Effect of Processing Conditions on Quality of Parboiled Rice

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Conditions of soaking and steaming of paddy (rough rice) during parboiling affected the cooking quality and color of parboiled rice. However, soaking affected the quality only above 60° C. The greater the severity of heat treatment during soaking and steaming, the lower the water uptake and the darker the color of the rice. Soaking (at 70° C. and above) had a relatively greater effect on the color of the rice, while steaming affected the cooking quality to a greater extent. Varietal difference in the effect of processing conditions on quality was observed. Besides nonenzymatic browning, the husk pigment and the bran also appeared to contribute to the color of parboiled rice. Specifications of parboiled rice color were determined from reflectance characteristics.

A PRECISE understanding of the effect of processing factors on the quality of parboiled rice and of the physicochemical changes occurring during parboiling is fundamental to the diversification of the production of this form of processed rice. This is important, for greater acceptance of parboiled rice improves the nutrition and the rice economy of a country. Roberts *et al.* (*12*) studied the effect of certain conditions on the color, expanded volume, and soluble starch content of parboiled rice. Qudrat-i-Khuda, De, and Rahman (*11*) observed certain dimensional changes in the grain after parboiling and alterations in its starch granules. Kurien *et al.* (*7*) noted similar grain-dimension changes and studied the effect of steaming on the cooking quality of the rice. A more comprehensive investigation covering wider processing conditions was desirable. A systematic study to this end was initiated and the results obtained so far are presented here. A detailed study of discoloration during parboiling has appeared recently (*6*).

Desired cooking characteristics of rice and the desired color of parboiled rice are not the same for all populations. The results presented here compare product characteristics objectively without considering these preferences.

Materials and Methods

Samples of Parboiled Rice. The samples of parboiled and semiparboiled paddy (rough rice) and rice used, in the varieties Bangara Sanna (BS) and Ratna Chudi (RC), have been described (*2*); they are referred to here by their self-explanatory code numbers. Only whole grains, hand-picked from the well mixed and cleaned samples, were used.

Cooking Quality. Cooking quality of the rice samples was studied with respect to their water uptake, iodine blue value of the gruel, and solids in gruel (excess cooking water). Five grams of rice were cooked (in duplicate) in 70 ml. of distilled water in wide glass tubes immersed in a boiling water bath (bath temperature 98° C., cooking-water temperature 96° C.) for 30 minutes. The gruel was strained through a sieve and the rice was weighed after quick wiping with filter paper to give its water uptake (grams of water absorbed per gram of rice). Iodine blue value of the gruel was obtained, after standing for 2 hours, by adding 1 ml. of iodine solution (*1*) to 1 ml. of gruel (in duplicate), diluting to 100 ml., and reading in a Klett-Summerson photoelectric colorimeter with a 600-mμ filter. Solids in the gruel were determined by evaporating to dryness and weighing.

Water-uptake values were highly reproducible (S.E. ± 0.028; 22 d.f.). Precision of the iodine blue value determination was less but satisfactory (S.E. ± 9.03; 32 d.f.), but that of gruel solids was poor.

Cracking of Rice in Water. About 1 gram of each sample (free from checks or other damage) was put into open test tubes and all the samples were simultaneously exposed to the atmosphere for 1 to 2 days for moisture equalization. Ten grains, in duplicate, were then put under water in a Petri dish and the total number of transverse cracks developed (*3*) per 10 grains were counted at intervals by flashing a hand light horizontally from the side. The major development of cracks took place in 20 to 45 minutes; it was complete within 1 hour in BS (fine-grained) and 1.5 hours in RC (medium-grained). The results were reproducible under a given set of conditions.

Color of Rice. Color of the samples was read in a Photovolt reflection meter (Model 610, standard Search Unit 610-Y) with amber (A), green (G), and blue (B) tristimulus filters. About 20 grams of the cleaned whole grains were put into the glass cuvette, tapped five times by dropping from a height of about 1.5 inches on a thick surface of paper, and read against paper standards calibrated previously against the reference enamel plaque supplied by the manufacturers. Each sample was read a number of times by turning the cuvette around its axis and also by pouring out and refilling at least three times (the sample itself was not replicated), and the average reading was taken. Tristimulus color specifications were calculated from the respective *A*, *G*, and *B* values by the following equations (*10*):

$$X = 0.8A + 0.18B$$

$$Y = G$$

$$Z = 1.18B$$

$$x = \frac{X}{X + Y + Z}, \quad y = \frac{Y}{X + Y + Z}$$

and dominant wavelengths and excitation purities were read from the chromaticity diagram for standard illuminant C (*8*). Color differences (ΔE) were calculated according to Adam's chromatic value diagram method by the following equation (*8*):

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

where

$L = 9.2\,V_y$

$a = 40\,(V_x - V_y)$

$b = 16\,(V_y - V_z)$

V_x, V_y, V_z = Munsel value functions of X, Y, and Z

Results

Cooking Quality. WATER UPTAKE. Increasing temperatures of soaking of paddy during parboiling up to 60° C. had no (BS) or only slight (RC) effect on the water uptake of the resulting rice during cooking (Table I). But the water uptake of parboiled rice was

Table I. Cooking Behavior of Parboiled and Semiparboiled Rice as Affected by Processing Conditions

(Water uptake expressed as g. water absorbed/g. rice on cooking for 30 min. at 96° C.)

Sample[a]	Water Uptake of Rice Milled: BS, Before steaming	BS, After steaming	RC, Before steaming	RC, After steaming
Untreated	3.27		3.12	
RT-a-10_0	—[b]	2.83[c]	—[b]	2.69[c]
b-10_0	—	2.52	—	2.41
c-10_0	—	2.55	—	2.16
50-a-10_0	—	3.08[c]	—	3.01[c]
b-10_0	—	2.62	—	2.32
c-10_0	—	2.50	—	2.11
60-a-10_0	—	2.91[c]	—	2.70[c]
b-10_0	—	2.54	—	2.18
c-10_0	—	2.34	—	2.08
70-a-10_0	—	—[c]	—	2.83[c]
b-1_0	3.13	2.93	3.20	
2_0		2.85		2.40
5_0		2.75		2.38
10_0		2.54		2.32
20_0		2.35		2.05
40_0				1.96
60_0				1.87
10_5				1.90
10_{10}				1.76
10_{20}				1.78
c-10_0	2.77	2.29	2.72	2.01
80-a-10_0	2.78	2.27	3.34	2.75
b-10_0	2.39	2.09	2.68	2.20
c-10_0	2.37	2.14	2.20	1.93

[a] First letter (omitted in this table because it is a common list) refers to paddy variety (B for BS, R for RC); second item gives temperature of soaking; lower case third letter gives soaking time (in general terms, a undersoaking, b optimal soaking, c oversoaking); the last figure indicates the time (min.), and its subscript, the pressure (p.s.i.g.), of steaming. For details see (2).

[b] Values for 20 unsteamed samples RT-a through 70-a were uniformly high, varying randomly between 3.25 and 3.75 in the two varieties; these have been omitted for the sake of clarity. Most of these samples appeared chalky and had high surface checks.

[c] Majority of these undersoaked, parboiled samples (with pronounced white belly) also showed some chalkiness and surface checks.

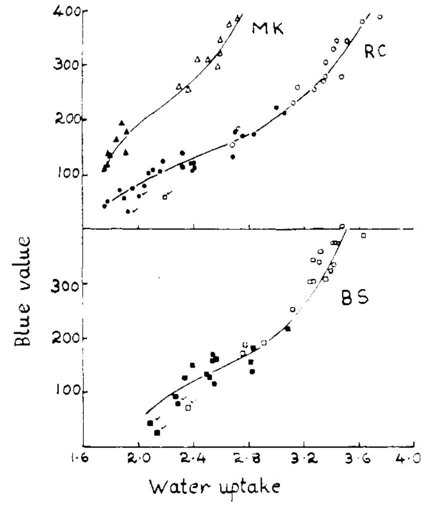

Figure 1. Interrelationship between water uptake and gruel–iodine blue value during cooking of rice

Water uptake expressed as grams water absorbed per gram rice in 30 min.; blue value expressed as Klett reading at 600 mμ

△,○,□. Rice milled from merely soaked paddy

▲, ●, ■. From soaked and steamed paddy.

√. Samples that had undergone heavy splitting during soaking

Table II. Cracking of Parboiled Rice in Water

[Experiments conducted at room temp. (20–21° C.)]

Sample	No. of Cracks/10 Grains after 1 Hr.[a]: BS	RC
RT-b-10_0	35	31
c-10_0	33	24
50-b-10_0	51	18
c-10_0	42	26
60-b-10_0	42	22
c-10_0	26	23
70-b- 1_0	46	
2_0	41	22
5_0	41	17
10_0	34	13
20_0	25	7
40_0		2
60_0		7
10_5		5
10_{10}		1
10_{20}		0
c-10_0	14	—
80-a-10_0	30	34
b-10_0	17	22
c-10_0	2	2

[a] While the relative pattern of cracking among samples remained always the same, actual values in an experiment depended on conditions, particularly ambient humidity at time of moisture equalization by exposure.

progressively reduced when the paddy had been soaked at 70° C. and above. The pattern of the results was the same whether the rice was milled before or after steaming; mere soaking at high temperatures reduced the water uptake appreciably (70-b, c; 80-a, b, c). Chalky samples and those with white belly had high water uptake. The time and temperature of soaking had a relatively greater effect in RC; this was probably related to its more rapid hydration characteristic (2).

Increasing severity of steaming of soaked paddy during parboiling, as observed earlier (7), progressively decreased the water uptake of the resulting rice. Quantitatively, this variable appeared to exert the maximum influence on the cooking quality of parboiled rice. In separate large-scale experiments (unpublished), it was observed that heaping of hot parboiled paddy in bulk prior to drying, as is often practiced in India (the so-called Champ process), had a similar effect on the cooking quality. This is not unexpected, since such heaping is practically equivalent to continued steaming of the paddy at atmospheric pressure for the same length of time.

Iodine Blue Value of Gruel. These values were proportional to the corresponding water-uptake values, irrespective of the nature of pretreatment of the rice (Figure 1). (The significance of the shape of the curves in the figure is not clear at this time.) However, the blue values (26 to 405) had a wider range than the water-uptake values (2.09 to 3.67 in BS, 1.76 to 3.75 in RC). The blue values for samples obtained on oversoaking of paddy at 70° and 80° C. (points marked with a tick in the figure) were lower than even their low water-uptake values would warrant. This was apparently due to leaching of soluble matter during the long soaking after bursting of the grain.

Gruel Solids. Data for loss of solids in the gruel, as in the case of blue values, also followed the pattern of water uptake. However, the precision of this determination was rather low; hence the results are not reported here. Generally stated, per cent loss of solids in the gruel of raw, soft-parboiled, and hard-parboiled BS rice was 4.5, 3.5, and 2%, respectively.

Cracking of Rice in Water. When tested for the development of transverse cracks on putting in water (3), the extent of cracking in the different parboiled samples decreased with increasing heat treatment (Table II); so did the rate of cracking. Rice milled from merely soaked paddy as well as from undersoaked steamed paddy—i.e., with white belly—cracked rapidly and became opaque in a short time (hence data not presented). Thus this property followed the pattern of water uptake (Table I) and the milling quality (2) of the samples.

Color of Parboiled Rice. As with cooking quality, increasing temperatures of soaking up to 60° C. appeared to have little (BS) or only slight (RC) color-inducing effect (Table III). Soaking at 70° induced more color, while at 80° this effect was more pronounced; over-soaking in either case accentuated the effect. Corresponding samples of rice obtained from merely soaked paddy gave erratic results because of chalkiness and surface checks (hence not presented), but the trend was similar. These effects of soaking temperature are brought out more clearly in Figure 2, which is drawn from the data of Table III. These results are in general agreement with those of Jayanarayanan (*6*) (who, however, soaked paddy for 2 hours at all temperatures, so that his data are not fully relevant to practical parboiling). The greater effect of soaking condition in RC is in keeping with its earlier behavior [Table II and (*2*)].

Increasing time and pressure of steaming, here again, had increasing color-inducing effect, also in agreement with earlier observations (*6, 12, 15*). It appeared, however, that, quantitatively, the color-inducing effect of high temperature soaking is more than that of severe steaming. The reverse appears to be the case with respect to cooking quality (Table I).

Specifications of the colors presented in the table seem to indicate that the dominant wavelength remains practically constant in the samples, but the excitation purity increases and the luminance, *Y*, decreases with increasing color. This indicates that the hue of the samples remains unchanged but the color becomes deeper and darker with increasing discoloration.

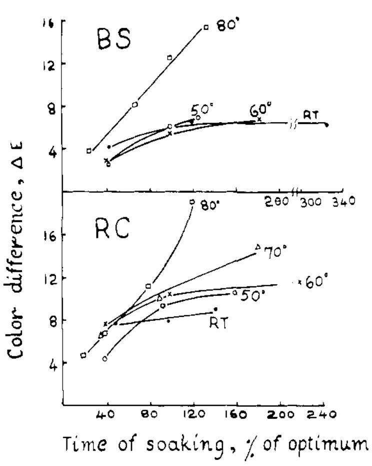

Figure 2. Effect of temperature and time of soaking on color of parboiled rice

Curves drawn from data of Table III. For facilitating comparison, soaking time expressed as per cent of optimal soaking time at respective temperature (2). Time and pressure of steaming same in all cases (10 min. at 0 p.s.i.g.)

Table III. Effect of Processing Conditions on Color of Parboiled Rice

Sample	Color Specification: Y	x	y	Dominant wavelength, mμ	Excitation purity, %	Color Difference, ΔE
			BS Rice			
Raw rice	48.2	0.342	0.347	578	16	
B-RT-a-10_0	41.7	0.345	0.351	578	18	4.1
b-10_0	38.2	0.345	0.348	579	17	6.6
c-10_0	38.4	0.348	0.350	580	18	6.3
B-50-a-10_0	46.8	0.342	0.355	575	18	3.5
b-10_0	39.2	0.349	0.354	578	20.5	6.3
c-10_0	37.4	0.346	0.351	579	18	6.9
B-60-a-10_0	45.0	0.342	0.354	575	18	3.5
b-10_0	40.2	0.347	0.355	577	20	5.5
c-10_0	38.4	0.353	0.355	579.5	21.5	6.8
B-70-b- 1_0	39.5	0.350	0.362	576	23	6.9
2_0	39.2	0.351	0.360	577	23	6.8
5_0	37.6	0.351	0.359	577.5	23	7.4
10_0	38.1	0.353	0.365	576.5	24.5	8.1
20_0	34.9	0.353	0.362	577.5	24	9.4
B-80-a-10_0	37.4	0.357	0.360	579	24	8.1
b-10_0	32.1	0.365	0.369	579	28.5	12.5
c-10_0	27.7	0.368	0.369	579.5	30	15.4
			RC Rice			
Raw rice	51.3	0.347	0.352	578	19	
R-RT-a-10_0	39.1	0.356	0.356	580	23	7.7
b-10_0	38.7	0.353	0.356	579	22	7.8
c-10_0	37.2	0.353	0.360	578	23	9.0
R-50-a-10_0	44.3	0.352	0.354	579	22	4.3
b-10_0	36.7	0.353	0.360	578	23	9.3
c-10_0	35.0	0.356	0.361	578	24	10.5
R-60-a-10_0	39.2	0.352	0.359	578	23	7.6
b-10_0	35.0	0.354	0.358	578.5	23	10.4
c-10_0	33.7	0.359	0.362	578.5	25	11.5
R-70-a-10_0	41.1	0.355	0.359	579	23	6.5
b- 2_0	37.5	0.351	0.357	578.5	22	8.8
5_0	36.8	0.353	0.359	578.5	23	9.2
10_0	35.9	0.357	0.362	578.5	25	10.0
20_0	33.5	0.361	0.368	577.5	27	12.1
40_0	34.5	0.359	0.366	578	26	11.4
60_0	35.3	0.368	0.364	580	28	12.1
10_5	33.0	0.364	0.359	580	26	12.8
10_{10}	35.2	0.365	0.365	579.5	27.5	11.9
10_{20}	28.7	0.377	0.379	579	35	16.6
c-10_0	30.2	0.367	0.365	580	28	14.9
R-80-a-10_0	40.5	0.353	0.357	578	23	6.7
b-10_0	35.1	0.360	0.369	577	27	11.0
c-10_0	25.0	0.386	0.368	583	34	19.8

Discussion

The combined severity of heat treatment during soaking and steaming is clearly the main factor which determines the cooking quality and color of parboiled rice. Soaking at a relatively low temperature (below 70° C.) and for the minimum time required, minimum degree of steaming, and quick cooling of the steamed paddy are thus necessary if parboiled rice of soft-cooking quality and low color is desired. Quick cooling after parboiling may be the most important factor in industrial-scale operations. Reverse conditions would be needed for a hard rice of high color. However, there were some indications that while steaming had relatively more effect on the cooking quality, soaking temperature had more effect on the color. If true, this may perhaps be taken advantage of in producing parboiled rice with contrary characteristics.

Discoloration during parboiling is chiefly due to nonenzymatic browning of the Maillard type (*4*), inhibited by bisulfite (*4, 6, 9*). But other factors also seem to be involved. A part of the bran is embedded in the endosperm during parboiling (*14*). This bran layer will doubtless add to the color of the rice; and its color is itself darkened by Maillard reaction, as the bran is rich in free sugars and amino acids (*16*). The husk pigment may also contribute by diffusing into the endosperm, as suggested earlier (*15*), or by being absorbed on splitting of the grain during soaking. This pigment has been found (in RC) to be appreciably soluble in hot water and is readily absorbed by milled raw rice on cooking in the husk extract (*5*). These two factors may partly explain the strong color-inducing effect of high temperature soaking (Figure 2); for soaking at high temperatures will favor increased bran embedding because of the high surface-moisture content (*2*), and also the penetration of the husk pigment because of bursting of the grain (*2*). The greater effect of soaking temperature in RC is significant in this context, because this paddy shows greater moisture gradient and quicker splitting during soaking (*2*). It also has a dark reddish husk, whereas the husk of BS is golden.

An effect of pH of the soaking medium on the color of parboiled rice has been demonstrated more recently by Jayanarayanan (*6*); discoloration increased on either side of pH 4.5. The pH could have a direct influence on the browning reaction besides modifying the color of the bran pigment at higher ranges, for the pigment is an acid-base indicator (*13*) and changes color (intensifies) in the approximate range of pH 7 to 9. The relative contribution of these two effects in Jayanarayanan's results has to be evaluated, because color was measured by him apparently on brown rice without further milling. The observed color-inducing effect of pH below 4.5 has to be further investigated.

Further work on the quality factors of parboiled rice and the physicochemical aspects of parboiling is being planned.

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Literature Cited

(1) Batcher, O. M., Deary, P. A., Dawson, E. H., *Cereal Chem.* **34,** 277 (1957).
(2) Bhattacharya, K. R., Subba Rao, P. V., J. AGR. FOOD CHEM. **14,** 473 (1966).
(3) Desikachar, H. S. R., Subrahmanyan, V., *Cereal Chem.* **38,** 356 (1961).
(4) Houston, D. F., Hunter, I. R., Kester, E. B., J. AGR. FOOD CHEM. **4,** 964 (1956).
(5) Indudhara Swamy, Y. M., Central Food Tech. Res. Inst., Mysore, unpublished data.
(6) Jayanarayanan, E. K., *Nahrung* **8,** 129 (1964).
(7) Kurien, P. P., Radhakrishna Murty, R., Desikachar, H. S. R., Subrahmanyan, V., *Cereal Chem.* **41,** 16 (1964).
(8) Mackinney, G., Little, A. C., "Color of Foods," Avi, Westport, Conn., 1962.
(9) Mecham, D. K., Kester, E. B., Pence, J. W., *Food Technol.* **15,** 475 (1961).
(10) Photovolt Corp., New York, N. Y., Bull. **605**.
(11) Qudrat-i-Khuda, M., De, H. N., Rahman, M., *Pakistan J. Sci. Ind. Res.* **5,** 238 (1962).
(12) Roberts, R. L., Potter, A. L., Kester, E. B., Keneaster K. K., *Cereal Chem.* **31,** 121 (1954).
(13) Srirangarajan, A. N., Desikachar, H. S. R., Central Food Tech. Res. Inst., Mysore, unpublished data.
(14) Subba Rao, P. V., Bhattacharya, K. R., J. AGR. FOOD CHEM. **14,** 479 (1966).
(15) Subrahmanyan, V., Sreenivasan A., Das Gupta, H. P., *Indian J. Agr. Sci.* **8,** 459 (1938).
(16) Winton, A. L., Winton, K. B., "Structure and Composition of Foods," Vol. **I,** Wiley, New York, 1935.

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RICE

Effect of Parboiling on Thiamine Content of Rice

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Parboiling destroys a part of the total thiamine content of paddy while protecting the remaining vitamin from milling loss. Soaking *per se* does not lead to loss, but much thiamine is leached out if paddy splits during soaking; soaking at high pH also may reduce it. Steaming destroys the thiamine partly. The thiamine is protected against milling loss by mere high temperature soaking of paddy (70° C. or above) or by soaking and steaming, but not by soaking alone at lower temperatures. This protection thus appears to be caused by embedding of the inner bran and scutellum layers in the endosperm, consequent on gelatinization, rather than by inward diffusion of the vitamin. Presence of more bran pigments in milled parboiled rice than in raw rice and their greater adhesion to the endosperm support this hypothesis.

NUMEROUS workers have demonstrated that milled parboiled rice contains more thiamine than milled raw rice (*1, 3, 4, 7–14, 17–20, 24*). However, it is not clear, despite a few studies (*8, 10, 11*), how different parboiling treatments would affect the vitamin content of the rice. Initial attempts to elucidate this aspect showed fairly large differences in the B_1 content of different parboiled samples; but no clear correlation with the processing history of the samples could be established. Followup of the vitamin content in paddy (rough rice) after each step of processing (soaking and steaming) as well as in the rice milled at each step, under a variety of processing conditions, led to a clearer understanding of the situation and also threw light on the mechanism of vitamin retention by parboiling. These results are given here.

Materials and Methods

Parboiled Paddy and Rice. Samples of parboiled and semiparboiled paddy and rice employed, in the two varieties of Bangara Sanna (BS) and Ratna Chudi (RC), have been described (*5*); they are referred to here by their code numbers.

Estimation of Thiamine. Thiamine was estimated in paddy and rice (5 grams) by the usual thiochrome method (*2*) with some modifications. (In the case of paddy, a little more than 5 grams of the sample were ground in a hand mill and the entire amount was weighed for extraction to avoid the difficulty of proper sampling from a nonuniform mixture of husk and powdered endo-