice in the thinnest fraction was small in all lots, ranging from 5.2 to 12.0%.

Kernel weights of the thinnest kernels, on the average, were about two-thirds those of the thickest kernels. The thickest fractions contained about 200 kernels in 5.0 g or an average weight per kernel of 0.025 g. The thinnest fractions contained about 300 kernels in 5.0 g or an average weight per kernel of 0.017 g.

Kernels with green bran are immature. The fourth column shows that percentage of kernels having green bran increased with decrease in thickness of each fraction. This relation indicates that separation according to thickness also makes a partial separation of the rice according to maturity—the thicker kernels were, on the average, more mature.

Data in the fifth column of Table I show that for five of the six lots, breakage of rough rice was minimal in one of the fractions of intermediate thickness (0.070–0.076 and 0.076–0.078 in.). Lot 3 is the exception. For lots 1 and 5, minimal breakage in one of the intermediate thickness fractions of the rough rice corresponded with minimal breakage in the brown and milled rice. In lots 2, 3, 4, and 6, breakage of milled rice increased with decrease in thickness.

The breakage in the brown rice (column 6) was slightly smaller in several instances than that in the rough rice as may be observed by comparing the respective figures in the two thickest fractions of lots 1, 2, 3, and 4, and suggests that some of the thicker, cracked, rough rice kernels may be sufficiently strong to survive intact the mechanical stresses of shelling.

TABLE I
Rough Rice Thickness, Distribution, and Breakage Data for Six Lots of Rice

Rough Rice				Wt % Breakage				
Thickness in.	Wt % of Total Rice[a]	No. of Kernels in 5 g	Wt % Green Bran Kernels	Rough Rice[b]	Brown Rice	Milled Rice	g of Bran[c]	g of Chips
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
			Variety: Bluebonnet Lot 1					
0.078–0.094	1.6	197	0.0	2.8	3.8	5.6[d]	88.8	9.6
0.076–0.078	9.6	203	0.1	2.4	2.2	3.8	92.9	8.5
0.070–0.076	76.8	226	1.5	2.4	3.2	5.4	101.1	9.1
0.064–0.070	12.0	302	18.7	9.5	13.6	33.2	146.8	22.7
0.064–0.094	100.0	247		4.0	4.4	8.6	110.5	12.1
			Variety: Bluebonnet Lot 2					
0.078–0.094	54.3	186	4.7	4.6	3.8	5.3	75.3	5.1
0.076–0.078	23.6	203	9.5	3.2	4.0	7.0	79.9	5.3
0.070–0.076	17.0	231	27.4	4.7	7.2	18.3	92.0	9.0
0.064–0.070	5.2	277	27.6	6.3	13.5	35.0[d]	119.2	34.4
0.064–0.094	100.0	205		4.1	4.9	9.6	84.6	8.6
			Variety: Bluebelle Lot 3					
0.078–0.094	35.1	199	2.5	6.3	6.2	10.0	88.0	6.5
0.076–0.078	24.2	219	3.1	8.5	7.5	11.1	93.3	7.9
0.070–0.076	31.7	249	7.8	8.4	10.6	19.0	111.4	11.9
0.064–0.070	9.1	328	17.8	15.0	22.8	63.3[d]	155.2	49.6
0.064–0.094	100.0	239		8.8	10.2	16.6	110.3	14.8
			Variety: Bluebelle Lot 4					
0.078–0.094	47.3	188	0.3	8.8	9.1	13.3	88.6	7.0
0.076–0.078	24.7	199	0.9	11.3	8.9	14.2	96.6	7.5
0.070–0.076	22.2	250	6.3	7.3	12.0	25.1	112.5	12.1
0.064–0.070	5.8	327	20.0	16.9	39.5	64.6[d]	139.2	37.6
0.064–0.094	100.0	203		10.5	11.2	20.0	101.9	11.7
			Variety: Belle Patna Lot 5					
0.078–0.094	5.3	205	0.2	19.5	26.4	35.6	92.8	14.4
0.076–0.078	20.0	210	0.2	15.9	20.9	28.2	93.2	9.9
0.070–0.076	65.9	234	1.0	9.7	15.4	24.3	100.8	12.1
0.064–0.070	8.8	303	7.4	16.4	29.7	52.2	178.4	52.0
0.064–0.094	100.0	244		13.1	18.4	27.0	104.6	14.8
			Variety: Bluebelle Lot 6					
0.078–0.094	31.9	194	2.0	10.4	12.3	17.2	91.0	9.6
0.076–0.078	28.2	215	4.6	9.4	12.2	19.9	97.6	8.8
0.070–0.076	31.5	234	12.0	11.9	19.1	31.9	115.3	13.7
0.064–0.070	8.4	332	32.1	19.3	52.7	76.9[d]	168.0	52.0
0.064–0.094	100.0	219		12.3	17.0	27.1	114.5	17.5

[a]Does not include rice of less than 0.064 in. thickness which passed through No. 4 screen.
[b]Kernels showing cracks in X-ray were classed as broken.
[c]Grams of bran from 800.0 g brown rice.
[d]Samples milled in McGill No. 1 mill.

Figure 1 shows the breakage in the rough rice plotted against breakage in the milled rice. For the unfractionated samples, the ratio for breakage was about 1:2 between rough and milled rice. For example, for lot 1, the ratio was 4.0:8.6. For the unfractionated controls, the normal regression equation is $y = 0.44 + 2.01x$ and correlation coefficient (r) is 0.99. For the various thickness fractions, normal regression equations and correlation coefficients are: for 0.078–0.094 in., $y = -1.96 + 1.88x$ and $r = 0.99$; for 0.076–0.078 in., $y = 0.23 + 1.63x$ and $r = 0.93$; for 0.070–0.076 in., $y = 3.12 + 2.37x$ and $r = 0.91$; for 0.064–0.070 in., $y = 8.44 + 3.28x$ and $r = 0.92$. Thus, the ratio between per cent broken rough and broken milled rice depends on the thickness of each fraction. The thinnest fractions have a high percentage breakage in the rough rice and with a ratio of about 1:3 between per cent broken rough to broken milled rice, an even higher breakage in the milled rice.

all the milled fractions (Fig. 2). Lot 5 is not plotted in Fig. 2 since the plotted points do not fit the general relation shown by the other lots. The data indicate that all the thickness fractions of a given lot have some characteristic in common in relation to strength (or weakness) of the kernels. Points representing a given thickness fraction in the various lots fall close to a straight line passing through the origin (zero breakage).

The amount of "bran" (bran layer, aleurone layer, germ, and chips) removed in milling increased with decrease in thickness of the kernels (Table I). The amount

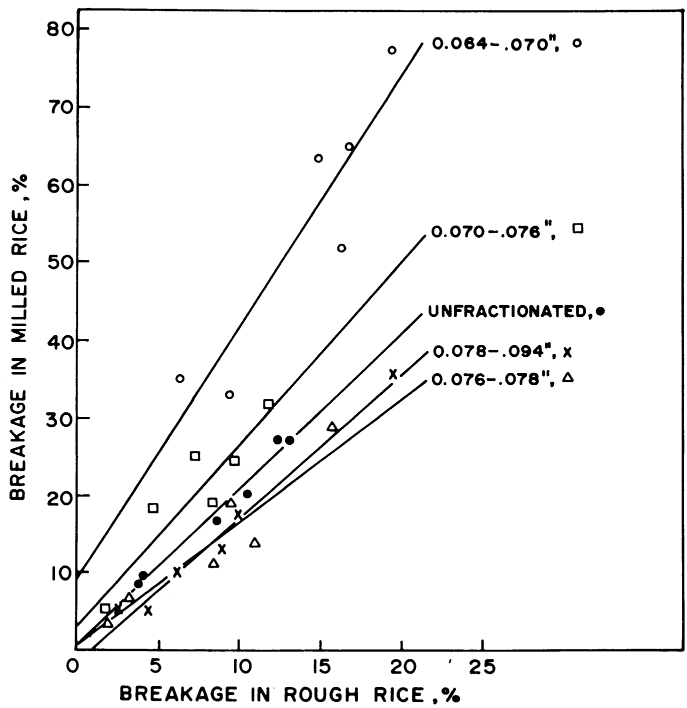

Fig. 1. Per cent breakage in the rough rice *vs.* per cent breakage in the milled rice.

of unaccounted-for material lost in milling 800.0 g of brown rice was always close to 4 g. The amount of total rice obtained in each case may be calculated by subtracting the amount of bran from 796 g. The amount of chips in the bran was always several times as large in the thinnest fraction as in any of the three thicker fractions. The contribution of the thinnest fraction to a decrease in total milled rice was thus large in comparison to its percentage in the rough rice.

GENERAL CONCLUSIONS

Different lots of rice may vary considerably in their distribution among the various thickness fractions. There is a ratio between broken rough and broken milled rice that depends for its magnitude on the thickness fraction (or unfractionated control) under consideration. The ratio was about 1:2 for the unfractionated samples and varied between 1:1.6 and 1:3.2 for the fractionated

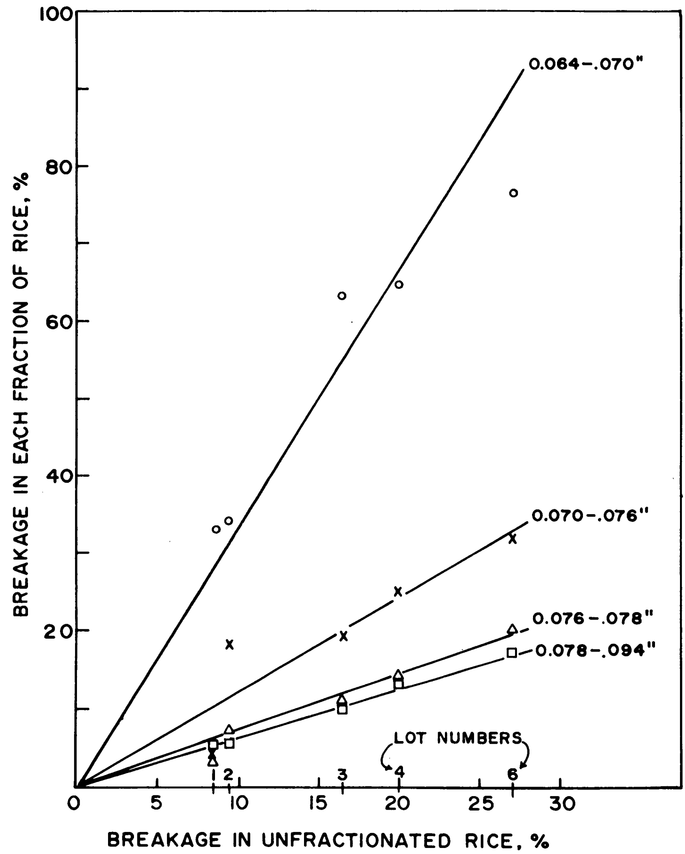

Fig. 2. Per cent breakage in the milled individual thickness fractions plotted above the per cent breakage in the milled unfractionated sample of each lot. Data from lot 5, Belle Patna, do not fit the indicated relationships.

samples. In five of the six lots, there was minimal breakage of the rough rice in one of the fractions of intermediate thickness. The breakage in all the milled thickness fractions tended to be larger, the larger the breakage in the milled unfractionated rice of a given lot.

The data presented suggest that breakage of rice during milling might be related to stresses applied to the rough rice in the field or during harvesting or drying. The conclusion is based on the relation between breakage in rough and milled rice in the control samples and in the various thickness fractions. The observed relation suggests that for every weak (cracked and broken) rough rice kernel that can be observed on the X-ray films, there are other weak kernels in proportion which become apparent by breaking when subjected to the stresses of shelling and milling.

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