WATER UPTAKE OF BEAN AND OTHER STARCHES AT HIGH TEMPERATURES AND PRESSURES[1]

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ABSTRACT

The water uptake of six bean starches at temperatures between 80° and 148°C. was measured. Water uptake differences between starches were small over this temperature range. All of the bean starches appeared to have a water uptake maximum at approximately 121°C. Also, there seems to be a secondary maximum water uptake at a higher temperature. The water uptake of starches from potato and white waxy corn was also determined.

The literature contains relatively little information on water uptake or solubility of *Phaseolus* bean starches at temperatures higher than 100°C. Kurtzman et al. (1) have demonstrated that the pattern of bean starch solvation in dimethyl sulfoxide is characteristic of the species, variety, and maturity of the plant of origin of the starch. Schoch and Maywald (2) have reported on the swelling power of some legume starches. Swelling power of other starches at temperatures below 100°C. has been reported on by a number of authors (3–6). Still other authors have reported on the water sorption and surface area of starches (4,7–9).

The present experiments were undertaken to determine if water uptake could be correlated with solvation in dimethyl sulfoxide, and to compare and contrast the water uptake properties of bean starch with other starches. The method of Kite et al. (3) appears to be an excellent method for such determinations. Unfortunately it is not easily adaptable to the high temperatures and pressures required for water uptake in our experiments.

In the present communication, data are presented showing water uptake per gram and solute per milliliter for bean starches at elevated temperatures and pressures. Data from potato and white waxy corn starches are included for comparison and contrast.

MATERIALS AND METHODS

Starches

The bean starches were prepared in this laboratory by the method of Watson (10), except that no 325-mesh screen was used.

The potato starch was a commercial preparation from Mallinckrodt.

The white waxy corn starch was prepared by the Northern Regional Research Laboratory, Peoria, Ill., using a sulfite steep.

Determination of Water Uptake

A sample (0.5 g.) was weighed into a tared 50-ml. stainless-steel centrifuge tube. Fifteen milliliters of water was added to the sample, and mixed gently. The centrifuge tubes were covered with aluminum foil to reduce evaporation, then

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[1] Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

placed in the autoclave (108° to 121° C.) or retort (126° to 148° C.). The samples were heated for 1 hr. The time required to reach the desired temperature and the time required for the temperature to cool below 100° C. were not part of the heating time. These times were much shorter for the small retort than for the autoclave.

Samples heated at 80° C. were weighed into a 15-ml. Corex tube. Ten milliliters of water was added then mixed gently. Samples were then heated in an oil bath (Hallikainen Instruments).

All samples were cooled to room temperature then put into a refrigerator overnight to equilibrate. The samples were removed from the refrigerator, and centrifuged at 12,100 × g in a Sorval RC-2 for 10 min. The supernatant was decanted then tested for total carbohydrates; the solids were weighed to determine water uptake. Water uptake was calculated as the total weight of sediments remaining in the tube per gram of anhydrous starch.

Carbohydrate analysis was done by the method of Hodge and Hofreiter (11) using phenol-sulfuric acid. The results were calculated as carbohydrate solute per milliliter of supernatant.

Calculations

Water uptake at each temperature indicated is the average of three or more determinations. The first determination was a single replicate. The second and subsequent determinations were the average of three replicates.

RESULTS AND DISCUSSION

It was originally thought that bean starch uptake of water would parallel swelling power. A recent article by Schoch and Maywald (2) gives the swelling power of some legume starches for temperatures below 100° C. The differences between their data and our data at 80° C. are substantial. However, water uptake as used in this paper is very different from swelling power. We have been able to repeat their experiment at 80° C. and in doing so established that there are three

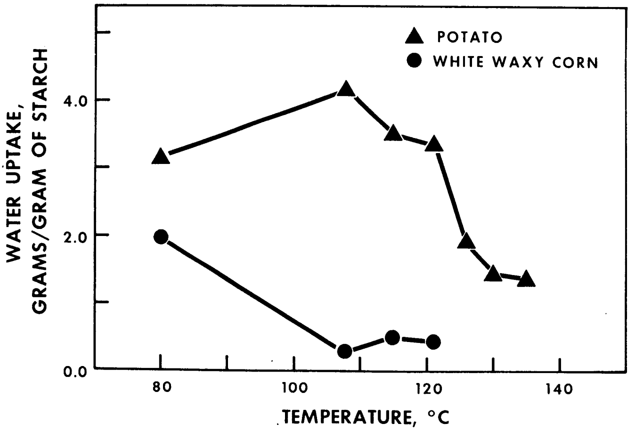

Fig. 1. Water uptake for white waxy corn, and potato starches from 80° to 135° C.

major differences due to the methods:

1. By our method, the samples were centrifuged after equilibrating overnight in a refrigerator. This gives more supernatant than centrifuging immediately after heating. Hence, swelling power was greater than water uptake.
2. Centrifuging at 12,100 × g will give more supernatant than centrifuging at 700 × g. The greater speed showed up as less apparent solubles, and less total gel weight. This is important because it contrasts a difference in the solubilities by the two methods.
3. Calculation, by our method, does not subtract the solute from the original sample. This may make water uptake appear the opposite of swelling power. When a sample approaches complete solubility, swelling power becomes very large, but water uptake becomes very small.

The objection may be raised that overnight storage of the starch allows retrogradation. However, starch does not require long storage to begin retrogradation; instead, retrogradation begins as soon as the starch begins to cool after gelation. Measurable retrogradation occurs within 1 hr. after autoclaving (12). Thus, it is unlikely that any measurements have been made on starches entirely free of retrogradation. We have chosen to give the starch time to come to a near-equilibrium state rather than to take measurements while rapid transitions are in progress.

Figure 1 shows that water uptake of potato starch increases with temperature in the lower range, and then decreases at an increasing rate. The white waxy corn starch shows a decrease in water uptake over the entire temperature range. It apparently reached a maximum water uptake at less than 80° C. Figures 2 and 3 show no evidence that bean variety had a major effect on water uptake over the entire temperature range. Water uptake for all varieties reaches a maximum at close to 121° C. With the possible exception of the green Fordhook, all of the bean starches seem to have a secondary water uptake maximum from 130° to 135° C. Even the green Fordhook appears to have a slight shoulder at the secondary water uptake temperature. The secondary water uptake maximum for the California small white is not pronounced, but the shoulder seems to indicate a definite second peak.

Bimodal swelling has been reported in other starches. Two sets of bonding forces have been suggested as the reason for this phenomenon (2,4). According to Badenhuizen (13), larger granules swell before smaller ones, and different rates of heating result in different gelatinization temperatures. The change from the autoclave to the retort makes the heating rate a tempting hypothesis. However, Badenhuizen suggests that the faster rates of heating, as in the retort, should lower the gelatinization temperature. The bean starches showed an increase in water uptake immediately after change over to the retort, but it was assumed that the heating rate was not the only cause of the secondary water uptake maximum.

Figure 4 shows wide differences in the amount of solute per milliliter at temperatures higher than 121° C. The amount of solute per milliliter was small for the bean starches until the water uptake reached a maximum. The secondary water uptake maximum peak has no obvious effect on the rate the solute goes into solution. To simplify the figure, only two bean starches—green Fordhook and California small white—are shown. However, all of the other bean starches were assayed and the average amount of carbohydrates in solution for each lies between the green Fordhook and the California small white bean starch curves.

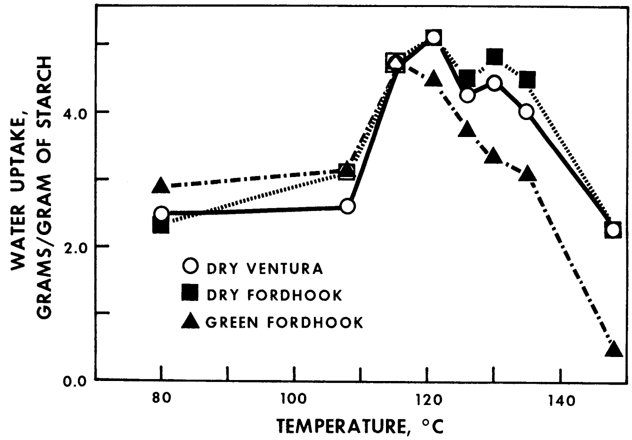

Fig. 2. Water uptake for three lima bean starches from 80° to 148°C.

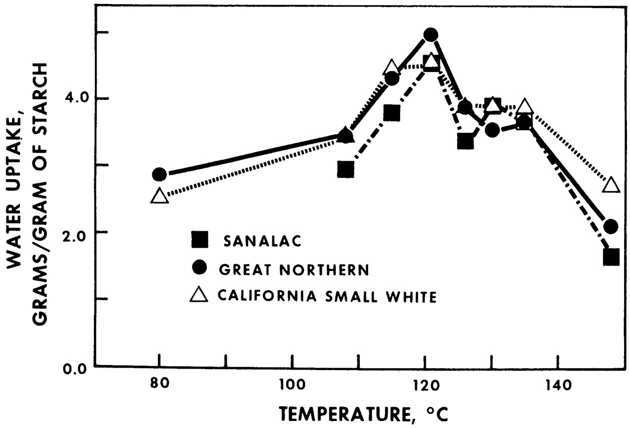

Fig. 3. Water uptake for three navy bean starches from 80° to 148°C.

Some correlation can be seen between the amount of solute per milliliter of water and the amount of solute per milliliter of dimethyl sulfoxide (1). The order of relative solubility is the same in both solvents. White waxy corn starch was the most readily dissolved in both solvents, followed closely by potato starch; with lima bean starches much less readily dissolved, and the navy bean starches the least easily dissolved. Solvent uptake does not correlate as well. The white waxy corn starch takes up water most easily followed by potato starch. The uptake of dimethyl sulfoxide by white waxy corn starch and potato starch differed only slightly. The bean starches were the most difficult to solvate in both solvents, but in dimethyl sulfoxide they varied more widely on the basis of their origin (1). This is in general agreement with the data of Leach and Schoch (14,15).

The data presented here show that bean starches were more resistant to water

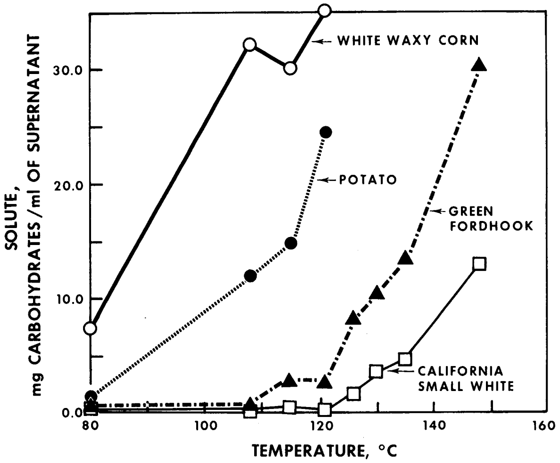

Fig. 4. Dissolution of starches from 80° to 148°C. The points for all other bean starches fall between those shown for green Fordhook and California small white. The lima bean starches were generally more soluble than the navy bean starches.

uptake, and gave less solute per milliliter than do many cereal and root starches (3,5,6). The high temperatures required for maximum water uptake suggest one reason beans require long cooking times. These properties of bean starches that appear to be a handicap could prove to be an asset for thickening foods that require high temperatures or prolonged heating during processing.

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[Received October 9, 1973. Accepted July 10, 1974]