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Effect of Water Hardness in Reconstituting Dehydrated Fruits and Vegetables[a]

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Certain dehydrated fruits and vegetables were reconstituted in waters made hard by the addition of several concentrations of certain salts and in distilled water for comparison. Effect was noted on percent water absorbed and on taste panel ratings for texture of reconstituted products. Considerable difference was found as to the effects of the various salts and also as to the response by the various products.

The firming effect of hard water in canning has long been recognized as a problem by the canning industry. Huenink *(7)* in 1915, found both calcium and magnesium salts in the form of chlorides or sulphates had a firming effect on canned beans and the effect increased with calcium or magnesium concentration. As bicarbonate, the result was less consistent, probably due to the instability of bicarbonates. This effect was later confirmed by others in cooking dried legumes *(3)* as well as in cooking peas *(15)*.

It was also noted that vegetables such as green beans, asparagus, spinach, peas, parsnips, and squash were able to absorb calcium or magnesium ion from the cooking medium when cooked in water containing these salts. The calcium and magnesium contents of these vegetables after cooking were found to be higher than when they were raw or when they were cooked in distilled water or cooked by steaming *(9, 10, 11, 16)*.

The firming effect of calcium and magnesium salts on vegetables can probably be attributed to several different reactions. The fact that vegetables low in protein and rich in pectin become firmer is believed to be the result of the formation of insoluble calcium or magnesium pectate *(8)*. On the other hand, the firming of legumes which are rich in protein is mostly due to the formation of calcium and magnesium picrates or the precipitation of protein by the calcium and magnesium salts *(4)*.

Although firming effect is considered undesirable in cooking many vegetables, it has been found to be helpful in preserving the natural structure of certain types of fruits during processing. Kertesz *(8)* found that apples, peaches, strawberries and tomatoes treated with calcium and other alkaline earth elements were rendered firmer and had better structure after canning and freezing. Since then, the usefulness of calcium salts in canning and freezing has also been reported by many other workers *(1, 2, 5, 12, 14)*. The relative effectiveness of calcium citrate, malate and lactate in treating apple slices was compared by Holgate and Kertesz *(6)* and the results were comparable when used on an equal basis as to calcium content. There seems to be some indication of a slight superiority of lactate in both firming effect and calcium-uptake.

The purpose of this study has been to note the effect of reconstituting certain dehydrated fruits and vegetables in waters made hard by the addition of different concentrations of certain salts. Comparisons were made as to the effect on the rate and final amount of water absorption, and on the firmness of the reconstituted product.

MATERIALS AND METHODS

Dehydrated products. The dehydrated products used were diced potatoes, flaked onions, French cut green beans, sweet corn and apple slices. Samples from the same lots of products were used as those for the study in this laboratory, using tap water *(13)*.

Reconstitution methods. Each product was reconstituted by the method which was arbitrarily selected as the standard for experimental purposes in the previous study in this laboratory *(13)* in which products were reconstituted in tap water. Exception to this was diced potatoes, and the reconstitution method for this product in these studies included preliminary soaking.

Determination of effects of hard waters. Each product was reconstituted in a series of waters made hard by adding the 5 salts commonly found in hard waters; magnesium sulphate, magnesium chloride, calcium sulphate, calcium chloride and calcium bicarbonate. The hard-water solutions were prepared with distilled water and chemically pure materials. The concentrations arbitrarily selected were 125, 250, 500 p.p.m. (calculated as calcium carbonate equivalent) for each salt, and also 1000 p.p.m. of all salts except calcium bicarbonate. The products were also reconstituted in distilled water for comparison. In all cases, the average figure from 3 determinations was obtained.

To note the rate of water absorption, percent water absorption was determined at one or two intervals during reconstitution of each product.

Methods of rating reconstituted products. *Percent Water Absorbed.* The percent water absorption was determined by the same method as that used in the former study in this laboratory *(13)*.

Taste Panel Ratings. Reconstituted products were judged subjectively for firmness by taste panel ratings by at least 8 judges. The judges were always given a pair of samples at one time, one of which had been reconstituted in distilled water, the other reconstituted in hard water. Products were not seasoned and they were tasted hot. The judges were asked to indicate which sample they considered firmer, or whether they did not find any difference between them. Results of these ratings were analyzed statistically by chi square.

For each product, the effect of a concentration of 500 p.p.m. was first determined, and if an effect seemed evident, decreasing concentrations were used until no effect was found. If the concentration of 500 p.p.m. of a given salt had not resulted in a significant effect, the effect of a concentration of 1000 p.p.m. of that salt was also determined.

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RESULTS AND DISCUSSION

Effect of hard waters on water absorption. Effect of different salts on the percent water absorbed when the 5 products are reconstituted to doneness is presented in Table 1. Data obtained for percent water absorbed at intervals during reconstitution indicated that when the final percent of water absorption in hard water differed from that in distilled water, the difference was generally in the same direction at each time-interval throughout reconstitution. Hence these data are not included here.

Differences (increases and decreases) in percent water absorption due to the presence of a salt were analyzed statistically, using the *t*-test. In general, calcium chloride and calcium sulphate decreased water absorption by all 5 products, in varying degrees for the different products. There seems to be a trend for increase in salt concentration to cause decrease in water absorption in most cases, but the trend is not consistent. Lack of consistency is probably due to experiment error and to lack of uniformity of the dehydrated product.

Effects of magnesuim salts were less pronounced and less consistent than effects of calcium salts. Both magnesium salts decreased significantly the percent water absorbed by diced potatoes and green beans. Magnesium sulphate consistently increased water absorption by apple slices, but the difference was significant only in one case, and this salt had very little effect on water absorption by flaked onions.

The effect of calcium bicarbonate was most inconsistent, probably due to the fact that this salt can readily be decomposed by heat during reconstitution.

No concentration of any salt had a significant effect on water absorption by sweet corn.

Effect of hard waters on texture as rated by taste panels. Taste panel ratings for texture of products reconstituted in hard waters are presented in Table

TABLE 1

Percent water absorption by products reconstituted in waters made hard by addition of certain salts

Addition to distilled water		Percent water absorbed by				
Kind of salt	Conc. in p.p.m. calculated as $CaCO_3$ equivalent	Diced Potatoes	Flaked Onions	Green Beans	Sweet Corn	Apple Slices
None		327	321	550	196	316
$MgCl_2$	125	304	326	529[1]	186	303
	250	299[1]	317	533[1]	189	311
	500	327	331	516[1]	197	310
	1000	307[1]	332	509[2]	184	299
$MgSO_4$	125	297[1]	324	549	190	338
	250	289[1]	323	529[1]	189	339[2]
	500	317	329	521	185	334
	1000	300	318	498[2]	184	323
$CaCl_2$	125	313	318	536	191	308
	250	277[2]	322	530	186	291
	500	307	322	508[2]	191	293
	1000	292[1]	305[1]	493[2]	183	261[1]
$CaSO_4$	125	301[1]	333	545	191	280[1]
	250	281[2]	323	547	194	288
	500	288[2]	320	540	183	290
	1000	293[1]	305[1]	500[2]	182	279[1]
$Ca(HCO_3)_2$	125	330	326	556	192	314
	250	319	336[1]	542	200	322
	500	312	318	520[2]	195	300

[1] Significant difference between distilled water and salt solution at 5% level.
[2] Significant difference between distilled water and salt solution at 1% level.

TABLE 2

Taste panel ratings for texture of products reconstituted in waters made hard by addition of certain salts

Addition to distilled water		Total no. of judges for					% of judges who rated hard water sample firmer for					Chi square value				
Kind of salt	Conc. in p.p.m. calculated as $CaCO_3$ equivalent	Diced Potatoes	Flaked Onions	Green Beans	Sweet Corn	Apple Slices	Diced Potatoes	Flaked Onions	Green Beans	Sweet Corn	Apple Slices	Diced Potatoes	Flaked Onions	Green Beans	Sweet Corn	Apple Slices
$MgCl_2$	125	10					45.0					0.100				
	250	10				8	50.0				43.8	0.000				0.125
	500	8	8	9	8	8	81.3	62.5	55.6	56.3	43.8	3.125	0.500	0.111	0.125	0.125
	1000	9	16	8	11	23	100.0	84.4	43.8	45.5	71.4	9.000[2]	7.563[2]	0.125	0.091	3.857[1]
$MgSO_4$	125	22				8	47.7				62.5	0.045				0.500
	250	22				13	38.6				42.3	1.136				0.308
	500	20	19	10	9	8	70.0	52.6	55.0	33.3	50.0	3.200	0.053	0.100	1.000	0.000
	1000	8	20	8	8	8	87.5	35.0	62.5	81.3	50.0	4.500[1]	1.800	0.500	3.125	0.000
$CaCl_2$	125	11					36.4					0.818				
	250	10	8			8	90.0	43.8			62.5	6.400[1]	0.125			0.500
	500	13	8	10	9	16	92.9	100.0	40.0	27.8	100.0	9.307[2]	8.000[2]	0.400	1.778	16.000[2]
	1000			8	9				75.0	33.3				2.000	0.000	
$CaSO_4$	125	12					37.5					0.750				
	250	18				8	63.9				68.8	1.389				1.125
	500	21	7	8	9	8	91.5	43.8	62.5	66.6	100.0	13.762[2]	0.144	0.500	1.000	8.000[2]
	1000		15	10	8			33.3	60.0	56.3			1.667	0.400	0.125	
$Ca(HCO_3)_2$	125	24				24	51.1				77.1	0.042				7.042[2]
	250	20	8			16	45.0	25.0			90.6	0.200	2.000			10.563[2]
	500	23	8	10	9	8	25.0	0.0	5.0	27.8	93.8	6.545[1]	8.000[2]	8.100[2]	1.778	6.125[2]

[1] Significant difference at 5% level.
[2] Significant difference at 1% level.

2, with statistical analysis by chi square. Some concentration of each salt except calcium bicarbonate resulted in significant or highly significant firming of potatoes, and some concentration of each salt except magnesium sulphate resulted in significant or highly significant firming of apple slices. Response of other products to different salts was less consistent, especially to calcium bicarbonate, which caused significant firming of apple slices but significant softening of diced potatoes, flaked onions, and green beans. This is the only instance in which any salt had a significant effect on the texture of green beans, and no salt had a significant effect on the texture of sweet corn. When a salt was found to have either a firming or a softening effect on a certain product, the effect, in general, became more pronounced with increased concentration of the salt as judged by taste panel ratings.

SUMMARY

Dehydrated diced potatoes, flaked onions, green beans, sweet corn and apple slices were reconstituted in a series of waters made hard by adding separately magnesium sulphate, magnesium chloride, calcium chloride, calcium sulphate and calcium bicarbonate to distilled water in several concentrations. Products were also reconstituted in distilled water for comparison.

Results are presented to show the effects of the different concentrations of each salt on the percent of water absorbed when the product is reconstituted to doneness. Calcium chloride and calcium sulphate caused in general a decrease in water absorption by all products, whereas the effects of magnesium salts were less pronounced and less consistent. The effect of calcium bicarbonate was least consistent of all the salts.

Taste panel ratings of the products reconstituted in these solutions indicated that some concentration of most salts caused firming of diced potatoes and apple slices. Response of other products to different salts was less consistent, and the effects of calcium bicarbonate on texture was most inconsistent of all the salts.

None of these solutions had a significant effect on sweet corn as to either percent water absorption or the texture of the reconstituted product.

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