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Water Absorption During Reconstitution of Dehydrated Fruits and Vegetables[a]

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Effects of two variables were noted on rate and amount of water absorbed during reconstitution of certain dehydrated fruits and vegetables. Increase in initial temperature of water resulted in slight increase in percent water absorbed in most cases, especially in the early stages of reconstitution. Increase in ratio of water to product resulted in a similar tendency. Taste panel ratings showed that within the limits of amounts of water absorbed in these experiments, the percent absorption had little effect in most cases on the palatability of the reconstituted product.

In spite of the fact that numerous directions for rehydrating and cooking fruits and vegetables may be found in special bulletins *(6, 7)*, in food journals *(1, 4)*, and in recommendations from manufacturers, extensive studies concerning the problem are rather scarce, and information necessary for establishing standard methods is incomplete. As a result, procedures recommended often differ greatly from one source to another, even for the same type of product. Since a product may vary from poor to excellent according to the method of reconstitution, the importance of optimum conditions for reconstituting dehydrated products is evident.

Factors that may affect the quality of dehydrated fruits and vegetables during reconstitution are many: period of soaking (if any), temperature of water, ratio of water to product, rate of heating, and length of cooking period are some of the more important examples. Only limited work concerning these factors is reported in the literature and the findings are sometimes controversial. For instance, Davis and Howard *(2)* recommend soaking of carrots at room temperature before boiling in order to obtain higher percentage of water absorption and better finished products. Fenton and Gifft *(3)* on the other hand, reported no appreciable difference in the amount of water absorbed in cabbage or potatoes according to whether or not the products were soaked. Working with other products such as beets, rutabagas, and yellow turnips, these investigators obtained greater water absorption by soaking, but soaking was not considered helpful since the palatability of their products was judged highest for unsoaked vegetables and for those soaked for short periods, whereas it was lowest for those which were soaked for a longer period (2½ to 7 hours). Apparently, the inherent nature of individual products is an important factor in determining their response toward various treatments during reconstitution; therefore, the need for studying a large number of products is further indicated.

It is evident that the optimum amount of water required for reconstitution depends largely on the product. Too little water will be expected to slow down the rate of water absorption, due to the smaller surface area in contact with water, and it may also result in an inferior product and increase the probability of scorching at a later stage of reconstitution. However, large quantities of surplus water should be avoided because flavoring materials and valuable nutrients such as water-soluble vitamins and minerals may be lost to a large extent.

The temperature of water to be used for soaking and cooking is another problem for consideration. Higher temperature permits faster rate of water absorption and hence reduces total time required for reconstitution. On the other hand, whether or not the increase in rate will result in a larger amount of final water absorption and how the increase affects the palatability of various products are unanswered questions at the present time.

The chief purpose of this study has been to determine the amount and rate of water absorption during the reconstitution of certain dehydrated fruits and vegetables under different conditions. The variables included have been the ratio of water to dehydrated product and the initial temperature of the water. Although it has been reported that palatability increased with increase in water absorption during reconstitution only up to a certain stage, and that further absorption of water gave unfavorable effect, it should be realized that the products were not compared at similar stages of cooking *(3, 5)*. The lower score could well have been the result of overcooking or under-cooking. Therefore, a few limited tests have also been conducted in the present study to note the relationship between the percent of water absorption and the palatability of the reconstituted product where samples were compared at approximately the same doneness but with different amounts of final water absorption due to difference in treatment.

EXPERIMENTAL

Dehydrated products. The dehydrated products used included diced potatoes, flaked onions, French cut green beans, sweet corn and apple slices. The products were supplied by the Quartermaster Food and Container Institute for the Armed Forces, as samples of products currently in use by the Armed Forces.

Reconstitution methods. Most of the studies were conducted with small (usually 4-serving) portions, and when the studies with small portions were completed for a given product, a few of the experiments were repeated with large (50-100 serving) portions.

For small portion studies, 2-qt. aluminum saucepans were used for all except apple slices, and for these 1-qt. pans were used. Saucepans were uncovered throughout, and the products were not stirred during reconstitution. Temperature changes were recorded in the center of the product at 5-min. intervals in all cases, to insure consistent temperature changes as experi-

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ments were repeated. For some products, gas heat was used and heating was controlled by using a manometer attached to a gas line; for others, electric units were used and heating was controlled by using different speeds.

For large portion studies, an Army stock pot of 10-gallon capacity was used, with gas heat to provide heating capacity similar to that of an Army field range.

Standard methods of reconstitution. Preliminary work was done with each product to select a method of reconstitution which could be considered standard, on the basis of the color, texture, and flavor of the finished product, and on the practicability of the method. The chief interest in this work is in connection with large-quantity cookery of dehydrated fruits and vegetables for the Armed Forces. Hence, for each product, the time required for the large portion to reach boiling was first noted, then for the small portion the intensity of heat found necessary to bring it to a boil in the same length of time was used.

These selected methods are as follows:

Diced Potatoes: Seven times the weight of water as potato, initial temperature of water 24° C.; bring to boil in 30 min., simmer 13 min., and drain. For small portions, 115 g. per run; for large portions, 3118 g. per run.

Flaked Onions: Seven times the weight of water as onion, initial temperature of water 24° C.; bring to boil in 12 min., simmer 18 min., and drain. For small portions, 115 g. per run; for large portions, 805 g. per run.

French Cut Green Beans: Fifteen times the weight of water as green beans, initial temperature of water 24° C.; soak 15 min., bring to boil in 25 min., boil moderately 15 min. and drain. For small portions, 56.7 g. per run; for large portions, 852 g. per run.

Sweet Corn: Five times the weight of water as corn, initial temperature of water 60° C.; soak 25 min., bring to boil in 25 min. and simmer 20 min., then drain. For small portions, 185 g. per run; for large portions, 1818 g. per run.

Apple Slices: Seven times the weight of water as apple, initial temperature of water 60° C.; soak 15 min., bring to boil in 8 min., simmer 8 min. and drain. For small portions 50 g. per run; for large portions 1026 g. per run.

Variables studied. The two variables studied for each product were the initial temperature of the water and the ratio of water to product. Keeping the ratio of water to product constant, water with different initial temperatures was used. Keeping the initial temperature of the water constant, different ratios of water to product were used, and these ratios were kept within what were considered reasonable limits from a practical standpoint. For the smallest ratio of water for each product, an amount was chosen which seemed to cover the product fairly well and which seemed adequate to prevent scorching by the time the product was done. The largest ratio in each case was the amount which was considered the largest apt to be recommended from a practical standpoint.

Approximately the same intensity of heat was applied when reconstitution was started in hot water as when reconstitution was started in cold water. Hence, less time was required for the product to reach the boiling point when started in hot water, and a shorter total time was required for reconstituting the product to doneness. In all cases, information was obtained for the product at intervals during reconstitution, and when it was considered "done." In addition, information was obtained for an extended cooking time for the sample started in hot water to give a total reconstitution time the same as for the sample started in cold water.

Determination of percent water absorbed. For the standard method of reconstitution and for each variable the rate of water absorption was determined. This information was obtained in terms of the percent water absorption (grams water absorbed per 100 g. dehydrated product). The methods of determination for the various products follow.

Small Portions

Diced Potatoes, Flaked Onions and Sweet Corn. Of the total portion of the vegetable to be used for a run, given weights (10 or 15 g.) were placed in each of 3 or 4 "cages," depending upon the number of time-intervals for which determinations were required. The "cages" consisted of fine wire mesh which allowed free circulation of water but which did not permit solid pieces to pass through it.

Preliminary work with these "cages" was done to determine the value of this method. Determinations from repeated runs showed that the percent water absorbed by the product within the "cage" was very similar to the percent water absorbed by the product outside the "cage" at the same time-interval in the same cooking. Hence, the percent water absorbed as determined from the product within the "cages" was considered indicative of the percent water absorbed by the entire lot of product at a given time in a cooking.

The "cages" were removed from the pan at intervals during reconstitution, and were weighed after a uniform method of drainage. The percent water absorbed by the product remaining in the pan outside the "cages" was noted at the end of each experiment, and these results served as a check on the results from the "cage" to be removed last. In general, these results from the remaining portions agreed well with those from the "cage" to be removed last, but they are not presented here. At least three runs were included in all cases, from which to obtain an average.

For diced potatoes and sweet corn, the results were considered acceptable if the difference between the highest and lowest figures in a series did not exceed 10% of the average. For the most part, this agreement was readily obtained. Occasionally when this agreement was not obtained, another run was added and the results were then considered acceptable if the difference between the highest and lowest figures in a series did not exceed 15% of the average.

Greater difficulty was encountered in obtaining good agreement between results in a series using flaked onions, no doubt due to the widely differing thicknesses and sizes of the flakes. If the difference between the highest and lowest figures in a series did not exceed 15% of the average, the results were considered acceptable; otherwise, one run was added and then if the difference between the highest and lowest of the four figures did not exceed 20% of the average, the results were considered acceptable, and all four figures were used in computing the average. Finally, if the results were not yet acceptable, 2 more runs were added (a total of 6 runs) and all figures were used in computing the average unless any were extreme. In most cases, however, the difference between the highest and lowest of the original three figures was found to be within 15% of the average.

Apple Slices and French Cut Beans. The apple slices and the pieces of green beans were too large for use of the "cages" described above to be practicable. Hence it was necessary to stop reconstitution, drain and weigh the entire lot of the product at each time-interval for which information was required. An additional problem was encountered in reconstituting apple slices. The slices tended to float on the surface of the water and this made it impossible to obtain reproducible results. This was overcome by placing over the surface of the apples a fine, wire mesh, arranged so as to keep the slices continuously submerged during reconstitution. At each time-interval when reconstitution was stopped, the product was turned into a strainer and drained by a uniform procedure.

For both apple slices and French cut green beans, results were considered acceptable if the difference between the highest and lowest figures in a series did not exceed 10% of the average, and no difficulty was encountered in obtaining this agreement.

Large Portions

Diced Potatoes, Flaked Onions and Sweet Corn. Weighed portions of the product were placed in each of 9-12 "cages" as for small portion studies of these vegetables. At each time-interval, three "cages" were removed, drained and weighed as for small portion studies, and the three figures were used in computing the average. Results were considered acceptable if the difference between the highest and lowest figures in a series did not exceed 10% of the average for diced potatoes and sweet corn, and 15% of the average for flaked onions. Immediately after removing the last "cage," the remaining vegetable was drained into colanders for 10 minutes, and then weighed. These results from the remaining portions served as a check on the results from the "cages" to be removed last. The results from the remaining portions are not presented here, but in general

they agreed well with those from the "cages" to be removed last.

Apple Slices and French Cut Green Beans. Water absorption for these products was determined only when they were reconstituted to doneness. "Cages" were not used for apple slices, and when treatment was complete, the entire lot of apple was turned into colanders, drained 10 minutes, and weighed. For green beans, large "cages" each holding 25 g. were used. For both these products, the differences between the highest and lowest figures in every series was within 10% of the average.

Relationship between percent water absorption and palatability. For each product, a pair of samples reconstituted to approximately the same degree of doneness but treated differently (one treatment resulting in high water absorption and one in low) were rated by a taste panel for color, texture, and flavor. The pairs were selected on the basis of percent water absorption as previously determined. In this part of the study, a portion of each sample was used for redetermining the percent water absorption, and these determinations in all cases showed a difference between the paired samples in the same direction as the original determinations, thereby giving assurance that the products being compared represented high and low water absorption.

The taste panels included 27-33 judges, and they were given one pair at a time, to score from 1 to 9 for each quality, color, texture and flavor. The average score for each quality was used for comparing the products.

RESULTS AND DISCUSSION

Effect of variables on percent water absorption. *Effect of Ratio of Water to Product.* Results of studies with small portions are presented in Figure 1. A slight tendency is indicated in most cases for decrease in the ratio of water to product to result in decreased percent of water absorbed by the time the product is reconstituted to doneness. This effect is most pronounced with flaked onions when only 4 times the weight of water as onions were used, and it is noticeable also, when only 11 times the weight of water as green beans were used. In all probability, if smaller amounts of water had been used with other products, similar effects would have been found.

In general, the rate of water absorption was gradual for all products, regardless of the ratio of water to product. With all ratios of water to product, diced potatoes and apple slices showed a fairly steady rate of water absorption during reconstitution. With all ratios of water to product, sweet corn, green beans and flaked onions showed more rapid absorption during the early stages of reconstitution than during the later stages.

Effect of Initial Temperature of Water. Results of studies with small portions are presented in Figure 2. Each increase in temperature of water for diced potatoes, sweet corn and apple slices gave some increase in water absorption at each time interval during reconstitution. The effect of initial temperature was rather more pronounced during the early stages of reconstitution however, since there was a tendency for the percent water absorbed to "level off" to some extent toward the later stages. This means that the rate of water absorption is greatest in the early stages of reconstitution when the initial temperature of the water is high, and when the initial temperature of the water is low, water absorption is somewhat steadier throughout reconstitution.

The effect of initial temperature of water on water absorption by green beans and flaked onions was somewhat inconsistent during reconstitution, but by the time these products were reconstituted to doneness, increase in initial temperature of water decreased water absorption, an effect the reverse of that with all other products.

During the extended cooking period for samples started in hot water (giving the total reconstitution time equal to that for samples started in cold water)

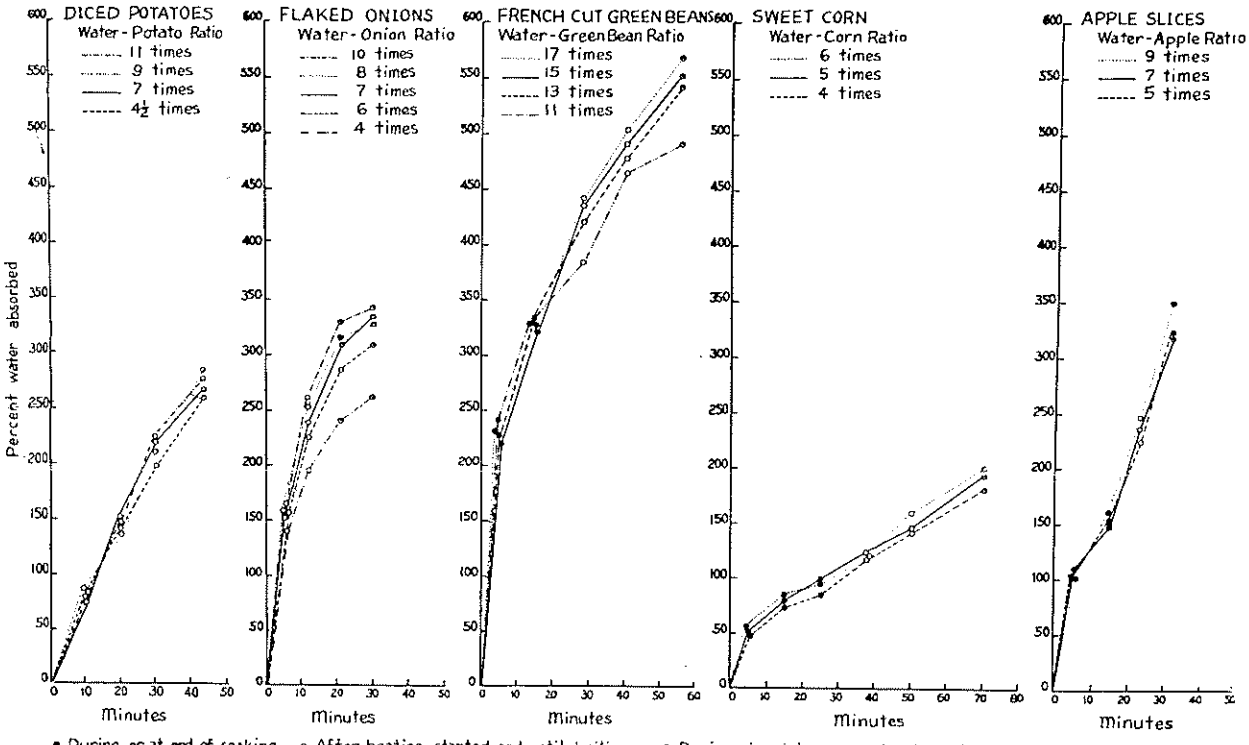

Figure 1. Effect of ratio of water to product on water absorption during reconstitution of dehydrated products.

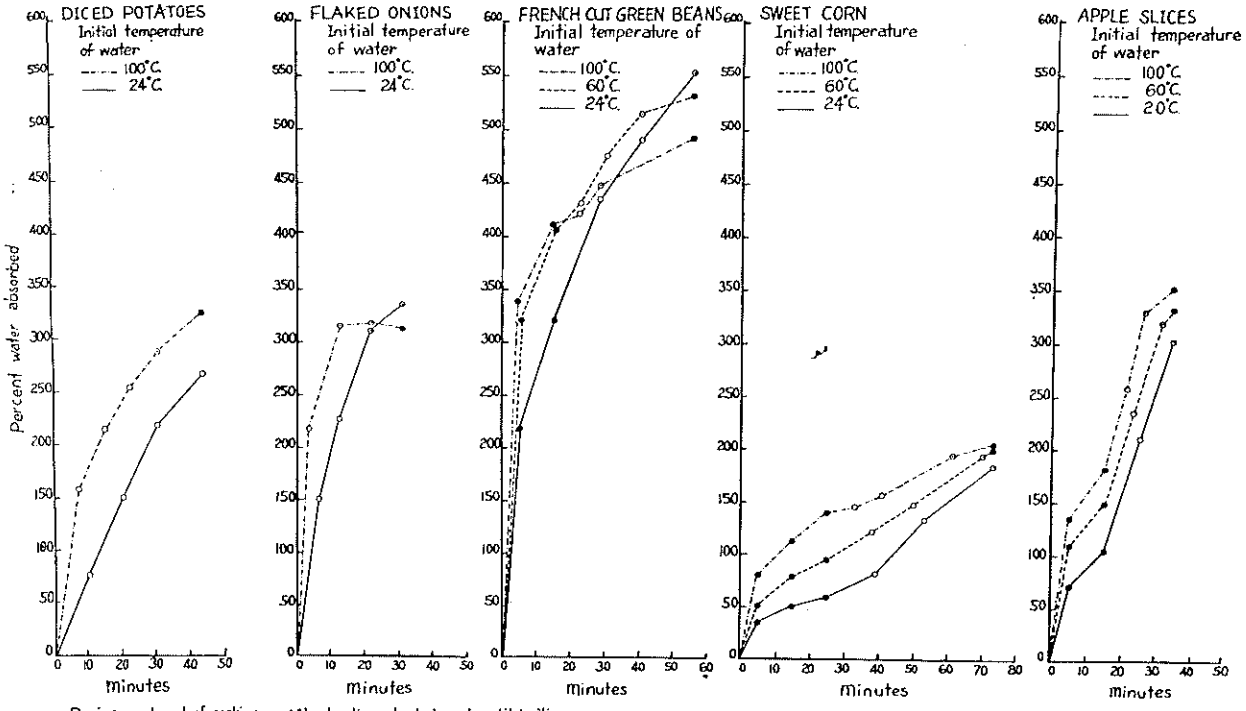

Figure 2. Effect of initial temperature of water on water absorption during reconstitution of dehydrated products.

water absorption increased at the rate similar to that for the period preceding, except for flaked onions and green beans. During this extended cooking period, increase in water absorption by green beans was very slight and there was no increase by flaked onions.

Large-Portion Studies. For comparison of results by large and small portions when reconstituted, bar graphs are presented in Figures 3 and 4. The general trends of effects due to ratio of water to product and due to initial temperature of water are similar for large and small portions. Data not included here also indicate that there was more rapid water absorption in the early stages of reconstitution by both large and small portions.

Results were analyzed statistically to determine whether the percent water absorbed by large portions was similar to that by small portions when the products were reconstituted to doneness. For each product in the study to determine the effect of ratio of water to product on water absorption, the average was obtained from all figures from all sets in the small-portion study, and this was compared with the average of corresponding figures in the large-portion study. These figures were analyzed statistically, using the *t*-test. Results from the study to determine the effect of initial temperature of water were similarly analyzed. For both studies, differences at the 1% level were found between small and large portions results for diced potatoes, sweet corn and apple slices. For diced potatoes and sweet corn, water absorption was greater by small portions, whereas for apple slices it was greater by large portions. No significant difference was found between small and large portion results from green beans or flaked onions.

Relationship between percent water absorption and palatability. Average scores for the products are presented in Table 1, with results of statistical analysis,

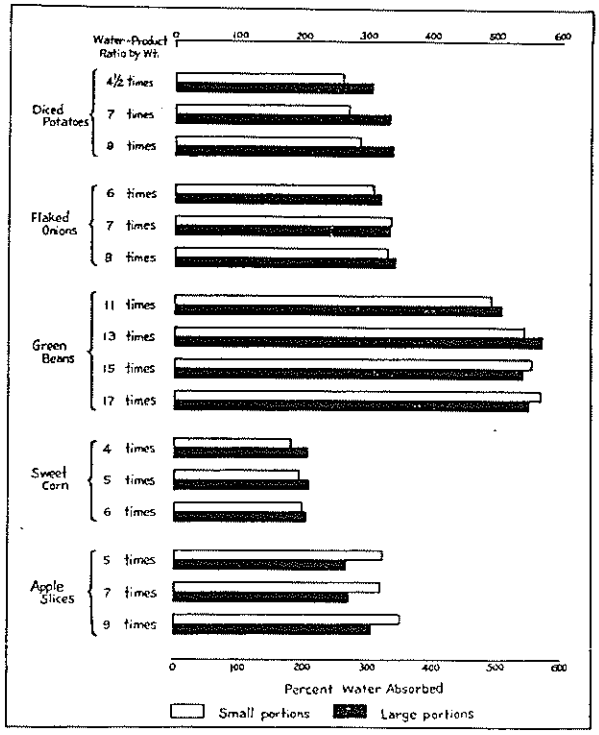

Figure 3. Comparison of effect of ratio of water to product on water absorption by small and large portions of dehydrated products when reconstituted.

using the *t*-test. In most cases, the difference between the scores of paired samples was only slight, and was not consistently in favor of low or high water absorption. However, for green beans (the pair with the greatest difference in water absorption) the sample with

TABLE 1

Comparison of taste panel ratings for products reconstituted to give low and high water absorption

Products		Diced Potatoes		Flaked Onions		Green Beans		Sweet Corn		Apple Slices	
Percent water absorbed, as originally determined		260	276	314	333	446	552	157	180	301	349
Abbreviated Reconstitution Method	Ratio of water to product, by wt.	4½	11	7	7	15	15	6	4	7	9
	Initial temperature of water, ° C.	24	24	100	24	100	24	60	60	24	60
Average Score [1] for	Color	6.7	7.6[3]	6.7	7.1[2]	7.6	6.0[3]	6.9	6.5	6.2	6.1
	Texture	6.2	6.8[2]	6.8	6.5	6.7	6.4	6.9	6.7	6.7	6.7
	Flavor	6.6	7.0	6.5	6.5	6.9	5.9[3]	6.5	6.5	6.9	6.8

[1] All scores are averages of scores by 27-33 judges who rated each quality from 1 to 9.
[2] Significant difference between scores of paired samples at 5% level.
[3] Significant difference between scores of paired samples at 1% level.

low water absorption scored higher for all 3 qualities, and for color and flavor the difference was significant at the 1% level. For diced potatoes, the sample with high water absorption scored higher for all three qualities; for color the difference was significant at the 1% level and for texture it was significant at the 5% level.

The similarity in scores for most products is probably due to the fact that all samples were reconstituted to approximately the same degree of doneness, without extremes in method, and with no sample "water-logged."

SUMMARY

The percent water absorbed was determined during the reconstitution of diced potatoes, flaked onions, French cut green beans, sweet corn and apple slices, and the effects were noted of varying the ratio of water to product and varying the initial temperature of the water. The chief studies were with small (4-serving) portions.

A slight tendency was found in most cases for decrease in the ratio of water to product to result in decreased percent water absorbed when the product was reconstituted to doneness, particularly when the smallest ratio of water was used with flaked onions and green beans. In general, the rate of water absorption was gradual for all products, regardless of the ratio of water to product. Increase in initial temperature of water caused increase in water absorption by diced potatoes, sweet corn and apple slices, particularly in the early stages of reconstitution. On the other hand, when green beans and flaked onions were reconstituted to doneness, increase in initial temperature of water resulted in decreased water absorption.

When some of these experiments were repeated with large (50-100 serving) portions, the general trends of effects were similar to those with small portions. Products differed in their behavior as to whether the percent water absorbed was higher or lower with large portions than with small portions.

As judged by a taste panel, only slight differences in palatability were found between samples of reconstituted sweet corn, flaked onions and apple slices, when paired to compare the effect of high and low water absorption by each product. For green beans, the sample with low water absorption scored higher, but for diced potatoes the sample with high water absorption scored higher.

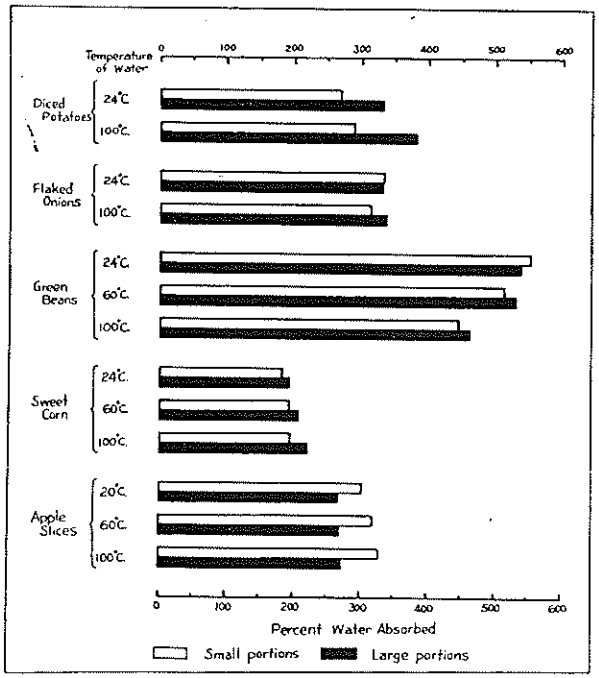

Figure 4. Comparison of effect of initial temperature of water on water absorption by small and large portions of dehydrated products when reconstituted.

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