STUDIES ON THE COOKING QUALITY OF RICE. ON THE PLASTOGRAM OF RICE[1]

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ABSTRACT

Culinary properties of rice seem to depend on rheological behavior. The Plastograph (Brabender) was used for investigation of the viscous properties of cooked rice. A linear relationship between moisture and mobility was obtained for raw rice. But for cooked rice, the relationship was expressed with two intersecting lines. The moisture and mobility at the point of intersection was characteristic of rice type. The reason for such results seems to be the change of the flow properties of cooked rice. The flow properties may be dependent on the relative amounts of bound and free water.

There are many reports on the cooking quality of rice. The culinary properties of rice are chiefly decided, not by its chemical taste such as sweet or salty, but by its physical taste or texture such as tough or soft. Accordingly, most studies of the cooking quality of rice have been conducted from the standpoint of its rheological properties (1,2,4,5,6,7). For example, some reports were published on the viscoelasticity of rice starch gel (1,2), the chain length of rice starch (3,4,5,8), and its behavior toward chemical reagents (8,11,12).

The farinograph is an instrument used for measuring the rheological properties of dough and is employed for testing the quality of flour.

For instance, Hlynka (10) investigated the relation between water contents and mobilities of dough and found that they were in linear relationship. He also reported that the value of the moisture at the zero point of the mobility was about the same as that of the bound water in dough so far reported.

On the other hand, there are many reports on the state of the water molecule in dough (10). The water added to flour is divided into two kinds, one of which is associated with a network in the dough with gluten and starch and has little effect on the flow properties and mobility of the dough, and the other exists in free state and greatly influences the flow properties. Hlynka (10) called the former "bound water" and latter "free water" in his report.

The present authors have found that the farinograph can be utilized for the studies on the state of the water molecule in cooked rice

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[1] Manuscript received June 13, 1961.

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and have investigated culinary properties of rice. The main feature of this method lies in the fact that, while the cooking quality of rice has so far been investigated with powdered rice, this method is applied to cooked rice in the same state as it is chewed in the mouth, and the change of consistency can be investigated.

Materials

Rice. Commercial Japanese rice (*Koshiji wase,* short-grain) and Thai rice (long-grain) were used. The Japanese unpolished rice was stored for 4 months and was polished, to remove 9% of the weight of the unpolished rice, 1 week before experiments. About Thai rice, the variety name, degree of milling, and the age of the rice after harvest were unknown. Moisture content of Japanese rice was 13.1% and that of Thai rice was 12.0%.

Rice Powder. Japanese raw polished rice was powdered to pass through a 100-mesh sieve. Pregelatinized rice powder was prepared by cooking Thai rice with twice its weight of water, drying at a temperature over 80°C., and powdering the dried rice to pass through a 100-mesh sieve. The moisture content of pregelatinized rice powder was 4.0%.

Cooked Rice. Polished rice (50 g.) was washed in a beaker with 100 cc. of water, the water was drained, and the washing was repeated twice more. About 1–1.5% of the initial weight of the rice was washed away. The washed rice was cooked with 1.0–2.0 times its initial weight of water in a rice cooker with lid.

Retrograded Cooked Rice. The resulting cooked rice was put in a closed vessel and left standing at 4°C. for 24 hours.

Equipment and Methods

Plastograph. The Plastograph (Brabender) has the same structure as the farinograph. A small mixing bowl, for 50 g. of flour, was used, because with a larger type of mixer for 300 g. of flour, cooked rice was not crushed into a homogeneous paste and therefore reproducible results were not obtained. In the present experiment, the cooked rice or retrograded rice was left standing at 30°C. for 30 minutes, and 70 g. of the cooked rice were put in the mixer; when more than 70 g. were employed, the rice was not crushed completely within 5 minutes. Some examples of the plastograms obtained by this method are shown in Fig. 1.

The plastograms were similar to those for flour. Difference in B.U. in 10 measurements under the same conditions was ±10 B.U. at the maximum viscosity, and ±5 B.U. with homogeneous rice paste at 5

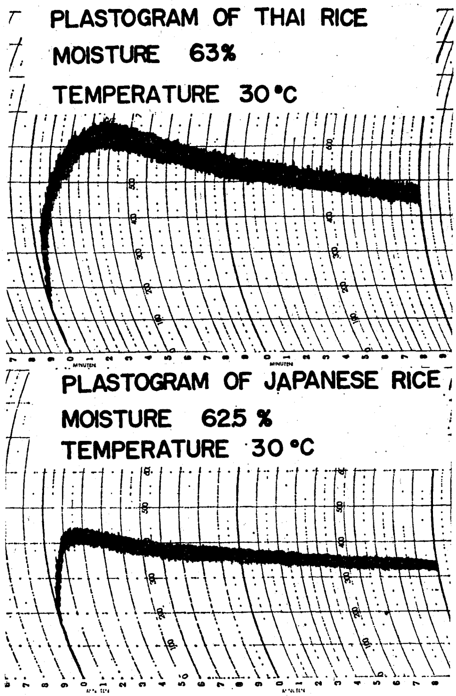

Fig. 1. Plastograms of cooked rice.

minutes after starting. The mobilities (reciprocal of consistency) were calculated from the consistency at 5 minutes after starting.

X-ray Studies. Gelatinized rice powder was prepared according to the method of Hizukuri *et al.* (9). The X-ray apparatus was Isodebyflex II-type (Seifert Co.).

Operating conditions were as follows: X-ray, Cu Kα ray (wave length, 1.5418 A) excited at 35,000V; tube current, 15 ma.; Cu Kβ ray was eliminated by a Ni-filter; width of receiving slit, 0.5 mm.; time constant, 1 second; sensitivity, 1,000 counts per second; scanning speed of goniometer, 1° per minute; chart speed, 10 mm. per minute.

Measurement of Rate of Digestion with Amylase. The degree of gelatinization of starch was measured by the rate of its digestion by amylase. In the present experiment, diastase J.P. was used as the source of amylase, and the experiment was carried out according to Watanabe's method (13) in which amylase (diastase) was reacted with rice powder at 30°C. The resulting reducing sugar was determined with 3,5-dinitrosalicylic acid.

Results

Relation between Moisture and Consistency.

a. *Raw rice (uncooked rice).* Recently Hlynka (10) reported that when the moisture was plotted as the ordinate and the reciprocal of consistency (B.U.), i.e. the mobility, as the abscissa, there was a linear relationship. A similar experiment with dough made of Japanese raw rice powder gave similar results, showing that the moisture and the mobility are in linear relationship as shown in Fig. 2.

b. *Cooked rice.* Investigation on the effects of water on the mobility of cooked rice (gelatinized rice) is shown in Fig. 3, by two lines intersecting each other.

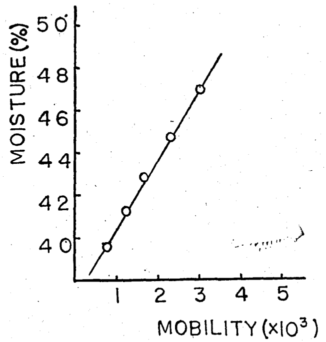

Fig. 2. Relation between moisture and mobility of dough made from raw rice powder.

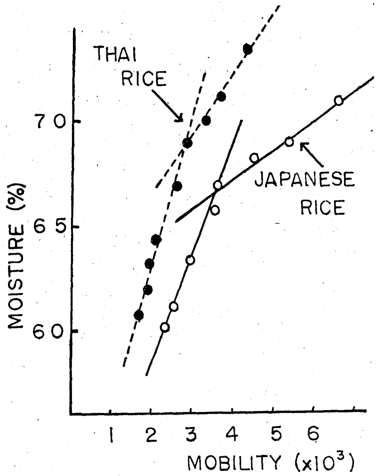

Fig. 3. Relation between moisture and mobility of cooked rice. Japanese rice was cooked with 1.0, 1.2, 1.4, 1.5, 1.6, 1.7, 1.8, and 2.0 times its weight of water; Thai rice was cooked with 1.0, 1.2, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, and 2.0 times.

The results of a similar experiment with Thai rice, which is longer than Japanese rice, are shown by a dotted line in Fig. 3. Cooked Thai rice exhibits smaller mobility than Japanese cooked rice; in other words, it is harder than the latter. Moreover, the point of intersection for Thai rice has higher moisture and smaller mobility than Japanese rice.

c. *Retrograded cooked rice.* The relation between the water content and mobility of the retrograded rice was investigated.

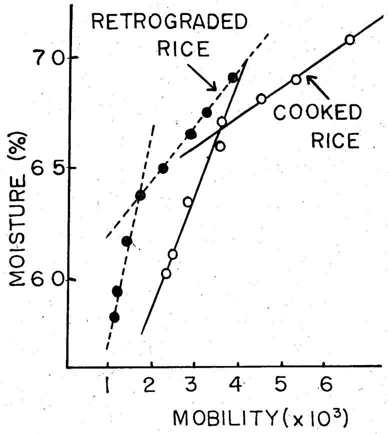

Fig. 4. Relation between moisture and mobility of cooked rice and retrograded cooked rice.

As shown in Fig. 4, the retrograded cooked rice had smaller mobilities than cooked rice; that is, it was harder than the latter. Besides, the point of intersection of the retrograded cooked rice had a smaller moisture content and smaller mobility than that of cooked rice. These results may be explained from the viewpoint of bound water, free water, and syneresis, and are discussed in the final section.

d. *Pregelatinized rice powder.* As shown in Fig. 5, the same result as in Fig. 3 was obtained. Judging from the result that pregelatinized rice powder also shows the two straight lines having an intersection, the relation between moisture and mobility does not depend on the water content at cooking but on the water content at mixing.

Difference in Degree of Gelatinization of Cooked Rice. To show that the configuration of rice starch does not change with the water content during cooking, the following two experiments were designed.

a. *Rate of digestion with amylase.* It is considered that such results as those expressed by two lines shown in Fig. 3, appear when the con-

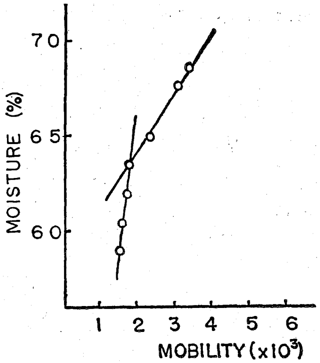

Fig. 5. Relation between moistures and mobilities of pregelatinized rice powder.

figuration of rice starch changes. Therefore, the effect of water on the degree of gelatinization was investigated with amylase. The rate of digestion with amylase, shown in Table I, indicates that the amount of water during cooking has no relation to the rate of digestion.

TABLE I

RATE OF DIGESTION OF COOKED RICE, COOKED WITH VARIOUS AMOUNTS OF WATER

WATER ADDED IN COOKING	REDUCING SUGARS
parts per hundred rice w/w	*mg. maltose/100 mg. rice*
120	61.3
140	62.6
160	62.7
180	62.5
200	63.2
Raw rice powder	14.6

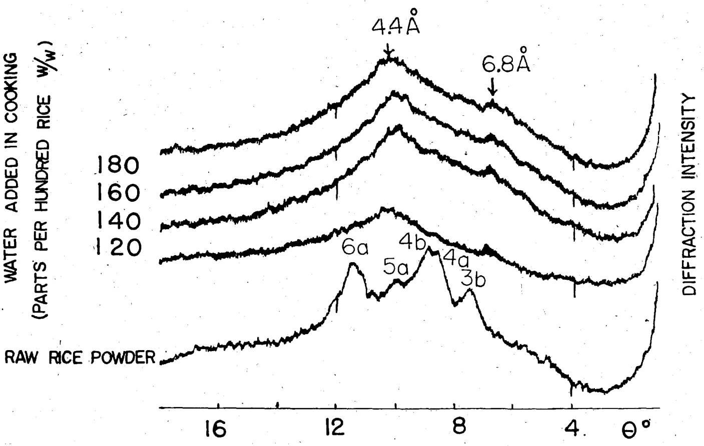

Fig. 6. X-ray patterns of rice powder cooked with various amounts of water.

b. *X-ray studies.* The X-ray patterns, in Fig. 6, show diffraction lines characteristic of gelatinized rice powder at 4.4 A and 6.8 A (9). But no change of X-ray patterns is observed from the change of the water content. Thus, the degree of gelatinization seems not to be changed by the amount of water used in cooking.

From the above results, we concluded that the configuration of rice starch does not change with the water content during cooking.

Discussion

Experiments on the relation between water content and mobility of powdered raw rice gave a linear relationship as shown in Fig. 2. Experiments on cooked rice did not show a linear relationship but two straight lines having a point of intersection, as shown in Figs. 3, 4, and 5. When the relation was expressed by two lines, it is considered that there is some difference in configuration or degree of gelatinization of rice starches cooked with various amounts of water. However, there are no differences in X-ray patterns and rate of amylase digestion.

Moreover, pregelatinized rice powder also shows the two straight lines. From these results, it does not seem reasonable to ascribe the relation to the difference in rice starch configuration.

When the relation between the water content and mobility is considered in viewpoint of free and bound water, it is found, as already shown in Figs. 3, 4, and 5, that the water content up to the intersection hardly influences the mobility, but that beyond that point it greatly affects the mobility. That is, it seems that the greater part of the water added up to the point of intersection enters the network of gelatinized starch as a sort of bound water and hardly exerts any influence on the flow properties; whereas the water added beyond the point of intersection exists as free water and greatly affects the mobility. Specifically, the water content at the point of intersection may be regarded as a measure of the amount of bound water which can be retained in the network of gelatinized starch.

In general, when gelatinized starch is left in a cold place, its disturbed molecular structure reverts to a micelle structure and the so-called retrogradation takes place. With this rearrangement of micelle structure, the bound water in the molecular chains is released as free water and causes syneresis. The displacement of the point of intersection to a lower water content (Fig. 4) is considered to be due to this phenomenon.

As shown in Fig. 3, the point of intersection for the sample of long-grain rice studied is located at a higher water content than for short-grain rice. According to many reports (3,4,5) the average chain length of the linear fraction of the starch of long-grain rice is longer than that of short-grain rice. Therefore, the gelatinized starch of long-grain rice can contain more water as bound water than that of short-grain rice, and as a result the point of intersection is displaced to a higher water content.

Acknowledgment

The authors are grateful to A. Watanabe, vice-director of Research Laboratories, T. Kanzawa and M. Kamada, for their kind advice. Thanks are also due to H. Okuto for his performance of X-ray studies and to Y. Uda for his generous assistance.

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