Rice Stickiness. II. Application of an Instron Method to Make Varietal Comparisons and to Study Modification of Milled Rice by Hot-Air Treatment[1]

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ABSTRACT

An objective Instron method was used to measure the stickiness of samples from 12 rice varieties. Long-grain rices as a class were statistically differentiated from medium- and short-grain rices. The substantial variation in the method allows statistically significant differentiation among various medium- and short-grain rices only when stickiness differences are quite large, ie, 0.8 g·cm. Reduction in stickiness by treatment of milled rice with a hot-air (149–260°C) blast was readily followed. At 204°C, stickiness of Calrose was reduced from 3.1 g·cm to 1.6 g·cm in 15 sec and to 0.4 g·cm in 30 sec, the latter value being typical of long-grain rice. Loss of gloss, sweet flavor, whiteness, and storage stability also accompanied hot-air treatments. Organoleptically determined stickiness of hot air-treated rices correlated at $r = 0.98$ with results from the Instron method. Plasma treatments of milled rices increased stickiness. Heating rice that had been immersed in safflower oil at 60°C reduced stickiness.

Stickiness theory and an objective Instron method to measure stickiness in cooked rices were discussed earlier (Mossman et al 1983). Fellers and Deissinger (1983) used the Instron method to demonstrate the effectiveness of short-time steam treatments of paddy in reducing stickiness.

Stickiness is greatest immediately after harvest and declines as rice ages (Barber 1972). Treatments to reduce rice stickiness, such as dry heat treatments with limited moisture change, steam treatments, and chemical treatments have been reviewed (Fellers and Deissinger 1983). The underlying mechanisms responsible for such declines in stickiness are not known. Formaldehyde and quinones have been used to reduce stickiness, and it was suggested that carbonyl might be involved (Barber 1972). Workers at the International Rice Research Institute (1976) found no evidence of carbonyl involvement with the epsilon amino group in lysine during natural aging.

While investigating the influence of crystalllinity on the epichlorohydrin crosslinking of starch in rice, Islam et al (1974) discovered that parboiling reduced crystallinity. Priestly (1976, 1977) used X-ray diffraction and found that crystallinity (starch retrogradation) did not occur during parboiling of Japonica rice, but that formation of a helical amylose complex, possibly with fatty acids, was involved. Shibuya et al (1977) were unable to relate textural changes in stored rice to changes in the amounts of free fatty acids, though undermilled rice changed the most.

In this article, use of the objective Instron method to compare the stickiness of several rice varieties and to determine stickiness changes due to hot-air treatments, safflower oil soak, and hydrogen and oxygen plasma treatments on milled rice is described.

[1]Mention of a trademark or proprietary product does not constitute recommendation of the product by the USDA over others that also may be suitable.

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MATERIALS AND METHODS

Rices and Their Preparation

Rices were obtained as paddy from state experiment stations at Biggs, CA, Stuttgart, AR, and Beaumont, TX. Calrose was obtained at the RGA mill in Sacramento, CA (Table I). The rices were stored at 2°C in plastic bags inside metal cans with friction lids and were milled as needed. Brown rice was milled on a McGill no. 3 mill with 12 lb of weight for 1 min. Brokens were removed in a Hart separator, and the head rice was used for experimentation. Typical milling data were previously described (Mossman et al 1983). Moistures were determined by the air-oven method for paddy and by the vacuum oven method for milled rices (AACC 1976). Amylose was determined by the method of Juliano (1971).

Stickiness Determination

Stickiness was determined by the standard WRRC Instron stickiness method (Mossman et al 1983). A water to rice ratio of 1.25 was used in steaming (cooking) the rice samples in preparation for the Instron. For each rice sample evaluated, four 8-g portions were cooked in separate beakers. Two 2-g samples of cooked rice from each beaker were evaluated on the Instron for a total of eight determinations. The stickiness values reported are the mean of eight determinations.

Heat Treatments

Milled Calrose (a medium-grain sticky rice) was exposed to 400 m/sec fluidizing hot air in a pilot toaster (Surface Combustion Co., Toledo, OH) for up to 60 sec at 149–260°C. One hundred-gram samples were heated in a rectangular container having a screened top 23 by 46 cm and a bottom 10 by 46 cm. Hot air flow was from the bottom to the top. Treated rice was immediately removed, placed in a container with a screened bottom, and cooled with fluidizing ambient air.

Instron Stickiness and Organoleptic Results for Heat-Treated Calrose Samples

Stickiness was determined by Instron and an organoleptic panel on Calrose control rice and Calrose heated with a hot-air blast for 10, 20, and 30 sec at 204°C. The cooking procedure was to add 200 g rice (adjusted to 10% moisture) to 300 g hot water in the top section of a double boiler, and heat over boiling water for 20 min. The top pan was removed and allowed to set for 10 min, then was uncovered and the rice fluffed with a fork. Portions of about 15 g each were placed in numbered cups for presentation to the panelists while still hot. The panelists were asked to eat each rice sample and to judge it according to the following scale: 1) not sticky at all; 2) just perceptibly sticky; 3) slightly sticky; 4) moderately sticky; 5) very sticky; and 6) extremely sticky. The test was run twice with 29 panelists in each section. Overall organoleptic stickiness scores were obtained for the control Calrose and for the three treatments by averaging the individual judgments.

Safflower Oil and Plasma Treatments

Milled Calrose was dipped in safflower oil at 25°C and drained overnight. In a second experiment, Calrose was soaked in safflower oil at 60°C overnight and then drained.

For plasma treatments, 25 watts radio frequency (13.56 MHz) was used to ionize the rarified oxygen or hydrogen. The 32-g samples were treated for either 2 or 10 min, with interruption at the half time to remix the samples.

RESULTS AND DISCUSSION

Varietal Comparison

Table I provides a list of the 12 rice samples evaluated. In addition to crop-year variation (1970 or 1973), samples were in storage (2°C) at our laboratory until evaluated in 1976. Figure 1 shows the average Instron stickiness values and the 95% confidence interval (within which the true value lies) for each rice. The larger interval applies to each rice in the top group, and the smaller one to each rice in the bottom group. The rices fell into two statistically different groups, one consisting of the long-grain varieties and the other made up of the medium- and short-grain varieties. No subgroups could be extracted from the long-grain group (Duncan's test). Overlapping subgroups appeared in the sticky rice group, but these did not correspond to medium- vs short-grain varieties.

TABLE I
Source of Rice Varieties and Other Characteristics[a]

Type and Variety	Crop Year	Source	Amylose (%,db)	Percent Moisture in Milled Paddy	Instron Stickiness
Long					
Bonnet-73	1973	Arkansas	19	9.9	0.70
Starbonnet	1973	Arkansas	20	9.9	0.40
Lebonnet	1973	Texas	21	10.0	0.45
Labelle	1973	Texas	17	9.7	0.60
Bluebelle	1973	Texas	20	10.2	0.45
Medium					
Calrose	1973	California	16	10.0	3.10
CS-M3	1973	California	16	10.5	2.25
3597	1973	California	15	10.1	3.60
Nato	1970	Arkansas	12	9.4	1.75
Nortai	1970	Arkansas	14	9.4	2.30
Short					
Caloro	1973	California	16	11.1	1.85
Colusa	1973	California	17	11.0	2.70

[a] Because the histories of these samples vary, Instron values and amylose values (determined in 1976) should not necessarily be considered typical for the varieties.

Perez and Juliano (1979) reported that Instron stickiness correlated negatively with percent amylose content of milled rices. Their results are not directly comparable with ours because of differences in sample preparation and operation of the Instron. However, the amylose and stickiness results in Table I are in general agreement; the five long-grain nonsticky rices had amylose contents of 17–21%, and the medium and short sticky rices displayed amylose contents of 12–17%.

Because changes in stickiness due to aging of the rough paddy rice are detectable even at 2°C, these values should not be considered absolute for these varieties. In addition, samples of the same variety can be expected to vary, depending on differences in sample histories. Fellers and Deissinger (1983) reported that degree of milling is also critical to the stickiness value determined by the Instron method. Regardless of these reservations, the method appears precise enough to discern subgroups, and therefore would be applicable for measuring and comparing freshly harvested varieties, samples of the same rice treated variously to reduce stickiness, or any other group of comparable samples.

Heat Treatments of Milled Rice

The idea of dry-heat treatments was to accelerate the natural

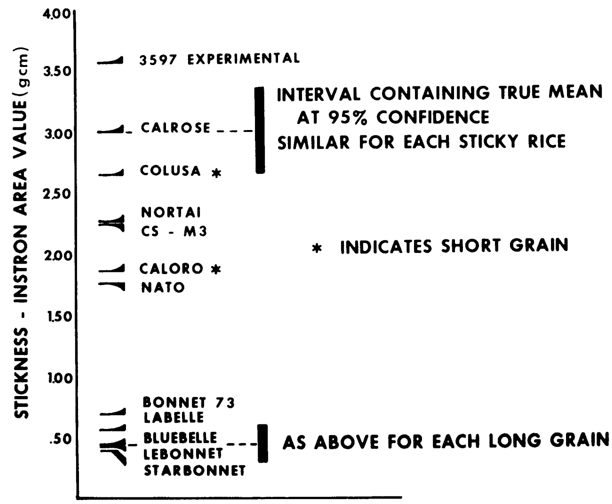

Fig. 1. Instron stickiness values for 12 rice varieties. During the stickiness test, eight individual readings were taken for each rice sample and the mean reported as the stickiness value. The vertical bars represent the 95% confidence interval for any specific mean. For example, the mean determined for Calrose was 3.0 g·cm and 95% of the time, the true mean can be expected to fall between 2.6 and 3.4 g·cm.

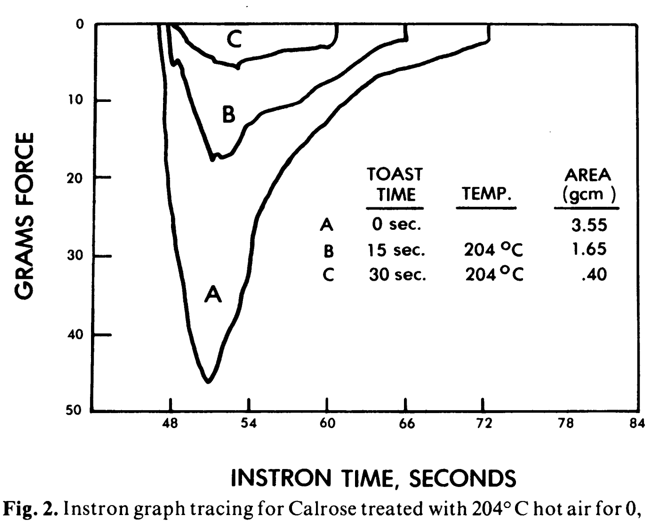

Fig. 2. Instron graph tracing for Calrose treated with 204°C hot air for 0, 15, and 30 sec. The Instron crosshead moves 0.0083 cm/sec.

aging process that reduces stickiness. Initially, we found that rice placed on an open tray for 5–30 min in an oven at 70–140°C reduced stickiness but caused severe fissuring and a very granular or gritty mouthfeel when cooked. Rapid loss of moisture probably created the stresses leading to cracking. This fissuring was not repaired when the rice was cooked and carried through to create a gritty texture. This suggests that a phenomenon occurring at the surface of the fissures may prevent subsequent repair by cooking. On the other hand, fissures in the endosperm of paddy rice are repaired by parboiling. Gritty texture is also of interest when certain long-grain rices are ground to flour and used in bread that then has a sandy texture (Nishita and Bean 1979). This phenomenon requires further investigation.

The oven work indicated that two reactions were occurring: desirable stickiness reduction and undesirable fissuring. Because stickiness is primarily associated with kernel surface, we reasoned that a very short hot-air blast may reduce stickiness with minimum cracking.

Figure 2 shows the stickiness portions (Mossman et al 1983) of the Instron tracings for Calrose treated with 204°C hot air flowing at 400 m/min for 0, 15, or 30 sec. Figure 3 summarizes the relationship between stickiness and time and temperature of hot-air treatment for Calrose. Results with the other medium- and short-grain rices were very similar. Stickiness is sharply reduced at 177°C and further reduced at 204 or 260°C. At 204°C, the stickiness of Calrose was reduced in 25–30 sec to the range typical of long-grain rices. When long-grain rices were exposed to hot air, stickiness as measured with the Instron dropped to zero even with the shortest treatment.

Although hot-air treatment of milled rice effectively reduced stickiness, gloss was lost almost immediately. Additionally, sweet flavor, whiteness, and shelf life were all reduced in direct relation to the severity of treatment. Under mild treatments the sweet flavor was reduced, and a bland product resulted. But as treatment progressed, toasted flavors developed, and at the most severe treatments burnt flavors occurred. The germ discolors first, because of its high sugar content and its position on the surface of the kernel. In severely treated samples, discolored germ tends to slough off in cooking. The grainy mouthfeel caused by cracking of the rice was only a problem in the more severely treated samples. A recommended treatment that minimizes adverse effects but substantially reduces stickiness is 204°C hot-air treatment for 15–20 sec.

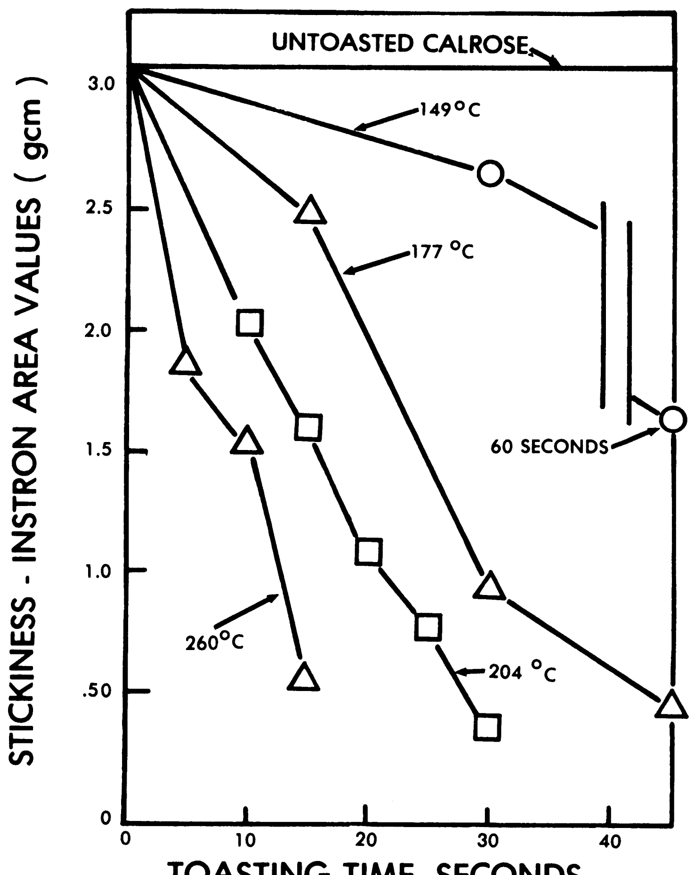

Fig. 3. Changes in Instron stickiness of Calrose rice due to hot-air treatment.

Instron Stickiness and Organoleptic Results for Heat-Treated Calrose Samples

Panel stickiness scores were correlated with the Instron stickiness values for Calrose rice heated at 204°C for 0, 10, 20, and 30 sec. The regression equation is:

$$y = 1.13x + 1.08$$

where y is the panel score and x is the Instron value in gram centimeters. The correlation coefficient was $r = 0.98$ and the standard error 0.28. The term 1.08 results from our beginning the panel scores at one and Instron values at zero.

Table II provides the corresponding panel scores and Instron values derived from the above equation. Stickiness became perceptible around 0.8 g·cm. Our untreated Calrose at 3.1 g·cm would be considered very sticky. Less water was used in our Instron cooking procedure (1.25 water to rice ratio) than for the panel (1.5 ratio). Other water to rice ratios would most likely result in a shifted correlation; therefore, recalculation will be needed for test conditions different from those specified here.

Other Treatments of Milled Rice

The early approach in this work was based on partial gelatinization or cooking (at moistures reduced from normal), holding for a period of time under conditions conducive for irreversible starch retrogradation, and subsequent drying. We immediately found that any addition of water to rice caused fissuring that could only be overcome by fully cooking the rice. We attempted to ameliorate the effect of water by adding salts, sugars, and glycerine, but this was not successful either.

We then attempted to dry heat the rice without moisture loss by

TABLE II
Relationship of Organoleptically Determined Stickiness with Instron Stickiness[a]

Panel Score	Varietal Description	Instron Value (g·cm)
1	Not sticky at all	0
2	Just perceptibly sticky	0.8
3	Slightly sticky	1.7
4	Moderately sticky	2.6
5	Very sticky	3.5
6	Extremely sticky	4.4

[a] These values were derived by entering panel scores 1 through 6 into the regression equation. Panel score = 1.13 (Instron value) + 1.08. The actual values used to obtain the regression equation ranged from 0.67 to 3.08 g·cm for the Instron stickiness values and from 2 to 4.7 for the panel scores. The verbal descriptions are those used with the corresponding numbers by the panel.

TABLE III
Instron Stickiness Values (g·cm) for Calrose Treated with Plasmas or Safflower Oil

Treatment	Control[a]	2 min	10 min (g·cm)	25°C	60°C
Hydrogen plasma	1.5	2.5	2.3	···	···
Oxygen plasma	1.5	1.7	2.0	···	···
Safflower oil soak	1.5	···	···	1.3	0.67

[a] The low value of 1.5 for the control Calrose was due to natural aging.

immersing the rice in food oil or some other liquid and heating. In safflower oil, in which water is immiscible, reduction in stickiness was achieved at both 25 and 60°C (Table III). These limited but promising experiments suggest that further work along these lines could be interesting.

Another approach was to evaluate the use of plasmas as a surface-treating phenomenon. Table III shows that both hydrogen and oxygen plasmas increased stickiness. If stickiness reduction during aging is due to α-helix complex formation, perhaps plasmas act to disrupt the complex. The free radicals active in the plasmas could have this effect on the rice surface. Although these experiments are very limited, they are in accord with those of Chaudry and Glew (1972), who discussed the surface damage done to rice by plasma. Hogan and Roseman (1961) attributed all of the changes they observed in hydration characteristics of rice to the heating during plasma treatment. We have found that heating and plasma treatments cause opposite changes in stickiness.

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