The Susceptibility of Different Starches to Digestive Ferments.

By W. E. Stone.

The question of the nutritive value and digestibility of many kinds of foods narrows down practically to a discussion of the amount of starch which they contain, since in many instances starch is the principal nutritive substance present. A knowledge, therefore, of the percentage of starch which such foods contain is about all we have been accustomed to ask in estimating their comparative value. Examples of such food materials are potatoes and rice, while the various cereal preparations are also characterized by their starch content, although this is not the only nutritive substance which they contain.

It has apparently not occurred to any one, or if so, such conjecture has not found circulation, that possibly there might be an inherent character in different starches by reason of which certain ones might be more or less digestible or nutritious than others. In the case of sugars this thought has lately come prominently to the front, Fischer particularly expressing the belief that certain sugars were more readily assimilated than others. Certain classes of sugars are known not to be digested or assimilated by the human organism. Certain others are not fermentable, and others ferment only slowly and incompletely. A study of the action of animal secretions, such as blood serum and infusions made from various glands, upon the more complex sugars, shows conclusively that different sugars exhibit a greatly varying range of resistance to these agents.

It would seem, therefore, quite reasonable to expect that the starches existing in so many physical modifications and derived from so many different sources might also present some phenomena of this sort. A very serious difficulty, however, in the way of obtaining experimental data to show this is that starch considered as a chemical compound is an exceedingly complex and unstable substance, which under the influence of not extreme conditions is easily changed into other and different substances. Few compounds have been studied more than starch, and yet we know actually very little about it as such. We know much of its derivative and decomposition products, but starch itself is insoluble in its unchanged state, and so defies any direct study of its molecular condition.

It is well known that starch is readily dissolved and at the same time converted into sugar by a number of the so-called enzymes or unorganized ferments. Prominent among these are diastase, one of the enzymes developed in the germination of grains; ptyalin, a characteristic constituent of saliva, and pancreatin, secreted by the pancreas. So far as the digestion of starch is concerned these are probably the principal agencies which change starch from its natural, insoluble form into the soluble and digestible modifications, and a study of their action upon starches ought to throw considerable light upon the comparative degrees of resistance of different starches to digestive action.

Such studies have been made with the coöperation of several students and at different times, leading to results which seem of general interest and application. As material for one study we selected the starches of wheat, maize, rice, the common potato and the sweet potato, as representing not only important food articles, but starches of different botanical character.

These were prepared in the laboratory in preference to using commercial preparations, with the attendant risk of adulteration. Moreover, acids and alkalies are commonly used in the preparation of the starch of commerce, and undoubtedly affect its character. The five kinds of starches were prepared by grating or grinding the raw materials, agitating with cold water, straining through coarse muslin and afterwards allowing the starch to settle from suspension in water after frequent washings. The materials thus obtained were probably quite pure starches, and at least were sufficiently free from impurities or foreign matter to satisfactorily serve the purpose of the experiment.

The plan of the investigation was to subject the different starches under identical conditions to the action of a ferment, and note the time when each kind of starch had been completely dissolved. As an indication of this result the well-known action of starch and iodine was employed. When the starch preparation no longer showed the blue color with iodine it was regarded as completely dissolved or changed.

Exactly stated, it was endeavored to obtain an identical physical condition of all the starches, and then to expose them under constant conditions of temperature and dilution to a uniform solution of the enzyme or digestive ferment.

A weighed quantity of the starches, one gram, or in some cases one-half gram, was heated with 50 or 100 cubic centimeters of distilled water in a boiling water bath during 30 minutes and then cooled to 65° C. An infusion of malt was made by digesting five grams of malt with 200 c. c.

of water at ordinary temperature for two or three hours. Ten cubic centimeters of this malt infusion were then added to each of the starch preparations, which were kept at from 60 to 65° C. The starches were all dissolved in the following order: Sweet potato, 6 to 8 minutes; common potato, 12 to 15 minutes; wheat, 60 to 90 minutes; maize, 90 to 120 minutes.

On diluting the starch in a subsequent series, using the same amount of malt infusion, the time of solution was much reduced, but followed the same relative order. In another series a larger amount of malt was used, and the time of solution was still shorter; for instance, the sweet-potato starch was completely dissolved in $2\frac{3}{4}$ minutes; potato starch, $3\frac{1}{2}$ minutes; wheat, 30 minutes; maize, 38 minutes. These results indicate very conclusively a decided difference in the behavior of these common starches toward diastase.

Similar experiments were then planned with these starches, with the addition of rice starch, and ptyalin, one of the active principles of the saliva.

At first raw starch was employed, but it seems to suffer little or no change even after some hours. Boiled starches, prepared as already described, received each two cubic centimeters of saliva and were kept at a temperature of 40°. After six minutes the potato starch no longer gave any iodine reaction: the sweet potato required 135 minutes; the maize, 145 minutes; rice, 385 minutes; wheat, 400 minutes. By increasing the amount of saliva to six cubic centimeters the following results were obtained: Potato, 3 minutes; sweet potato, 70 minutes; maize, 90 minutes; rice, 165 minutes; wheat, 170 minutes.

On increasing the temperature to 60° potato starch was almost immediately dissolved in two minutes; sweet potato, 25 minutes; maize, 35 minutes; but rice and wheat were not wholly converted in five hours, indicating that a continuation of this temperature for any considerable time destroys the activity of the ferment.

These results were no less striking than those obtained from diastase, although the order of conversion is changed somewhat. Wheat required about 80 times as long for complete solution as potato.

The experiments with pancreatic ferments were carried out in the same way as already described, so far as the staches were concerned. Using commercial preparations of pancreatin at the rate of .2 grams to .2 grams of the starches gave these results: Potato starch was dissolved in 58 minutes; sweet potato, 317 minutes; maize, 337 minutes; rice and wheat not wholly changed after 10 hours. Fresh preparations of pancreatic fluids from the pancreas of both the ox and swine showed that starches of potato, sweet potato and maize were dissolved in the order stated, while rice and wheat were much more resistant and were not finally completely dissolved.

Pancreatin seemed less active than the other ferments, but certain of the starches were much more susceptible to it than others.

To sum up briefly the result of many experiments, which have here been presented only in outline:

(1) The starches of potato, sweet potato, maize, rice and wheat vary greatly in their susceptibility to the action of enzymic ferments.

(2) This variation reaches such a degree that under precisely the same conditions certain of the starches require eighty times as long as others for complete solution or saccharification.

(3) This variation is exhibited toward all of the common enzymic ferments studied, viz., diastase, ptyalin, pancreatin, in the same relative order, with slight exception.

(4) This order, beginning with the starch which is most easily changed, is, for malt extract, sweet potato, potato, wheat and maize; for saliva, potato, sweet potato, maize, rice and wheat; for pancreatic fluids, potato, sweet potato, maize, with wheat and rice unchanged.

(5) Certain of the experiments indicate that the rapidity of the change in particular cases is very clearly proportional to the concentration of the solution of the ferment.

(6) It seems reasonable to assume that the same relative degree of susceptibility exhibited by these starches in the experiments described would still obtain when they are subjected to the action of the same enzymes in the processes of digestion.

(7) The facts here presented have very important bearings upon industrial operations involving the use of starches, upon questions of physiology and nutrition and upon the study of the different starches from the purely scientific standpoint.

In seeking for some explanation of this phenomena only two possible causes suggest themselves—either there is some physical difference in these starches by which the action of the ferments is hindered or held in check, or they are inherently different in their molecular structure, or in other words, are isomeric compounds. The first reason seems to me not a valid one. The starches were in each case thoroughly gelatinized by boiling so as to break up the individual grains and form a transparent gelatinous mass, afterward diluted with water, so as to afford a complete mixture with the solution of the enzymes. The second hypothesis seems reasonable, since we already know that different sugars perfectly soluble are nevertheless quite differently susceptible to the action of ferments and enzymes, and the reason is traced directly to their isomeric condition, i. e., to different molcular constitution. There is certainly nothing improbable in the thought that a similar variation or isomerism exists among starches. Should this explanation, which now seems the only reasonable one to offer, be correct, the theoretical value of the observations presented will quite equal or exceed any practical application they may possess, since the possibility of isomeric starches has not heretofore been entertained.

A New Photo-Micrographic Apparatus. By A. W. Bitting.

While it is possible to make excellent photo-micrographs with simple apparatus, a microscope, a camera with a ground glass and a few books cr blocks to make the necessary adjustments, such arrangements are inadequate for laboratory work. To meet the needs of the laboratory many forms of apparatus have been devised, some of which are admirably adapted to the particular work for which they are intended. Most of them have a limited range of adjustment and not well adapted to all kinds of work.

The object of the writer in constructing a new apparatus was to get one more nearly adapted to all laboratory conditions than is now provided.

The requisites of a good photo-micrographic apparatus are rigidity, ease and accuracy of adjustment and adaptibility to all kinds of work. The first condition has been met by using metal in the construction, thus obviating shrinking, swelling and warping, inherent qualities of wood. The second and third requirements have been met in the mechanical construction.

The cut shows the stand in working order in the inclined position. The apparatus consists of an upright cast-iron post supported by three cast legs. The center of this post is bored out to receive the elevating post. Near the top is a sprocket wheel, which is turned by a screw and crank. A binding screw is also placed in the top to clamp the elevating post in position. The upright post, with its legs, stands 28 inches high. The