Mechanism of Action of Starch as a Tablet Disintegrant V: Effect of Starch Grain Deformation

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Abstract ☐ Corn and waxy maise starches were observed under a light microscope and a scanning electron microscope. The effects of pressure and moisture were studied in both individual grains and in tablets. The starch grains were deformed by pressure and did not regain their original shape when moistened, nor was there significant swelling. The deformed cornstarch grains appeared to retain their birefringence. The regaining of the shape of starch grains is apparently not the mechanism of action as a tablet disintegrant.

Keyphrases ☐ Tablet disintegration—effect of starch grain deformation on mechanism of action ☐ Starch as tablet disintegrant—effect of moisture and pressure on starch grain deformation ☐ Microscopy—visualization of starch grain deformation

In attempting to determine the mechanism of action of starch as a tablet disintegrant, an attempt was made to approach the problem in a systematic manner (1–4). It was found that a limited amount of swelling of the grains occurred (1) and that pores and porosity (4) generally could not be correlated with disintegration times. These phenomena are then not the major mechanisms by which starch causes tablet disintegration.

Fuhrer (5) suggested that potato starch grain deformation due to compression results in swelling of the grains. Fuchs (6) showed cornstarch grain deformation due to compression. Both authors neglected to show the effect of moisture on the deformed grains.

The purpose of this paper is to illustrate starch grain deformation using both the light microscope and the scanning electron microscope. Individual starch grains

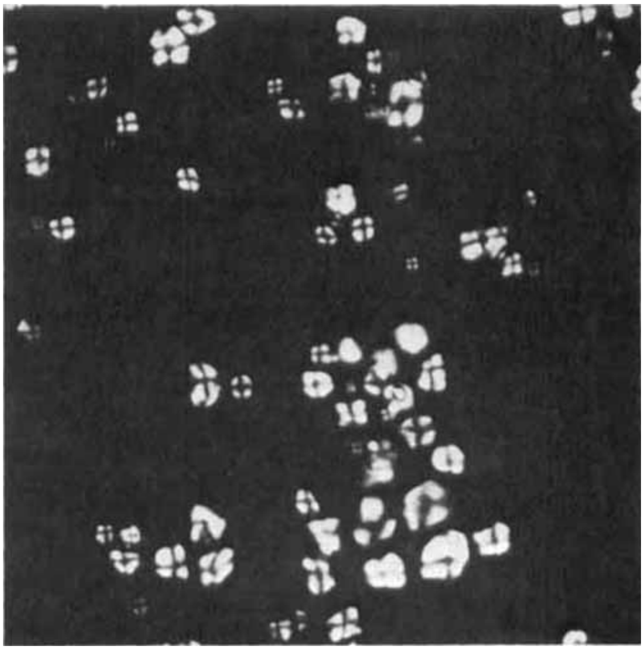

Figure 2—*Cornstarch grains compressed at 10,000 psig. seen with polarized light (approximately 350×).*

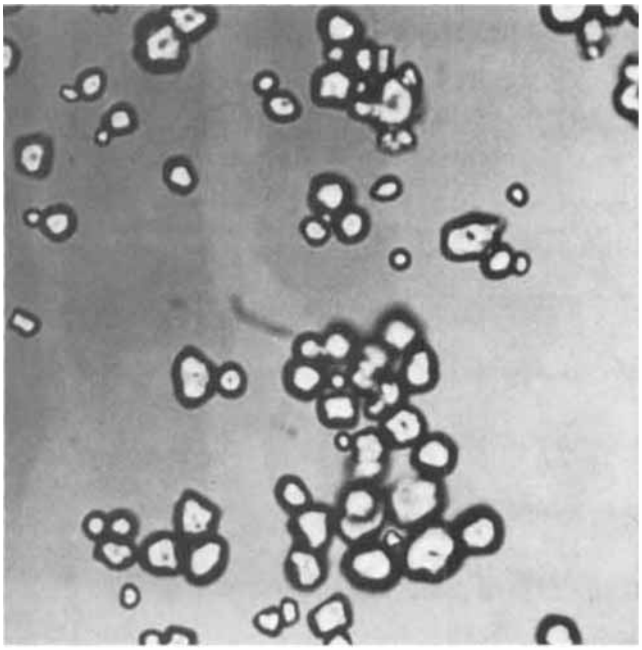

Figure 1—*Cornstarch grains compressed at 10,000 psig. (approximately 350×).*

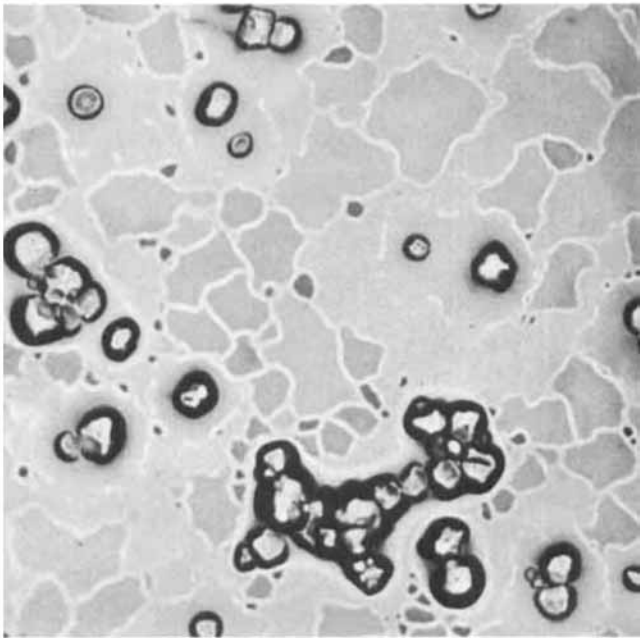

Figure 3—*Moistened cornstarch grains compressed at 10,000 psig. (approximately 350×).*

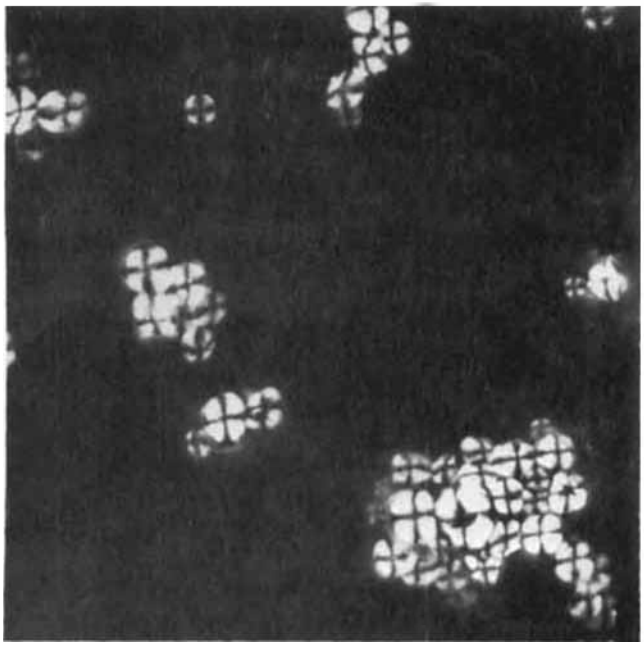

Figure 4—*Moistened cornstarch grains compressed at 10,000 psig. seen with polarized light (approximately 350×).*

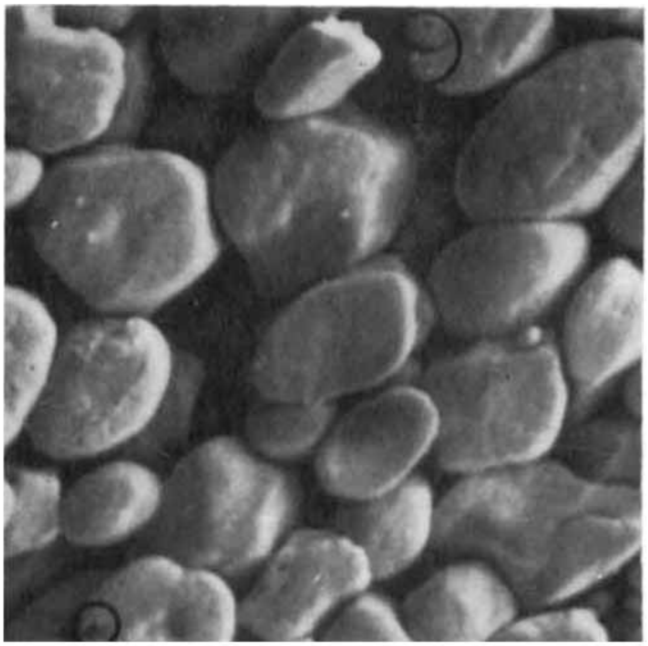

Figure 6—*Surface of a waxy maise starch tablet compressed at 2000 psig. (approximately 2300×). Circled areas indicate apparently damaged grains.*

and starch tablets were studied. Individual grains and tablets moistened with water were also investigated.

EXPERIMENTAL

Starch USP[1] and waxy maise starch[2] were the two starches used. Individual starch grains were compressed to 10,000 psig. between two microscope slides on a hydraulic press[3]. These grains are seen in Figs. 1 and 2. The photomicrographs using polarized light were taken of the same grains as those using bright field illumination.

To determine the effect of moisture on the compressed grains, the starch grains were compressed between two microscope cover glasses to 10,000 psig. on the hydraulic press. A cover glass with the adhering grains was placed over a drop of distilled water in the concavity on a culture microscope slide so that the grains were exposed to the moisture but not touching the water. The heat of the substage lamp slowly vaporized the water. The water vapor condensed on the cover glass and slowly moistened the grains. Photomicrographs were taken just as the grains became moistened (Figs. 3 and 4).

Very thin tablets, using 1.27-cm. diameter flat-faced punches and die, were made on the hydraulic press at 10,000 psig. The tablets

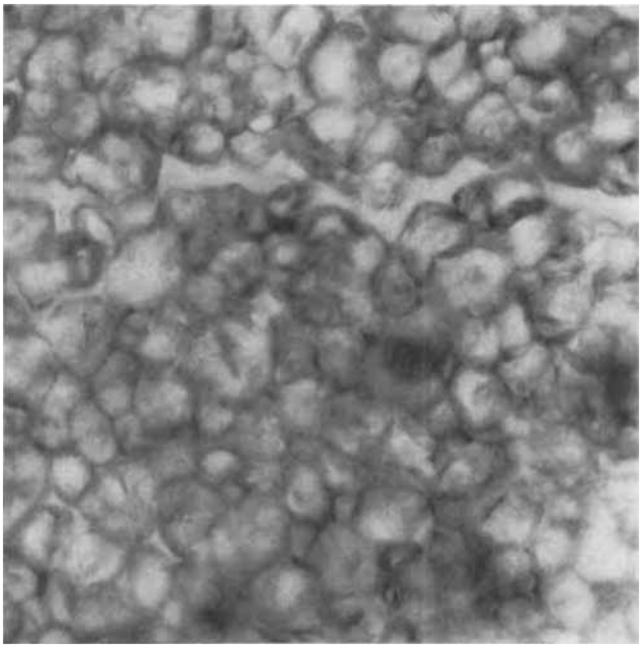

Figure 5—*Cornstarch compressed into a thin tablet at 10,000 psig. (approximately 560×).*

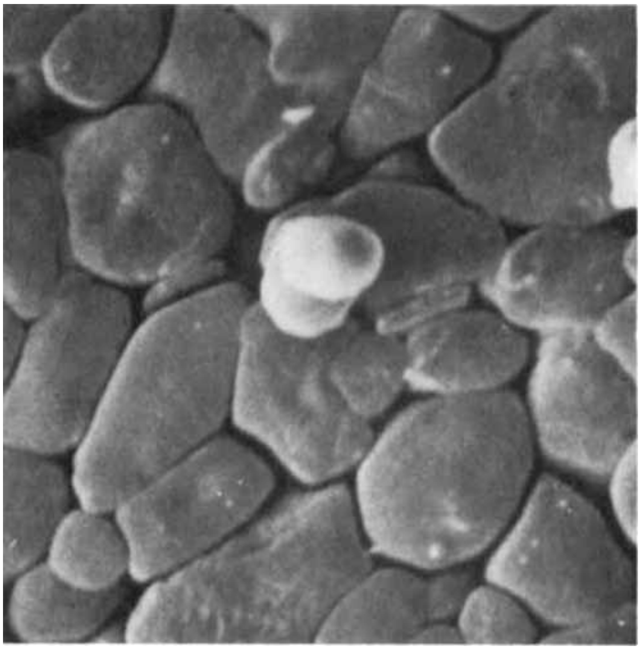

Figure 7—*Surface of waxy maise starch tablet compressed at 5000 psig. (approximately 2300×).*

[1] STA-Rx, Staley Mfg. Co.
[2] Amioca, National Starch and Chemical Corp.
[3] Carver Laboratory Press, model B, Fred S. Carver, Inc., Summit, N. J.

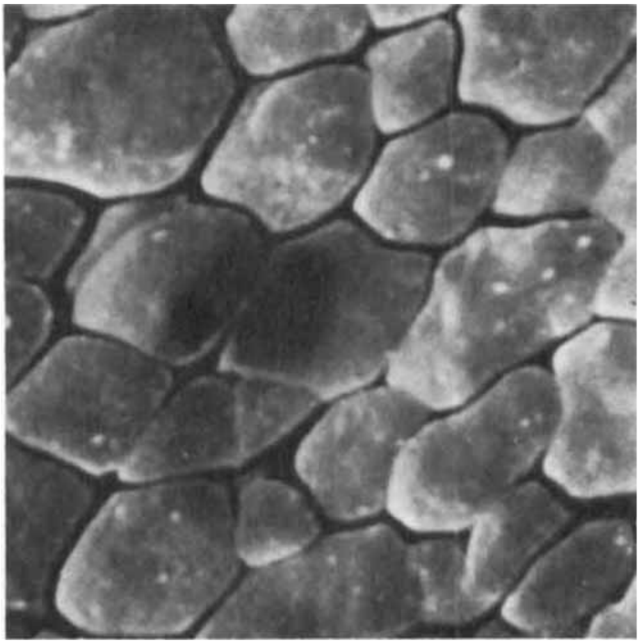

Figure 8—*Surface of waxy maise starch tablets compressed at 10,000 psig. (approximately 2300×). The white specks and black patch are processing artifacts.*

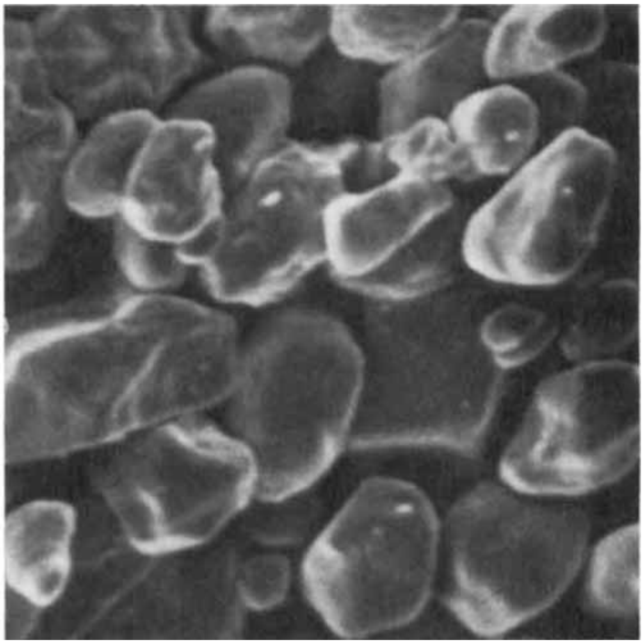

Figure 10—*Cross-sectional view of waxy maise starch tablet compressed at 2000 psig. (approximately 2300×).*

were made to determine grain deformation when the grains are cushioned by layers of other starch grains (Fig. 5).

Starch weighing 0.500 g. was compressed with 1.27-cm. diameter flat face punches and die on the hydraulic press to 10,000 psig. Pictures were taken of tablet surfaces (Figs. 6–9) and cross sections (Figs. 10–12) by a scanning election microscope[4] at 10 kv. Carbon and gold were used to coat the surfaces. The effect of moisture on the compacted starch was determined by placing a fraction of a milliliter of distilled water on the tablet surface (Figs. 13–18). Even though most of the moisture is subsequently removed during the evacuation that precedes the coating process, the effect of the moisture remains.

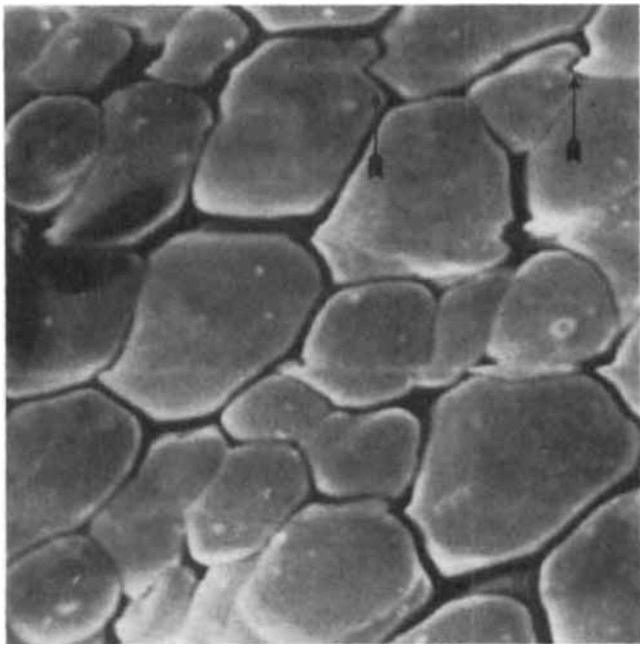

Figure 9—*Surface of cornstarch tablet compressed at 10,000 psig. (approximately 2300×). Arrows point to examples of how well the grains will deform to fill up the void spaces.*

[4] Japan Electron Optics Laboratory Co. Ltd., model JSM-5.

DISCUSSION

Figure 1 shows the deformation of the cornstarch grains. Figure 2 shows the same field using polarized light. The characteristic hilum can be seen in the deformed grains, indicating that the grain structure has not been destroyed. Figure 3 shows the compressed grains just as they became moistened. The background patches are due to the condensing water. The only noticeable difference seen was that the moistened grains appeared more translucent. Figure 4 again

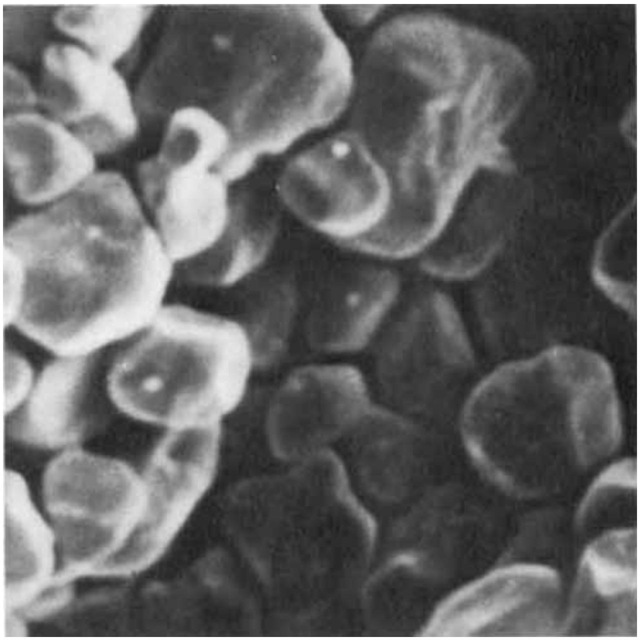

Figure 11—*Cross-sectional view of waxy maise starch tablet compressed at 5000 psig. (approximately 2300×).*

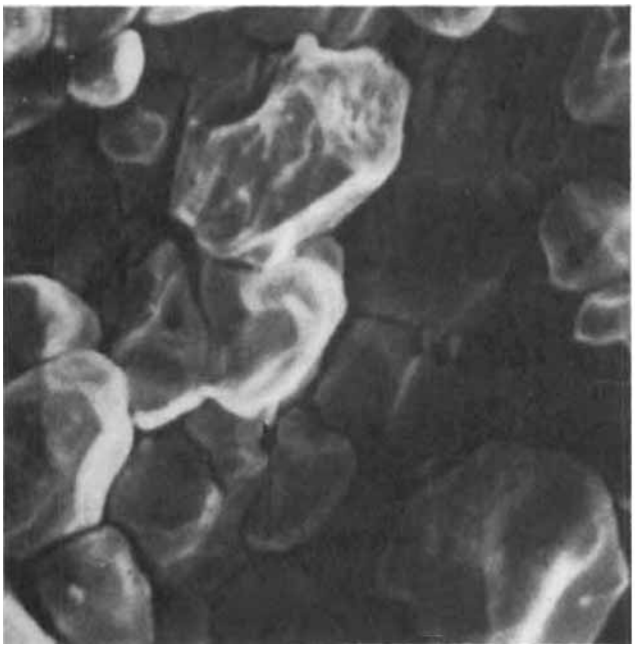

Figure 12—*Cross-sectional view of waxy maise starch tablet compressed at 10,000 psig. (approximately 2300×). Arrows point to examples of how well the grains deform to fill up the void spaces.*

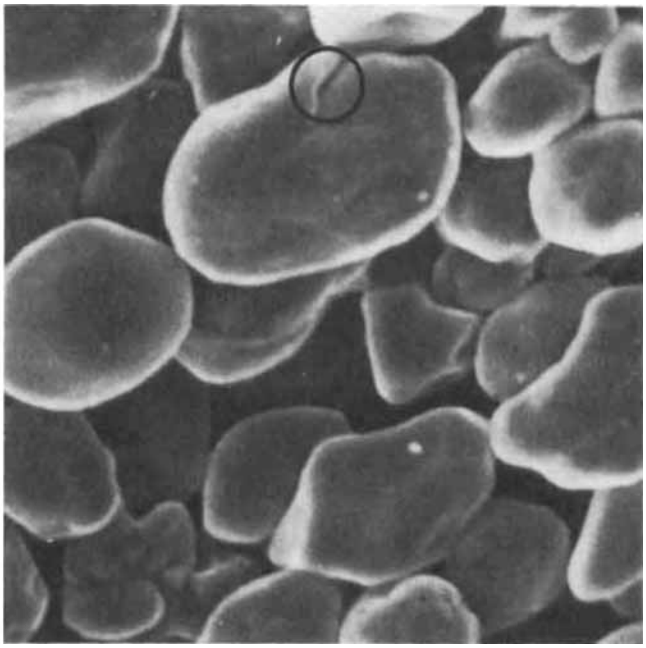

Figure 14—*Surface of waxy maise starch tablet compressed at 5000 psig., photographed after addition of water (approximately 2300×). Circled area appears to show a damaged grain.*

shows the hilum, again indicating the starch grain structure is intact. No noticeable swelling occurred in the deformed grains. When moistened the deformed grains do not regain their original shapes. The photomicrograph of the surface of the thin tablet shows the deformation of the grains (Fig. 5). This is readily apparent by observing the grains along the crack that appeared. Examination of individual grains from the tablet under bright field illumination and polarized light showed no noticeable differences from those seen in Figs. 1 and 2. Any damage to the grain structure is not discernible.

The light microscope has limitations as to magnification and the thickness of the sample that can be viewed. The scanning electron microscope allows a tablet of regular thickness to be used so that the effect of moisture on the tablet can be observed. Tablet cross sections can also be observed and higher magnifications can be obtained. This technique visualizes depth so as to give a "three-dimensional" view.

In Figs. 6–9, as pressure increases from 2000 to 10,000 psig., the grains on the surface become flatter and more deformed. They take the shapes necessary to fill the void spaces. At 5000 and 10,000 psig., the grains take on an appearance of a jig-saw puzzle. Figure 9 clearly shows how intricate the patterns may get. The results were the same for corn and waxy maise starches. The cross sections of the tablets (Figs. 10–12) show more of the depth (approximately

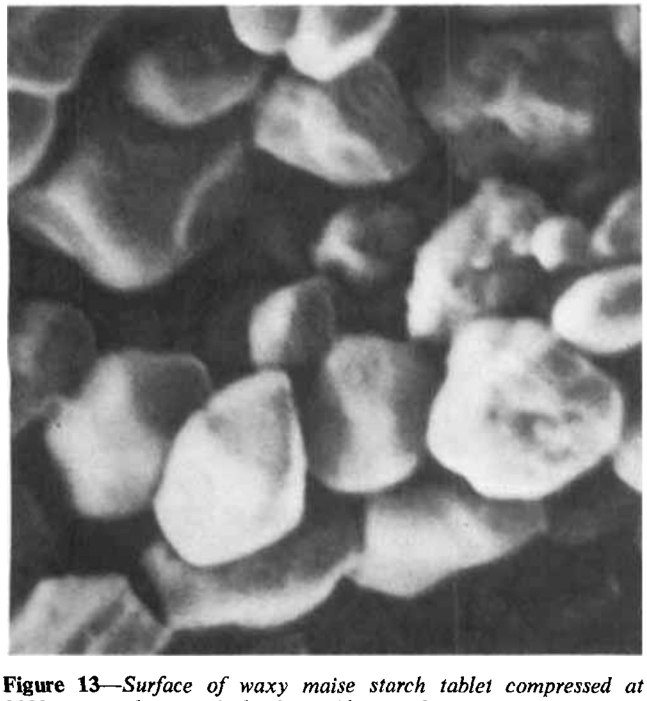

Figure 13—*Surface of waxy maise starch tablet compressed at 2000 psig., photographed after addition of water (approximately 2300×).*

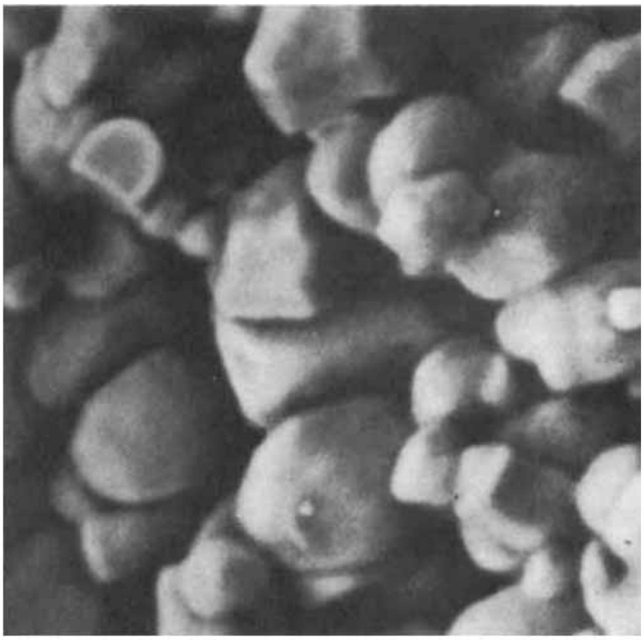

Figure 15—*Surface of waxy maise starch tablet compressed at 10,000 psig., photographed after addition of water (approximately 2300×).*

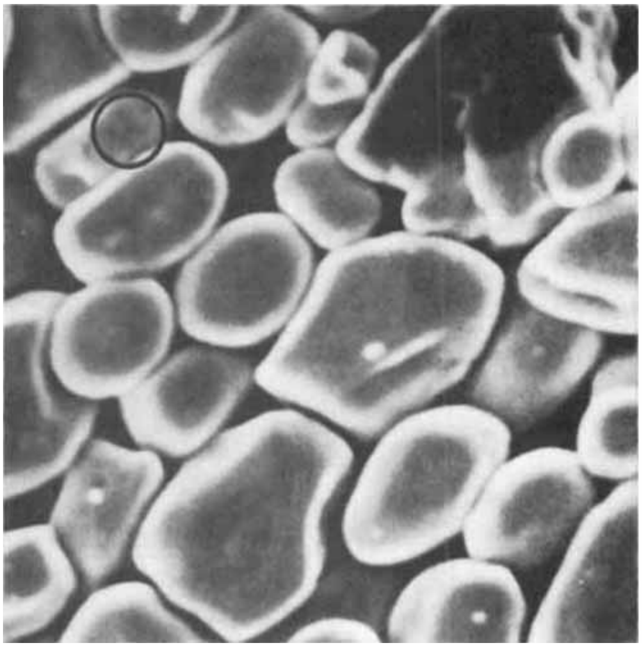

Figure 16—*Surface of cornstarch tablet compressed at 2000 psig., photographed after the addition of water (approximately 2300×). Circled area indicates the "pitted" appearance of some grains.*

Figure 18—*Surface of cornstarch tablet compressed at 10,000 psig., photographed after addition of water (approximately 2300×). Circled areas show "pitted" appearance of some grains.*

20 μ) and also how the grains deform to give the closest packing. The extent of deformation increases with pressure.

When water was added to the tablet surface, there was an immediate "swelling" or "blistering" effect. Figures 13–18 show that the packing of the starch grains, at all pressures, is disrupted. The smooth surface and pattern of grains neatly fitting together seen in Figs. 6–9 are no longer evident. The starch grains do not appear to regain their original shape but remain deformed. The tighter the initial packing, the greater is the disruption.

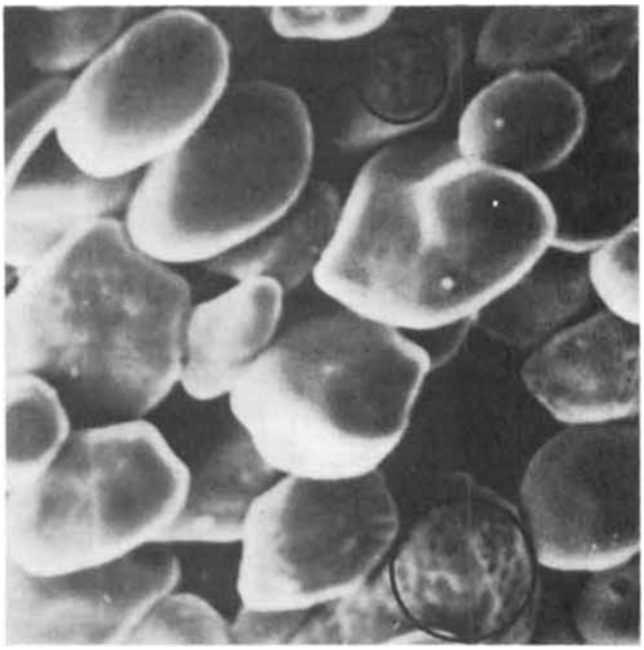

Figure 17—*Surface of cornstarch tablet compressed at 5000 psig., photographed after addition of water (approximately 2300×). Circled areas show "pitted" appearance of some grains.*

Close examination of the grains revealed that some of the grains moistened with water had a pitted appearance similar to a peach pit (Figs. 16–18). This was observed only rarely in nonmoistened grains. Any significance of this effect is not clear at present.

CONCLUSIONS

1. Both cornstarch and waxy maise starch grains deform when subjected to pressure.
2. Starch grains are sufficiently plastic to deform in all directions.
3. Starch grains deformed by pressure do not regain their original shape when pressure is released or when they are moistened with water.
4. Deformed cornstarch retains its birefringence.
5. The regaining of the shape of the starch grains after being deformed by pressure is apparently not an important mechanism of action of starch as a tablet disintegrant.

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