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Factors Affecting the Texture of Rehydrated Potato Granules[a,b]

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The effect of the various steps in the add-back manufacturing process on texture of rehydrated granules was studied. Conditions of cooking, mashing, mixing, aging, and drying affected the amount of cell breakage during processing and consequently the texture of reconstituted material. Differences in the appearance and manner of water resumption of two widely different samples are described. Improvement of texture was noted on addition of glycerol monolaurate during the mixing step.

Potato granules are a dehydrated product consisting of singe intact cells and cell agglomerates. The granulation or separation of the cells is usually accomplished by mixing previously dried powder with cooked potato to bring the over-all moisture content to 35 to 40%. The mixing serves to lower the moisture content of the cooked potato to a point where it is no longer adhesive and the cells can be separated without breakage. After a standing period, during which complete moisture equilibration takes place, the damp powder is given a second mix and dried in suspension in a stream of heated air. The equipment used at these laboratories has been described in detail *(1)*.

Potato granules, if properly made, have several advantages over other types of dehydrated potatoes. They have high bulk density and thus conserve shipping space. They are a fully cooked product and may be rehydrated for use by the addition of hot water. They are dried very rapidly. Even though the powder is recycled many times in the mixback drying process, the total time in the drying atmosphere is much less than that of potatoes in other dehydration processes. Less damage due to heat is therefore sustained.

A disadvantage is the recycling of a large proportion of the product for use as the granulating agent. Approximately 12 to 18% of new dry solids are added to the process during each cycle. This may result in cumulative damage. If, by mishap, improper conditions are used on one cycle, the product of many cycles may be damaged. A considerable amount of new material must then be added in diluting out the damaged material. Likewise, the change in quality of the raw material is not determined until a considerable amount of new material is produced. It is very important in producing potato granules that the process be closely controlled at all times and complete records be kept of conditions during processing.

PROCESSING VARIABLES

In the processing of potato granules, good texture has been very difficult to attain. The texture of the reconstituted granules should be mealy. The product should be tolerant to a wide range of water temperatures on reconstitution. It should absorb the water slowly enough so that a uniform mix can be obtained, but not so slowly that further thickening takes place on standing. In the usual method of preparing granules, 4 parts by weight of fluid are heated to 180° F. and one part by weight of granules whipped in by means of a fork or a mixer. It is advantageous to have granules of such nature that they can be reconstituted in water up to the boiling temperature. They can then be served hotter. A product having a wider range of tolerance to water temperature is also easier for the cook to prepare. Most of the potato granules prepared at the present time become pasty if reconstituted at temperatures above 180° F., and one of the objectives of this research was to determine the factors affecting texture and means of improving it.

The physical and chemical nature of the potato cells are affected by conditions during each step of the processing from the cooking to the drying step. A further complication is that certain processing variables are dependent upon other steps in the process and so must be radically changed to become compatible when another step in the process is varied.

Cooking. In the present study, whole potatoes were steam cooked at atmospheric pressure on trays. It was found that overcooking was quite detrimental to good texture. Potatoes which were peeled and which were exposed to condensate from the top of the cooker had much poorer texture and were difficult to granulate. Much better texture was obtained when washed, unpeeled potatoes were cooked. It was noticed, however, that the color of the resulting granules from unpeeled potatoes was darker than that of peeled potatoes. The unpeeled potatoes granulated better, and there was less 14- to 65-mesh material in the dried product. This was a decided advantage since coarse material because of its slow rate of drying is more easily heat damaged.

Since only material passing a 65-mesh screen is taken off as product, the 14- to 65-mesh material is always recycled, subjecting it to cumulative heat damage. This material must eventually be discarded if not broken down, thus impairing the economics of the process.

Mashing. After cooking, the potatoes may be mashed before mixing with dry material for granulation or the potatoes may be mixed and mashed in the same operation. In large scale operations, it has been found advantageous to mash between rolls set with a clearance of about 1/16 inch. Smooth rolls with a diameter of 24 inches will "nip" whole potatoes and do an efficient job of mashing. In the present study, roll mashing was not found to be practical for small batches. The rolls did not become heated, the material tended to "ride" on the rolls, and considerable cell damage took place. Condensation on the rolls from the steam in the potatoes caused considerable slippage and

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abrasion, and the potatoes were cooled by contact with the cold rolls. Excessive cooling before mashing caused case hardening, increasing the amount of oversize material produced.

Mixing and aging. It has been found necessary to employ 2 mixing periods separated by an aging period to attain proper granulation. In batch runs, a planetary food mixer was used; in continuous runs, a 6-inch conveyor having a central shaft fitted with paddle mixing blades served as a mixer. The aging period apparently served to allow moisture to equalize between wet and dry material, but this equalization was inadequate unless the preliminary mixing was thorough. If the second mixing period was eliminated, coarsening again occurred—perhaps because a certain amount of adherence between cells took place during the equalization. It was necessary to use great care to make sure that the mix was thoroughly cooled during aging to assure proper breakdown in the second mix. The amount of cooling was more important to proper granulation than the time of aging, suggesting that cooling was at least as important as moisture equalization in the aging step. It has been demonstrated many times that if the material is not at room temperature or below after aging, the amount of coarse material immediately rises.

The technique employed in mixing was greatly influenced by the rate of absorption of water by the dry seed material. A drier seed material proved slower to absorb the moisture, as did a coarser powder. The slower the moisture absorption by the powder, the gentler the mixing action necessary. The cooked material at high moisture was fragile and easily damaged. Water should be removed rapidly by the dry powder to increase the resistance of the cells to mechanical breakage. On the other hand, when an appreciable portion of the moisture of the wet material was lost before the cells were thoroughly separated, they could then be separated only with great difficulty. These cell aggregates tended to remain intact and were easily heat damaged in drying. The mixing efficiency of the mixer had its effect on the required mixing time. The small planetary mixer required less mixing than the larger continuous mixer.

Drying. The rate of drying of the damp powder determines its final bulk density and color and the characteristics of the reconstituted product. Pneumatic drying, or entrainment of the powder in a heated stream of air, provides the necessary drying conditions. The drying system used in the present study (Figure 1) consisted of 53 feet of vertical 8-inch duct, a constriction to 5 inches where the powder was introduced, and a cyclone dust collector for removal of the dried powder from the air stream. This system had the advantage of simplicity, but in the type of cyclone collector used in this study, there was a tendency of the coarser particles to be held in the air stream. This resulted in scorching due to longer exposure to the high temperatures. At the lower air velocities, because of faster drop out of coarse material, scorching was not so noticeable.

The centrifugal action in a cyclone is damaging to the potato granules. In a set of experiments in which the damp powder was introduced at the entrance to the cyclone, eliminating the passage through the air duct, the cell damage was sufficient to make the product pasty on reconstitution. Since the air velocity was not higher than that used when the material was dried in a duct and removed by the cyclone, it was concluded that the centrifugal action on the powder, while it was in the damp fragile condition, resulted in the damage. Some damage undoubtedly occurred in the cyclone in the duct system. This was minimized, however, by low air velocities and by the fact that the powder was quite dry by the time it reached the cyclone.

A drying system has been designed *(2)* in which the abrasion has been minimized. In this system no cyclone collector is employed to remove the dry powder from the air stream.

Better texture in the product was obtained when drying at 300° than at 250° F. Much higher temperatures (600° F.) resulted in puffing of a large proportion of the cells. These were quite fragile and could not be used as mixback material.

Rapid drying was advantageous in preventing heat damage in the powder. Since abrasion damage was greater at higher moisture contents, as discussed above, this damage should be decreased by faster drying rates. The rate of drying was determined by the moisture content of the powder and by the temperature and velocity of the air stream.

The air velocity in the pneumatic drying system was of great importance. Data presented in a previous paper *(1)* show that at an air velocity of 73 feet per second, excessive cell breakage

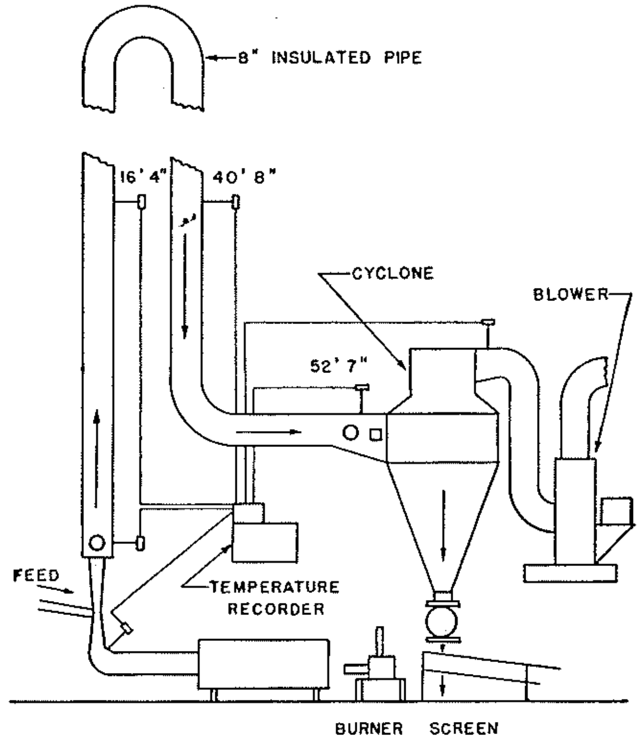

Figure 1. Diagram of drying system.

took place, but at an air velocity of 41 feet per second, the cell damage was slight in samples put through the pneumatic drying system ten times in succession. This indicated that the lowest feasible air velocity that will carry the material through the system should be used. Since the moisture content of the material decreased with each successive cycle, moisture content is a function of the number of cycles, as was shown in the previous paper. It was also shown that the greatest cell damage occurred at the highest moisture content of the damp powder.

To minimize cell breakage, a low air velocity in the drying duct was used, the current system being operated at about 30 feet per second. At these low air velocities, there was danger of material dropping down against the air stream at the point of introduction of the mix, and subsequent burning of the material. To minimize this possibility, the feed was introduced to the dryer into a constricted section (5 in. diameter as compared to 8 in. duct diameter in the dryer). Thus, the air velocity was considerably higher at this point than in the rest of the drying duct. This higher velocity should also facilitate the separation of the cells in the drying step.

PHYSICAL CHARACTERISTICS AND THEIR EVALUATION

Of the factors affecting the texture of reconstituted granules, one of the most intensively investigated has been the amount of extracellular starch. It was believed at the outset that pastiness and poor texture were primarily due to breakage of cells in processing, freeing starch to give a gummy texture to the product. It has been found, however, that cell breakage is not the only factor affecting texture. Samples of comparable broken cell content may have widely different texture depending on the physical character of the granules. It appears that more significant than broken cell content of the dry material is the susceptibility of this material to cell damage on reconstitution. The investigators are of the opinion that actually more cells are broken when the material is reconstituted than during the processing. Processing, however, markedly affects the susceptibility to cell damage during reconstitution.

The rate of absorption of water in reconstitution appears to be of great importance in determining texture. Poor texture is often associated with rapid regain of water. Samples which have been found best in texture and which show the lowest free starch content on reconstitution have been those which took the longest time for absorption of the moisture.

The extent to which the cells shrink affects the final texture. Those samples consisting largely of cells which showed a large difference between the cell size of the dried and reconstituted products had poorer texture than samples showing little swelling of cells on reconstitution. This factor in turn seems to be controlled by the rate of temperature of drying in the pneumatic system. Samples dried at higher temperatures (300° F. and up) gave better texture than those dried at 250° F. and showed less cell shrinkage on drying. The pH of the water of reconstitution also affects texture, a more alkaline water giving a poorer texture *(1)*.

The extracellular starch in the rehydrated product may be present as a result of damage during processing or damage during reconstitution. One of the shortcomings of the analytical test for free starch *(1)* is that it does not measure the susceptibility of the granules to breakage during reconstitution. Two products which showed approximately the same amount of extracellular starch by the iodine method *(1)* but which on reconstitution had very different texture characteristics were examined under the microscope at a magnification of 70X. (In the reproductions shown in Figures 2-9, magnification is 50X. due to reduction.) Product A, a commercial sample, which was known to have a very good texture even when reconstituted in boiling water, was compared with product B, a laboratory sample, which became quite pasty when reconstituted in water at 180° F.

A study of these two materials under the binocular microscope showed that product A in the dried state had an average cell size which was more than double that of product B. In addition, many of the cells of product A had been puffed in drying and were hollow. When these absorbed water, the starch swelled inwardly and filled the hollow portion. Many of these cells were open, and as the starch swelled, the air was forced out through these small openings. Product B swelled outwardly; when the starch was stained with iodine, it could be observed that the cell wall swelled faster and to a greater degree than the intracellular starch. Mechanical stirring of product A had little effect upon it; but in product B, the intracellular starch shelled out of the cell wall quite easily. Even when the cells of product A were crushed, there was no observed separation of cell walls from the starch therein.

Figures 2 and 3 of products A and B, respectively, at the same magnification show the difference in appearance of the dry material. Product A shows puffed, rounded cells appearing very much like a spray dried product. This effect can be produced during very rapid

Figure 2. Product A, dry material.

Figure 3. Product B, dry material.

drying at high temperatures. The cell is prevented from shrinking and may even swell due to rapid vaporization of water in the interior. Product B was dried slowly and showed none of these "puffed" cells.

Figures 4 and 5 show products A and B, respectively, during the absorption of water. Product B takes up water extremely rapidly with considerable swelling. Product A does not increase greatly in cell size upon absorbing water. The swelling of the starch takes place by filling of the hollow portion of the cell. Air bubbles may be seen in a large proportion of the cells. As water absorption continues, these are forced out through

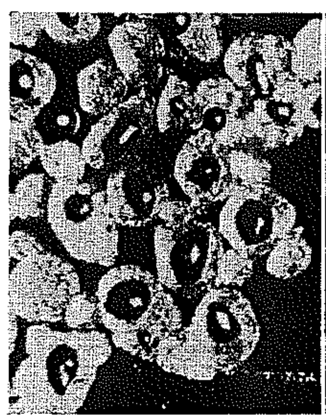

Figure 4. Product A, absorbing water.

Figure 5. Product B, absorbing water.

openings in the cell walls. Even though there are cell wall openings, the starch remains within the cells and the texture is not adversely affected.

Figures 6 and 7 show products A and B, respectively, after moisture absorption is completed and cells are stained with iodine. It will be noted that cells of product

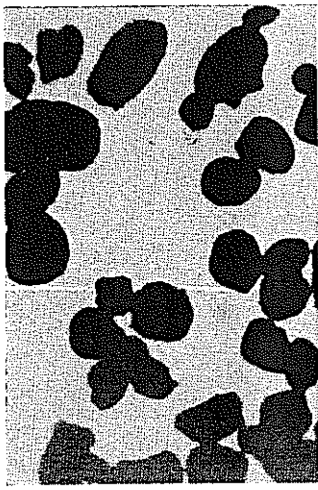

Figure 6. Product A, after staining.

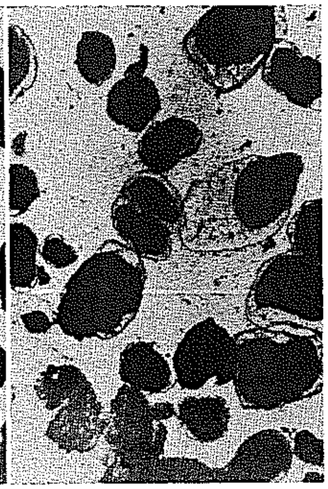

Figure 7. Product B, after staining.

A are completely filled with starch, whereas many cells of product B have swelled and are only partly filled with starch.

Figures 8 and 9, respectively, show product A after severe mechanical abrasion and product B after less severe breakage. No separation of cell wall from starch can be seen in A, but many cell walls, which have been loosened and separated from the starch, are visible in product B.

Considerable effort has been expanded at these laboratories on a method for evaluation of texture by determination of the viscosity of reconstituted samples. This procedure, described in detail in a previous paper *(1)*, consists in careful preparation of a uniform sample of reconstituted product of a definite moisture content and at a definite temperature, and subsequent determination of its viscosity with a Brookfield Synchro-lectric

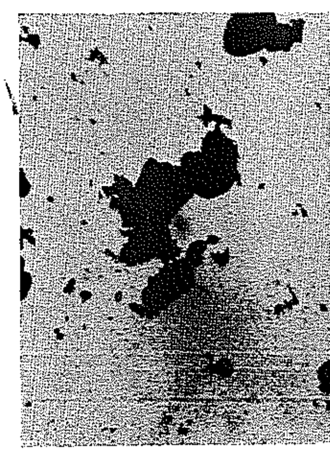

Figure 8. Product A, after abrasion.

Figure 9. Product B, after abrasion.

Viscometer in conjunction with a Brookfield Helipath Stand. Viscosity is determined from the torque on a rotating T-shaped spindle, and the helipath stand lowers the rotating spindle at a constant rate into the material, thus placing always fresh material in the path of the spindle.

The conclusion was advanced in the previous paper *(1)* that the value of the peak viscosity is of little significance in comparing samples from different sources. The significant property is the shape of the viscosity-reconstitution temperature curve. Samples which showed a viscosity peak at a low temperature of reconstitution were found to be pasty and poor in texture. This property has been correlated to some extent with broken cell content. An ideal sample would be expected to show a viscosity maximum at a high temperature and to have a broad peak.

Examination of Figure 10 will show extremes in viscosity profiles that have been found in laboratory samples made here. Sample A, an older product, was found on reconstitution to give a poor, pasty texture. Samples B, C, and D had good texture, and show a continuous increase in viscosity with increasing recon-

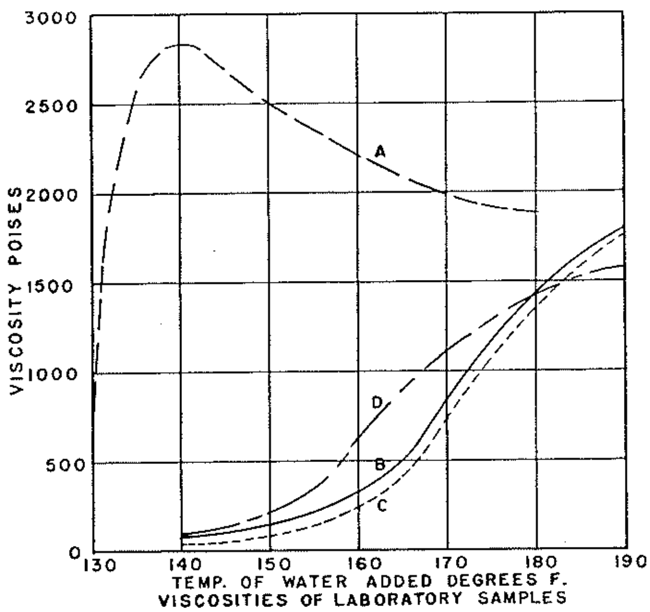

Figure 10

stitution temperature. Samples B and C were treated with 0.25% and 0.50% glycerol monolaurate, respectively, and showed the best texture when reconstituted.

The differences in processing technique between Sample A and the others include the following: (a) The potatoes for Sample A were peeled and mashed before mixing; the others were not peeled and were mashed during mixing, for reasons mentioned in the discussion of the cooking step. (b) Sample A was dried at 250° F., the others at 300° F. (c) Sample A was aged 45 minutes, the others one hour. In the later runs, great care was taken that the samples were cooled to room temperature or below before drying. (d) The moisture content of the damp powder immediately before drying for Sample A was 37%; for the others, 42%.

The viscosity profiles of several commercial samples are compared with Sample B from this laboratory in Figure 11. Sample E gave poor texture on reconstitution, as evidenced by the low temperature of maximum viscosity. Samples F and G both gave good texture, Sample G having the best quality at high water temperature.

Glycerol monolaurate. The effect of the use of glycerol monolaurate as an addition agent during the processing was studied with encouraging results. Samples B and C of Figure 10 contain 0.25% and 0.50% (dry basis), respectively, of glycerol monolaurate. This material introduced no difficulties in processing and was successfully processed at 43% mixback moisture in the batch process. It was added as a water suspension during the first mix. The color and flavor of reconstituted product were as good as that of the control sample (D). The treated samples could be reconstituted at 180°, and showed the best texture and mealiness of any materials yet produced at these laboratories.

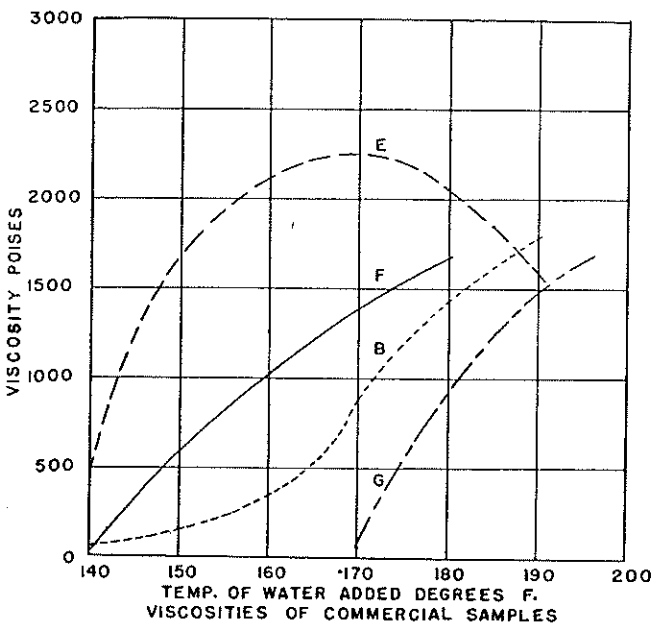

Figure 11

A clue to the action of glycerol monolaurate might be found in the behavior of such substances toward the linear A-fraction of the starch, which has been stated to be the primary cause of pasty texture. In reference to separation of starch fractions, Schoch *(3)* says, " . . . when a starch sol is treated with polar organic substances containing a hydrophilic group (such as hydroxyl or carboxyl) attached to a hydrophobic residue, the A-fraction adsorbs this material by polar attraction for the hydrophilic group. The resulting absorption complex is insoluble by reason of its hydrophobic leading and consequently separates from solution."

SUMMARY

Effect of certain operating variables on the texture of reconstituted potato granules is given. Overcooking affected texture adversely, but cooking without peeling was beneficial. The mixing equipment and speed of mixing must be chosen carefully to be compatible with the rate of moisture exchange between recycle granules and freshly mashed potatoes. Cooling of the mix during the aging step is essential to fine granulation. High rates of drying improve texture, but very high air temperatures give poor texture. High air velocities cause cell breakage in the pneumatic drying, the damage being greatest when the moisture content of the powder is highest.

Alkalinity of reconstitution water affected texture, lower pH giving better texture. The shape of the viscosity-reconstitution temperature curve was indicative of the manner in which a sample will reconstitute. Glycerol monolaurate gave much improved texture when added in amount of 0.25% on a dry basis. In general, the higher the rate of water absorption by the sample, the poorer the texture.

LITERATURE CITED

1. Cooley, A. M., Severson, D. E., Peightal, D. E., and Wagner, J. R. Studies on dehydrated potato granules. *Food Technol.*, 8, 263-269 (1954).

2. Neel, G. H., Smith, G. S., Cole, M. W., Olson, R. L., Harrington, W. O., and Mullins, W. R. Drying problems in the add-back process for production of potato granules." *Food Technol.*, 8, 230-234 (1954).

3. Schoch, T. J. "The Fractionation of Starch," from *Advances in Carbohydrate Chemistry.* 1945, Vol. 1, Ed. by Pigman, W. W., and Wolfram, M. L. Academic Press, New York.