Processing Conditions and Milling Yield in Parboiling of Rice

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Rate of absorption of water by paddy (rough rice) increases with the temperature, but is relatively low below the gelatinization point; beyond this point, the grain absorbs water rapidly, preferentially on its surface layers, leading to early bursting and leaching. Hence for best efficiency, soaking for parboiling should be done slightly below the gelatinization point, or, more conveniently, by starting at 70° to 75° C. and allowing natural cooling. Milling quality of parboiled paddy depends on severity of heat treatment during parboiling and conditions of drying; the more severe the heat treatment, the better it is able to withstand adverse drying. Insufficient soaking leads to increased breakage. Simple soaking of paddy at or above 70° C. also improves milling quality. Rate of hydration of paddy as well as improvement in its milling yield by parboiling shows varietal difference.

Although the engineering (*3*) and hygienic (*4, 5, 12, 14, 16*) aspects in modernization of the traditional process of parboiling of rice have received considerable attention, not much effort has been made to study the optimum processing factors. Parboiling is essentially precooking of rice within the husk, followed by drying. Hydration characteristics of paddy (rough rice), efficiency in soaking, and subsequent gelatinization of the starch by steaming are, apart from drying, the most important processing factors involved. The only detailed study of some of these factors was by Mecham, Kester, and Pence (*13*); others had touched on them in general (*4, 9–11, 14, 16, 17*). Results of a more comprehensive laboratory investigation into the processing conditions and their effect on the milling yield are presented here.

Materials and Methods

Paddy. Three varieties of paddy, procured from a nearby rice breeding station (November-December 1963 harvest), were employed: S-1092, Bangara Sanna (BS), a hard, fine grained variety; S-718, Ratna Chudi (RC), soft, medium grained; and S-139, Mysore Kaddi (MK), hard, medium grained. The protein contents (N × 5.95) of the brown rices were: BS 7.47, RC 6.48, and MK 7.23% (as is). Two varieties (BS and RC) were used throughout, the third (MK) being used occasionally. The samples were 6 to 9 months old at the time of processing, being stored in the laboratory at room temperature (20° to 30° C.) during the interval.

Hydration Studies. Paddy, after washing, was soaked in distilled water at different temperatures (±1.5° C.) in an aluminum vessel fitted with a stirrer and heated over a wire gauze by Bunsen burners. Samples were withdrawn at intervals and wiped quickly with filter paper, and moisture was determined in 20 grams (in duplicate) by drying at 105° C. for 20 hours.

Parboiling. The paddy (2 to 3 kg.) was soaked as above, tap water (pH 6.9 to 7.1) being used throughout. Samples (300 to 600 grams) were withdrawn at desired intervals, spread in small wire-mesh trays, and steamed in an autoclave connected to the main steam line; steaming at atmospheric pressure was carried out with the cover of the autoclave on loosely. They were then air-dried in the shade (1 to 2 days). The dried samples were all simultaneously exposed to the atmosphere (in wide-mouthed bottles) for 4 to 5 days for moisture equalization before milling (hence minor differences in moisture content were ignored). Their average moisture content was 13.6%.

A large number of samples were prepared in this way for these and other (*2, 15*) studies. Soaking was carried out at different temperatures and generally for three periods at each temperature: The middle period corresponded to the optimal soaking time—i.e., the minimum time of soaking necessary to give a finished rice without any ungelatinized core or "white belly"—of that paddy at that temperature. The time and pressure of steaming were also varied (see Table II). Each sample is referred to in the text by a descriptive code number, also shown in the table. To separate the effects of soaking and steaming, half of each sample of soaked paddy was dried and milled as such; the other half was milled after steaming.

Milling. All milling (150-gram lots of paddy) was done in a McGill miller (No. 1), pressure being applied with the hands. To obtain reproducibility by this procedure, milling was continued in each case, regardless of time, until only white endosperm powder (in raw and soft parboiled paddy) or practically nothing at all (in hard parboiled paddy) issued through the mill. This was considered as full milling and was tested to give satisfactory results. Whole and broken grains passing out through the mill were recovered by winnowing and sieving and included in calculating the total yield. The yield of head rice was calculated by determining brokens (less than three fourths of a grain) in 20-gram portions by hand picking.

Parboiling and milling operations were generally not replicated.

Results and Discussion

Hydration Characteristics of Paddy. The rate of absorption of water by paddy (BS variety, Figure 1) increased with increasing temperature, but there were two distinct patterns of absorption depending on the actual temperature.

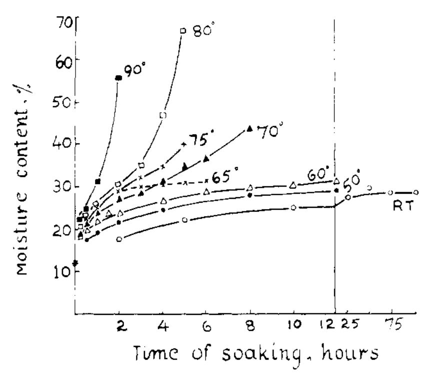

Figure 1. Hydration characteristics of BS paddy at different temperatures

All moisture data on wet basis.
Part of sample soaked at 75° C. (×) withdrawn after 2 hours and then soaked at 65°C. (– – – – – –). Room temperature (RT) approximately 23–27°C.
* Moisture of original paddy (11.5%)

Up to 60° C., the paddy absorbed water at a relatively slow rate and reached essentially an equilibrium (about 29% moisture at room temperature and 50° C.; 30 to 31% at 60° C.). But at 75° C. and above, the rate, after an initial phase, increased sharply and progressively. The temperature of 70° C. represented the transition point between these two patterns. Absorption of water by paddy was thus clearly related to the gelatinization of its starch, the rate of absorption increasing sharply once the gelatinization of the grain had set in. The existence of these two distinct patterns is not brought out clearly by Mecham *et al.* (*13*).

The other two varieties of paddy showed similar characteristics of hydration, but with slight differences in the rate, which was highest in RC (although a medium grained variety), next in BS (fine), and least in MK (medium) (cf. Table I). In keeping with the quicker rate of water absorption in RC, the transition in its pattern of hydration occurred earlier (at about 65° C.) than in BS—probably indicating a lower gelatinization temperature for its starch. The lower protein content of RC (see Materials) might also be responsible for its more facile hydration. These data showed the importance of testing each variety for its optimal soaking conditions.

In preliminary experiments, freshly harvested paddy had a lower rate of water absorption than stored paddy. This had been noted earlier (*13*) and is well known to millers. But this aspect was not studied further.

Another characteristic was the existence of a moisture gradient in paddy during soaking, as inferred by Mecham *et al.* (*13*). This was evident from the fact that at increasing temperatures of soaking, optimal absorption of water in the center of the grain (just sufficient for the subsequent gelatinization by steaming) corresponded with a higher and higher total moisture content of the paddy (Table I). Here again, the gradient was only slight below the gelatinization temperature but became pronounced beyond that point. This property had important bearings on the optimal conditions for soaking, as discussed below.

Optimal Conditions for Soaking. Increasing the temperature reduced the time needed for optimal soaking of paddy (Table I). However, the temperature could not be increased beyond the gelatinization point without undesirable consequences. Whenever the grain attained a total moisture content of 30 to 31% during soaking, the husk began to split and solid matter gradually started to leach out (as evident from turbidity and iodine color of the steep water, and from deformity of the endosperm on subsequent drying and milling). Hence soaking at temperatures above the gelatinization point, which was associated with a high moisture gradient in the grain resulting in excessive total moisture contents on optimal soaking (Table I), invariably led to extensive splitting and leaching of the paddy. The slight moisture gradient existing at lower temperatures did not cause this difficulty, since the total moisture content under these

Table I. Optimal Soaking Time and Corresponding Moisture Content of Paddy at Different Temperatures

Soaking Temp., ° C.	Optimal Soaking Time,[a] Hr.		Moisture Content,[b] %	
	BS	RC	BS	RC
25[c]	60	52	28.3	28.9
50	9.5	7.5	28.5	—
60	6	5	28.7	30.8
70	4	2.75	30.7	35.0
75–65[d]	3.25	—	30.0	—
80	3	2.5	35.0	43.8

[a] Approximate; determined by withdrawing samples at intervals and examining for white belly in finished rice.
[b] Values (wet basis) read from corresponding hydration curves.
[c] Average room temp. (23–27°).
[d] Soaked at 75° C. for 2 hr., then at 65°.

Table II. Sample Description and Milling Yields of Raw, Soaked, and Parboiled Paddy

Sample No.[a]	Soaking Conditions			Steaming Conditions		Milling Yield,[c] %			
						Before Steaming		After Steaming	
	Temp., ° C.	Time hr.	%[b]	Time, min.	Pressure, p.s.i.g.	Total	Head	Total	Head
				BS PADDY					
—		Nil		10	0	67.5	31.5	67.0	21.0
B-RT-a-10_0	RT[d]	26	45	10	0	68.0	36.0	70.0	65.0
b-10_0		72	120	10	0	67.0	38.5	69.5	67.5
c-10_0		195	325	10	0	65.5	32.0	69.5	67.0
B-50-a-10_0	50	4	40	10	0	68.0	37.0	70.0	57.5
b-10_0		9.5	100	10	0	68.5	44.0	69.5	67.5
c-10_0		12	125	10	0	66.5	36.5	69.5	67.5
B-60-a-10_0	60	2.5	40	10	0	68.0	28.0	70.0	64.5
b-10_0		6	100	10	0	68.0	47.0	70.0	68.0
c-10_0		11	185	10	0	65.0	23.0	70.0	68.0
B-70-a-10_0	70	1.5	40	10	0	68.5	39.0	—	—
b- 1_0		4	100	1	0	69.0	51.5	69.0	56.5
2_0				2	0			69.5	63.0
5_0				5	0			70.0	67.5
10_0				10	0			70.0	68.0
20_0				20	0			70.0	68.0
c-10_0		7	175	10	0	69.5	60.0	70.0	67.0
B-80-a-10_0	80	2	65	10	0	69.5	56.0	70.5	68.5
b-10_0		3	100	10	0	69.0	62.0	70.5	69.0
c-10_0		4	135	10	0	66.5	53.0	67.5	62.5
				RC PADDY					
—		Nil		10	0	71.0	7.5	70.5	2.0
R-RT-a-10_0	RT[d]	26	50	10	0	71.5	9.0	73.5	73.5
b-10_0		50	95	10	0	71.5	9.5	73.5	73.5
c-10_0		74	140	10	0	70.5	9.5	73.0	72.5
R-50-a-10_0	50	3	45	10	0	72.5	10.5	73.5	70.5
b-10_0		7	95	10	0	71.5	12.5	73.5	73.5
c-10_0		12	160	10	0	71.0	16.5	73.5	72.5
R-60-a-10_0	60	2	40	10	0	72.5	6.5	73.5	72.5
b-10_0		5	100	10	0	71.5	23.0	73.5	72.5
c-10_0		11	220	10	0	68.0	14.5	73.5	73.5
R-70-a-10_0	70	1	35	10	0	71.5	16.0	73.5	73.0
b- 2_0		2.5[e]	90	2	0	72.5	31.0	73.5	71.5
5_0				5	0			74.0	73.5
10_0				10	0			74.0	73.5
20_0				20	0			74.0	73.5
40_0				40	0			74.0	73.5
60_0				60	0			74.0	73.5
10_5				10	5			74.0	74.0
10_{10}				10	10			74.0	74.0
10_{20}				10	20			74.0	74.0
c-10_0		5	180	10	0	73.0	65.5	73.5	73.0
R-80-a-10_0	80	1	40	10	0	72.5	25.5	73.5	73.5
b-10_0		2	80	10	0	73.0	70.5	73.0	73.0
c-10_0		3	120	10	0	73.0	70.0	73.5	73.0

[a] First letter refers to paddy variety (B for BS, R for RC); second item gives temp. of soaking; lower case third letter gives soaking time (in general terms, a undersoaking, b optimal soaking, c oversoaking); last item indicates time (min.), and its subscript, pressure (p.s.i.g.) of steaming.
[b] Approximate percentage of optimal soaking time for respective temp.
[c] Brown rice yields of paddy varieties: BS 75.7%, RC 79.4%.
[d] Room temp. (23–27° C.).
[e] Soaked for 2.5 hr., followed by draining out and holding for 30 min.

Table III. Effect of Processing and Drying Conditions on Breakage of Parboiled Rice (BS) during Milling

Processing Conditions					
Soaking		Steaming			
° C.	Hr.	P.s.i.g.	Min.	Drying Conditions[a]	Brokens in Milled Rice, %
RT	64	0	10	Shade	3
				Sun	36
				Mechanical	94
		15	10	Shade	1
				Sun	2
				Mechanical	6
80	3	0	10	Shade	3
				Sun	5
				Mechanical	11

[a] Sun drying performed by spreading sample in tray in sun, with occasional stirring (ca. 6 hr.). Mechanical drying in a cross-flow dryer at 60° C. with tray load of 0.5 kg./sq. ft. (ca. 1 hr.). Moisture content of dried samples between 10 and 12%.

conditions did not exceed 31% (cf. Figure 1 and Table I). Analysis of 100-grain weight of paddy (RC) showed a loss of over 2% in weight after soaking at 80° C. for 3 hours but none at 60°.

A temperature slightly below the gelatinization point (around 65° C.) thus appears optimal for rapid and efficient soaking in practice. Perhaps an equally feasible, but more convenient, method would be to start the soaking at 70° to 75° C. and then allow the batch to cool naturally as the soaking proceeds. The example in Figure 1 and Table I, where the paddy was soaked at 75° C. for 2 hours and then changed to 65°, seems to bear this out. A sample withdrawn from this batch after 3.25 hours gave excellent finished rice without any deformity or white belly; but no significant splitting had ensued even at the end of 4 hours. The method of partial soaking followed by draining out and "holding" (for equilibration of moisture), suggested by Mecham *et al.* (*13*), is feasible at all temperatures but does not appear to offer any special advantage. Up to 65° C., this procedure is unnecessary; the method will work at temperatures above 70°, but will need careful control of the timing. The total time will not also be appreciably reduced.

A very detailed study of the hydration kinetics of paddy has recently appeared (*1*). The relevant results of this study, although differing in absolute values, follow a pattern similar to that reported here.

Milling Yield. Parboiling, as expected (*8–11, 17*), brought about a striking improvement in the milling quality of paddy (Table II). But mere soaking at 70° and 80° C. also markedly improved milling performance, evidently caused by gelatinization of the surface layers, as could also be observed on visual examination of these samples after milling. The cooking quality and color (*2*) and the thiamine contents (*15*) of these samples also approached those of fully parboiled rice. This explained the rationale of the practice of home-scale parboiling by mere hot-water soaking of paddy. However, appreciable gelatinization cannot be achieved in this manner without extensive leaching and deformity of the grain. Mere steaming of paddy, suggested as a method of arresting lipase activity (*7*) and for curing freshly harvested rice (*6*), resulted in increased breakage.

When milled raw, RC gave much more breakage (ca. 90%) than BS (ca. 55%); but when parboiled, breakage in RC (0 to 1%) appeared to be even less than in BS (1 to 6%). This draws attention to varietal suitability for parboiling.

Effect of Processing and Drying Conditions on Milling Quality of Parboiled Rice. Undersoaking during parboiling (with resulting white belly) led to increased breakage during milling (*13*); and so did oversoaking in some cases. Otherwise, wide variation in processing conditions appeared to have little effect on the milling quality of parboiled paddy (Table II). However, as the subsequent analysis and experiments showed, this was largely fortuitous, and a result of shade drying of the samples. The generally excellent milling performance of all the samples in the present work (employing shade drying) was in striking contrast to the observations of Mecham *et al.* (*13*), who employed quick mechanical drying (38° C., cross flow). Good head yields could be obtained by these workers only on steaming at high pressure (20 p.s.i.g., 8 minutes), whereas 5 minutes' steaming at atmospheric pressure gave excellent milling performance in the present study. This anomaly was clarified by the results presented in Table III, which showed that under adverse drying conditions, good milling performance could be obtained from parboiled paddy only when produced by more severe heat treatment. [Samples produced by severe steaming or by soaking at 80° C. resisted cracking when put in cold water (*2*), probably an indication of their ability to resist checking under adverse drying conditions.] Similarly, even when shade-dried, very short steaming ($70\text{-b-}1_0$ and 2_0, Table II) gave more breakage, although the samples appeared to be completely gelatinized on visual examination. Thus a certain minimum degree of heat treatment is required for optimal milling performance of parboiled paddy, the actual degree depending on the circumstances of its drying. Conversely, these data show the importance of careful drying for obtaining satisfactory milling yields from parboiled paddy without resorting to severe heat treatment which may have other undesirable consequences (*2, 15*).

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