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Macrostructure of selected raw starches and selected heated starch dispersions[1]

ZOE ANN HOLMES and AL SOELDNER
Department of Foods and Nutrition, and Department of Botany and Plant Pathology, Oregon State University, Corvallis

Similarities and differences between raw starches and heated starch-water dispersions were determined pictorially using a scanning electron microscope.

Starch is usually an important component in gravies, sauces, puddings, and baked products. These foods rely upon starch for many of their structural and textural properties. With the expanding frozen entrée field (1) and substantial use of starch-containing items prepared both in-house and commercially, the factors influencing these properties and the resulting final quality are of great interest. Delineation of the physico-chemical behavior of starch in these foods is made complex and difficult by the interactions of a wide variety of ingredients and the many thermal stresses. Thus, it is helpful to examine simple systems of starch and water before introducing ingredient complexity.

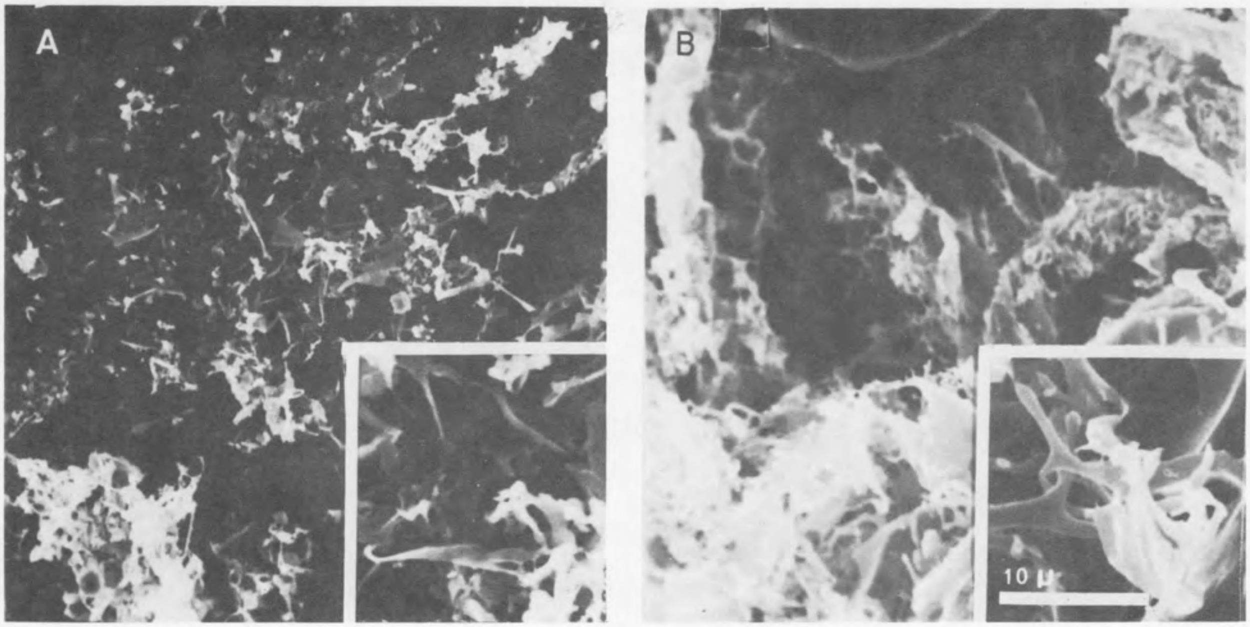
Although the changes that occur during heating of starch in a water dispersion have been extensively studied because of their impact in the institutional market, it is pertinent to review this widespread component of foods. The composition and structure of the starch, the swelling properties of the starch under a variety of conditions, and the stability of the starch determine the product quality. This article was designed to present in pictorial form a review of starch and the gelatinization of starch in a simple system.

Experimental methods

Corn starch[2], wheat starch[2], wheat flour[3], rice starch[4], potato starch[5], Thermtex[6], Purity W[6], Nesco gel starch[7],

[1]Technical Paper No. 5265, Oregon Agricultural Experiment Station.

[2]National Biochemical Corporation, Chicago.
[3]Fisher Mills, Inc., Seattle.
[4]United States Biochemical Corporation, Cleveland.
[5]Allied Chemical Corporation, Morristown, NJ.
[6]National Starch and Chemical Corporation, Bridgewater, NJ.
[7]The New Era Milling Company, Arkansas City, KS.


A
B
10 µ

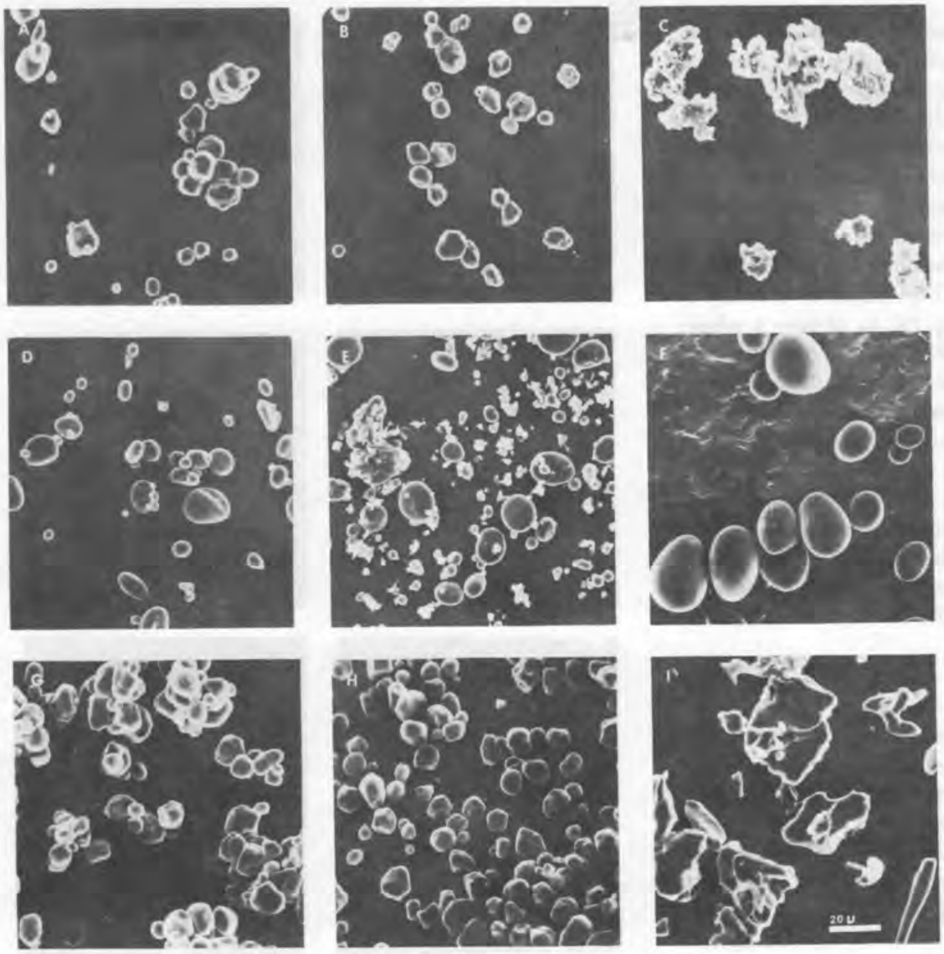


FIG. 2. *Scanning electron micrographs (700X) of selected raw starches (left to right): A, corn starch; B, waxy corn starch; C, rice starch; D, wheat starch; E, wheat flour; F, potato starch; G, Purity W; H, Thermtex; I, Nesco gel starch.*

emphasized the fact that it has a characteristic ability to change molecular shape. This photomicrograph (Figure 1-A) may be showing some of the random coils or crystalline or helically intermolecularly bonded regions. The contrasting larger, bushy amylopectin starch polymer is apparent in micrograph Figure 1-B. Amylopectin also has the α-1,4 linkages, but in addition it has α-1,6 bonds which create a branched structure, giving it a globular shape (3).

Starches have the two glucose polymers, amylose and amylopectin, in a relatively organized structure called a granule. The exceptions are the waxy starches, which contain only amylopectin. Each starch granule has its own distinctive structures, some of which are shown in Figure 2. Basically, granules are either small and spherical or larger and ellipsoidal.

As can be seen in Figure 2-A, corn starch is made up of some round spherical granules and others which are more angular. The variation in shape may be caused by packing of the granules in the endosperm. In a detailed SEM review of starch granules, Hall and Sayre (4) attributed the round granules to the floury endosperm and the more angular granules to the horny endosperm. The waxy maize granules (Figure 2-B) have greater variation in surface structure than normal corn starch. Additionally, graininess is observable in the waxy maize. The distinctive nature of each variety of starch can be seen in Figure 2-C. These rice starch granules are among the smaller ones studied. Most granules appear polygonal and are in clusters. These appear somewhat like portions of the rice kernel endosperm in the SEM micrographs reported by Watson and Dikeman (5). Possibly because of the small granule size, separation of the starch during processing may have been difficult and so inadequate.

The wheat starch and the wheat flour in Figures 2-D and 2-E, respectively, are analogous to those observed by other workers (6). There generally appear to be two sizes of wheat starch granules in the micrographs, large lenticular shaped granules and small spherical granules with intermediary sizes. Although surfaces are relatively smooth, the granules show depressions, possibly due either to packing in the endosperm or to extraction during processing. Non-spherical or lenticular portions in the wheat flour (Figure 2-E) may be flour protein. The larger potato starch granules are ellipsoidal or oval in shape (Figure 2-F). However, the granules are not uniform in size.

In order to withstand modern processing and storage conditions, native starches are chemically or physically modified to change their properties. The purpose of this modification usually is to develop characteristics for specialized purposes. This can be achieved by mild degradation, crosslinking of chains, modification with phosphate or other esters, or pregelatinization. In addition to the native starches shown in Figure 2, three of these modified starches are shown. Purity W (Figure 2-G) has been modified by crosslinking waxy maize. This has contributed to its increased cold temperature stability, making it particularly useful for frozen products. The appearance of the modified starch, Purity W (Figure 2-G), and that of the native starch (Figure 2-B) were not greatly dissimilar. Higher magnification did show a greater number of pin holes. This might be a result of starch modification or refining (4) to obtain a whiter product. Thermtex (Figure 2-H) is a starch modified for faster heat penetration and stability. It is similar to that of waxy maize (Figure 2-B). Nesco gel starch (Figure 2-I) is a wheat starch which has been pregelatinized to permit usage at lower heating temperatures than usual with non-pregelatinized wheat starch. The pregelatinized wheat starch shows considerable deformation. On closer examination at a higher magnification, these granules appeared to be collapsed with some sticking of the granules to one another. There was no observable exudate.

Starch-water dispersion

Although the composition and shape of the dry granules are of interest, their contribution to the properties of the food item after processing or cooking is of greater concern. The properties followed when starch is heated with water are the gelatinization temperatures, the degree of pasting (viscosity), and the stability to thermal and physical stresses (heating and cooling). Viscosity and gelling are properties followed during cooling and retrogradation.

Figure 3 is a pictorial representation of the effect of heat at eight end-point temperatures on the most basic corn starch-water system. The 5 percent dispersion of starch approximates the concentration typical for some starch-containing gravies, puddings, soups, and other entrées. From 30° to 50°C. (Figure 3-A, 3-B), there is essentially no change in the appearance of the granules. In this range, the granules are still held together by inter- and intra-molecular hydrogen bonding within and between the amylose and amylopectin. Although few changes are observable, with temperature increase hydrogen bonds are weakened and absorption of water within the granule is facilitated.

At 60°C. (Figure 3-C), there was a slightly noticeable change in granule appearance. There were some dimpling and a few doughnut-shaped granules. This was even more pronounced at 65°C. (Figure 3-D), as might be expected from viscosity increase. Goering et al. (7) also observed this viscosity increase as well as a loss of birefringence or the cross-shaped appearance of the granule observed with a polarizing microscope. At 70°C. (Figure 3-E), the gelatinization process was extensive. At 75°C. (Figure 3-F) and 80°C. (Figure 3-G), there appeared to be collapse and deformation. At 85°C. (Figure 3-H), considerable fragmentation and loss of granule integrity occurred.

Many starch-containing foods have either pure wheat starch or wheat flour added for thickening. Micrographs at four selected temperatures of 30°, 55°, 80°, and 85°C. (Figure 4) are shown. As expected and reported by Hoseney et al. (8), the granules swelled at a lower temperature than did the corn starch granules. As seen in Figure 4 and other intermediary micrographs, the observable changes begin to occur between 30° and 55°C. At 55°C., gelatinization of starch is visualized as a swollen granule with considerable exudate on the exterior (Figure 4-B). Contrary to the historical view that amylopectin is responsible for viscosity and amylose for gel strength, Miller et al. (9) reported that amylose may also contribute to viscosity. When granules were

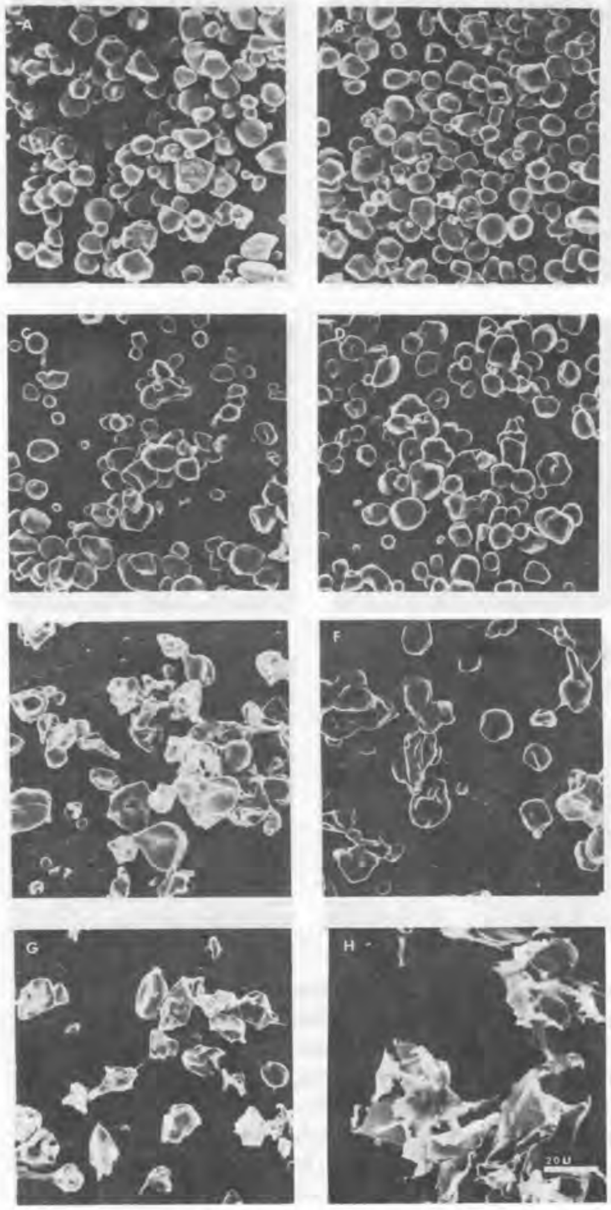


FIG. 3. *Scanning electron micrographs (700X) of corn starch-water dispersion at selected temperatures (left to right): A, 30°C.; B, 50°C.; C, 60°C.; D, 65°C.; E, 70°C.; F, 75°C.; G, 80°C.; H, 85°C.*

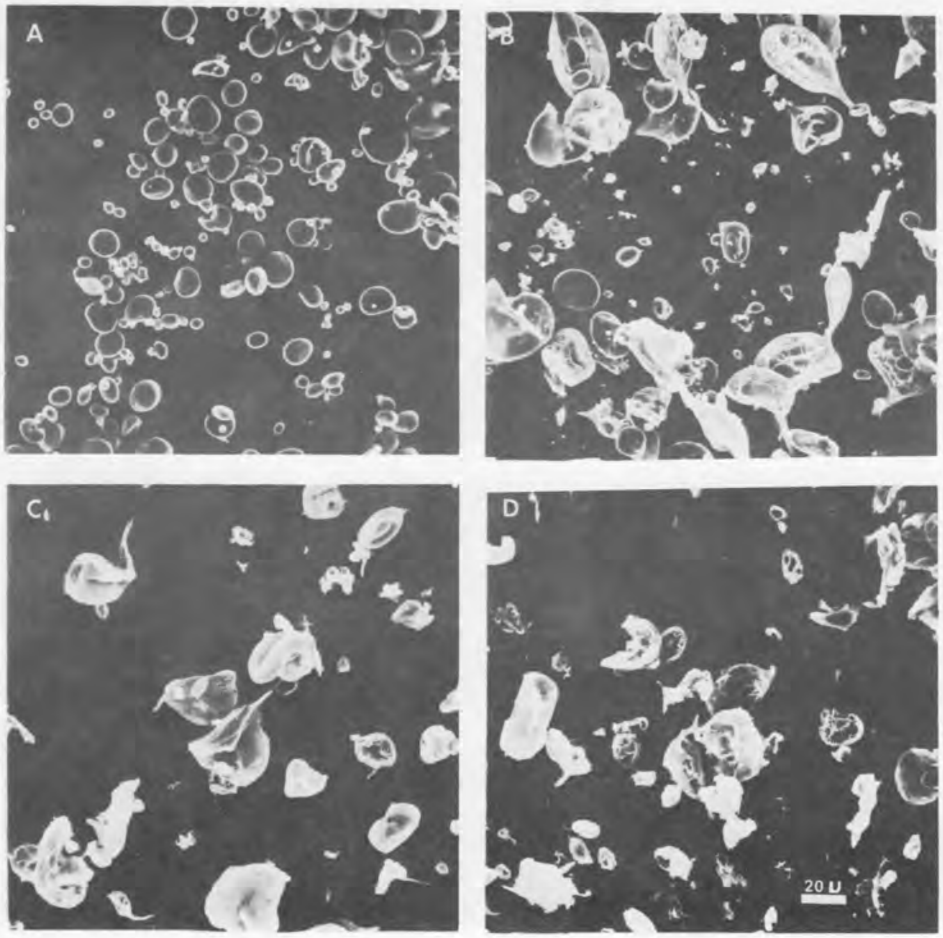


FIG. 4. *Scanning electron micrographs (400X) of wheat starch-water dispersions heated to selected temperatures (left to right): A, 30°C.; B, 55°C.; C, 80°C.; D, 85°C.*

removed from the dispersion, Miller et al. (9) observed that the exudate stained blue with iodine and contributed to viscosity. Amylose also stains blue in unmodified starches, and the hydrophilic nature of its polymer would contribute to viscosity.

Summary

The similarities and differences between raw starches and heated starch-water dispersions were determined pictorially using a scanning electron microscope. The photomicrographs showed that raw unmodified starches ranged from small and round to large and ellipsoidal in shape, with variation in uniformity and smoothness of the surface. Heating of corn and wheat starch in water dispersions caused swelling of the starch granule, some exudate, and eventual loss of original granule integrity. The scanning electron microscope is a sensitive, useful tool to evaluate changes which occur in starch systems.

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