CCXVI. THE LOSS OF GLUCOSE FROM DRIED PEAS ON SOAKING.

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THE common treatment of dried peas when used as human food is to subject them to a prolonged soaking so that they may imbibe water and to follow this up by boiling the peas.

Hutchison [1927] says of this process, "...soaking (is) inevitably accompanied by some loss of protein and mineral matter and also of carbohydrates." Similar statements are met with in many cookery books and have given rise to the idea that such a loss is considerable and may cause a decided drop in the food value of the peas.

Masters [1918] investigated the loss incurred by beans on soaking and found that 100 g. soaked in 250 cc. tap or distilled water lost 1.5-2.2 % solids and of this a considerable proportion consisted of nitrogenous extractives and salts. It was decided to carry out similar experiments with peas with regard to the loss of carbohydrate.

At the same time, opportunity was given to investigate the further statement of Hutchison [1927], that "peas do not readily soften in water containing lime...hence the importance of adding soda to hard water in which pulses are to be soaked."

EXPERIMENTAL METHODS.

The loss of carbohydrate from peas when soaked in various solutions was determined as follows.

100 g. of dried peas were placed in 250 cc. of the liquid and kept overnight. In the morning the surplus was strained off through butter-muslin and measured. This fluid, if acid, was neutralised with anhydrous sodium carbonate and estimations of reducing sugar carried out, using Benedict's method. An osazone was made from the specimen in any series giving the strongest reaction, and a heavy crop of glucosazone crystals resulted in every case. Therefore all reducing substances were calculated as glucose. No iodine reaction was obtained with any fluid investigated, and there were only minute traces of any non-reducing sugar giving rise to reducing sugars on hydrolysis. Each fluid gave faint reactions with the protein colour tests, but no differences

were noticed in sugar titrations when carried out before or after removal of the traces of protein.

For experiments on the rate of cooking, the peas when strained from their soaking fluids were loosely tied in butter-muslin and immersed in an open saucepan of boiling water. This water was kept boiling vigorously for 40 minutes when the peas were removed. Peas soaked in distilled water were invariably well cooked in this time, and the others were compared with them.

EXPERIMENTAL RESULTS.

A = cc. fluid remaining after soaking (originally 250 cc.).
B = g. glucose in A, i.e. glucose lost from 100 g. peas.

Inorganic acids.

Concentration of solution	0		0.015 N		0.03 N		0.06 N		0.125 N		0.25 N		0.5 N	
	cc.	g.	cc.	g.	cc.	g.	cc.	g.	cc.	g.	cc.	g.	cc.	g.
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
HCl	147	0.13	147	0.25	148	0.24	150	0.24	151	0.13	154	0.17	153	0.62
HNO ₃	145	0.11	147	0.19	149	0.18	150	0.17	152	0.11	153	0.12	152	0.38
H ₂ BO ₃	144	0.16	145	0.15	145	0.15	145	0.15	145	0.13	—	—	—	—
H ₂ SO ₄	144	0.11	145	0.18	147	0.21	150	0.21	152	0.14	152	0.13	152	0.21
H ₃ PO ₄	135	0.16	138	0.20	140	0.30	143	0.45	146	0.52	148	0.53	150	0.30

Organic acids.

Concentration of solution	0		0.015 N		0.03 N		0.06 N		0.125 N		0.25 N		0.5 N	
	cc.	g.	cc.	g.	cc.	g.	cc.	g.	cc.	g.	cc.	g.	cc.	g.
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Formic	146	0.12	148	0.41	152	0.54	154	0.60	154	0.60	154	0.59	154	0.43
Acetic	140	0.13	141	0.28	144	0.43	148	0.76	150	0.78	155	0.80	154	0.80
Lactic	143	0.10	144	0.37	144	0.47	150	0.49	152	0.49	158	0.50	160	0.47
Oxalic	134	0.12	140	0.35	142	0.39	148	0.45	150	0.45	150	0.23	154	0.14
Malic	140	0.13	142	0.18	142	0.21	144	0.32	146	0.44	150	0.51	154	0.55
Tartaric	140	0.11	144	0.22	144	0.28	143	0.35	148	0.42	150	0.45	150	0.46
Citric	138	0.12	138	0.18	138	0.25	138	0.31	142	0.38	148	0.45	148	0.42

Of the inorganic acids boric acid alone appears to have no effect. The results with hydrochloric, nitric and sulphuric acids are similar to each other. There is a decrease of water taken up by the peas with increased strength of acid. The sugar lost does not run parallel with this change in absorption, neither does it vary directly with strength of acid. With 0.5 N acids most sugar is lost, but with 0.125 N only as much as with distilled water. There is another peak of relatively high sugar loss at 0.015 N–0.06 N. These results suggest that, though with the strongest acid used, hydrolysis of a complex carbohydrate may account for the increased glucose loss, in the lower concentrations some other factor is responsible for the result. This factor is not a simple increase in permeability of the plant cells since with distilled water there is a maximum uptake of water with a minimum of sugar loss.

Phosphoric acid differs from the other inorganic acids in that more sugar is lost from the peas on soaking. This loss is greatest from 0.06 N to 0.25 N and is considerably decreased at 0.5 N. As with the other inorganic acids the amount of liquid taken up by the peas decreases steadily with increasing

strength of acid. The curve obtained on plotting the glucose loss against concentration of acid in the case of phosphoric acid is unlike that obtained from the other inorganic acids, but similar to that obtained from the organic acids.

The results with organic acids are similar to those obtained with the inorganic, but there is a greater glucose loss with each concentration.

The degree of imbibition of liquid by the dry peas is the same as with inorganic acids both quantitatively and qualitatively. These two sets of results again show that glucose removal is not solely a matter of permeability. The most powerful agent in these experiments was acetic acid which at 0.125 *N* removed 0.78 g. glucose from 100 g. peas.

The shape of the curves obtained from these results is unlike that from the inorganic acids, there being no dip after the maximal rise at 0.06 *N* except for a small one in the case of formic acid and a pronounced one with oxalic acid. These two acids give curves similar to that obtained with phosphoric acid. In no case was there anything comparable with the second rise in glucose removal seen with HCl, HNO₃ and H₂SO₄ between 0.25 *N* and 0.5 *N*.

The fall of glucose with the stronger solutions of oxalic acid was unexpected in view of the statement so often put forward in cookery books and by Hutchison [1927] that the presence of calcium causes a decrease in the permeability of peas when soaked. Therefore peas were soaked in an 0.25 *M* solution of CaCl₂; this gave 0.14 g. glucose per 100 g. peas and a residual fluid of 137 cc., whilst the control with distilled water gave 0.15 g. glucose in 147 cc. residual fluid. Hence the extra calcium had no effect on loss of glucose, but depressed water imbibition, again showing the independence of the two phenomena.

This result led to further experiments with salts in the soaking liquids.

Alkalis.

Concentration of solution	0		0.015 <i>N</i>		0.03 <i>N</i>		0.06 <i>N</i>		0.125 <i>N</i>		0.25 <i>N</i>		0.5 <i>N</i>	
	cc.		cc.		cc.		cc.		cc.		cc.		cc.	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
NaOH	140	0.16	140	0.11	140	0.08	136	0.07	136	0.07	134	—	130	—
Na ₂ CO ₃	146	0.16	139	0.14	140	0.17	140	0.16	142	0.17	146	0.15	152	—
NaHCO ₃	136	0.13	138	0.13	140	0.11	140	0.11	143	0.11	150	0.11	154	0.19

Of the alkalis sodium hydroxide gave a small decrease in glucose removal, sodium bicarbonate a still smaller decrease, and sodium carbonate had no effect. At the highest concentration of sodium hydroxide and carbonate it was not possible to estimate the glucose as the Benedict's solution was decomposed.

Two of the alkalis behaved in the same way as the acids in decreasing the amount of water taken up by the peas. This was not so with sodium hydroxide, probably because at concentrations greater than 0.06 *N* the peas in the cold became pulpy and difficult to strain from the liquid.

Salts.

Concentration of solution	0		0.015 M		0.03 M		0.06 M		0.125 M		0.25 M		0.5 M	
	cc. A	g. B	cc. A	g. B	cc. A	g. B	cc. A	g. B	cc. A	g. B	cc. A	g. B	cc. A	g. B
Sodium tartrate	139	0.17	140	0.16	141	0.15	144	0.15	142	0.15	160	0.13	170	0.14
Sodium bitartrate	140	0.14	142	0.21	144	0.22	146	0.32	145	0.36	150	0.47	154	0.53
Na ₂ SO ₄	142	0.14	142	0.14	144	0.14	146	0.14	160	0.14	170	0.11	175	0.09
NaHSO ₄	142	0.13	148	0.20	150	0.25	152	0.23	154	0.20	158	0.16	160	0.19
Na ₂ PO ₄	136	0.15	136	0.15	138	—	138	—	146	—	153	—	154	—
Na ₂ HPO ₄	136	0.15	138	0.14	140	0.12	142	0.12	144	0.12	146	0.17	—	—
NaH ₂ PO ₄	138	0.17	138	0.17	142	0.17	142	0.16	144	0.17	150	0.17	160	0.18

With the majority of the salts there was no appreciable difference in the amount of glucose removed from 100 g. peas, as compared with that removed by distilled water. The two exceptions were sodium hydrogen tartrate which gave a steady increase with increase of concentration and sodium hydrogen sulphate which gave a result similar to that with sulphuric acid, *viz.* a rise at the lower concentrations tailing off at the higher concentrations.

All the salts behaved like the acids and alkalis in lessening the amount of water taken up by the dried peas. This was specially marked with sodium tartrate and sodium sulphate which when used at a concentration of 0.5 M so decreased the imbibition of water that the peas remained wrinkled after 12 hours' soaking, although the salt concentration in the soaking fluid caused them to become as soft as though cooked.

Effect on rate of cooking.

When peas soaked in 0.5 N solutions of various organic and inorganic acids were cooked in vigorously boiling water for 45 minutes they became quite soft, but their outer coats remained hard, and therefore they appeared to be less cooked than the control peas which had been soaked in distilled water. This effect was not seen at 0.25 N and lower concentrations where the acid-soaked peas behaved exactly as the controls and were well cooked in 40 minutes.

With the alkalis, soaking in 0.25 N solutions in the cold rendered the peas as soft as though cooked and they disintegrated to a pulp on being placed in boiling water. Lower concentrations did not affect the time required for cooking. Similar softening in the cold accompanied by disintegration on heating occurred with sodium tartrate and bitartrate, sodium sulphate and bisulphate and the three sodium phosphates at high concentrations. This softening is therefore not due solely to increased alkalinity since some high salt concentrations, even of acid salts, have the same effect.

Peas soaked in 0.25 M CaCl₂, NaCl, KCl and distilled water gave identical results as to time of cooking and also in glucose removed during 12 hours' soaking.

From these results it appears that so far as carbohydrate loss is concerned, it is immaterial whether peas are soaked in hard or soft water. Further

the addition of the customary "pinch" of bicarbonate does not alter this slight loss or accelerate the cooking of the soaked peas. Its only effect is the usual attainment of a bright green colour by the peas soaked in a weak solution of alkali.

Although the carbohydrate loss incurred on soaking peas is negligible from the point of food value, it is markedly altered by the presence of acids in the steeping fluid. This alteration is not a direct function of p_H since organic acids of the same normality differ markedly amongst themselves in power to extract glucose from peas, and are 2-4 times more powerful in this respect than inorganic acids of the same normality. Any increase of ionic concentration reduces the water imbibed by dried peas.

Hence the increase in glucose loss with acids is not the result of a simple change in permeability of the cell wall, but is probably due to the liberation of glucose from some preformed combination in the plant cells.

SUMMARY.

1. Dried peas on soaking in distilled water for 18-24 hours lose 0.1-0.15 % glucose, *i.e.* about 0.2 % of their total carbohydrate.
2. This loss is unaltered by the addition of alkalis to the soaking fluid.
3. The addition of acids causes a marked rise in loss of glucose.
4. This glucose loss is more marked with organic acids than with inorganic acids.
5. The uptake of water by dried peas is depressed by the addition of acids, alkalis or salts to the soaking fluid.
6. The rate of cooking of peas is unaltered by previously soaking them in acids, alkalis, or salts unless the concentration of alkali or salt is high enough to soften the whole pea in the cold (this would render the pea inedible).

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