THE FORMATION OF CRACKS IN RICE DURING WETTING AND ITS EFFECT ON THE COOKING CHARACTERISTICS OF THE CEREAL[1]

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Milled raw or parboiled rice developed transverse lines of cracks when soaked in water. It took a longer time for the cracks to develop in parboiled rice than in raw rice. Formation of cracks was accelerated by temperature in the case of parboiled rice; whereas a retarding effect was observed above 70°C. in raw rice.

After grains were soaked in water to develop these cracks, both raw and parboiled rice required a shorter cooking time, and the cooked grains were also longer than in the case of the unsoaked control samples.

The absorption of water by rice grains made them opaque, and this property was used to study the mode of water penetration during soaking. In the initial stages, water entered the grain near its germ end and along the top line of fusion. Transverse lines of cracks developed after some time, and water entered the grain through these cracks subsequently. If the grains were already cracked before wetting, water absorption was quite fast, and the grains became opaque within a few minutes.

The development of checkings or cracks in rice and other grains during dehydration as a result of quick or uneven removal of water is well known, but the occurrence of similar cracks during hydration or wetting is very little understood. Rice is very susceptible to this type of cracking during moistening or wetting (3), and the object of the studies reported here is to investigate this phenomenon and to study its effect on the cooking property of the rice.

[1] Manuscript received for publication August 9, 1960. Contribution from the Division of Biochemistry and Nutrition, Central Food Technological Research Institute, Mysore, India.

Initial studies revealed that the development of these cracks was dependent on time and the temperature of the soak water, and, hence, the progressive development of these cracks at different temperatures in both raw and parboiled rice was first studied. Rice grains which develop cracks during milling or dehydration are known to break and cook to a pasty mass and yield a viscous gruel; it was, therefore, thought that cracks formed during wetting or soaking of rice in water may also cause the rice to cook poorly. The effect of wetting on the cooking properties of the rice was, therefore, studied. Attempts were also made to see whether the study could throw some light on the mode of water penetration during soaking in water.

Materials and Methods

Data have been presented here on two varieties: Ratnachudi (soft medium grain) and Bangarasanna (hard fine grain) as representative of about six varieties on which observations were made. The paddy samples were parboiled by soaking in water at 70°C. for 3 hours, draining off the soak water, steaming for 15 minutes, and drying in the sun. The parboiled and raw samples of paddy were milled thoroughly to remove the bran and sieved to remove broken grains.

For studying the effect of time and temperature on the development of cracks, ten sound grains free from visible cracks or other defects were suspended in water maintained at the desired temperature, and the cracks or striations appearing on the surface of the grains were counted at different periods. The appearance of the cracks was best seen by observing the grains under water in a beaker and illuminated from beneath. Under such transmitted light the cracks appeared as dark lines on the grain. Raw and parboiled rice of Bangarasanna variety was used for these studies.

From the above experiments, it was found that parboiled rice required 45 minutes to develop cracks to the maximum extent; whereas, in the case of raw rice, a similar degree of cracking developed within 15 minutes. Hence, for the cooking studies, 25-g. samples of the raw and parboiled rice were soaked in water for 15 and 45 minutes, respectively, for full development of cracks, and then cooked in 150 ml. boiling water; the cooking time and the loss of rice solids in the cooking water (gruel) were measured. Unsoaked control samples of rice and also raw and parboiled rice samples, soaked only for such period as would not allow cracks to develop (about 4 and 15 minutes for raw and parboiled rice, respectively), were also cooked under similar conditions for comparison. The minimum time needed for the rice grains to cook to a soft consistency (as pressed between two glass plates) without presenting a core of hard opaque starch was taken as the cooking time. The excess cooking water was drained through a strainer, evaporated to dryness first over a water bath and then to constant weight in an oven at 110°C., and weighed. Since differences between the two treatments (soaked and unsoaked) in the size and shape of cooked grains could be seen visually (Fig. 1), the average length and breadth of the raw and parboiled cooked grains were measured using the method described earlier (1).

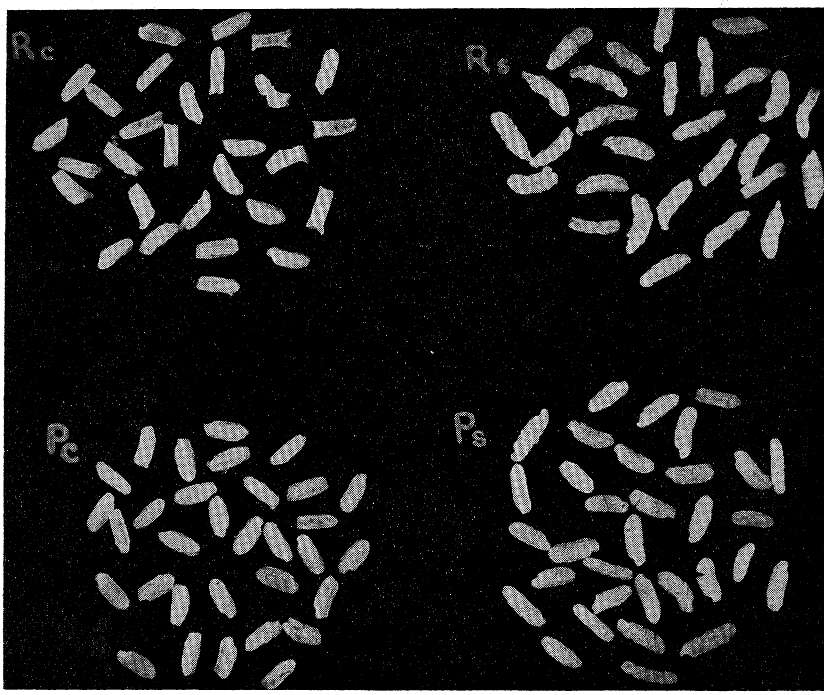

Fig. 1. Effect of presoaking rice in water prior to cooking on the appearance of cooked grains. c, control (unsoaked); s, soaked; R, raw; P, parboiled.

In the course of the above studies, it was observed that the absorption of water during soaking of rice grains, which are normally flinty or translucent, made them opaque. This fact suggested a method for studying the mode and extent of water penetration in rice during wetting. Initial experiments indicated that the top (dorsal) line of fusion may be the line at which water penetrates the grains. Tests were, therefore, carried out on select sound grains, along with grains with visible surface cracks for comparison, to observe the extent of water penetration. Photographs of the grains were taken at short intervals during soaking until the whole grain was opaque.

Results and Discussion

Development of Cracks during Soaking. The development of cracks on the grains immersed in water seems to be a direct effect of hydration, since the development of these lines is a gradual process and depends upon the temperature of the soak water (Figs. 2 and 3). At ordinary temperatures (30°C.), a certain time (about 3 or 4 minutes in the case of raw rice and about 20 minutes in the case of parboiled rice) elapses before the cracking starts, which suggests that hydration precedes cracking. Parboiled rice requires a longer time to develop cracks because it is less permeable to water and has a lower rate of hydration.

The effect of temperature generally is to hasten the water imbibition by both the raw and parboiled rice, and hence the initial lag period before the grains start cracking is shortened. The time taken for maximum development of cracks is also reduced at high temperature. It can be seen from Fig. 2 that the lag period of parboiled rice at 30°C. is 20 minutes; it is reduced to about 5 minutes at 90°C. In raw rice the cracking process is hastened as the temperature is increased to 60°–70°C. At higher temperatures the number of cracks become fewer, and this is especially marked at 90°C. The few cracks become cemented within a short period because of the rapid gelatinization of the starch.

Cracks in Relation to Cooking Characteristics of the Rice. The effect of the cracks on the cooking quality of the rice is shown in Table I. Since the cracks permit entry for water into the rice grain, the cooking time is reduced by presoaking the grains for a sufficient

TABLE I

EFFECT OF PRESOAKING RICE IN WATER ON ITS COOKING CHARACTERISTICS

Rice Variety	Time of Soaking	Time Needed for Cooking	Loss of Solids in Cooking Water	Average Dimensions of Cooked Grains[1]	
				Length	Breadth
	minutes	*minutes*	%	*mm*	*mm*
Ratnachudi (raw)	15	12	8.2	9.73 ± 0.51 [a]	3.05 ± 0.16
	4	19	8.6	....	....
	0	20	9.0	7.98 ± 0.44 [a′]	3.01 ± 0.16
Bangarasanna (raw)	15	13	9.0	9.79 ± 0.65 [b]	2.76 ± 0.16
	4	21	8.8	....	....
	0	21	10.8	7.73 ± 0.36 [b′]	2.79 ± 0.20
Ratnachudi (parboiled)	60	15	4.8	9.39 ± 0.91 [c]	3.15 ± 0.16
	15	22	4.9	....	....
	0	25	5.1	7.83 ± 0.44 [c′]	3.38 ± 0.20

[1] The average lengths and breadths respectively of the uncooked grains were 5.25 ± 0.07 and 1.96 ± 0.04 for Ratnachudi (raw); 5.48 ± 0.07 and 1.67 ± 0.04 for Bangarasanna (raw); and 5.22 ± 0.07 and 1.99 ± 0.02 for Ratnachudi (parboiled) varieties of paddy.
The differences between a and a′; b and b′; c and c′ are highly significant ($P < 0.001$).

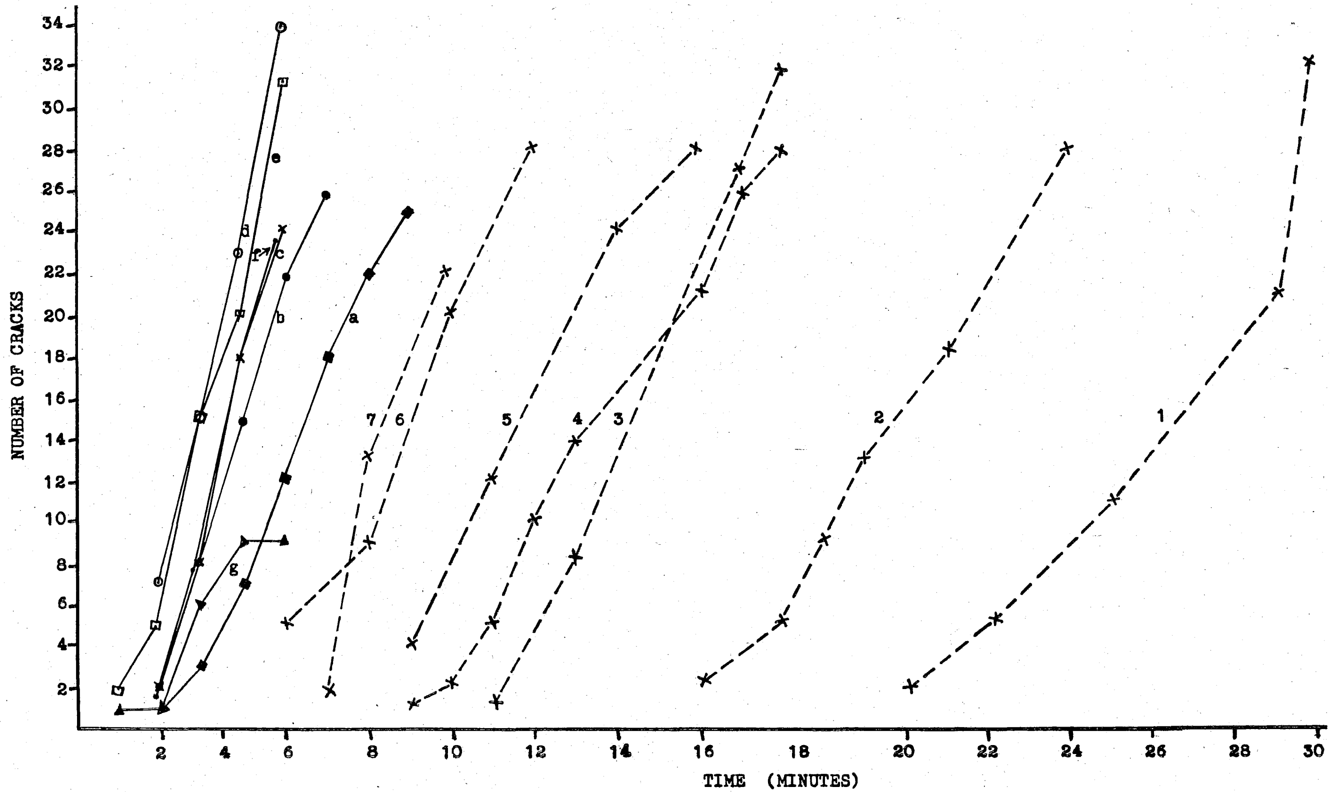

Fig. 2. The effect of time and temperature on the formation of cracks in rice during wetting. 1, 2, 3, 4, 5, 6, and 7 and a, b, c, d, e, f, and g represent curves for parboiled and raw rice, respectively, at 30°, 40°, 50°, 60°, 70°, 80°, and 90°C.

period of time to develop cracks. The effect of wetting *per se* (without the development of cracks) was negligible. The cooking time for these samples was very nearly the same as for the unsoaked control samples. It was feared that the development of cracks might increase the leaching of rice solids into the cooking water. This has not, however, been found to be the case. The reduction in cooking time, by providing points of entry for water, has brought the loss of solids in the cooking water (gruel) to levels either equal to or less than that for the control samples.

The effect of soaking on the general appearance of cooked raw and parboiled grains is presented in Fig. 1. The soaked grains, on cooking, were considerably longer than those cooked without presoaking, although the differences in the breadth of the cooked grains were not significant (Table I). Water entered the grain through the transverse lines of cleavage and caused greater expansion of the grain along the length. (See below for mode of water entry through cracks.) When the rice was put directly into boiling water, the formation of cracks was minimized, and the cooking time was longer.

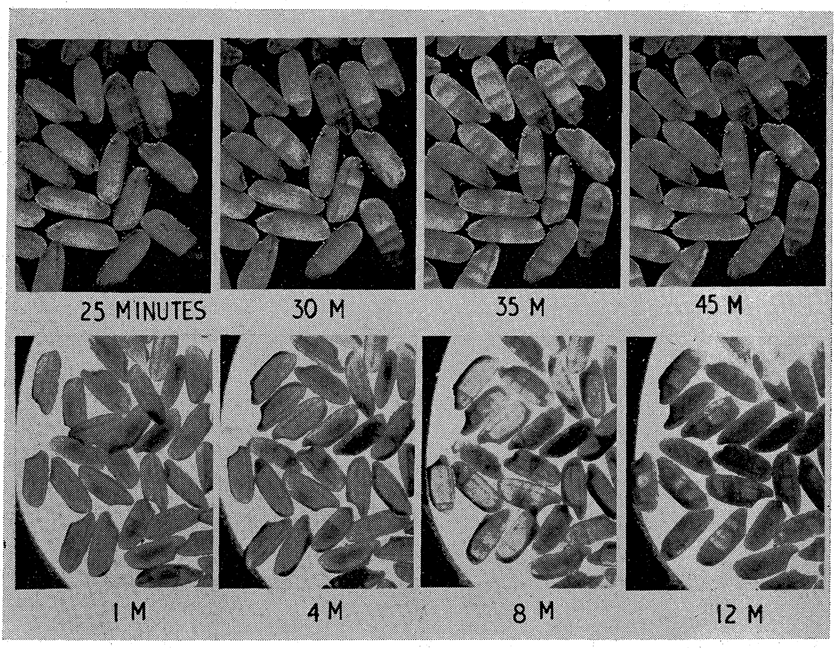

Fig. 3. Rice grains at different stages of wetting. Top row, parboiled (photographed by reflected light); bottom row, raw grains (by transmitted light). The longitudinal striations on the raw rice grains, which are visible both before and after treatment, represent lines of bran not removed during milling.

Mode of Water Penetration during Soaking. When raw rice grains immersed in water were observed under a microscope with low power (×20) it was seen that a dark line first developed near the germ tip and along the dorsal line of fusion. This later spread inward like a shadow, and, after a time, transverse cracks developed as dark lines. These lines then broadened into dark bands. The band or shadow increased in area with increased time of soaking. It appeared that the dark lines or shadows represented portions wetted by the water. Actual photographs taken through transmitted light (bottom illumination) have confirmed the above view (Fig. 3). This can be very clearly seen in the raw rice. The white islands, or pockets, in the endosperm represent portions not wetted by the water.

Figure 4 presents photographs (by reflected light) of raw rice grains with progressive wetting. Examination of the photographs shows that water began to enter the sound grain at points near the germ end, and that entry was along the top line of fusion. The area of the white (opaque) region gradually extended inward until cracks developed, and, thereafter, the water movement was on both sides of the transverse lines of cracking. In grains which had slight cracks before soaking in water, the pattern was similar, but the entry of water

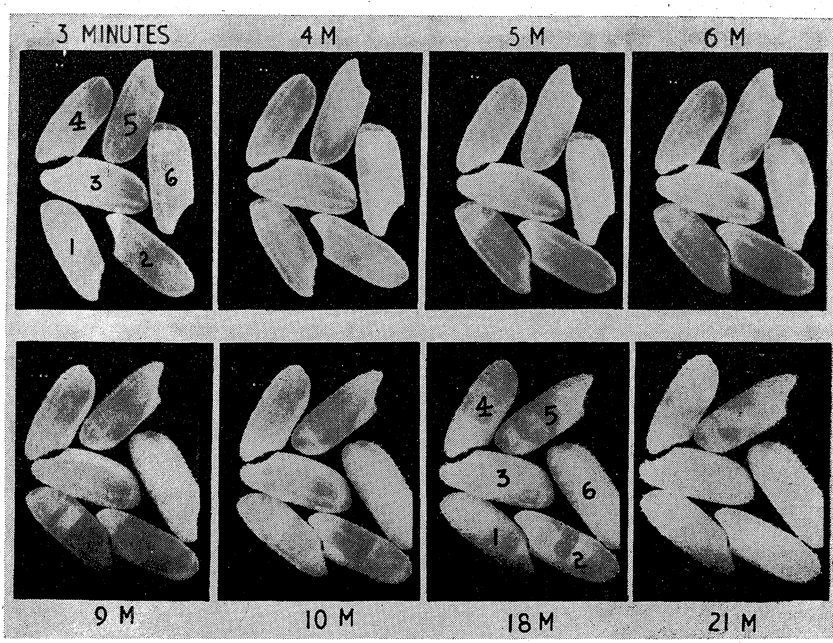

Fig. 4. Penetration of water in raw rice grains. Grains 3, 4, 5: sound grains without cracks; grains 1 and 2: with slight cracks; grain 6: with extensive cracks.

through the cracks was fast, and the grains became opaque much earlier than did the sound grains. In the case of the grain with extensive visible cracks, the whole grain became opaque in about 5 minutes. The pattern presented by parboiled rice was of the same type although the results were not quite as clear (Fig. 5). Even when visible cracks were present, the rate of absorption of water, as judged by the increase in the opaque surface, was slow. There is also some evidence that the top line of fusion became cemented in grain 1 as a result of full gelatinization during parboiling. In other grains, however, the entry of water was, as in the case of raw rice, mostly along the line of fusion. The rate of entry was, however, very slow.

Another feature of soaking is the accumulation of gas bubbles around the grains. These bubbles increase in size and number during the soaking and are not, therefore, due entirely to the film of air around the surface of the grain before it is put into water. Presumably, the entry of water displaces the air inside the grain.

A fundamental aspect which needs to be pursued is the reason for the development of cracks during wetting and the orientation of these cracks mostly parallel to the short axis (breadth) of the grain. Whether the cracking is due to stresses set up by differential hydration of the

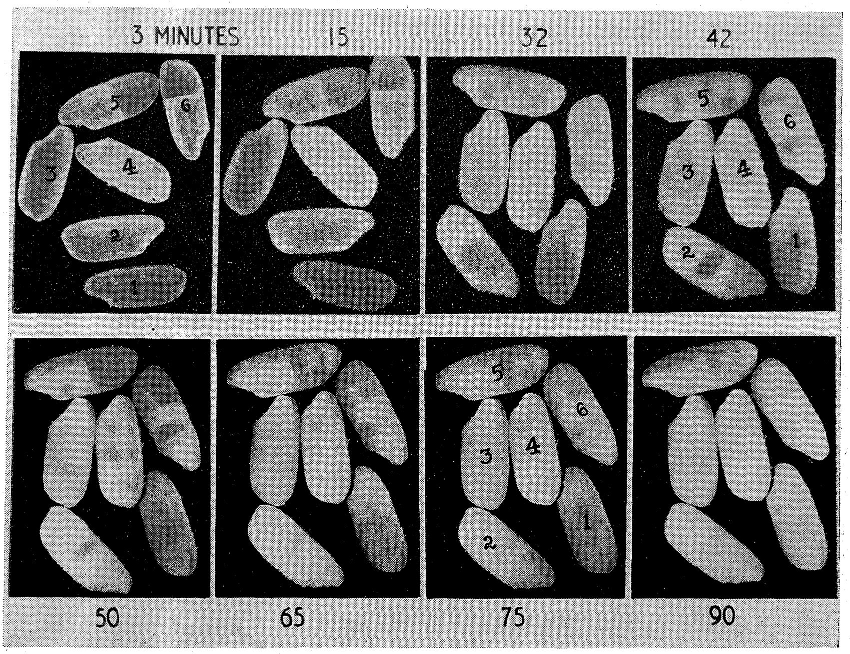

Fig. 5. Penetration of water in parboiled rice grains. Grains 1, 2, 3, 4: sound grains free from cracks; grains 5 and 6: with visible surface crack before wetting.

different constituents or release of internal stresses already existing inside the grain, as has been postulated in the case of wheat (2), is to be further investigated. It is also proposed to study the water penetration in paddy where the rate of water movement would be slow. The development of cracks, if any, in such a case has to be observed by X-ray photographs.

Acknowledgment

The authors wish to thank Mr. K. V. Achyutha Rao for the photographs.

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