CCXII. THE CHEMISTRY OF COOKING.

I. THE CHEMICAL CHANGES OF CARBOHYDRATES IN THE SWEET POTATO ACCORDING TO VARIOUS METHODS OF COOKING¹.

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CHEMICAL analyses of the raw materials of our common food substances have already been made by various authors, but until now the changes of chemical composition during cooking have been little understood in spite of their evident importance from the point of view of nutritive value. The present paper represents a study of the chemical changes in the carbohydrates of the sweet potato brought about by various methods of cooking.

Method of cooking.

As the fundamental types of cooking, the authors took the following three procedures, boiling, steaming and baking. The conditions of the experiment are tabulated below. Materials were chopped and cooked just as they are prepared for the table, only without salt or any spices.

Table I. *Conditions of experiment.*

Exp. No.	A	B	C	D	E	F	G
Method of cooking	Boiling	Boiling	Boiling	Steaming	Steaming	Baking	Baking
Origin of the sample	Takatsuki	Shinden	Do.	Yagi	Koma	Yagi	Koma
	Osaka-fu	Kyoto-fu		Hyogo-ken	Kyoto-fu	Hyogo-ken	Kyoto-fu
Weight (g.)	134	255	317	217	174	187	549
Water (cc.)	200	500	400	300	—	—	—
Added material	—	—	—	—	—	Butter	—
						0.5	
Time of cooking (mins.)	15	24	17	35	33	13	17
Highest temp.	100°	100°	100°	100°	100°	190°	175°

Steaming. In Exps. E and G, Kafuku's apparatus was used to measure moisture.

Baking. In Exp. F, the material (8 mm. thick) was kept at 190° for 3 minutes, and it appeared to be overbaked. In Exp. G, it was kept at 175° for 1 minute with good results.

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Gain and loss during cooking.

The sweet potato generally lost weight by cooking, especially in the case of baking, where the loss was due entirely to the removal of water.

The soluble sugar was lost in boiling or steaming, the loss in boiling being 0.4 % of the fresh material, or, about 5 % of the total soluble sugar.

Table II. *Loss by cooking.*

	Exp. No.	A	B	C	D	E	F	G
	Fresh wt.	105	98	97	98	97	63	76
	Dry wt.	—	90	95	100	99	101	101
Loss of sugars	Monosaccharides	0.6	—	—	0.2	—	—	—
	Disaccharides	0.6	—	—	0.2	—	—	—

The figures represent percentages of the respective fresh or dry weights before cooking.

Chemical changes during cooking.

It is known that starch, by the action of heat and water, is partly hydrolysed into soluble sugars. Such a partial hydrolysis of starch must be expected to occur in cooking sweet potatoes even if no water is added, as the tissue itself contains about 60 % moisture. Thus even in baking, one might expect increase in the amount of soluble sugars. Contrary to the expectation, the soluble sugars diminished considerably, and the starch-like substance increased instead. This fact is of great importance in discussing the nutritive value of the cooked food.

Table III. *Change of chemical composition by cooking.*

Method of cooking	Exp. No.	Sample	Dry matter as 100				
			Moisture %	Monosaccharides	Disaccharides	Dextrin	Starch
Boiling	A	Fresh	64	11.9	19.4	—	42.5
		Cooked	(67)	17.6	13.6	—	54.5
	B	Fresh	65	13.1	27.4	10.0	28.7
		Cooked	68	12.8	20.9	3.4	41.9
	C	Fresh	60	13.5	25.5	15.0	—
		Cooked	61	11.8	18.7	3.3	—
Steaming	D	Fresh	69	15.8	15.5	—	33.9
		Cooked	68	19.7	11.9	—	44.7
	E	Fresh	58	13.6	15.2	17.4	22.9
		Cooked	57	10.5	15.8	13.3	35.6
Baking	F	Fresh	67	12.7	20.0	—	11.9
		Cooked	47	12.5	18.1	—	11.7
	G	Fresh	62	13.4	17.1	24.5	28.9
		Cooked	49	12.2	14.1	17.6	38.8

Moisture. About 5 to 10 g. of the material were dried to a constant weight at 105°. The decrease in weight was assumed to be moisture.

Monosaccharides. About 20 g. of material was treated for 45 minutes with hot water. In the extract, reducing sugar was determined by Bertrand's method. Only in Exp. G, Willstätter's iodimetric method was adopted also.

Disaccharides. One part of the extract was hydrolysed with 3 % H₂SO₄ for 30 minutes on a water-bath. The increase in reducing power was assumed to represent disaccharides.

Dextrins. The rest of the extract was boiled with 3 % HCl for 2 hours

under reflux over a direct flame. The increase in reducing sugar less that derived from disaccharides was assumed to originate from dextrins.

Starch. The water-insoluble residue was hydrolysed by boiling with 3 % HCl for 2 hours. The reducing sugar thus formed was assumed to represent starch.

Cellulose. The residue from the starch was boiled for 30 minutes with 1 % KOH, filtered, and the solid, taken to be cellulose, was washed well with water, alcohol, and ether and dried to constant weight at 105°.

Cooking and digestibility.

The increase of insoluble polysaccharide and decrease of soluble sugars by cooking naturally suggest that cooked sweet potato would be more resistant towards the digestive enzymes. Contrary to expectation, the cooked sweet potato was more easily hydrolysable by diastase than the raw material. Further, by diastatic hydrolysis of the boiled material less dextrin and much more soluble sugar was formed.

Table IV. *Digestibility.*

A.						
	Control*		Fresh material		Boiled material	
Time of digestion (hrs.)	0	2	0	2	0	2
Monosaccharides	21.7	20.3	20.5	37.5	34.3	98.8
Dextrins	49.9	55.3	51.8	78.5	56.9	68.6
B.						
	Control*		Fresh material		Steamed material	
Time of digestion (hrs.)	0	2	0	2	0	2
Monosaccharides	21.9	32.1	22.6	35.6	33.3	84.2
Disaccharides	24.6	32.0	12.5	31.2	26.5	51.9
Dextrins	79.6	82.4	80.0	82.4	71.2	84.4

* Control for autolysis. Fresh material and boiled diastase solution were used.

Digestibility. The material was the same as was used in Exp. C, and that of the steamed one was the same as Exp. E. 400 cc. 1 % diastase (Pharmac. Jap.) was mixed with 20 g. of finely chopped material; in an aliquot of 150 cc. reducing sugar, disaccharides and dextrins were determined as described above. The remainder was kept for 2 hours in a thermostat at 40°, and the determination was repeated. The same was done with the steamed material. A control sample with boiled enzyme solution and fresh material was similarly treated. In measuring digestibility of steamed material, Willstätter's method was used to determine reducing sugars.

DISCUSSION.

The peculiar increase in the starch fraction after cooking cannot be explained by loss of soluble sugars by diffusion because, even in Exp. B where the loss of dry weight is about 10 %, assuming that this 10 % loss is caused

by soluble sugars only, the apparent increase in starch cannot exceed 4 %, whilst the actual increase is, as is shown in Table III, more than 13 %.

Link and Tottingham [1923, 1925] observed a marked amount of caramelisation of sugars in plant tissues when they were heated to 80°. Since during cooking the temperature may rise as high as 230° in frying, considerable polymerisation of soluble sugars should take place, especially in the case of baking.

On the other hand, the easier digestibility means that the starch has undergone partial hydrolysis. The partially hydrolysed starch may remain in the starch fraction, if the degree of hydrolysis is slight. Thus, the apparent increase in the starch fraction and the easier digestibility after cooking can be explained by the polymerisation of soluble sugars and the partial hydrolysis of starch itself.

Daikuhara [1902] has reported that the taste of sweet potato is independent of the soluble sugar content of the raw material. It seems probable therefore that the increased sweetness of cooked sweet potato, important from a practical dietetic point of view, is connected with partial hydrolysis of the starch during cooking. Further experiments on this point are necessary.

SUMMARY.

1. Chemical changes in the carbohydrates of sweet potato after boiling, steaming and baking were compared.
2. Sweet potato loses weight during cooking, especially by baking, owing to loss of moisture.
3. The decrease in soluble sugars and dextrins by cooking is most remarkable in baking.
4. The starch fraction always increases in cooking.
5. The digestibility of boiled and steamed material is much greater than that of the raw substance.
6. By the action of heat and water, the starch of sweet potato undergoes partial hydrolysis, whilst soluble sugars and dextrins polymerise to some extent.

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