Milling of Paddy in Relation to Yield and Quality of Rice of Different Indian Varieties

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The effect of extended milling of three coarse, two medium-fine, and one fine-grained Indian variety of paddy was evaluated with respect to yield, breakage of rice, grain dimensions, protein, and amylose contents in relation to water uptake ratio values and cooking quality of rice. The coarse variety, IR 8, gave the highest yield of brown rice (83%). The extent of breakage of rice depended on the variety but increased in all cases with the degree of milling. In comparison, Palman 579, a medium-fine variety, proved resistant to breakage during milling. Bulk density and 1000-kernel weight of coarse varieties were higher than those of the fine and medium-fine varieties. The amylose content of rice increased with the degree of polish to the extent of 5.8 to 8.4%. There was a corresponding increase in the water uptake ratio as well. The correlation coefficients between water uptake ratio values and amylose were statistically highly significant. The values ranged from +0.784 to +0.995. The variety RP 5-3 was most susceptible to alkali degradation, whereas Basmati 370 was least susceptible. Basmati 370 rice cooked to individual grains showing maximum elongation which increased with the degree of milling.

Milling of paddy and factors influencing it are important technological considerations in the processing of rice for the market. Inappropriate conditions of drying (Henderson, 1954; Wasserman et al., 1957; Angladette, 1963), moisture content (Prominsky et al., 1961), chalkiness, infestation (Schroeder, 1967), and fluctuating relative humidity and temperature (Autrey et al., 1955) cause increased breakage of raw rice during milling.

Information about the effects of extended milling on the yield and quality of rice is scanty. The results of milling to varying degrees of polish of some commercially important Indian coarse and fine varieties of paddy are reported in this paper. Significant differences were observed in the yield, grain dimensions, physico-chemical, and related parameters of rice quality of various varieties.

MATERIALS AND METHODS

Samples of six varieties of paddy [IR 8, Jaya, and HM 95 (coarse), Palman 579 and RP 5-3 (medium-fine), and Basmati 370 (fine)] were obtained from the Punjab Agricultural University, Ludhiana. After cleaning, the samples were preserved in air-tight plastic containers.

The coarse varieties are of the high yielding *indica* type. Their cultivation has spread over larger areas in India. Basmati 370 is endowed with an aromatic flavor and has considerable export market. It is a long duration variety (140–150 days) and yields about 900 kg/acre. HM 95 is a short-duration variety ripening in about 95 days after transplanting compared with 125–145 days for other varieties. The medium-fine varieties, Palman 579 and RP 5-3, lack the aromatic flavor of Basmati 370, but on the average yield about 2300 and 2450 kg per acre, respectively.

Milling. A weighed sample (100 g) of paddy of each variety was dehusked using the Laboratory Satake Sheller with rubber rolls adjusted to grain size so as to minimize the breakage of rice. The shelled rice and husk were weighed separately for determining the yield of brown rice.

The shelled rice (50 g) of each variety was subjected to extended milling to varying degrees of polish in the Kett Polisher, Type TP-2 (Kett Electric Laboratory, Japan) consisting of an outer stainless steel perforated enclosure in which a stainless steel vertical rotor rubs the grain against the casing. The polishing times ranged from 10 to 300 sec.

The degree of polish was determined by subtracting the weight of bran from that of the brown rice and was expressed as the percentage of brown rice. The broken grain was separated by hand and weighed. The yields of total milled, head, and broken rice were expressed as a percentage basis of cleaned paddy.

Physical Characteristics. *Length–Width Ratio (L/W).* Ten kernels of paddy and of brown and milled rice of each variety were arranged lengthwise and then widthwise for cumulative measurements in centimeters.

1000-Kernel Weight (Grams). This was determined by weighing 1000 grains of paddy as well as of milled rice of each variety.

Bulk Density (Grams per Milliliter). The volume of 100 g of paddy (ml) was determined by gently pouring the grain into a 250-ml graduated cylinder for obtaining the bulk density.

Density (Grams per Milliliter). The kerosene oil displacement procedure (Bhattacharya et al., 1972) was employed.

Porosity (Percent). This is an index of voids in the bulk lots of paddy and rice and was calculated from the expression:

$$\text{porosity \%} = (\text{density} - \text{bulk density})/\text{density} \times 100$$

Angle of Repose. This was determined according to the method of Anderson and Alcock (1954).

Analysis. The samples of rice were analyzed for moisture and protein content (N × 5.96) according to AACC methods (1962) and for amylose by the rapid procedure developed by Juliano (1971).

Cooking Quality. The procedure described by Bhattacharya and Sowbhagya (1971) was adopted. The samples were cooked optimally (2 g in 20 ml of boiling water) for the predetermined times which varied from 21 to 23 min. The quality of cooked rice was evaluated on the basis of water uptake ratio (grams of water absorbed/grams of rice), elongation ratio (length of cooked grain/length uncooked grain), physical appearance, cohesiveness, and splitting.

Relationship between Water Uptake Ratio Values and Amylose. Correlation coefficients were calculated between the water uptake ratio values and amylose contents of rice of each variety milled to varying degrees of polish.

Alkali Test. Ten full-sized kernels of rice were placed in separate petri dishes to which 1.4% KOH solution (35 ml) was added. The extent of alkali reaction indicated by the disintegration and spreading of the kernels at room temperature (30°) was recorded photographically at intervals of 1, 4, and 24 hr.

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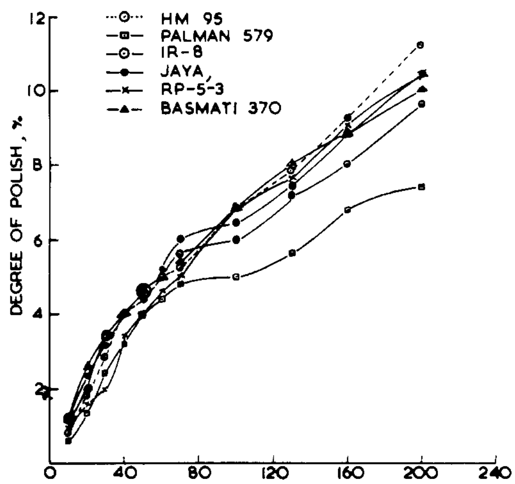

Figure 1. Effect of milling time on degree of polish (percent) of different varieties of rice.

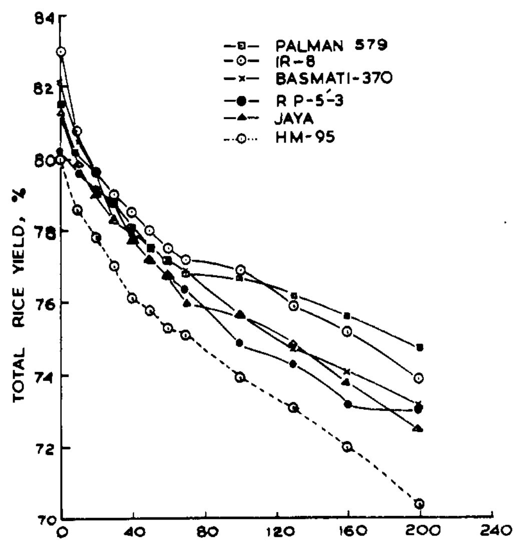

Figure 2. Effect of milling time on yield of total rice (percent) of different varieties.

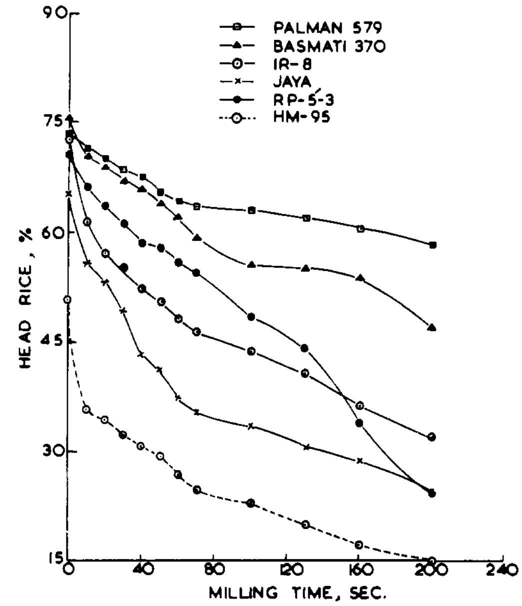

Figure 3. Effect of milling time on yield (percent) of head rice of different varieties.

RESULTS AND DISCUSSION

Yield of Brown Rice and Moisture Differential in Paddy. Moisture contents of the paddy varieties were optimum for milling (Table I of supplementary material; see paragraph at end of paper). The husk contained 4.5 to 5.5% less moisture than the brown rice. A maximum yield of 83% of brown rice was given by the coarse variety, IR 8; Basmati 370 and Jaya gave 82% each whereas HM 95 gave the lowest yield of 79.9%.

Effect of Milling on Physical Characteristics. The coarse varieties of paddy, IR 8 and Jaya, had notably higher 1000-kernel weights and lower L/W ratios than the medium-fine to fine-grained varieties (Table II of supplementary material). A similar trend was manifested by the brown as well as polished rice of these varieties. Differences in the density (1.11–1.15) of paddy samples were negligible. The density of brown rice was found to increase slightly (1.39) compared with that of the paddy rice. The values increased from 1.41 to 1.45 on milling to about 4% polish, and from 1.43 to 1.49 when the extent of polishing was doubled. The varietal differences were hardly reflected in this regard. The bulk density of paddy of coarse varieties, IR 8 and Jaya, was highest (0.57–0.58) compared with that of Basmati 370 (0.50). The bulk density of brown rice was higher by about 39.7 to 58.8% compared with those of the corresponding varieties of paddy. On milling to 4.0% and 8.8 to 11.2% polish, similar increases in the bulk density of rice were observed. Porosity values decreased on milling; the coarse varieties decreased by 48.7 to 49.1% compared with 53.9 and 56.5% for RP 5-3 and Basmati 370, respectively. The angle of repose of the long-grained fine varieties was approximately 40°; that of coarse varieties was 35°. A distinctly higher angle of repose (45°) was observed in the case of HM 95 paddy, which is a medium-fine variety.

Effect of Milling on Degree of Polish. The degree of polish increased curvilinearly with the time of milling (Figure 1). However, varietal differences became more evident as the milling time was increased from 60 to 200 sec. The behavior of varieties was similar during initial polishing for about 60 sec. The variety, Palman 579, however, was found to be highly resistant to polishing even when milled for more than 200 sec. The maximum amounts of polish (percent) removed on subjecting each variety to milling for 200 sec were, respectively: HM 95, 11.2; RP 5-3, 10.4; IR 8, 9.6; Jaya, 10.4; Basmati 370, 10.0; and Palman 579, 7.4.

Yield of Total Milled Rice. The yield of variety HM 95 decreased steeply from 80% to about 70.5% when milled for 200 sec (Figure 2). The decrease of total rice yield was minimum in the case of the hard-grained variety, Palman 579, when milled similarly. The varieties IR 8, Jaya, RP 5-3, and Basmati 370 occupied intermediate positions in this regard. Up to 60 sec of milling, all these varieties interacted similarly, but further milling brought about wide contradictions in their behavior to polishing (Figure 1).

Yield of Head Rice. The varietal differences of head rice were conspicuous; the yield of Palman 579 decreased from 72.5 to 57.5% on milling for 200 sec compared with the decrease of 50 to 15% in the case of the HM 95 variety milled similarly (Figure 3). Basmati 370 maintained a higher head rice yield whereas IR 8, Jaya, and RP 5-3 showed considerably decreased yields varying from 32.5 to 25%.

Breakage of Rice. The breakage of rice incurred by HM 95 was very high even during the initial 40 sec of milling, whereas breakage was least in the case of Palman 579. Despite long grains, Basmati 370 and Palman 579 withstood breakage during prolonged milling. The coarse varieties were relatively more susceptible to breakage during milling (see Figure 4 in the supplementary material).

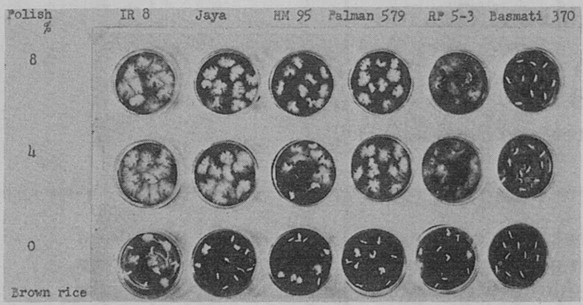

Figure 5. Pattern of alkali reaction (24 hr) on different varieties of rice milled to 4 and 8% polish.

Protein and Amylose Contents of Rice. The overall reduction in protein content of rice varied from 0.5 to 1.2%, when milled for 200 sec (Table IIIa of the supplementary material). The amylose content of brown rice ranged from 20.3% (HM 95) to 25.3% (Jaya). There was a considerable increase in the amylose content of rice of each variety as polishing was increased, the overall increase being 5.3 to 8.4% (Table IIIb of the supplementary material).

Water Uptake Ratio. It was interesting to observe that the brown rice of each variety showed almost the same water uptake ratio, which increased differently on milling (Table IV of the supplementary material). There was a significant increase in the water uptake ratio of rice when milled even for 10 sec with the exception of HM 95 and Palman 579 which showed a negligible change. Further polishing generally increased the water uptake ratio; the increase was minimum for HM 95 and Palman 579. A higher water uptake ratio was shown by the rice of Jaya and Basmati 370 varieties.

Elongation Ratio. There was a considerable increase in the elongation ratio (1.62 to 2.12) of rice compared with a ratio of 1.13 to 1.22 of the brown rice (Table V of the supplementary material). The increase in polish to 8% nominally increased the elongation ratio values. Among the varieties tested, Basmati 370 rice showed the maximum elongation ratio (2.38).

Relationship between Water Uptake Ratio Values and Amylose Contents. The values of correlation coefficients for the varieties were statistically highly significant and ranged from +0.784 to +0.995 (Table VI of the supplementary material). Improvement of cooking quality due to increased degrees of polish as inferred from the water uptake ratio values was associated with concomitant increases in the amylose contents of rice which have been regarded as important criteria of the cooking quality of rice by several workers (Sanjiva Rao et al., 1952; Deatherage et al., 1955; Williams et al., 1958; Reyes et al., 1965; Juliano, 1967; Kongseree and Juliano, 1972). However, the degree of milling seems to be highly important since the cooking quality of brown rice was very much inferior to that of milled rice. Removal of the pericarp (bran) layers adhering to the endosperm by appropriate milling coincident to increased amylose content would contribute to better cooking quality.

Alkali Reaction. The grains of RP 5-3 were highly susceptible to alkali degradation while those of Basmati 370 were most resistant even on being submerged for a prolonged period of 24 hr (Figure 5). The degradation of IR 8, Jaya, HM 95, and Palman 579 grains was in between those of RP 5-3 and Basmati 370. The extent of degradation progressed with the increased degree of polish of rice. The behavior of Basmati 370 was quite distinct in its being resistant to alkali degradation. Depending on the degradation pattern of different varieties of rice, numerical scales have been proposed by Little et al. (1958), Hall and Johnson (1967), and Bhattacharya and Sowbhagya (1972) for quantitative evaluation of cooking quality. The test, at best, indirectly reflects the gelatinization temperature of rice starch and has only an indirect relevance to cooking quality as pointed out by Halick et al. (1960) and by Juliano et al. (1964).

Thus, it is evident that interaction between milling conditions and varieties is of high significance to the yield potential and quality of rice. Attempts have been made to attribute quality to various compositional, enzymatic, and physical properties of rice. However, there is no single method as yet on which reliance can be placed for unequivocal prediction of quality of rice in an inclusive sense. An integrated approach as above seems useful for identifying genetic variations with regard to the milling and cooking behavior of rice. For example, among the varieties tested, Palman 579 showed a marked resistance to polishing and suffered the least damage due to breakage. The high correlation between amylose and water uptake ratio values observed in this study in the case of each variety indicated concretely the contribution of this factor to the improved cooking quality of rice with the degree of polish.

Supplementary Material Available. Tables I (yield of brown rice and moisture differentials in paddy varieties), II (physical characteristics of paddy and different varieties of rice), IIIa and IIIb (effect of milling on the protein and amylose content, respectively, of different rice varieties), IV (effect of milling on water uptake ratio), V (relationship between water uptake ratio and amylose content), and VI (milling effect on elongation ratio), and Figure 4 (effect of milling on rice breakage) will appear following these pages in the microfilm edition of this volume of the journal. Photocopies of the supplementary material from this paper only or microfiche (105 × 148 mm, 24× reduction, negatives) containing all of the supplementary material for the papers in this issue may be obtained from the Journals Department, American Chemical Society, 1155 16th St., N.W., Washington, D.C. 20036. Remit check or money order for $4.00 for photocopy or $2.50 for microfiche, referring to code number JAFC-75-1183.

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