Physicochemical Properties of Rice in Relation to Rice Bread[1]

K. D. NISHITA and M. M. BEAN, Western Regional Research Center, Science and Education Administration, U.S. Department of Agriculture, Berkeley, CA 94710

Cereal Chem. 56(3):185-189

ABSTRACT

Successful development of a rice bread for people allergic to wheat has led to the study of physicochemical properties of rice that affect bread characteristics. While all rice types produced breads equal in appearance, soft cooking rices with low amylose content, low gelatinization temperature, and low amylograph viscosity upon cooling to 50°C produced breads with superior crumb properties. Flours from rices with properties differing from those above produced breads with sandy, harsh crumb characteristics. Rice bread cannot be produced from waxy rice flour alone. Up to 25% nonwaxy flour may be replaced with waxy rice flour without seriously affecting loaf volume. Rice properties related to 100% rice bread may also be important when rice is blended with wheat in composite flours.

A yeast-leavened rice bread, suitable for people allergic to proteins in wheat flour (eg, those with coeliac disease), was formulated (Nishita et al 1976). This product is currently being developed for commercial use by the private sector. During the formulation study, it was observed that some rice flours produced moist, soft-textured breads while others produced sandy, harsh-textured breads. Information available from studies on physicochemical properties of rice has been related mostly to eating and processing qualities of milled white rice (Halick and Kelly 1959, Juliano et al 1965, Kurasawa et al 1969). Perdon and Juliano (1975) showed that aged milled rice with 20–25% amylose content made fermented rice cakes with softer texture and larger volume than those made with rices containing lower or higher percentages of amylose. These and other workers at the International Rice Research Institute (1976) also reported that amylose content of rice was a major factor that affects volume expansion during popping of heated raw rice and the texture of yeast-leavened rice bread. It seemed pertinent to investigate further the role of amylose and other physicochemical properties of rice in relation to crumb characteristics in bread. Such information would permit selection of appropriate rice varieties for flours for baking purposes. The work reported here examines the relations among amylose content, gelatinization behavior, cooked rice quality, and texture of bread made with flours from several rices.

In addition to breads made with 100% rice flour, these studies also have application in composite flour breads when rice makes up a significant portion of the flour blend. In countries where wheat is imported and rice supplies are significant, broken rice can be milled into flour and added to the wheat flour, or added during milling of the wheat. Various studies (Dendy et al 1973, Interpan 1972, Mosqueda-Suárez 1958) have shown successful addition of 20–30% rice on a replacement basis.

MATERIALS AND METHODS

A rice flour, made from California short-grain and medium-grain white rices, was obtained from C. E. Grosjean Rice Milling Co., San Francisco, CA 94124. Two Texas flours, one made from medium-grain rice and the other from long-grain rice, were obtained from Riviana Foods, Inc., Houston, TX 77001. Particle-size distribution, determined as described in Nishita et al (1976), is shown in Table I.

IR-2071-137-5-5-1 (abbreviated in this paper as IR-2071) was obtained as milled rice from The International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines, and made into flour in a Wiley mill equipped with a 60-mesh screen.

Seven varieties of paddy rices with contrasting properties were obtained from the USDA, Regional Rice Quality Laboratory, Beaumont, TX 77703. California long-grain (3764) paddy rice (1976 crop) was obtained from Rice Experiment Station, California Cooperative Rice Research Foundation, Inc., Biggs, CA 95917. Calrose paddy rice was obtained from Rice Growers Association of California, P.O. Box 958, Sacramento, CA 95804. Paddy rices were dehulled with a McGill sheller, MS-1, with settings between 15 and 25, lower ranges for long grain and upper ranges for short/medium grain, depending on the rice sample. The resulting brown rice was debranned and polished, 30 sec for each step, on a McGill miller No. 3 with 12-lb weight placed at the extreme position on the arm. Portions of the whole kernel milled rice were reserved for cooked rice quality tests measured by an informal taste panel. Rice flour was made with the remaining milled rice by passing it, first, through a coffee grinder (Hobart Mfg. Co., Troy, OH 95374) set at 1.5, and then through the Brabender Quadrumat Junior mill No. 46, fitted with Brabender reel sifter, No. 64 grit gauze.

Amylose was determined at 620 nm by the method of Juliano (1971). Pure amylose from Nutritional Biochemicals Corporation, ICN Life Sciences Group, Cleveland, OH 44128, was used for the standard curve.

Gelatinization temperature and pasting characteristics of each flour were determined with a C. W. Brabender amylograph equipped with a 700 cm-g sensitivity cartridge and a cooling coil. The method of Halick and Kelly (1959) was used except the 10% slurries (50 g rice flour/450 ml water) were heated to 97°C instead of 94°C. Heating to 97°C permitted measurement of maximum peak viscosity above 94°C. Since our laboratory is located at sea level, the slurries did not boil over at 97°C. The 20% slurries (100 g rice flour/400 ml water) were heated until the paste viscosity exceeded the measuring capacity of the amylograph. Gelatinization temperature was determined as the point where the viscosity curve left the base line. Gel strength of 10% pastes held at refrigerator temperature for 24 hr was determined by the embedded disk method with the gelometer attachment to the Corn Industries viscometer (Gaertner Scientific Corp., Chicago, IL 60614) (Smith 1967).

TABLE I
Particle-Size Distribution of Commercial Rice Flours

	U.S. Standard Sieve No.			
	+100 (%)	+140 (%)	+200 (%)	-200 (%)
CA sh/med	40.1	27.6	13.8	18.5
TX med	53.7	6.5	25.5	14.3
TX long	59.9	6.3	22.0	11.8

[1]Presented at the AACC 62nd Annual Meeting, San Francisco, October, 1977. Reference to a company or product named by the USDA is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of others that may also be suitable.

Cold paste viscosity, which reflects cooked rice quality, was measured by a gel consistency test developed by IRRI (Cagampang et al 1973). Rice flour (100 mg) was heated in a 13 × 100-mm culture tube with alkali and dye, chilled, and laid horizontally over ruled paper; the length (mm) of the gel flow was measured after 60 min.

Protein content was determined by AACC Method 46-11.

For eating quality tests, 15-g rice samples in six beakers (150 ml) were cooked inside the pan of a National Rice-o-mat cooker (Model SR-18E, Matsushita Electric Industrial Co., Ltd., Osaka, Japan). Rice-water ratios of 1:1.7 and 1:2.0 were used for short/medium-grain and long-grain rices, respectively. Each beaker was covered with a watch glass (2.5-in. diameter) and 180 ml water surrounded the beakers. The cooker was kept covered during a 20-min cooking followed by a 10-min steaming period. The rice was then fluffed with a fork. Taste tests were made immediately.

Rice bread was prepared by the formula described in an earlier paper (Nishita et al 1976). Bread texture was determined 24 hr later by an informal panel of judges.

RESULTS AND DISCUSSION

Rice flour has had only limited use for bread-baking purposes since it does not contain gluten necessary for the dough to form structure and retain gases produced during the fermentation process. The physicochemical properties of rice flour in relation to baking characteristics have not been explored. It is generally accepted that starch components play a significant role in influencing cooking and processing behaviors of rice (Halick and Kelly 1959, Webb and Stermer 1972). For example, in the United States, long-grain rice usually has starch with higher amylose content and higher gelatinization temperature, and makes fluffier, drier cooked rice than does short-grain or medium-grain rice. Or, conversely, short-grain and medium-grain rices have starches with low amylose content and low gelatinization temperature, and make soft, often sticky, cooked rice. These factors were used as a guide in attempting to relate rice properties to rice bread characteristics.

Figure 1 shows rice samples in this study grouped according to amylose content and gelatinization temperature. Low, intermediate, and high ranges for both properties were arbitrarily selected to facilitate grouping of rices. (The gelatinization temperature classification used in this study differed from that used by Beachell and Stansel [1963]). Their classification was as follows: low, <70°C; intermediate, 70–74°C; and high, 75°C or higher.) The varieties examined fell into four groups. All three ranges of amylose content were represented but samples with intermediate gelatinization temperatures (ie, 65–70°C) were not available. Varieties with low amylose and low gelatinization temperature (those grouped at bottom left) made soft, sticky cooked rice; those with high amylose and low gelatinization temperature (bottom right) made dry, firm cooked rice; the remainder varied in cooking quality from soft to dry. Only the varieties in the bottom left group (ie, low amylose, low gelatinization temperature) produced bread with good crumb texture. Particle size of the flours was not a factor as shown by comparison of the commercial varieties (Table I). The two Texas rices were similar in particle-size composition but different from CA sh/med. Nevertheless, the CA sh/med and TX med made soft breads while TX long made sandy bread. All three varieties made breads with good loaf volumes (Table II), above 5cc/g baked weight. In fact, all varieties produced breads more or less equal in volume and appearance. Only IR-2071 and IR-8, as shown in Table II, had specific volumes less than 5.0 cc/g baked weight.

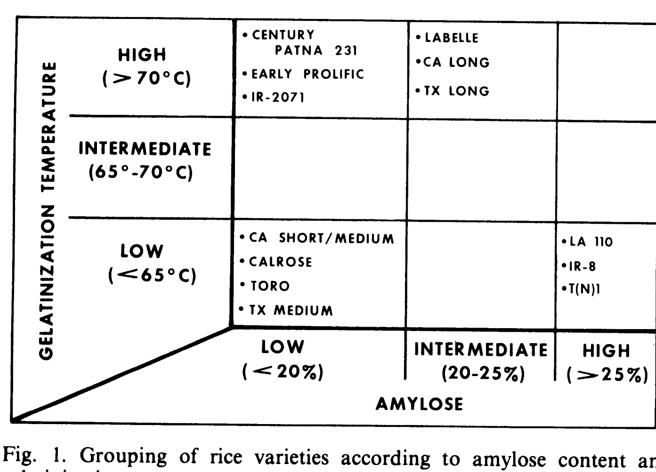

Fig. 1. Grouping of rice varieties according to amylose content and gelatinization temperature. (Actual values are given in Table I.)

Since gelatinization behavior of starch influences the textural quality of cooked rice (Juliano et al 1964, Kurasawa et al 1969), its importance to bread crumb characteristics was examined. Figure 2 depicts amylograph curves obtained with flours representative of each group in Fig. 1. The sharp rise in the slope of the four short curves on the left side reflected the viscosity changes of 20% slurries immediately upon swelling of the starch. Thus, the initial gelatinization temperature can be estimated as the point of departure from the zero base line. Halick et al (1960) have shown that these values are close to the birefringence end-point temperature, determined microscopically. These short curves showed wide variations in gelatinization temperature, starting from a low of 60.0°C for Calrose (curve A) to a high of 73.5°C for Century Patna 231 (curve D).

The amylograph curves on the right show the full gelatinization history of 10% slurries of the same rice flours during heating to 97°C, holding, and cooling to 50°C. With the 10% slurries, viscosity due to initial swelling of the starch is not measurable on the amylograph but subsequent swelling and starch breakdown are recorded. The difference in viscosity values between hot paste and paste cooled to 50°C is referred to as the setback value (Beachell and Stansel 1963) and reflects the retrogradation behavior of a starch (Masurs et al 1957).

Curve A for Calrose, a medium-grain rice that made the best bread, showed lowest gelatinization temperature (60.0°C), lowest maximum hot-paste viscosity (750 Brabender units [BU]), and lowest viscosity after cooling to 50°C (715 BU). Calrose showed negative setback value, ie, final viscosity was lower than peak viscosity.

Curve B for IR-8 also showed low gelatinization temperature (60.5°C) but, unlike Calrose, it reached a much higher peak viscosity (1,020 BU) at a higher temperature (almost 97°C). Unlike the

TABLE II
Loaf Volumes, Weights, and Specific Volumes of Breads Baked from Different Rice Varieties

Rice Variety	Volume (cc)	Weight (g)	Specific Volume (cc/g baked weight)
Low/low			
CA sh/med	675	130.5	5.2
Calrose	715	130.5	5.5
Toro	725	128.5	5.6
TX med	740	130.5	5.7
Low/high			
Century Patna 231	695	129.5	5.4
Early Prolific	705	130.5	5.4
IR-2071	645	131.5	4.9
Int/high			
Labelle	690	130.5	5.3
CA long	700	129.0	5.4
TX long	722	130.0	5.6
High/low			
LA 110	680	130.5	5.2
IR-8	625	132.5	4.7
T(N)1	725	128.5	5.6

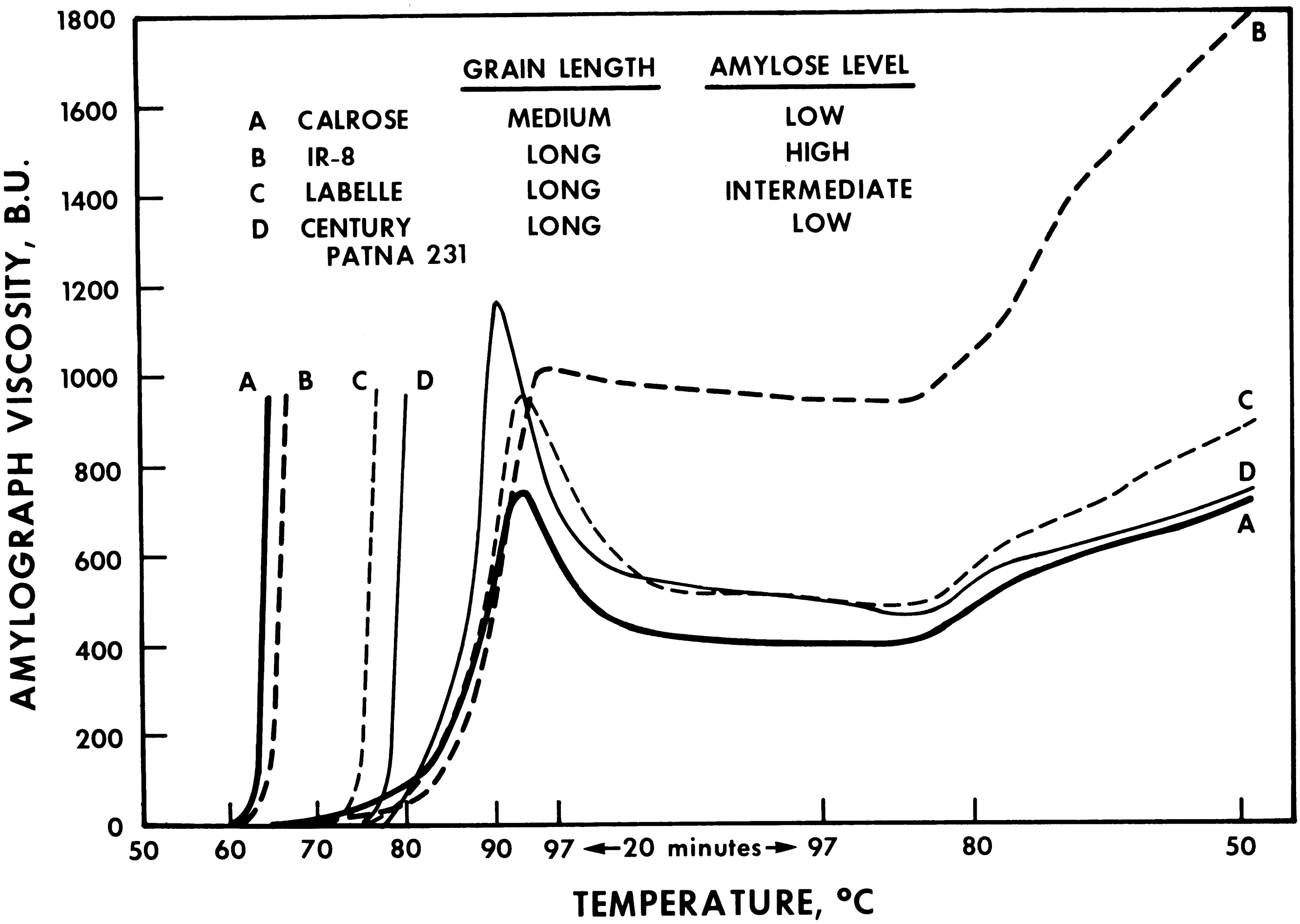

Fig. 2. Amylograph curves for four contrasting rice varieties shown in Fig. 1. Short curves, 20% slurries; full curves, 10% slurries.

TABLE III
Some Physicochemical Properties of Rice Varieties in Relation to Cooked Rice Quality and Bread Texture

a	b	c	d	e	f	g	h	i	j	k	l
					Viscosity, BU						
Rice Variety	Grain Length	Protein[a] (%)	Amylose (%, db)	Gelatinization Temperature (°C)	Peak	Cool to 50°C	Setback	Gel Strength (g-cm)	Gel Consistency (mm)	Cooked Rice Quality	Bread Texture
Low[b]/Low[c]											
CA sh/med	Sh/med	6.0	18.9	62.0	680	770	+90	0	82	...[d]	Soft
Calrose	Medium	5.5	19.9	60.0	750	715	−35	0	88	Soft	Soft
Toro	Long	5.7	19.9	59.5	790	915	+125	0	82	Int	Soft
TX med	Medium	7.8	15.0	64.0	790	665	−125	0	64	...[d]	Soft
Low/High											
Century Patna 231	Long	6.1	16.6	73.5	1,165	740	−425	0	87	Soft	Sandy/dry
Early Prolific	Medium	6.4	15.5	70.5	1,215	790	−425	0	79	Int	Sandy
IR-2071	Long	9.9	11.6	75.0	1,035	905	−130	0	89	Soft	Sandy
Int/High											
Labelle	Long	7.0	22.4	71.0	950	890	−60	49	83	Int	Sandy/dry
CA long	Long	6.1	24.2	70.0	605	805	+200	156	79	Soft	Sandy/dry
TX long	Long	8.2	21.1	70.5	790	900	+110	6	45	...	Sandy
High/Low											
LA 110	Medium	6.6	25.8	62.5	1,020	1,725	+705	352	93	Hard	Sl. sandy
IR-8	Long	7.2	25.7	60.5	1,020	1,810	+790	437	52	Hard	Sandy/harsh
T(N)1	Sh/med	8.6	24.9	63.0	915	1,650	+735	300	50	Hard	Sl. sandy

[a]14% moisture basis, N × 5.95.
[b]Amylose content: Low, <20%; intermediate, 20–25%; high, > 25%.
[c]Gelatinization temperature: Low, <65°C; intermediate, 65–70°C; high, > 70° C.
[d]Only available as flour, not kernels.

other rices, IR-8 retained its high viscosity during the holding cycle, and continued to increase in viscosity during the cooling cycle until it reached just over 1,800 BU at 50°C. IR-8 showed high positive setback value. IR-8, a long-grain rice with high amylose content, made a very dry, harsh, and crumbly bread.

Curve C is for Labelle, another long-grain rice but with an intermediate amylose content, and high gelatinization temperature (71.0°C). Its peak viscosity (950 BU) was between that of Calrose and IR-8, but the rest of the curve paralleled that for Calrose except at a slightly higher viscosity. Its setback value was also negative. Bread made from Labelle had slightly sandy, dry crumb.

Curve D is for Century Patna 231, also a long-grain rice, but with low amylose content and the highest gelatinization temperature (73.5°C). It had a high maximum peak viscosity (1,165 BU), but a final viscosity at 50°C similar to that of Calrose, and a negative setback. Century Patna 231 made bread that was sandy, dry, and crumbly.

Except for initial gelatinization temperature with 20% slurries and setback values with 10% slurries, other amylograph pasting characteristics may not be important in predicting rice bread characteristics. Figure 3 shows two samples, Texas medium-grain and Texas long-grain rices, that had identical peak viscosity and peak temperature values but different bread crumb characteristics. The medium-grain rice had a low amylose content, low gelatinization temperature (64.0°C), and lower setback value; the long-grain rice had slightly higher amylose content, considerably higher gelatinization temperature (70.5°C), and higher setback value. The medium-grain rice produced soft, moist bread; the long-grain rice produced crumbly, sandy bread.

Table III summarizes the physicochemical properties of the rice varieties studied as they relate to eating quality of the cooked rice and bread texture (columns k, l). The rice varieties are grouped according to amylose content and gelatinization temperature, as in Fig. 1. Only the first four rices in the low amylose/low gelatinization group made both soft/intermediate quality cooked rice *and* soft breads. All the others showed variable cooked rice quality and varying degrees of sandiness. Grain length in itself did not appear to be important. For example, Toro, a long grain, produced bread with soft texture, whereas Early Prolific, a medium grain, and T(N)1, a short/medium grain, produced breads with sandy texture.

Protein content has been shown to greatly influence cooking and eating quality of milled rice (Juliano et al 1965, Oñate et al 1964). Higher protein rices required longer cooking time, showed slower water absorption, and produced less tender, less cohesive cooked rice. Protein content of rices shown in Table III, column c, did not appear to be directly related to bread characteristics.

The data indicated that a combination of low amylose content *and* low gelatinization temperature was necessary for soft bread texture. If either factor were high (as demonstrated by all the rices other than the first four), the bread texture was sandy. In addition, a low final amylograph viscosity at 50°C (Toro is the exception) and a soft-to-intermediate eating quality of the cooked rice were also necessary for a soft-textured bread. Cagampang et al (1973) reported that, with a 9% milled rice paste, high final viscosity on cooling to 50°C and high setback values were good indicators of the "flakiness" of the cooked rice. Rice with these properties most likely would not be suitable for bread flour. This was confirmed by results shown in Table III for LA 110, IR-8, and T(N)1. All had high values for viscosity on cooling to 50°C and high setback values. Cooked rice was hard and bread texture was slightly sandy to harsh.

Cagampang et al (1973) found close correlations among high setback values (more than +400 BU), hard gel consistency (27-35 mm), and very flaky cooked rice. Our gel consistency data for high amylose varieties did not relate as well to corresponding setback values. We found that determination of gel consistency by the IRRI method (column j) or gel strength by the embedded-disk method

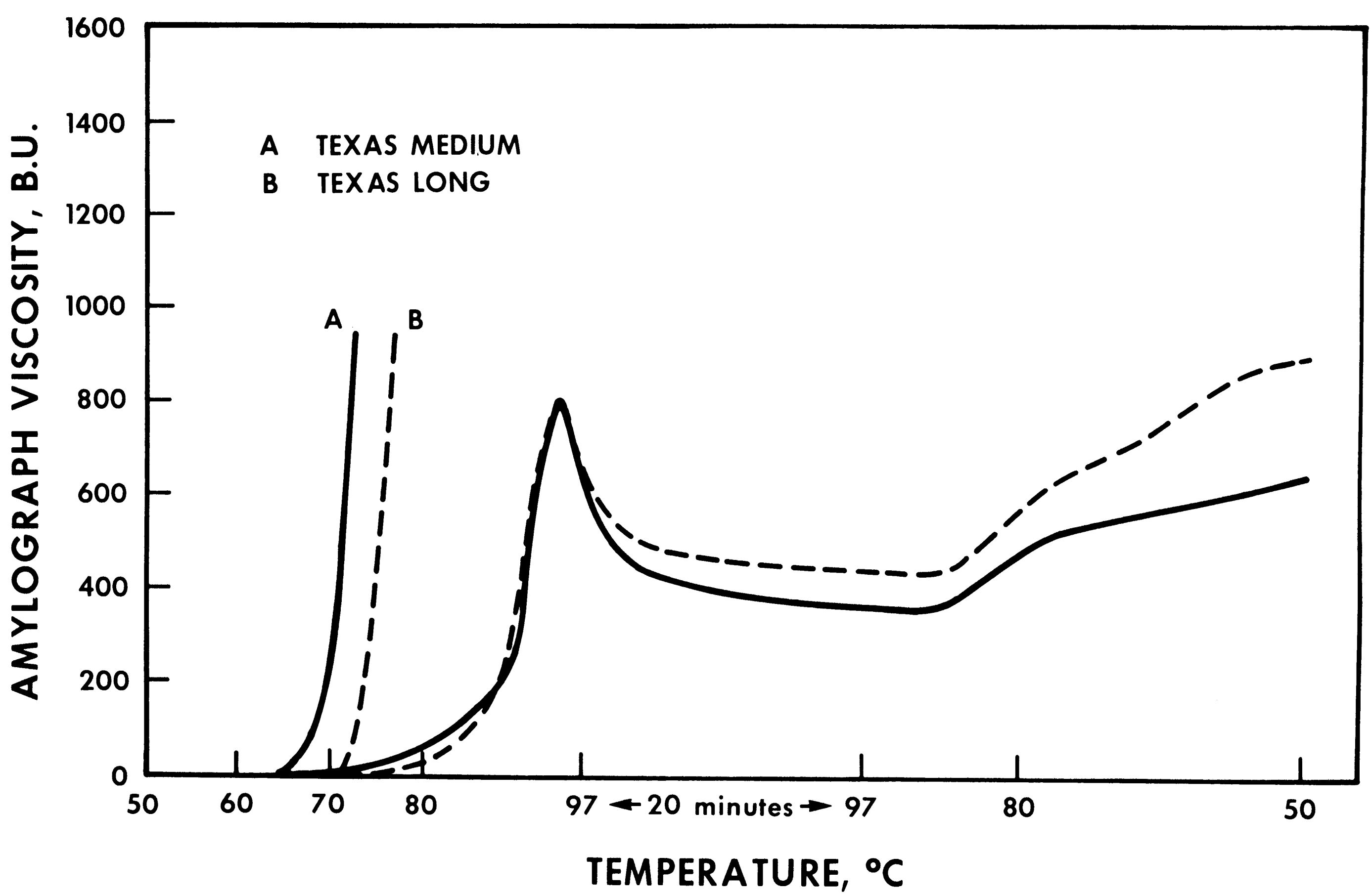

Fig. 3. Amylograph curves for two Texas rices with different baking properties. Short curves, 20% slurries; full curves, 10% slurries.

(column i) was more useful for eliminating rices unsuitable for bread making. Indication of little or no gel by these methods was necessary for soft bread characteristics (eg, low/low rice varieties). However, presence of soft or no gel structure (eg, low/high rice varieties) did not always predict soft bread crumbs, but presence of a firm gel (52 mm or lower by the IRRI method, or over 300 g-cm by the embedded-disk method, shown by the high/low rice varieties) indicated sandy bread texture.

Rices with higher amylose content or higher gelatinization temperature require more water during cooking to achieve the same degree of "doneness" as those with lower values for these properties (Juliano 1971). IRRI reported improving volume and texture of a yeast-leavened rice bread made with IR-22 milled-rice flour (28–30% amylose)(Cagampang et al 1973) by increasing the water level from 75 to 140% of the rice flour (IRRI 1976). In our experiments, when absorption water was increased from 75 to 100 and 140% in rice bread made with Starbonnet, a long-grain rice with 22.4% amylose, 72.5°C gelatinization temperature, and 6.7% protein (14% moisture basis), no improvement in texture was obtained and loaf volume decreased. At 140% absorption sidewalls were weakened, top crust collapsed, and crumbs were pasty but sandy. Tests with two other flours, Century Patna 231 (low/high) and IR-8 (high/low), at 140% absorption levels produced loaves with similarly poor external appearance as the loaf with Starbonnet. But the bread with Century Patna 231 was pasty but not as sandy as IR-8 or Starbonnet breads. The differences in baking behavior among these samples may reflect inherent differences due to the combined effect of amylose content and the molecular properties of amylose and amylopectin described by Cagampang et al (1973).

If low amylose content and low gelatinization temperature are crucial for bread softness, the question arises: Would the incorporation of some waxy rice flour, which is low in both properties, improve texture of the rice bread? Waxy rice flour has virtually no amylose and cooks into a pasty rice. Limited tests with short-medium rice showed that more than half of the flour had to be of the nonwaxy type. A 100% waxy rice flour bread was a flat, gummy loaf that did not rise. A 50% waxy rice flour bread was not satisfactory. The loaf with 25% waxy rice flour had good volume, but the texture was slightly gummy when short/medium rice flour represented the remaining 75% flour. In tests containing blends of long-grain rice flour and waxy rice flour, the sandy texture could not be diluted out before volume decreased and texture became quite gummy. At 25% replacement of waxy rice for long-grain rice flour, the texture of the bread was slightly sandy and somewhat gummy.

In areas of the world where wheat is imported and rice is plentiful, up to 30% rice (Interpan 1972, Mosqueda-Suárez 1958) has been used successfully in composite flour breads. In this laboratory when 30% rice flour was used in blends with wheat flour, the harsh, sandy texture contributed by the poorer bread quality rices could be detected by experienced judges. When rices that performed well in the 100% rice flour breads were used, the presence of the rice in wheat bread was not detected through textural differences. Thus, the same rice characteristics, important to 100% rice bread, was important when rice was blended with wheat flour. Loss in loaf volume resulting from 10% replacement of the wheat flour by rice flour can be compensated for by increasing proof time or by using certain surfactants or α-amylase (Tanaka 1972).

SUMMARY

Quality of breads made from rice flours was affected by several physicochemical properties of the rices, many paralleling factors that alter eating quality of milled rice. Low amylose content, low gelatinization temperature, low amylograph viscosity of paste cooled to 50°C, and soft eating quality of the cooked milled rice are useful characteristics for predicting good bread-making properties. Normally selecting short/medium-grain over long-grain rices would favor good baking quality, but occasionally a short/medium-grain rice with poor baking characteristics, or a long-grain rice with desirable baking characteristics may be available.

Besides the application shown here for 100% rice bread, the same quality characteristics appear to influence crumb properties of wheat bread incorporating 30% rice flour.

ACKNOWLEDGMENTS

The authors wish to acknowledge appreciation for the rice samples provided by B. D. Webb and B. O. Juliano and the technical assistance of Viola M. Ashby and A. P. Mossman.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved methods of the AACC. Method 46-11, approved April 1961. The Association: St. Paul, MN.

BEACHELL, H. M., and STANSEL, J. W. 1963. Selecting rice for specific cooking characteristics in a breeding program. Intern. Rice Comm. Newsletter (spec. issue):25.

CAGAMPANG, G. B., PEREZ, C. M., and JULIANO, B. O. 1973. A gel consistency test for eating quality of rice. J. Sci. Food Agric. 24:1589.

DENDY, D. A. V., CLARKE, P. A., and JAMES, A. W. 1973. The use of blends of wheat and non-wheat flours in breadmaking, p.134. In: Composite Flour Programme. Food and Agriculture Organization of the United Nations: Rome, Italy.

HALICK, J. V., BEACHELL, H. M., STANSEL, J. W., and KRAMER, H. H. 1960. A note on the determination of gelatinization temperatures of rice varieties. Cereal Chem. 37:670.

HALICK, J. V., and KELLY, V. J. 1959. Gelatinization and pasting characteristics of rice varieties as related to cooking behavior. Cereal Chem. 36:91.

INTERNATIONAL RICE RESEARCH INSTITUTE. 1976. IRRI annual report for 1975. IRRI: Los Baños, Laguna, Philippines.

INTERPAN. 1972. Joint report on the Colombian-Netherlands composite flours project carried out in Bogotá 1971-1972. Instituto de Investigaciones Technológicas, Avenida 30, No. 52A-77, Apartado Aéreo 7031, Bogotá.

JULIANO, B. O. 1971. A simplified assay for milled-rice amylose. Cereal Sci. Today 16:334.

JULIANO, B. O., CAGAMPANG, G. B., CRUZ, L. J., and SANTIAGO, R. G. 1964. Some physiochemical properties of rice in Southeast Asia. Cereal Chem. 41:275.

JULIANO, B. O., OÑATE, L. U., and del MUNDO, A. M. 1965. Relation of starch composition, protein content, and gelatinization temperature to cooking and eating qualities of milled rice. Food Technol. 19:1006.

KURASAWA, F., KANAUTI, Y., YAMAMOTO, I., HAYAKAWA, T., and IGAUE, I. 1969. Some physico-chemical properties of non-waxy paddy rice starch in Niigata Prefecture. Part I. Relation of properties of starch to eating and cooking qualities of milled rice. Agric. Biol. Chem. 33(6):798.

MASURS, E. G., SCHOCH, T. J., and KITE, F. E. 1957. Graphical analysis of the Brabender viscosity curves of various starches. Cereal Chem. 34:141.

MOSQUEDA-SUÁREZ, A. 1958. A new type of bread. Wheat-and-rice bread. Food Technol. 12:15.

NISHITA, K. D., ROBERTS, R. L., BEAN, M. M., and KENNEDY, B. M. 1976. Development of a yeast-leavened rice-bread formula. Cereal Chem. 53:626.

OÑATE, L. U., del MUNDO, A. M., and JULIANO, B. O. 1964. Relationship between protein content and eating quality of milled rice. Philipp. Agric. 47(9 and 10):441.

PERDON, A. A., and JULIANO, B. O. 1975. Amylose content of rice and quality of fermented cake. Staerke 27(6):196.

SMITH, R. J. 1967. Characterization and analysis of starches. Vol. 2, p. 608. In: WHISTLER, R. L., and PASCHALL, E. F. (eds.). Starch: Chemistry and Technology. Industrial Aspects. Academic Press: New York.

TANAKA, Y. 1972. Quality improvement of rice bread. Jpn Agric. Res. Q. 6(3):181.

WEBB, B. D., and STERMER, R. A. 1972. Criteria of rice quality, Chap. 4, p. 118. In: HOUSTON, D.F. (ed.). Rice: Chemistry and Technology. The Association: St. Paul, MN.

[Received May 8, 1978. Accepted September 12, 1978]