Comparison of Starch Pasting Properties in the Brabender Viscoamylograph and the Rapid Visco-Analyzer[1]

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ABSTRACT

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Cooking properties of flours and starches measured in the Brabender Viscoamylograph and the Rapid Visco-Analyzer (RVA) were compared to determine if operational differences in the instruments affect starch performance when the time-temperature sequence is constant. Samples suspended in buffer were analyzed in both instruments by heating from 30 to 95°C, holding 30 min at 95°C, cooling from 95 to 50°C, and holding 30 min at 50°C. An RVA 20-min test was developed to determine if the RVA could detect the effect of cooking conditions on starch performance. In this test, samples suspended in distilled water were equilibrated to 50°C for 2 min, heated for 10 min to a maximum temperature of 95°C, and cooled for 8 min to a minimum temperature of 50°C. When the same time-temperature profile was used in both instruments, curves for starches were similar, although correlation coefficients for pasting parameters ($r \geq 0.897$) suggested that the instruments are not interchangeable. Results from the two instruments were less similar for flours. When different time-temperature profiles were used in the RVA, differences in cooking properties were detected. The RVA is an alternative instrument for measuring starch cooking properties that allows simulation of actual production processes.

Background on the Viscoamylograph

Pasting characteristics of starch and starch-containing products were first recognized by Caesar (1932) and Caesar and Moore (1935) using a consistometer. Since then, the Corn Industries' viscometer (Kesler and Bechtel 1947), the Ottawa starch viscometer (Voisey et al 1972, Voisey and Paton 1977, Voisey et al 1977), the Haake Rotovisko (Čeh and Stropnik 1976, Dengate and Meredith 1984), and many other instruments (reviewed by Smith 1967 and Dengate 1984) have also been used to study starch pasting properties.

The first Brabender amylograph became available in the 1930s. The viscoamylograph, as it is now called, has become the standard piece of equipment used by the industry for characterization of starches and starch-containing products. The amylograph was originally used for evaluation of rye flour quality and control of α-amylase activity in malt-supplemented wheat flour. Anker and Geddes (1944) demonstrated the utility of the amylograph in flour and starch technology.

A standard amylograph method is now employed for measurement of diastatic activity in wheat flour (AACC 1983). However, the literature is replete with methods for determining starch viscosity profiles using the amylograph (Anker and Geddes 1944, Dengate and Meredith 1984, Johnson 1954, Kempf and Kalender 1972, Kite et al 1957, Mazurs et al 1957). In general, a starch suspension is heated at a rate of 1.5°C/min to 95°C, held at 95°C for a period ranging from 10 to 60 min, then cooled at a rate of −1.5°C/min to 50°C and, optionally, held at 50°C for an additional time. A method employing addition of carboxymethylcellulose to the starch slurry was used to increase the sensitivity of the amylograph to early stages of granule swelling (Crossland and Favor 1948). Rapid amylograph tests for wheat and rye flours were developed using special attachments and procedures (Anonymous 1978). Sharp (1986) described a rapid

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amylograph procedure and mathematical conversions of the data for quickly estimating the quality of rice flour. Other procedures commonly used today are outlined by Shuey and Tipples (1980).

Anker and Geddes (1944) originally recommended the measurement of the temperature of first perceptible increase in viscosity, maximum viscosity, and the temperature at maximum viscosity from amylograph curves. Mazurs et al (1957) described five significant points of interest from a Brabender curve: peak viscosity, viscosity at 95°C, viscosity after holding at 95°C, viscosity at 50°C, and viscosity after holding at 50°C. Starches from different species were distinguished by measuring peak viscosity (P), hot paste viscosity (H), and cold paste viscosity (C) and calculating breakdown (H/P), setback (C/P), total setback (C/H), and relative breakdown $[(P - H)/(C - H)]$ (Leelavathi et al 1987).

Pasting characteristics were shown by Sandstedt and Abbott (1961) to be pronouncedly affected by starch concentration. Mazurs et al (1957) developed a graphical presentation of amylograph data to compare characteristics independent of starch concentration. This technique was further refined by Bhattacharya and Sowbhagya (1978) and used to estimate quality characteristics of rice flour from amylograph profiles (Bhattacharya and Sowbhagya 1979).

Modifications to the amylograph have been described that increase the versatility of the instrument. Sandstedt and Abbott (1961) designed a 70-ml bowl adaption for the amylograph that made the instrument more useful for testing small experimental samples. Voisey and Nunes (1968) developed an electronic recording amylograph with increased precision and a wider range of sensitivity than the standard model. The Viscograph E, the latest model available from the C. W. Brabender Co. (South Hackensack, NJ), has electronic controls that replace the mechanical controls on the original models. Also available from Brabender are an automatic programmer attachment, an electronic temperature control unit, a platinum resistance temperature detector, a pressure chamber for high-pressure cooking of high-amylose starches, and a special amylograph bowl with paddle sensors that expand the uses of the amylograph.

Background on the Rapid Visco-Analyzer

The Australian CSIRO Wheat Research Unit and Bread Research Institute jointly developed the Rapid Visco-Analyzer (RVA) to quickly estimate sprout damage in wheat (Ross et al 1987). Abnormally high levels of α-amylase present in sprouted wheat alter the baking and cooking properties of flour made from the grain. Performance of products made with this flour is poor, especially for oriental noodles, which is the end use of approximately one-third of the wheat exported from Australia. The RVA proved useful in screening individual loads of wheat for sprout damage during the 1986–1987 Australian wheat harvest (Ross et al 1987). The RVA was well suited for this application because it required only a small sample (4 g), was rugged and simple to operate, and gave results in 3 min.

Use of a modified RVA to study starch pasting characteristics was first reported by Walker et al (1988). Student laboratory experiments demonstrating starch cooking properties with the RVA have been developed (Deffenbaugh and Walker 1989). Advantages of the RVA for these applications were small sample size requirement, complete analysis in 20 min or less, durability and ease of operating the machine, versatility of test procedures, and direct demonstration of starch applications in foods. Pasting characteristics of an all-purpose flour measured by the RVA were found to be similar to those measured by the Brabender Visco-amylograph (Walker et al 1988).

This paper further compares starch cooking parameters measured with the Brabender Viscoamylograph and the RVA using the same time-temperature sequence. The effect of operational differences in the two instruments is discussed. In addition, a rapid 20-min test was developed for the RVA. A comparison of the two RVA tests illustrated that the RVA was sensitive to the effects of the time-temperature sequence and reaction conditions on starch performance. Comparisons between methods were made for several wheat flours, native starches from different sources, native and mutant maize starches, and native and modified tapioca starches.

MATERIALS AND METHODS

Flour and Starches

Commercial samples of all-purpose flour (9.4% moisture, 10.1% protein, 0.53% ash) and bread flour (10.4% moisture, 12.3% protein, 1.4% ash) were from Pillsbury Co., Inc., Minneapolis, MN. Softasilk cake flour (11.6% moisture, 7.6% protein, 0.37% ash) was from General Mills, Inc., Minneapolis, MN. Commercial starch samples used were: wheat starch from Henkel Corp., LaGrange, IL; pure food powder starch (maize), unmodified tapioca starch no. 1, unmodified potato starch, Freezist M starch (hydroxypropyl substituted and slightly cross-linked tapioca), and Fruitfil 1 starch (cross-linked tapioca) from A. E. Staley Manufacturing Co., Decatur, IL; and Amioca (waxy maize) and Hylon (high-amylose) starches from National Starch and Chemical Corp., Bridgewater, NJ.

Chemicals

Reagent grade sodium phosphate dibasic (Fisher Scientific Co., Pittsburg, PA) and citric acid monohydrate (Sigma Chemical Co., St. Louis, MO) were used.

Proximate Analyses

Moisture of flours was analyzed according to AACC method 44-40, protein (N × 5.7) was determined according to method 46-12, and ash was determined according to method 08-01 (AACC 1983).

Brabender Viscoamylograph Profiles

Concentrated amylograph buffer was prepared by dissolving 14.8 g of sodium phosphate dibasic and 10.3 g of citric acid monohydrate in 1 L of deionized water. Diluted buffer was made by blending a 46.0-ml aliquot of the concentrated buffer with deionized water to 460 ml total volume.

For viscoamylograph tests, starches and flours were scaled on a 14% moisture basis. Samples of 100 g of all-purpose flour or bread flour; 55 g cake flour; 45.5 g of wheat, maize, tapioca, or Hylon (high-amylose maize) starch; 32.0 g of Freezist M (modified tapioca), Fruitfil 1 (modified tapioca) or Amioca (waxy maize) starch; or 30.0 g of potato starch were suspended in 460 ml of diluted amylograph buffer and transferred to the amylograph bowl. If comparisons were to be made between samples, concentrations yielding a constant peak viscosity would be required (Battacharya and Sowbhagya 1978). Because that was not the purpose of this study, sample concentrations were chosen to yield midscale viscosity profiles on the viscoamylograph that were convenient for presentation. Gelatinization, pasting, and setback were determined in triplicate by heating from 30 to 95°C at 1.5°C/min, holding at 95°C for 30 min, cooling from 95 to 50°C at −1.5°C/min and holding at 50°C for 30 min.

RVA Profiles

Design and operation of the RVA as used to test for sprout damage in wheat were described by Ross et al (1987). Modifications were made to one RVA as described by Walker et al (1988) to make it suitable for measuring starch pasting properties.

Amylograph profile. Gelatinization, pasting, and setback properties of the flours and starches were measured in the RVA using reaction conditions and a time-temperature profile equivalent to that used in the viscoamylograph. Sample quantities used were: 5.000 g for all-purpose or bread flour; 2.990 g for cake flour; 2.520 g for wheat, maize, tapioca, or Hylon starch; 1.820 g for Freezist M, Fruitfil 1, or Amioca starch; and 1.714 g for potato starch. Samples and diluted amylograph buffer having a total weight of 28 g and starch/water ratios the same as those used in the viscoamylograph were added to a sample cup. A disposable plastic stirring paddle was placed in the cup and rotated

by hand for 15–30 sec to wet the sample. The sample, cup, and paddle were inserted into the RVA such that the paddle was held firmly in the drive motor clutch. When the test cycle was activated, the split copper block automatically clamped around the can. The paddle automatically started spinning at 900 rpm for 7 sec to disperse the sample and then slowed to 160 rpm. The sample temperature was allowed to equilibrate to 30°C for 2–3 min before the test was started. The temperature was raised manually from 30 to 95°C at 1°C/40 sec, held at 95°C for 30 min, lowered manually from 95 to 50°C at −1°C/40 sec and held at 50°C for 30 min. These heating and cooling rates were equivalent to ±1.5°C/min. The viscosity profile was recorded on a strip chart recorder operating at a speed of 30 cm/hr and 1 V full-scale response. Relative viscosity is reported as 0–100% full scale. All sample analyses were performed in triplicate.

Rapid 20-min RVA test. Samples were prepared by combining the flours or starches with deionized water at the same starch ratios used in the viscoamylograph and RVA amylograph profile tests. Water rather than buffer was chosen as the solvent to make this test as simple as possible. Total sample size was held constant at 28 g. Sample temperature was equilibrated at 50°C for 2 min, then put on the heating cycle for 10 min with a maximum temperature of 95°C and then put on the cooling cycle for 8 min with a minimum temperature of 50°C. The heating and cooling rates were the maximum rates possible with the machine. The actual sample temperature profile was measured by inserting a thermocouple probe into the sample can above the paddle. The probe was inserted through a hole drilled in the copper block into the sample can, which had a hole punched in the side. The hole in the can was covered with a piece of masking tape to prevent leaking. The viscosity profile was recorded on a strip chart recorder operating at a speed of 2 cm/min and 1 V full-scale response. For some samples, viscosity was greater than 100%. In these cases, full-scale response was changed to 2 V and a maximum viscosity up to 200% was registered. Designation of relative viscosity units as a percentage is arbitrary and values above 100% do not reflect out-of-scale readings. However, to avoid overloading the stirring motor, viscosity measurements beyond 200% should not be made. In those cases, sample concentration must be reduced. All sample analyses were performed in triplicate.

Profile Analysis

Peak viscosity, time to peak, viscosity at 95°C, viscosity after 30 min at 95°C, viscosity at 50°C, viscosity after 30 min at 50°C, and maximum setback viscosity were measured from viscoamylograph profiles and RVA amylograph profiles. Peak viscosity, time to peak, and maximum setback viscosity were measured for the RVA rapid 20-min test profiles. Pearson correlation coefficients were determined for average values of comparable parameters between tests. General curve shape is shown with representative profiles.

RESULTS AND DISCUSSION

Comparison of Viscoamylograph and RVA Amylograph Profile Results

Gelatinization, pasting, and setback profiles of the flours, native starches, native and modified tapioca starches, and native and mutant maize starches measured in the viscoamylograph are shown in Figures 1A–4A, respectively. Comparable curves from the RVA amylograph profile tests are shown in Figures 1B–4B, respectively. While the temperature profiles used in these two tests were the same, it must be noted that other test conditions were not identical. Heating rates may have varied due to differences in heat transfer rates to the sample from the heated air bath in the viscoamylograph or the heating block in the RVA. Cooling rates may have varied between the two methods due to variability in tap water temperature and flow rate. Both heating and cooling rates would also be affected by heat transfer rates throughout the sample. The temperature probably changed at a slower rate in the larger sample (490–560 g total) in the viscoamylograph compared to the 28-g sample in the RVA.

The stirring mechanisms in the viscoamylograph and the RVA are also different. The viscoamylograph has stationary pins in the bowl around which a set of moving pins rotates at 75 rpm. In comparison, a sample in the RVA is stirred at 160 rpm by a paddle. While the shear modulus is too complicated to calculate in either machine, it appears intuitively that the RVA exerts much more shear on the sample than the viscoamylograph. Pasting occurs, in part, due to the shearing of swollen, gelatinized starch granules (Atwell et al 1988); pasting properties are likely to vary when shear rates vary.

Differences in starch pasting properties between the Brabender Viscoamylograph and the Ottawa starch viscometer were reported by Doublier (1987). He ascribed the differences to different pasting conditions that lead to quite different swelling and solubilization. The same is likely true for the viscoamylograph and the RVA.

Despite differences in some operating conditions, the general shapes of comparable curves from the two tests were similar. Specific details were also common to results from the two tests. For example, note the reproduction of the small peaks in the flour profiles (Fig. 1A and B) shortly after the onset of setback between 80 and 90 min. Also, peak shapes were very similar for starches analyzed by the two techniques (Figs. 2A and 4A vs. 2B and 4B). In the case of the flours, however, the peaks were sharper and more well defined in the RVA amylograph profiles (Fig. 1B) than in the viscoamylograph profiles (Fig. 1A). Perhaps viscosity breakdown was more rapid in the RVA because of the

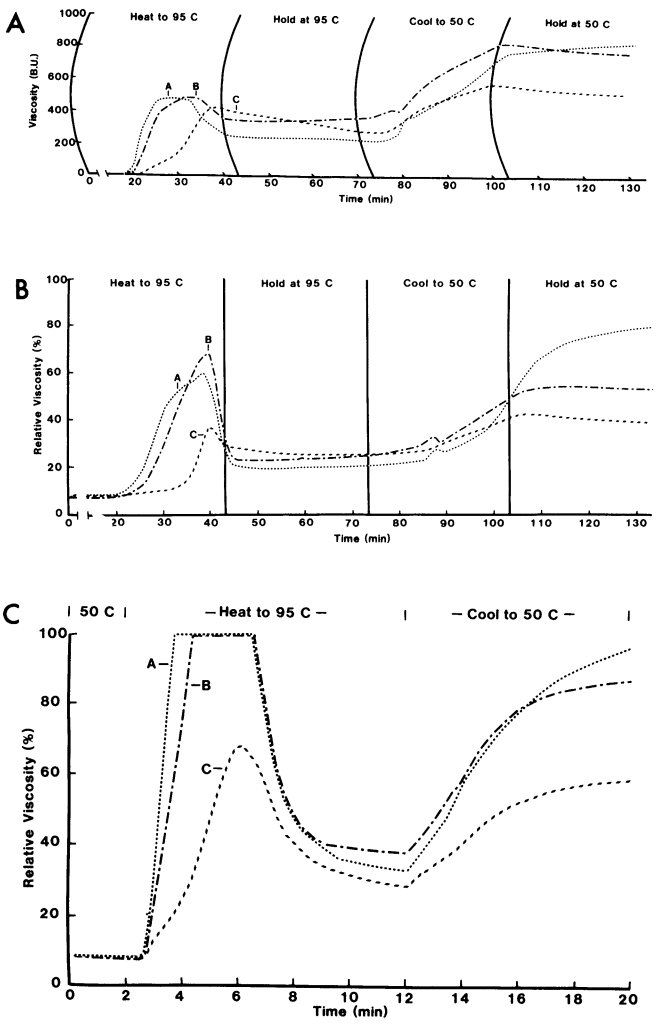

Fig. 1. Gelatinization, pasting, and setback of commercial all-purpose flour measured in **A,** the Brabender Viscoamylograph; **B,** the Rapid Visco-Analyzer amylograph profile test; and **C,** by the Rapid Visco-Analyzer 20-min test. Within each graph, lines designated A, B, and C represent all-purpose flour, bread flour, and cake flour, respectively.

higher shear rate compared with the viscoamylograph. A sharper peak would result.

Parameters of starch cooking characteristics from the viscoamylograph and RVA amylograph profile tests are reported in Tables I and II. Pearson correlation coefficients for average values of peak viscosity, time to peak, viscosity at 95°C, viscosity after 30 min at 95°C, viscosity at 50°C, viscosity after 30 min at 50°C, and maximum setback viscosity between the two tests are given in Table III. All parameters determined by the two methods were positively correlated. Correlation (r = 0.341) between peak viscosities for the flours and starches was relatively low (Table III). This may be due to differences in the susceptibility of different types of starch granules to the different operating conditions, especially shear rates, between the two methods. Correlation coefficients for the other parameters were higher ($r \geq 0.834$), suggesting that these parameters were not affected by differences in the tests to the same degree as peak viscosity.

As suggested above, some starches appeared to be more sensitive than others to differences between the two tests. Consider, for example, setback viscosities of the native and mutant maize starches shown in Figure 4A (viscoamylograph) and Figure 4B (RVA). Maximum setback viscosity was low relative to peak height in the RVA compared with the viscoamylograph; the effect appeared greater as amylose content increased (i.e., Hylon high-amylose > normal maize > Amioca waxy maize). Soluble amylose is largely responsible for retrogradation during setback (Leelavathi et al 1987). Perhaps the amylose fraction in maize starches is especially sensitive to extended exposure to the higher shear in the RVA. This would explain why setback of normal maize starch was reduced and setback of Hylon high-amylose starch was essentially eliminated in the RVA compared with the viscoamylograph (Fig. 4A and B). Amioca waxy maize starch, which is devoid of amylose and the other flours and starches, did not show this tendency (Figs. 1A and B, 3A and B).

Correlation coefficients for all parameters were higher when only values from the starches were analyzed (Table III). Scatter plots (not shown) of viscoamylograph and RVA values of each parameter indicated that RVA values for flours tended to be higher than RVA values for starches when compared with corresponding viscoamylograph values. The anomalous behavior for the flours suggests that other components (i.e., protein, endogenous enzymes, etc.) and treatments such as chlorination of cake flour have a significant effect on the performance characteristics of the starch.

Discriminatory power was similar for the two instruments. Whereas the range of viscosity units in the viscoamylograph is larger than the RVA, the standard deviation is also larger in the viscoamylograph. Coefficients of variance for measuring viscosity averaged over all viscosity parameters and all samples were 4.2 and 4.16% for the viscoamylograph and RVA, respectively. Coefficients of variance for measuring time to peak averaged over all samples were 0.88 and 1.20% for the viscoamylograph and RVA, respectively.

Analysis of RVA Rapid 20-min Test Results

The actual heating and cooling rates of the sample during the

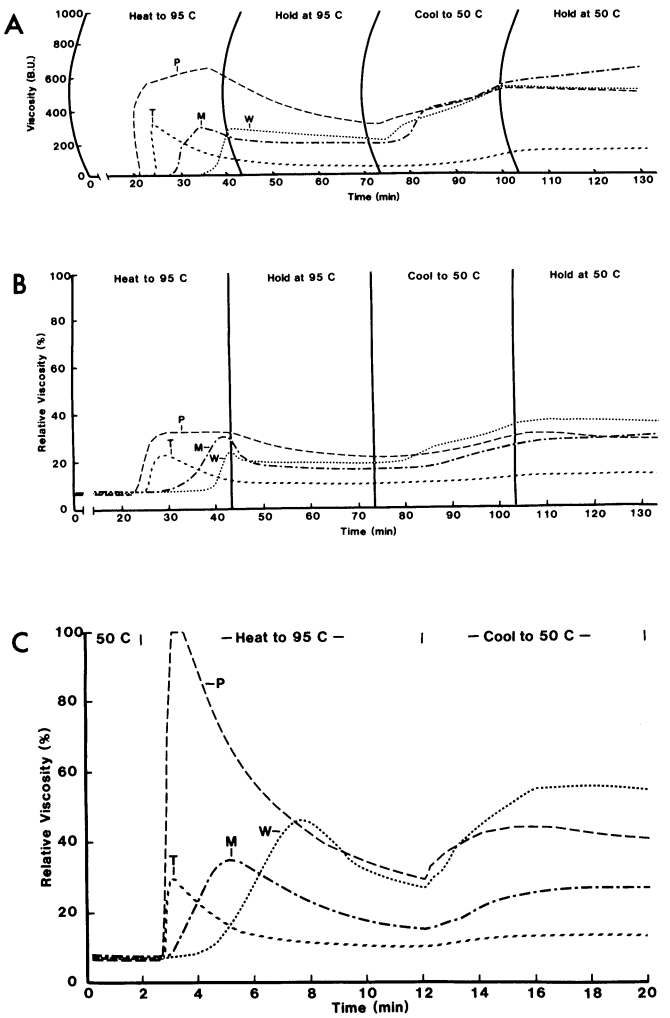

Fig. 2. Gelatinization, pasting, and setback of native maize starch (M), potato starch (P), tapioca starch (T), and wheat starch (W) measured in **A,** the Brabender Viscoamylograph; **B,** the Rapid Visco-Analyzer amylograph profile test; and **C,** the Rapid Visco-Analyzer 20-min test.

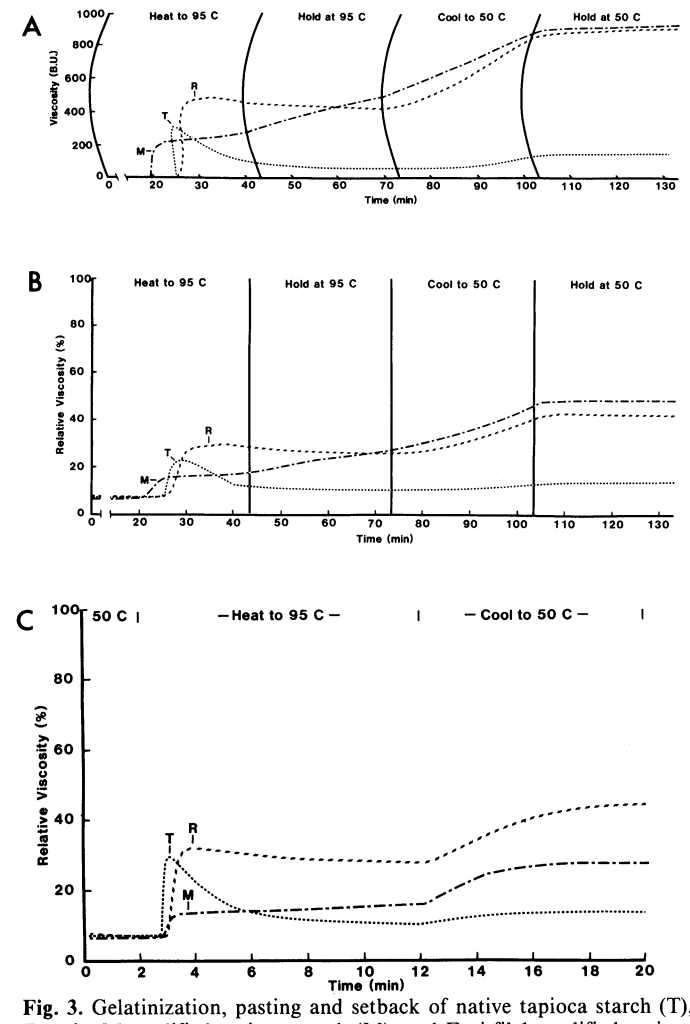

Fig. 3. Gelatinization, pasting and setback of native tapioca starch (T), Freezist M modified tapicoa starch (M), and Fruitfil 1 modified tapioca starch (R) measured in **A,** the Brabender Viscoamylograph; **B,** the Rapid Visco-Analyzer amylograph profile test; and **C,** the Rapid Visco-Analyzer 20-min test.

20-min test are shown in Figure 5. Sample temperature equilibrated to 50°C during the initial 2-min period. Sample temperature increased asymptotically toward 95°C during the heating phase and reached a plateau at approximately 10 min. The cooling rate approached 50°C asymptotically.

Gelatinization, pasting, and setback profiles of the flours, native starches, native and modified tapioca starches, and native and mutant maize starches measured by the RVA rapid 20-min test are shown in Figures 1C–4C, respectively. The RVA 20-min test was sensitive to differences in the samples studied but required only 20 min per sample to demonstrate gelatinization, pasting, and setback.

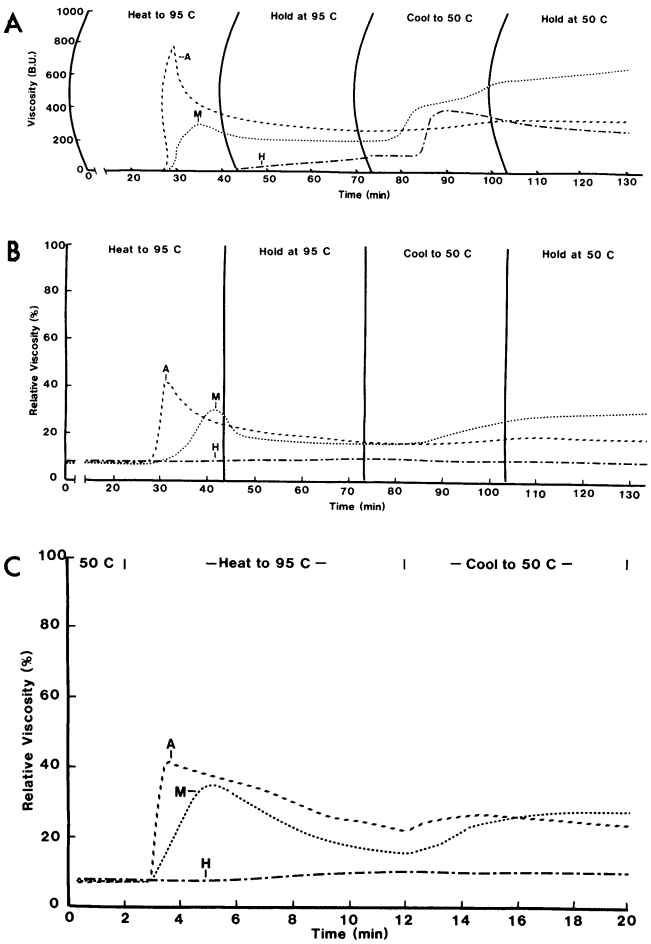

Fig. 4. Gelatinization, pasting, and setback of normal maize starch (M), Amioca waxy maize starch (A), and Hylon high-amylose maize starch (H) measured in **A,** the Brabender Viscoamylograph; **B,** the Rapid Visco-Analyzer amylograph profile test; and **C,** the Rapid Visco-Analyzer 20-min test.

For many of the samples studied, general similarities existed in curve shapes for the RVA 20-min profiles and the visco-amylograph and RVA amylograph profiles; compare curves for wheat flours (Fig. 1A–C), tapioca, wheat, and maize starches (Fig. 2A–C), native and modified tapioca starches (Fig. 3A–C), and normal and mutant maize starches (Fig. 4A–C).

The viscoamylograph is traditionally used to estimate performance characteristics of flours and starches. However, the long, slow heating protocol may not simulate actual production processes, and the ability of the viscoamylograph to predict flour or starch performance in practice is somewhat limited for this reason. The RVA rapid 20-min test provided an alternative method by which to study cooking properties of flours and starches. Some samples demonstrated widely different characteristics under different time-temperature conditions. Consider, for example, native potato starch shown in Figure 2A–C. From the viscoamylogram or RVA amylograph profile, a product developer might choose potato starch for an application requiring moderate viscosity that is sustained during a 30-min cook to suspend particulates. If the actual cooking process is faster than the heating profile represented in the viscoamylogram (such as in the RVA 20-min test), the potato starch will not perform as expected. Instead, the potato starch will quickly develop an extremely high viscosity (so high that blenders, mixers, or pumps could be damaged) as shown in Figure 2C. Furthermore, the potato starch will not maintain the viscosity level needed to suspend particulates throughout the remainder of the cooking time. The RVA could have been used by the product developer to more accurately estimate starch cooking properties under operating conditions similar to actual practice.

Peak viscosity, time to peak, and maximum setback viscosity were determined from viscoamylograph and RVA rapid 20-min test profiles (Table IV). Pearson correlation coefficients for average values of these parameters between the two tests are given in Table V. The ability of the RVA rapid 20-min test to closely predict peak viscosity, time to peak, and maximum setback

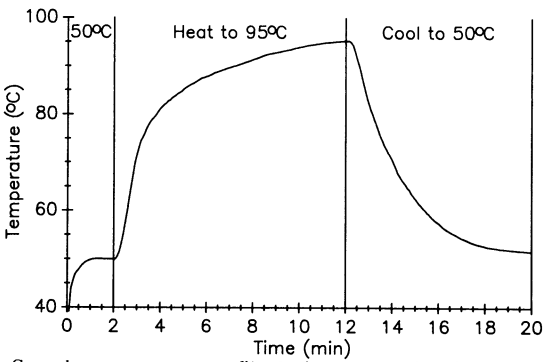

Fig. 5. Sample temperature profile during the Rapid Visco-Analyzer 20-min test.

TABLE I
Parameters of Flour and Starch Cooking Properties Measured in the Viscoamylograph

Sample	Peak Viscosity (BU)[a]	Peak Time (min)	Viscosity at 95°C (BU)	Viscosity After 30 min at 95°C (BU)	Viscosity at 50°C (BU)	Viscosity After 30 min at 50°C (BU)	Maximum Setback Viscosity (BU)
All-purpose flour	483 ± 7	30.7 ± 0.3	254 ± 6	232 ± 19	737 ± 56	846 ± 58	846 ± 58
Bread flour	488 ± 11	35.9 ± 0.3	365 ± 11	358 ± 11	804 ± 37	755 ± 41	813 ± 39
Cake flour	426 ± 4	42.1 ± 0.3	416 ± 4	293 ± 15	604 ± 39	578 ± 100	607 ± 41
Amioca starch	771 ± 7	31.6 ± 0.8	359 ± 3	260 ± 6	330 ± 2	323 ± 5	335 ± 1
Freezist M starch	no peak	21.0 ± 0.1[b]	292 ± 10	493 ± 16	887 ± 27	933 ± 30	933 ± 30
Fruitfil I starch	482 ± 6	36.5 ± 0.1	450 ± 7	419 ± 8	841 ± 25	910 ± 23	910 ± 23
Hylon starch	no peak	no peak	10 ± 0	86 ± 4	355 ± 23	265 ± 10	404 ± 40
Maize starch	315 ± 26	38.5 ± 0.4	261 ± 32	215 ± 28	552 ± 58	640 ± 63	640 ± 63
Potato starch	644 ± 2	39.4 ± 0.6	600 ± 4	314 ± 3	512 ± 8	491 ± 10	523 ± 9
Tapioca starch	324 ± 7	27.9 ± 0.1	97 ± 2	53 ± 1	139 ± 4	154 ± 5	154 ± 5
Wheat starch	298 ± 7	44.6 ± 0	280 ± 9	230 ± 21	543 ± 40	530 ± 35	551 ± 41

[a]BU = Brabender unit.
[b]Time of inflection.

TABLE II
Parameters of Flour and Starch Cooking Properties Measured by the Rapid Visco-Analyzer Amylograph Profile Test

Sample	Peak Viscosity (%)	Peak Time (min)	Viscosity at 95°C (%)	Viscosity After 30 min at 95°C (%)	Viscosity at 50°C (%)	Viscosity After 30 min at 50°C (%)	Maximum Setback Viscosity (%)
All-purpose flour	58.1 ± 1.8	38.4 ± 0.1	24.9 ± 1.7	19.4 ± 1.0	46.4 ± 5.5	74.2 ± 5.1	74.2 ± 5.1
Bread flour	67.9 ± 1.9	38.8 ± 0.7	29.3 ± 0.7	25.6 ± 0.6	47.6 ± 2.0	49.8 ± 2.3	51.8 ± 2.4
Cake flour	36.5 ± 0.5	40.1 ± 0.3	29.3 ± 0.9	25.5 ± 0.1	43.5 ± 4.9	38.5 ± 0.8	42.2 ± 0.5
Amioca starch	41.5 ± 0.3	31.2 ± 0.3	24.0 ± 0.6	17.2 ± 0.9	19.4 ± 0.7	19.1 ± 0.3	20.1 ± 0.7
Freezist M starch	no peak	22.8 ± 0.2[a]	19.0 ± 1.5	29.8 ± 2.6	46.0 ± 0.6	48.4 ± 0.4	49.2 ± 0.5
Fruitfil I starch	29.3 ± 0.4	38.0 ± 0.2	28.4 ± 0.3	26.1 ± 0.5	41.1 ± 0.3	42.8 ± 0.7	43.6 ± 0.3
Hylon starch	no peak	no peak	8.3 ± 0.3	9.6 ± 0.2	9.3 ± 0.3	9.1 ± 0.3	9.7 ± 0.2
Maize starch	30.6 ± 1.3	41.4 ± 0.4	28.2 ± 2.0	16.9 ± 1.5	28.0 ± 2.6	32.0 ± 3.1	32.0 ± 3.1
Potato starch	33.1 ± 0.2	39.6 ± 1.6	32.5 ± 0.2	20.6 ± 0.8	28.0 ± 1.0	27.4 ± 1.0	29.5 ± 1.4
Tapioca starch	24.2 ± 1.6	29.1 ± 0.4	12.0 ± 0.4	9.8 ± 0.3	12.5 ± 0.8	13.3 ± 1.1	13.4 ± 1.1
Wheat starch	24.0 ± 0.6	43.3 ± 0.2	24.0 ± 0.6	18.9 ± 0.5	36.5 ± 1.7	37.0 ± 1.7	38.8 ± 2.0

[a]Time of inflection.

TABLE III
Pearson Correlation Coefficients for Parameters of Flour and Starch Cooking Properties Measured in the Viscoamylograph and RVA[a] Amylograph Profile Test

Parameter	Flours and Starches (*r*)	Starches Only (*r*)
Peak viscosity	0.341	0.897
Time to peak	0.922	0.985
Viscosity at 95°C	0.893	0.910
Viscosity at 95°C/30 min	0.957	0.990
Viscosity at 50°C	0.906	0.921
Viscosity at 50°C/30 min	0.859	0.947
Maximum setback viscosity	0.834	0.898

[a]Rapid Visco-Analyzer.

TABLE IV
Parameters of Flour and Starch Cooking Properties Measured by the Rapid Visco-Analyzer 20-min Test

Sample	Peak Viscosity (%)	Peak Time (min)	Maximum Setback Viscosity (%)
All-purpose flour	156.2 ± 1.6	5.17 ± 0.10	98.0 ± 2.6
Bread flour	139.2 ± 5.7	5.84 ± 0.13	86.3 ± 5.0
Cake flour	67.9 ± 1.2	5.98 ± 0.07	59.0 ± 1.0
Amioca starch	40.7 ± 1.3	3.54 ± 0.07	29.0 ± 1.0
Freezist M starch	17.5 ± 1.3[a]	2.88 ± 0.01[b]	30.0 ± 1.7
Fruitfil I starch	32.1 ± 0.1	3.77 ± 0.11	44.3 ± 0.6
Hylon starch	no peak	no peak	10.0 ± 0
Maize starch	35.9 ± 0.8	5.18 ± 0.10	28.0 ± 1.7
Potato starch	105.1 ± 1.1	3.16 ± 0.01	45.0 ± 1.0
Tapioca starch	27.4 ± 1.8	3.13 ± 0.07	13.0 ± 1.0
Wheat starch	46.9 ± 0.8	7.63 ± 0.3	55.3 ± 1.1

[a]Maximum viscosity at 12 min.
[b]Time of inflection.

viscosity in the viscoamylograph was relatively low (Table V). However, this was expected since the RVA 20-min test is an inherently different test from analysis with the viscoamylograph. Water was used to disperse the sample for the RVA 20-min test, whereas the viscoamylograph samples were dispersed with buffer. Heating and cooling rates were much faster in the RVA 20-min test than in the viscoamylograph. Shear rates, heat transfer rates, and sample size were also different as discussed before. Despite the low correlations between parameters measured in the viscoamylograph and the RVA 20-min test (Table V), the RVA 20-min test could be used to obtain a rough estimate of proper sample concentration for viscoamylograph analysis. One viscoamylograph run, taking over 2 hr and using 100 g of sample, might provide very little information if sample concentration were too high or too low. One or two screening runs with the RVA, taking only 20 min and 3–5 g of sample each, could assist a researcher in choosing the appropriate concentration for a viscoamylograph run. This would also facilitate the researcher who has only limited quantities of test material; cooking characteristics could be estimated without preparing large quantities (i.e., 100 g of flour) for one viscoamylograph run that could be easily lost if the wrong sample concentration were chosen.

TABLE V
Pearson Correlation Coefficients for Parameters of Flour and Starch Cooking Properties Measured in the Viscoamylograph and RVA[a] 20-min Test

Parameter	Flours and Starches (*r*)	Starches Only (*r*)
Peak viscosity	0.239	0.443
Time to peak	0.698	0.732
Maximum setback viscosity	0.641	0.630

[a]Rapid Visco-Analyzer.

Versatility of the RVA

The RVA amylograph profile and the rapid 20-min test represent only two testing protocols that are possible with the RVA. There is no time advantage over the viscoamylograph when doing an RVA amylograph profile, and manual temperature control is required. Despite these disadvantages of the amylograph profile test, it allowed illustration of alternative ways to use the RVA. Advantages of the RVA in this application were the small sample size and ease of operation.

The RVA can also be used to estimate flour or starch performance under any other time-temperature sequence desired. This would allow researchers to simulate time-temperature profiles used in actual production processes. Walker et al (1988) used a 12-min test (5 min at 95°C; 7 min at 50°C) on the RVA that was adequate for certain applications. In addition to its versatility, the RVA requires only small (3–5 g) samples, is simple to operate, and costs less than the traditional viscoamylograph. Whereas methods with the Brabender viscoamylograph are well established, Doublier (1987) notes that using only this instrument can result in erroneous interpretations and unreliable conclusions when studying rheological properties of starches. The RVA is an alternative instrument for measuring starch cooking properties and may have advantages in certain applications.

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