A Soup Model Study Comparing Flour Peak Viscosity During Heating and Viscosity of Flour Gels During Reheating

CHARLES S. GAINES, ANITA KASSUBA, and PATRICK L. FINNEY[1]

Cereal Chem. 72(3):233–236

ABSTRACT

A viscograph was used to study a model soft wheat flour-water gel system that was based on the apparent viscosity of commercial soups when reheated to a serving temperature of 60°C. Unless flours were produced from highly field-sprouted wheats, there was no relationship between the hot paste peak viscosity attained during first heating and the viscosity of the same pastes that were allowed to gel, stored, and were then reheated to serving temperature. Sound, unsprouted flour produced hot paste peak viscosities as low as 57 BU (50 g of flour/450 ml of water) and consistently high reheated gel viscosities. Adding malted flour to the model system, reduced the hot paste peak viscosity much more than it reduced the viscosity of the reheated gels, especially at low levels of malt. The prediction of the viscosity at serving temperature of flour-thickened soups could be better accomplished using direct measurement of α-amylase activity or determination of the reheated gel viscosity rather than the viscograph hot paste peak viscosity.

Annually, critically important amounts of soft wheat flour are sold to soup manufacturers as viscosity thickening agents and to producers of batters and breadings as mix components. Buyers of flours for those purposes require a minimum hot paste viscosity value to guard against purchasing flour from field-sprouted wheats. From crop years in which there is widespread preharvest sprouting, those minimum viscosities can be difficult to achieve without sourcing geographically diverse areas or expensive reserves of unsprouted wheat, stored from previous years.

The thickening power of flours and starches is often evaluated by an amylograph/viscograph. AACC method 22-10 (diastatic activity for flour, with the amylograph) (AACC 1983) allows for a heating to a peak viscosity at 95°C. The method has variously been modified and extended to a cooling period from 95 to 50°C and holding at that temperature for 30 min or longer (Sheuy and Tipples 1982). Sheuy and Tipples cite two procedures commonly used by soup canners. Both use peak viscosity and a holding time at 95°C. One method uses 50 g of flour and the other uses 60 g of flour. Pratt (1971) reports that soft wheat flours acceptable for soups require a minimum of 700 BU for the buffered amylograph method and 500 BU for the flour-water amylograph method, further stating that viscosities should be as "high as possible".

This study compared viscograph apparent viscosities of heating flour slurries and of reheated wheat flour gels. We could not find that application utilizing soft wheat flours reported in the literature. Fanta and Christianson (1991) observed an inverse relationship between the increase in hot paste viscosity caused by the addition of ethylene-co-acrylic acid to maize starch and the weakening of the strength of resulting starch pastes. Their data suggests that corn starch gel strength and hot paste viscosity rely on very different inter- and intramolecular associations of the solubilized starch macromolecule.

Higher potato flour hot paste viscosity has been linked to a synergistic effect between long branch chain length amylopectin and intermediate size amylose chains (Jane and Chen 1992). Lower peak hot paste viscosity has been shown to be associated with greater amylose content in the starch among mutant maize genotypes (Wang et al 1993). Medcalf and Gilles (1966) reported that the peak viscosity of wheat and maize starch swelling in an amylograph could be increased by as little as 0.05M sodium chloride.

Comparisons of various methods of assessing the degree of field-sprouting damage have been published. D'Appolonia et al (1982) observed good agreement between amylograph hot paste peak viscosity of wheat flour, falling number, and the grain amylase analyzer, which directly measures the effect of α-amylase on a β-limit dextrin substrate (nephelometry). Hsu and Varriano-Marston (1982) also found excellent agreement between the nephelometric method and α-amylase activity purified from malted barley. The nephelometric method was later to become AACC standard method 22-06.

Flour produced from severely field-sprouted wheat likely is not acceptable for thickening soup. However, it is common that many sound, unsprouted wheats do not meet soup manufacturers' minimum hot paste peak viscosity specifications. Many factors (crop year, location of growth, cultivar, and amylose-amylopectin ratio) affect the evaluation of viscograph hot paste viscosity. Could those lower viscosity soft wheat flours produced from sound, unsprouted wheats be acceptable as thickening agents? Ultimately, it is the viscosity of soup when reheated by the consumer that is a critical feature of a flour's thickening power. The lack of reports in the literature suggest it is unclear how well initial heating peak viscograph viscosity relates to the viscosity of reheated soup that is thickened with flour.

Because soups contain many varied ingredients, a simple model system (flour and water) was used to evaluate the hot paste peak viscosity of flours. Additionally, those pastes were evaluated for viscosity after they are sealed hot, allowed to cool and gel, were stored, and were subsequently reheated to serving temperature. Using the flour-water model, we investigated the peak hot paste methodology used by the miller and soup processor to predict the ability of a soft wheat flour to thicken soup. Of interest was whether a flour from sound, unsprouted wheat that produces a relatively low hot paste peak viscosity, can perform as a thickener in the model system as well as a flour that produces a higher hot paste peak viscosity. Also, could direct measurement of α-amylase activity (nephelometry) better predict the viscosity of the model system when it is reheated to serving temperature?

MATERIALS AND METHODS

Apparent Viscosity Measurements

Soups. Five commercial soups (cheese, cream of chicken, cream of potato, cream of mushroom, and tomato) were evaluated in a Brabender visc(k)ograph (PT-100) without adding additional water. Soup weight was 425 g (portions of two cans) and had

[1]U.S. Department of Agriculture, Agricultural Research Service, Soft Wheat Quality Laboratory, Ohio Agricultural Research and Development Center, Ohio State University, Wooster.

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of a product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that also can be suitable.

a volume to the top of the viscograph bowl pins. Soups were heated to 95°C at a rate of 5°C/min, the fastest rate possible at those viscosities that would not cause excessive temperature fluctuations as identified by the electronic control module.

Flours. Eighteen soft wheat flours were evaluated using the same viscograph. Unless designated otherwise, 50 g (14%, mb) of flour and 450 ml of distilled water were heated from 30 to 95°C at a rate of 5°C/min (similar to the methods used by soup processors). The hot pastes were held at 95°C for 5 min, and the percent difference in viscosity after 5 min and the peak viscosity was calculated as the setback percentage. The peak viscosity during this initial heating was referred to as the initial heating peak viscosity (IHPV).

The viscograph was zeroed on the chart baseline during the initial stage (2 min) of heating. After the initial heating and holding period, hot flour pastes were poured into hot pint (473 ml) canning jars that had been heated in boiling water at least for 5 min. Jars were sealed with hot lids that had been similarly heated. Gels were stored at room temperature for three days, unless designated otherwise.

Reheating of flour gels. After storage, jars were unsealed and gels were transferred into the viscograph cup. The weight of gel evaluated equaled that of the commercial soups (425 g). They were reheated from 30 to 95°C at a rate of 5°C/min. Before reheating the gels, the viscograph was zeroed on the chart baseline using 450 ml of water. During initial heating and reheating of gels and soups, the viscograph chart was marked at each 5°C increase and each 1°C increase between 90 and 95°C. The viscosity at each marked increment was later transcribed into a computer spreadsheet for subsequent analysis. The viscosity of the reheated gels measured at 60°C was referred to as the reheated gel viscosity at 60°C (RGV_{60}).

pH and α-Amylase Activity

The pH of all gels was monitored using 10 g of gel to 100 ml of distilled water. Gels were evaluated for pH after reheating measurements and subsequent cooling to room temperature. α-Amylase activity of flours was measured using AACC method 22-06 (1983).

Model Variables

Flour and 450 ml of distilled water was the base model system. Model variables (on a 450-ml water batch size basis) were: flour concentration (20, 30, 40, 50, and 80 g of flour), sodium chloride concentration (0, 1, 2, 3, and 4 g), malt (activity unknown) concentration (0, 0.28, 0.073, and 0.146 g), gel storage time (0, 1, 3, 6, 9, and 18 days), and cultivar (Arthur, Becker, Caldwell, Cardinal, Coker 983, Excel, Frankenmuth, Fillmore, Geneva, Ohio 498, and Severn). A total of 23 soft wheat flours were used, including 11 soft wheat cultivars and two commercial soft white wheat flours.

Analyses

All analyses and model treatments were duplicated and evaluated by the Winstar statistical PC package (Anderson-Bell). Data were analyzed for means, standard deviations, analysis of variance, linear correlation, and subsequent plotting. Plots contain data ± 1 standard deviation. Small deviations are not always obvious in the plots.

RESULTS AND DISCUSSION

Commercial Soups

Five commercial soups from one manufacturer were evaluated for apparent viscosity during heating to 95°C in the viscograph (Fig. 1). A reasonable serving temperature was considered to be 60°C, which was used to compare all subsequent viscosity measurements of laboratory produced gels, the RGV_{60}. It was assumed that some consumers heat soup to 100°C, hold it, and allow it to cool to a serving temperature, but those variables of how long the soup would be boiled and how long it would be held before cooling could not be predicted and were not included in this study. We simply heated the product from room temperature to 95°C at a controlled rate. Commercial soup RGV_{60} values ranged from 440 to 890 BU. The general range and ranking in viscosities among the five soups was maintained between 50 and 80°C.

The soups studied were the condensed type. Their label gave instructions for diluting them, if desired. Dilution produced RGV_{60} values at or below the lower range of the viscograph and was not accomplished for this study. The goal or base RGV_{60} for the model flour-water gel system was chosen to correspond to the upper end (800–900 BU) of the RGV_{60} range of the undiluted commercial soups. The viscosity of reheated commercial soups is variously influenced by other ingredients in addition to flour. However, our simple model system relied only on the flour-water gel to produce viscosity at serving temperature.

Flour Concentration

The amount of flour required by the model system to attain the desired reheated gel viscosity range was determined by studying flours from two sound wheats (Severn and Arthur) that produced different viscosities. A range of 20–80 g (in 450 ml of distilled water) was studied (Fig. 2). As flour concentration increased, the Severn sample produced greater IHPV values, but lower RGV_{60} values than did the Arthur sample. That relationship appeared constant for flour concentration of 40 to 80 g. Based on those and other trials, a flour concentration of 50 g was chosen for model system studies, as it produced ~900 BU RGV_{60}. Although that is more than the amount of flour utilized in commercial soups, it is the similar to that required by the popular soup methods for evaluating hot paste viscosity (50 and 60 g of flour/450 ml of distilled water).

Sodium Chloride Concentration

All of the commercial soups examined contained table salt, and the influence of sodium chloride concentration on the model was investigated. The influence on IHPV and RGV_{60} values of sodium chloride concentration (up to 4 g per 50 g of flour) was evaluated for two cultivars, Arthur and Severn (Fig. 3). Both IHPV and RGV_{60} values increased ~100 BU when salt concentration was increased to 4 g, which agreed with findings of Medcalf and Gilles (1966). At the more realistic concentration of 1 g of salt per 50 g of flour there was no significant difference in RGV_{60} ($P = 0.83$) from the control. Salt was not included in the model system.

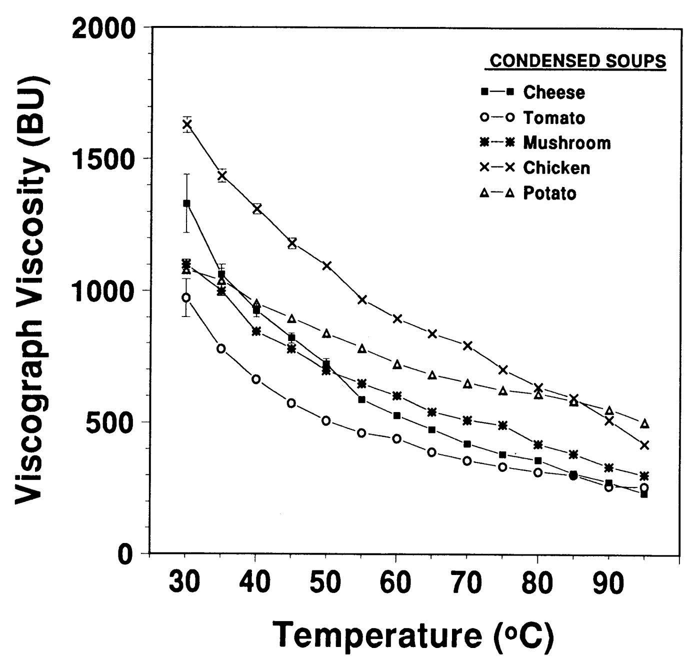

Fig. 1. Viscograph viscosity during the heating of five commercial soups (condensed type).

Storage Time

Preliminary trials revealed that model system gels formed when the heated pastes cooled to room temperature and were set within 1 hr of standing at room temperature. However, the influence of storage time from 1 to 18 days for Becker and Fillmore cultivars (which produced different RGV_{60} viscosities) was evaluated (Fig. 4). Within a cultivar, mean differences in RGV_{60} values up to 18 days were small and not statistically significant. Three days storage time was chosen for subsequent studies.

IHPV Setback and Model System pH

Setback is the viscosity difference between the IHPV and the viscosity after holding the temperature of the pastes at 95°C for 5 min. It is sometimes used as indicator of a flour's potential to perform as a thickening agent. In this study, setback viscosities and pH values were not found to be statistically correlated with the other measured parameters (Fig. 5). Soup manufacturers consider that a small setback indicates a sound flour (Shuey and Tipples 1982). We monitored pH in the event that short-term microbiological spoilage would become a problem.

Cultivars and α-Amylase Activity

The α-amylase activity and RGV_{60} values were compared to the IHPV of the 18 flours (Fig. 5). IHPV values >57 BU produced RGV_{60} values >675 BU. All of those apparently sound, unsprouted wheats had α-amylase absorbance values <0.17 and produced consistently good reheated gel viscosities. Only the three severely sprouted wheats having IHPV <50 BU, produced lower RGV_{60} values. Those wheats were obviously more easily distinguished using α-amylase activity than IHPV. Ideally, the miller and soup manufacturer should be able to identify flours that will not thicken soups before they are sold and utilized for that purpose, but not misidentify flours that will produce strong gels.

Additional Malted Flour

Three levels of malted flour (normal baker's malt flour of unspecified activity) were added to two flours produced from Excel and Caldwell wheats. Figure 6 shows the percentage decrease in the IHPV and RGV_{60} values from those flours. Excel had the lower IHPV (415 vs. 465 BU) with no malt added, and had a larger decrease in IHPV when malt was added (had lower viscosity with added malt). However, Excel had a higher RGV_{60} (985 vs. 803 BU) when no malt was added, and retained a higher RGV_{60} with added malt (985 vs. 803 BU) when no malt was added, and had a smaller decrease in viscosity when malt was added (retained a higher RGV_{60} with added malt). Thus, compared to Caldwell, when malt was added to Excel, it produced lower IHPV values, but higher RGV_{60} values. The lower viscosities caused by 0.3% added malt were still higher than those of the three sprouted wheats used in this study. Those observations show

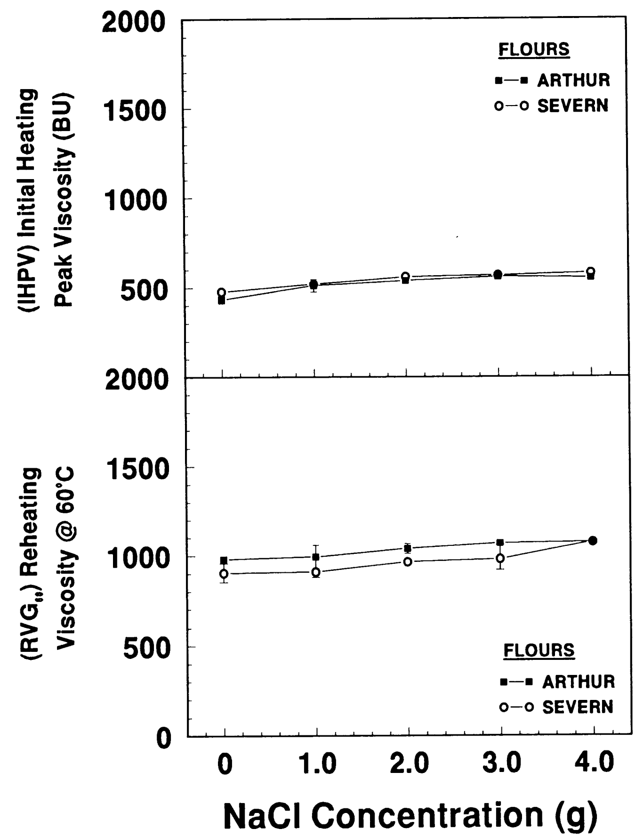

Fig. 3. Influence of sodium chloride concentration on the hot paste initial heating peak viscosity and the viscosity of the gel reheated to 60°C for two soft wheat cultivars.

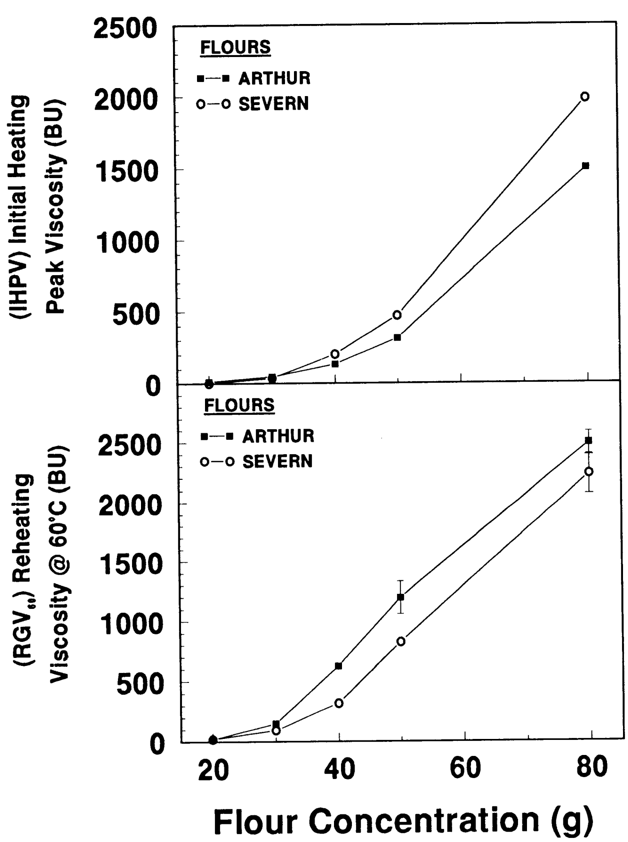

Fig. 2. Flour concentration vs. the hot paste initial heating peak viscosity and the viscosity of the gel reheated to 60°C for two soft wheat cultivars.

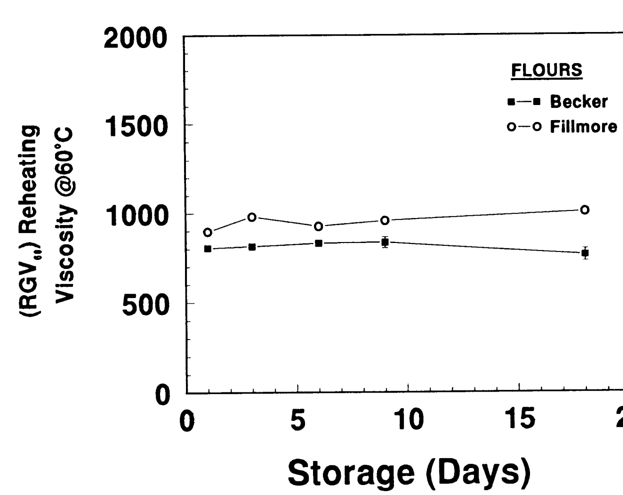

Fig. 4. Influence of storage time on the viscosity of the gel reheated to 60°C for two soft wheat cultivars.

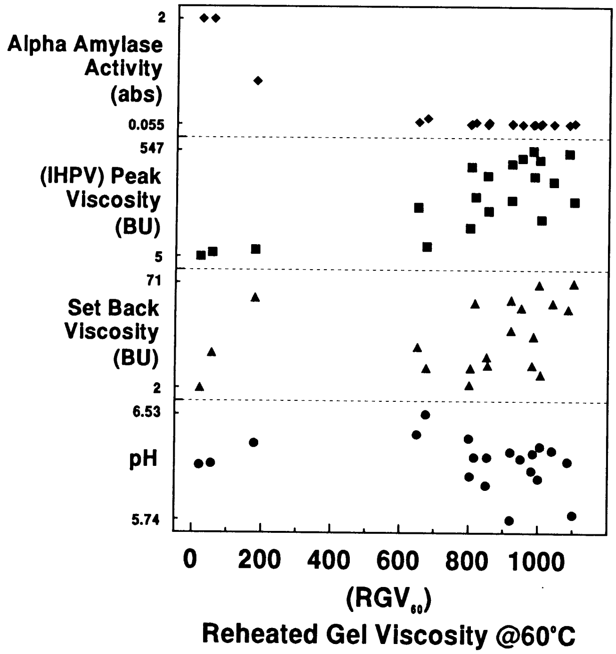

Fig. 5. α-Amylase activity, initial heating hot paste peak viscosity, setback viscosity, and gel pH for 18 flours vs. the viscosity of the gel reheated to 60°C.

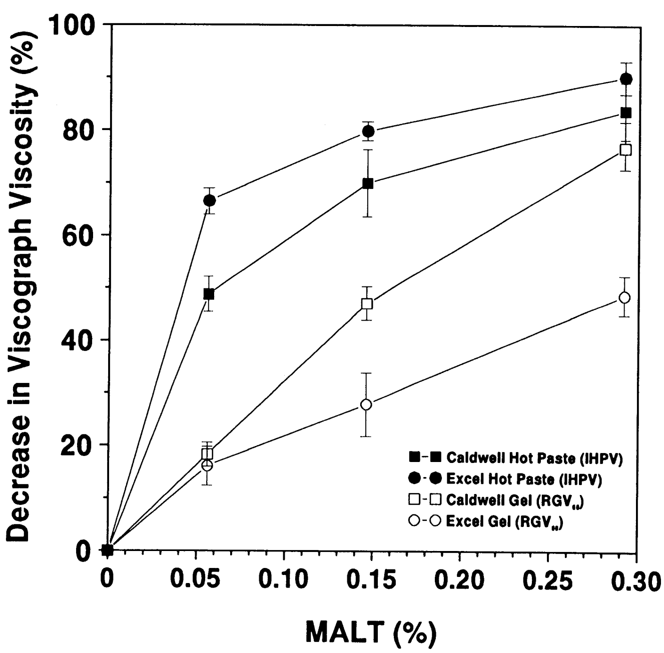

Fig. 6. Effect of added malted flour on reduction (the percentage) in the hot paste initial heating peak viscosity and the viscosity of the gel reheated to 60°C for two soft wheat cultivars.

the importance to thickening power of an intrinsic or base viscosity contributed by flour components other than amylolytic enzymes. The data also suggest that the effect of added malt (and likely field sprouting) can be different for IHPV and RGV_{60}.

CONCLUSIONS

The apparent viscosity of a model flour-water gel system was studied. The selected viscosity range of the model system was based on the apparent viscosity of commercial soups when reheated to a serving temperature of 60°C. Sodium chloride concentration, storage time, set back, and gel pH had little or no association with the viscosity of model system gels heated to serving temperature. Among sound, unsprouted flours there was no correlation between the viscograph peak pasting viscosity attained during first heating and the viscosity of the gel reheated to serving temperature. Reheated gel viscosity was relatively constant (unless α-amylase activity was elevated) when produced from flours producing 57 to 534 BU IHPV. As measured, the viscograph hot paste viscosity was a poor predictor of the viscosity of model gels when reheated to serving temperature, unless flours were severely sprouted. Several relatively low hot paste peak viscosity flours thickened the model system as well as a flours that produced a higher hot paste peak viscosities. Apparently, wheats that produce relatively higher hot paste viscosities may not produce higher reheated gel viscosities and vice versa. The cause for those results is not known, but those results agree with those of Fanta and Christianson (1991) that corn starch gel strength and hot paste viscosity rely on very different inter- and intramolecular associations of the solubilized starch macromolecule. Further research in this area should give breeders and millers better guidance towards improving wheat quality.

When α-amylase activity was elevated by adding malted flour to the model system, the gel viscosity when reheated to serving temperature was not as affected, as the larger reduction in the viscosity of the initially heated paste would suggest. In this study, the hot paste viscosity of 15 sound flours varied from 57 to 534 BU without indication of field sprouting. Apparently, considerable variability in hot paste peak viscosity can be tolerated without producing an associated reduction in the viscosity of gels reheated to serving temperature. Instead of using hot paste peak viscosity, the direct measurement of α-amylase activity is more likely to avoid the possibility of encountering wheats or flours having elevated amylolytic activity. If the direct measurement method is not possible, an evaluation of the gel viscosity at serving temperature also should be a better monitor of α-amylase activity than hot paste peak viscosity, although it takes much longer to accomplish. This study suggests that improved methodologies may assist the miller to better meet the soup processor's requirements for thickening soup with soft wheat flour.

ACKNOWLEDGMENTS

We appreciate the assistance of John Donelson, Lonnie Andrews, and Barb Renner.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. Method 22-06, revised September 1992. The Association: St. Paul, MN.

D'APPOLONIA, B. L., MacARTHUR, L. A., PISESOOKBUNTERNG, W., and CIACCO, C. F. 1982. Comparison of the grain amylase analyzer with the amylograph and falling number methods. Cereal Chem. 59:254.

FANTA, G. F., and CHRISTIANSON, D. D. 1991. Influence of poly (ethylene-co-acrylic acid) on the paste viscosity and gel rheology of cornstarch dispersions. Cereal Chem. 68:300.

HSU, E., and VARRIANO-MARSTON, E. 1983. Comparison of nephelometric and phadebas methods of determining α-amylase activity in wheat flour supplemented with barley malt. Cereal Chem. 60:46.

JANE, J.-L., and CHEN, J.-F. 1992. Effect of amylose molecular size and amylopectin branch chain length on paste properties of starch. Cereal Chem. 69:60.

MEDCALF, D. G., and GILLES, K. A. 1966. Effect of a lyotropic ion series on the pasting characteristics of wheat and corn starches. Staerke 4:101.

PRATT, D. B., JR. 1971. Criteria of flour quality. Page 201 in: Wheat Chemistry and Technology, 2nd Ed. Y. Pomeranz, Ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

SHUEY, W. C., and TIPPLES, K. H. 1982. The Amylograph Handbook. Am. Assoc. Cereal Chem.: St. Paul, MN.

WANG, Y.-J., WHITE, P., and POLLAK, L. 1993. Physicochemical properties of starches from mutant genotypes of the OH43 inbred line. Cereal Chem. 70:199.

[Received August 17, 1994. Accepted January 11, 1995.]