Effect of heating rate and freezing and reheating of corn and wheat starch-water dispersions[1]

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Evaluation of scanning electron micrographs showed that a heated starch-water dispersion is sensitive not only because of the type of starch but also to the mode of heating, cooling, and reheating.

An increasing number of institutional food services have reported the implementation of either a frozen food or a chill food delivery system (1-3). In the near future, more than 40 percent of food service operations such as fast food, hotel/motel, full-service operations, and colleges are planning to add a cook-chill or freezing system to their present form of service. Concurrent with this trend, food items are being subjected to many different thermal stresses with the different methods of heating, cooling, freezing, and reheating, such as heat exchangers, convection or microwave ovens, and freezing methodology. Many of these techniques distort the traditional time-temperature relationships and associated changes in the food. This article reports a pictorial study of changes that occurred in corn and wheat starch when heated and reheated by a variety of methods.

The influence of end-point temperature upon the characteristics of starch-water dispersions has been extensively studied (4-6). Historically, it has been assumed that the speed at which a starch-water dispersion is heated influences ultimate viscosity of the product and gel strength. This influence was reported as early as 1933 by Woodruff and Webber (6), who noted that firmer gels were obtained with a faster heating time. In a more recent study with cream pie fillings (7), this influence was again reported.

In the early 1940s and 1950s, frozen food manufacturers made an attempt to manufacture pot pies using wheat flour as the thickener (8). Because of the unappealing, watery, curdled product, a number of researchers (9,10) investigated the effect of freezing and/or reheating on starch-containing food items. Factors such as type of starch, presence of other ingredients, mode of heating, heating rate, freezing method, freezing rate, and storage all have been observed to influence the starch granule and/or the quality of the frozen starch-containing food item (9-13).

Experimental technique

A 5 percent corn[2] or wheat[2] starch-water dispersion was used for all tests. Analysis and evaluation of the scanning electron micrographs are made on the basis of many samples prepared under a variety of conditions and stresses. The micrographs included in this paper were selected as representative of the heating or cooling and reheating stresses currently investigated.

The effect of rate of heating was determined using an oilbath at 100 ± 2°C. or 200 ± 2°C. The corn or wheat starch-water dispersion was placed in the oilbath, heated while being slowly stirred, and removed when the temperature of the dispersion reached 85°C. Sampling for the scanning electron microscope (SEM) and Brookfield viscometer determinations was done immediately upon removal of the dispersion from the oilbath.

Samples to be frozen and reheated were prepared by heating the starch-water dispersions with programmed heating of 1.5°C. per minute for temperatures of 20.5° to 88°C. at 75 r.p.m. agitation.[3] This may simulate stirring action which may occur in a heat exchanger. Upon completion of heating, SEM samples were removed; 200 gm. of the mixture was placed in a half-pint polyethylene freezing container, frozen in a frost-proof freezer[4] at -22°C., and stored for eight weeks.

After being defrosted in a refrigerated room (5°C.) for 18 hours, starch-water dispersions were reheated in either a waterbath or a microwave oven. The waterbath[5] at 93 ± 4°C. was used to reheat starch-water dispersions to 70 ± 1°C. Dispersions were reheated in a microwave oven[6] for 1.5 minutes to reach a product temperature of 75 ± 10°C. All temperatures, except those obtained in the microwave oven, were determined with a temperature recorder.[7] A thermometer[8] made for the microwave oven was used when appropriate. Upon completion of reheating, SEM samples were removed.

A viscometer[9] was used for viscosity determinations of corn or wheat starch-water dispersions heated in the oilbath. Scanning electron micrographs were prepared according to methodology reported in the initial paper (14) in this series.

[1]Technical Paper No. 5266, Oregon Agricultural Experiment Station.

[2]National Biochemical Corporation, Chicago.

[3]In a Brabender Visco/Amylo/Graph, Model VA-V; C. W. Brabender Instruments, South Hackensack, New Jersey.

[4]Deluxe Frigidaire Food Freezer, Model 191, General Motors, Dayton, Ohio.

[5]Thelco Model 84, Precision Scientific Company, Chicago.

[6]Minute Master Microwave Oven, Litton, Inc., Minneapolis.

[7]Multipoint Temperature recorder, Leeds and Northrup, North Wales, Pennsylvania.

[8]Litton, Inc., Minneapolis.

[9]Brookfield Synchro-Lectro Viscometer, Model RVF, spindle 3, speed 20; Brookfield Engineering Laboratories, Inc., Stoughton, Massachusetts.

Results and discussion

As seen when the two corn starch-water dispersions heated to 85°C. at 100°C. (Figure 1-A) or 200°C. (Figure 1-B) are compared, the slower heated starch appears to have more exudate and granule deformation. Although some exudate and deformation is present in the samples heated rapidly, the samples appear to have more granule tearing and fragmentation. Additionally, the exudate appears to be less uniformly exuded from granules.

When photomicrographs represented in Figures 1-C and 1-D are evaluated, it appears that the granules in the wheat starch-water dispersions heated rapidly had more fragmented, concaved and deformed granules, and filamentous material than those heated slowly. The slowly heated dispersions appear to have lost some granule integrity; however, one cannot make an over-all generalization based on the results of this experiment because the effect of heating rate is masked by the individual characteristics of the starches themselves.

Five percent wheat starch and corn starch dispersions had similar heating patterns for each heating temperature (Figure 2), although it is known that optimum gelatinization temperature for wheat, as determined by loss of birefringence, is approximately 10°C. lower than that for corn starch (4).

Rather than holding end-point temperature constant, it might be pertinent to investigate heating rate versus optimum gelatinization end-point temperature. The viscometer readings in this study indicated that corn starch heated at a rapid rate was approximately 2.4 times thicker than that heated at the slow rate (300 versus 125 centipoises). The comparison for the wheat starch indicated that the rapidly heated dispersion was 1.8 times thicker than the slowly heated dispersion (234 versus 43 centipoises). These results are similar to those reported by Bechtel (5), who observed that corn starch not only attained maximum viscosity at a slightly lower temperature but had a greater maximum viscosity when the dispersion was heated rapidly rather than slowly. This would indicate again the relationship of cooking time as well as temperature to the ultimate quality of a food item.

Five percent starch dispersions were frozen, stored, and reheated in either a waterbath or a microwave oven. As can be seen from Figure 3, there does appear to be a difference between fresh and frozen reheated starch-dispersions. SEM micrographs of frozen, thawed (5°C.) starch-water dispersions were also analyzed. However, the micrographs were not interpretable and are not included in this report. This may have been an artifact of SEM techniques or have been due to the crystalline nature of the starches after thawing. Representative photomicrographs (Figure 3) of reheated corn and wheat starch indicate that the method of reheating influences the appearance of the granule. Microwave reheating appears to give a more crystalline appearance than waterbath reheating.

The freshly heated corn and wheat starch dispersions (Figure 3-A, 3-D) appear to have few defined, swollen granules but rather only fragments and portions of the granules. The Brabender curves for the two starches indicate that the corn starch and wheat starch fragmentation could have been due to heating past the gelatinization point. The long heating time in conjunction with stirring would enhance the possibility of granule breakdown. The Brabender curves showed a decrease in viscosity of the corn starch, reflective of probable granule breakdown. In scanning electron microscopy investigations of unmodified tapioca starch, Chabot et al. (15) found that there were no intact swollen granules

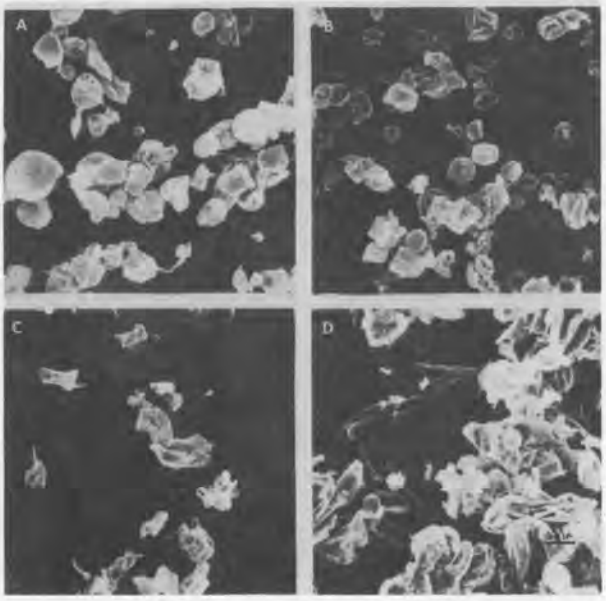

FIG. 1. *Scanning electron micrographs (400X) of corn and wheat starch-water dispersions heated at 100° or 200°C.* (left to right): *A, corn starch at 100°C.; B, corn starch at 200°C.; C, wheat starch at 100°C.; D, wheat starch at 200°C.*

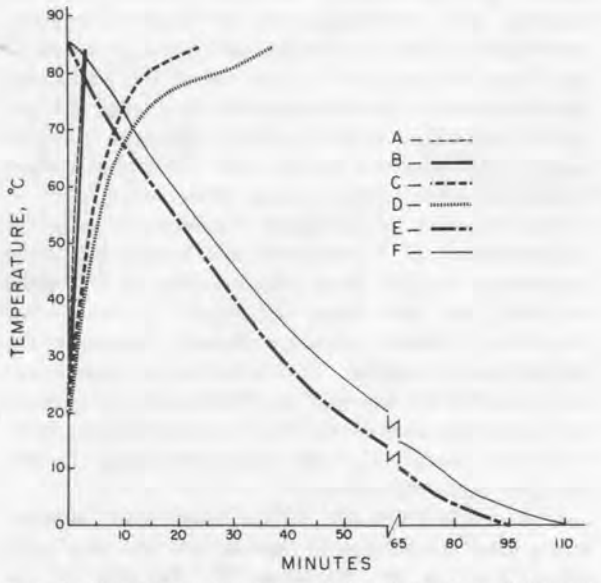

FIG. 2. *Temperature increase with heating rate and decrease with freezing: A, heating rate, wheat starch, 200°C.; B, heating rate, corn starch, 200°C.; C, heating rate, wheat starch, 100°C.; D, heating rate, corn starch, 100°C.; E, freezing rate, wheat starch; F, freezing rate, corn starch.*

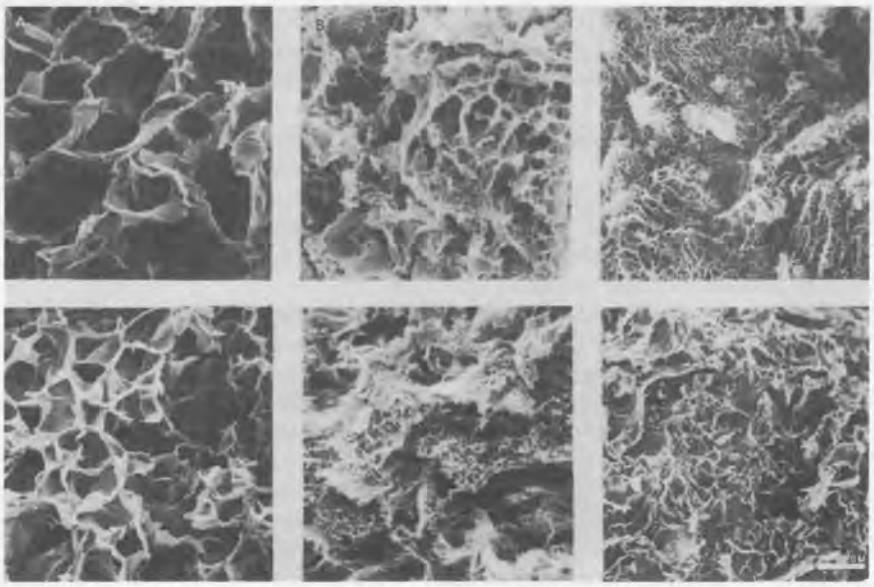

FIG. 3. *Corn and wheat starch-water dispersions (700X) fresh and frozen reheated by microwave or waterbath* (left to right): *A, corn starch, fresh; B, corn starch, frozen, reheated waterbath; C, corn starch, frozen, reheated microwave; D, wheat starch, fresh; E, wheat starch, frozen, reheated waterbath; F, wheat starch, frozen, reheated microwave.*

at peak viscosity and that the starch dispersion had a honeycomb arrangement of non-granular starch similar to that shown in Figure 3 in this paper. Possibly the crystalline appearance in the four frozen reheated samples is due to retrogradation of the starches.

The pictures in Figure 3-B, 3-C, 3-E and 3-F appear very similar to polyacrylamide gel SEMs published in 1979 (16). As shown by the cooling portion of the graph in Figure 2, gelation likely occurred during the freezing process. The tighter, more crystalline appearance of the frozen starch dispersions reheated in the microwave oven (Figure 3-C, 3-F) as compared to those reheated in the waterbath (Figure 3-B, 3-E) may be due to the time-temperature relationship and to partial reversal of retrogradation. The waterbath took from four to five times longer to reheat than the microwave reheated sample. This longer time may have permitted more retrogradation reversal. Some reversal of retrogradation during reheating of a frozen starch product has been noted when a different methodology was used (12). The appearance of the starch-dispersions represented by the photomicrographs in Figure 3 is unlike that reported by Hood et al. (10). This difference likely underscores not only the effect of variety but also the influence of both temperature of gelatinization and interaction of added ingredients on granule structure during preparation, freezing, and reheating.

Summary

In this study, evaluation of scanning electron micrographs emphasized that a heated starch-water dispersion is sensitive not only because of the type of starch but also to the mode of heating, cooling, and reheating. Differences in granule appearance were seen with both corn and wheat starch-water dispersions when they were heated at different rates. Both freezing and reheating influenced the starch-water dispersions. Microwave oven reheating appeared to yield a product with more retrogradation of the starch component. For an understanding of the effect of temperature-time stresses on this common ingredient, starch, much more study is needed.

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