Rice Cracking in High Rate Drying

By TOSHIZO BAN

Chief, Grain Processing and Handling Equipment Laboratory,
Institute of Agricultural Machinery

In the valuation of the drying method of rice an important matter is to keep the cost down for the removal of a certain weight of moisture content from rice kernels. However, prior thereto the prerequisite is to ensure a higher yield of head rice, excluding broken rice at the time the rice has been milled.

The increase in the ratio of broken rice at the time of milling differs by the disparity in processing methods such as milling after drying, but since the correlation was found between the ratio of broken rice of milled rice which has undergone a normal processing and the degree of cracking or the crack ratio of brown rice, the fewer the cracked kernels the higher the value in Japan.

Numerous studies have been made for a long time to investigate the relation between the drying or moistening, and cracking[6),7)] and the major cause of this crack outbreak is said to be sudden moistening or drying. Therefore, in the drying method for the purpose of high rate drying a certain limitation is inevitable in the drying rate.

Although the high rate drying is not accepted as the best method for a practical purpose, it is advantageous in that it can turn out more grains in a shorter time even by small holding capacity of the grain dryer. So the investigation of a possible acceleration of the drying rate of rice is deemed as a major significance.

This paper intends to touch on the relation between the drying condition and cracking, in the case of forced air drying normally practiced as the drying method of rice. Here the drying rate shall be expressed by mean drying rate which has been obtained by subtracting final moisture content from the initial moisture content and then dividing the same by the drying time. Moisture content is to be expressed by wet basis.

The relation between drying rate and cracking in forced air drying with comparatively lower temperature air

In Japan cracked kernels graded as damaged kernels at the time of officially inspecting brown rice are the brown rice kernels with a crack ring or rings broke out on the surface, as shown in Fig. 1. To keep cracked kernels of such a degree down to a fe wprecentage through the drying process is being demanded in Japan. Then in actual drying, what are the drying conditions in which cracked kernels are kept at such a degree of percentage?

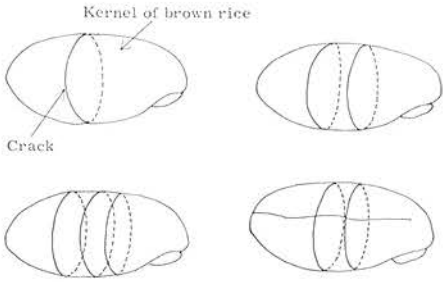

Fig. 1. Examples of cracked kernel graded as damaged kernel for official inspection in Japan.

Even if the rice is dried under a certain condition the degree of crack differs by rice varieties and pattern of culture. In case various varieties of rough rice in which the distribution of the moisture in rice kernel is in a state of equilibrium at the start of drying and on which cracked kernel can not be recognized in brown rice are placed in the form of thin layer and dried down to 13.5 per cent of the moisture and humidity, crack ratios show rather wide deviation.[1]

The considerable differences in the outbreak of cracking are sometimes witnessed by varieties and pattern of culture. Kernels with relatively medium outbreak of cracking were selected and dried in the form of thin layer under various degree of humidity and temperature of air.

The results thereof have clarified the relation between the initial moisture content and heated air temperature as well as the relation between the mean drying rate and outbreak degree of cracking as indicated by Fig. 2 and Fig. 3.[1]

These show the conditions in which cracking breaks out, when the final moisture content has reached around 13.5 per cent under continuous ventilation. The figures show that the higher the initial moisture content, the more cracking develops when the moisture content reaches near 13.5 per cent.

Therefore, it was found that the mean drying rate could not be raised. Moreover, in case the drying is to be carried out from 20 per cent moisture content to near 13.5 per cent by checking the crack ratio within a few percentage at a continuously constant air temperature, it was found that the limitation of the mean drying rate is about 1.5 per cent on an average and this trend has been confirmed[3] by many rough rice drying experiments since then.

In the intermittently ventilate drying, if a proper condition can be selected the question arises whether it is possible to raise the mean drying rate which has been computed by the time including non-ventilating time, over the limit of continuous ventilation stated above.

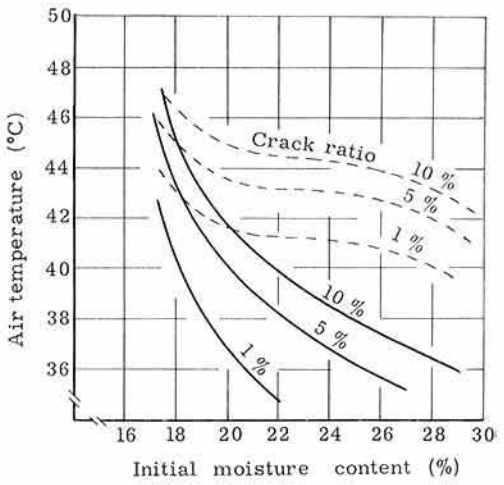

Fig. 2. Relation among initial moisture content, air temperature and crack ratio in thin layer drying

Note: (1) Absolute humidity of air;
—— 0.007 kg/kg, - - - - 0.024 kg/kg
(2) Final m.c.; about 13.5%
(3) Initial crack ratio; 0%
(4) Crack ratio (%)
$$\frac{\text{Cracked kernels in sample}}{\text{Total kernels of sample}} \times 100$$
(5) Cracked kernel; One graded as damaged kernel for inspection
(6) Variety of rice; KUSABUE
(7) Moisture content; Wet basis

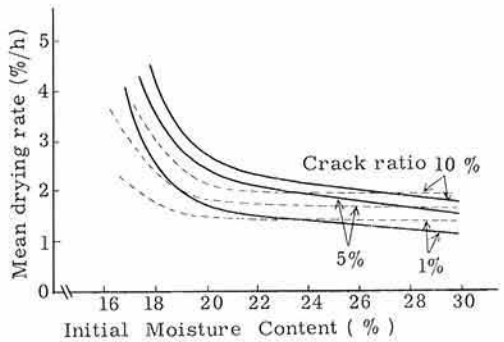

Fig. 3. Relation among initial moisture content, mean drying rate and crack ratio in thin layer drying

Note: (1) Same as Fig. 2
(2) Mean drying rate;
$$\frac{\text{Initial m.c. (\%)} - \text{Final m.c. (\%)}}{\text{Drying time (h)}}$$

However, it has been confirmed that there is practically no possibility to raise the same.[3] In this case the moisture content after drying is around 13 to 14 per cent by intermittently drying. However, in case the moisture reduction is down to 17 per cent or 18 per cent, the mean drying rate can be raised further.

Also in the case of high rate drying it does not necessarily happen that the cracking breaks out immediately after the drying. Even if the rough rice is stored as a whole under air-tight condition in which neither drying nor moisture adsorption occurs, a phenomenon of increasing cracks is witnessed as time goes by. And the cracking becomes stable and shows almost constant value in about 48 hours.[1] Because of such a result it has been proposed in Japan that the investigation of crack ratio in the test for driers, etc. should be conducted after the elapse of more than 48 hours.

The samples mentioned in this paper are the ones kept air-tight at 30°C temperature after being dried and then taken out after the elapse of 48 hours and the rough rice was husked by hand and the crack ratio of brown rice was investigated by naked eye.

Cracking under very high rate drying with high temperature air

One experiment deemed as worthy of attention was carried out by the Institute of Agricultural Machinery in 1969 on rough rice harvested at the Institute's attached farm.

The rough rice with high moisture content was dried immediately after harvest or dried naturally under normal condition. And the moisture content thereof has been conditioned nearly at 24 per cent and 18 per cent respectively. Then the rough rice was forced to be dried by air bringing about the moisture content nearly 13.5 per cent under various temperatures of 40°C to 130°C by air flow rate of 8~11 $m^3/S \cdot 100$ kg of paddy, and at the point where the moistrue content reached 13.5 per cent the investigations have been made on the relation between the increase in crack ratio and heated air temperature and the initial moisture content.[2]

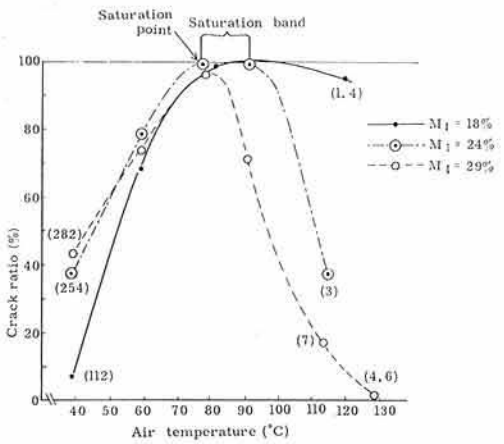

Fig. 4. Crack ratio on various air temperatures for wide range in forced air drying

Note: (1) M_I; Initial moisture content
(2) Values in brackets at near points show drying time in minute from M_I % to about 13.5%
(3) Final moisture content; about 13.5%
(4) Initial crack ratio; 0%
(5) Cracked kernel; One graded as damaged kernels for official inspection
(6) Variety of rice; TAMAYODO

The results thereof are shown in Fig. 4. Upon adopting the forced air temperature at t°C, crack ratio reaches the maximum at t=80°C, and it was found that under the temperature higher than this crack ratio it declines. That is, the raising of forced air temperature brings about the saturation point of crack ratio (temperature at which the crack ratio reaches 100%) and saturation band of crack ratio (band of temperature at which the cracking is maintained at 100%).

At a higher temperature above this saturation band, the higher the initial moisture content the less the crack ratio. Such a phenomenon can be assumed that the drying of rough rice at high temperature invites the gelatinization of brown rice, thereby brown rice becomes difficult to be cracked.

By applying the air at t=130°C which ex-

ceeds the saturation band of crack ratio to rough rice with 29 percent moisture content, it is possible to ensure 13.5 per cent moisture content in about five minutes. The crack ratio at this point was small and the rice kernels husked and milled manifested a glass-like transparency and the cooked rice lacked in stickiness.

Under the test by the Brabender Amylograph the breakdown thereof was approximately zero B.U. (Refer to Fig. 5). Although

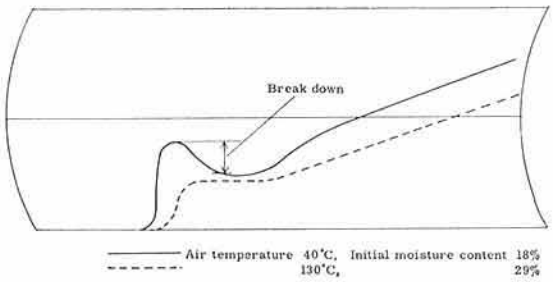

Fig. 5. Amylograph curves of milled rice.

it is difficult to render a judgment just by those factors it can be assumed that the rice has become a nature similar to parboiled rice.[5]

There are 2 or 3 researches directed to ensure an easier process after drying by improving the structure of kernels by exposing the green rough rice to a high temperature for a short duration (Heating with infrared radioation by M. D. Faukmer et al.[4] and heating with heated sand which is now being performed by A. U. Khan).

But the result of this experiment suggests the possibility to have the drying down to a low moisture content with high safety for storage by forced air drying of the most optimum high temperature at the same time to produce the rice similar to parboiled rice.

Moreover, due to the expectation of very high rate drying, holding capacity can be reduced drastically. The increase in fuel cost presents a problem. The fuel cost can be kept around twice at the most compared with that of the ordinary drier now being marketed commercially. And it is deemed that this cost can be reduced to a certain extent by further studies and if there is such a merit in due consideration of other advantages, it is assumed that the method can be put into practical use.

Such a drying method has the possibility of changing the rice quality unfavorable to the accustomed taste of Japanese for rice. In this point it seems it is still too early to apply for general driers in Japan. However, our efforts should be directed towards the research based in such idea and the Institute is challenging the development of this kind of drier.

References

1) Ban, T. et al.: Relation between drying rate and quality on grain moving driers. Institute of Agricultural Machinery, 1965 Annual report 89–107 (1966). [In Japanese.]
2) Ban, T. et al.: Very high rate drying with high temperature air. I.A.M. 1969 Annual Report 163–170 (1970). [In Japanese.]
3) Ban, T. et al.: Studies on circulation driers. Institute of Agricultural Machinery, 1970 Annual report 41–47 (1971). [In Japanese.]
4) Faulkner, M. D. & Miller, M. F.: Effect of high temperature and moisture for preconditioning rice for milling. *Rice Journal*, **72**(4), 31–35 (1969).
5) Ferrel, R. E. & Pence, J. W.: Use of the amylograph to determien extent of cooking in steamed rice, *Cereal Chm.* **41**(1), 1–(1964).
6) Okamura, T.: Relation between cracked kernels ratio in brown rice and broken kernels ratio in milled rice. *Nogaku-Kenkyu*, **22**, 91–105 (1934). [In Japanese.]
7) Okamura, T.: Studies on Cracking of Rice. *Nogaku-Kenkyu*, **27**, 165–194 (1937). [In Japanese.]