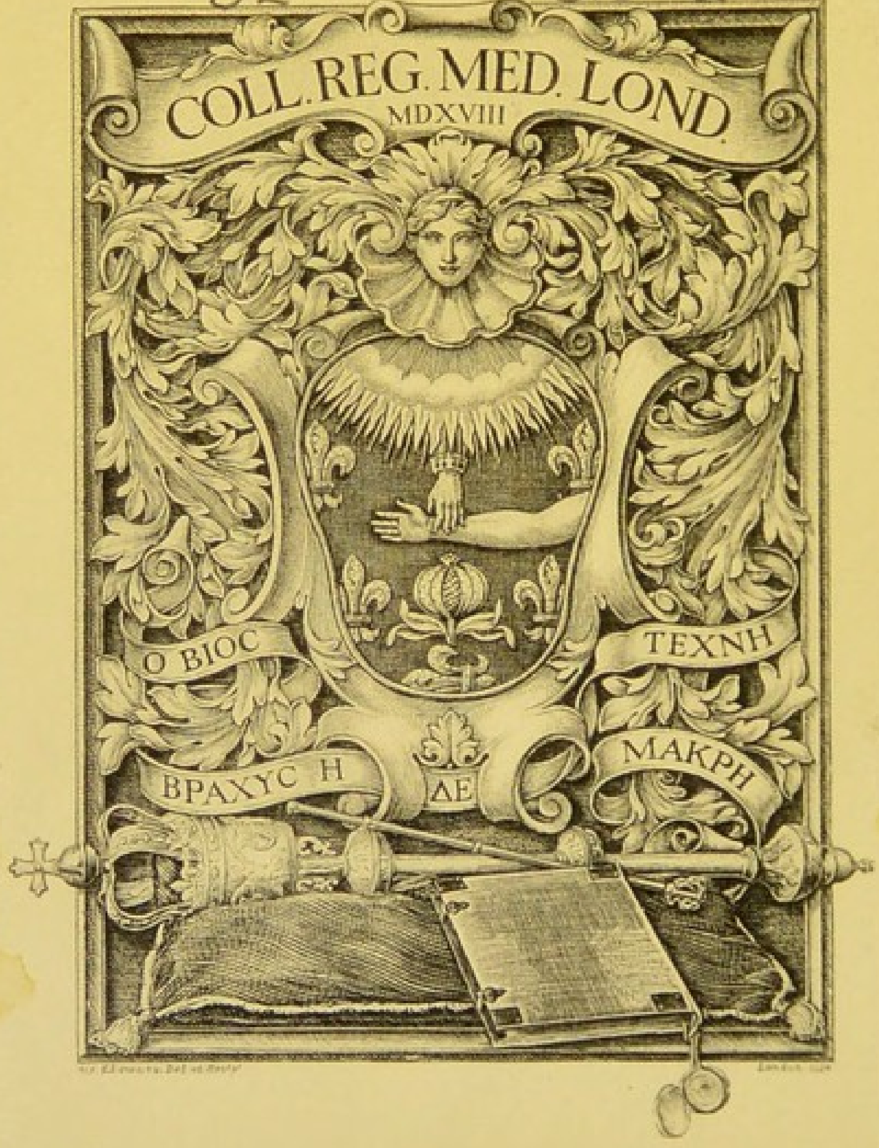
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CONTRIBUTIONS TO THE PHYSIOLOGY OF DIGESTION, AND TO DIETETICS.

BY

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EDINBURGH: 1903.

Ad
Matrem meam carissimam
in
piam memoriam.
W.G.A.R.

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PREFACE.

At the request of some medical friends, the Author has ventured to collect in one volume, those contributions which, during the last nine years he has made on various subjects relating to the Physiology of Digestion and to Dietetics.

No one is more fully aware of their slight worth than the writer, but he hopes that the suggestions which he has made may prove of as much value to others as they have proved to himself.

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26 Minto Street,
Edinburgh, October, 1903.

THE DIGESTION OF SUGARS IN HEALTH.

It is only within the last century that the consumption of cane sugar has become general; until a comparatively recent period its expense limited its use to the wealthy, while to the poor it was almost unknown. When a sweetening agent was desired, honey was commonly employed, and nearly every cottager kept his beehive, a custom which has now fallen into desuetude. As the price of cane sugar has fallen, so has its consumption increased. According to M'Culloch, the amount consumed in Great Britain in 1700 was 10,000 tons. In 1790 it reached 81,000 tons; although in 1808 the duty had risen to 27s. per cwt., 142,000 tons were used; while in 1864 there were imported 551,105 tons, a quantity equal to 30 lbs. per head. In 1891 the home consumption of raw and refined sugars was 1,352,676 tons, which is equivalent to an annual consumption of 80 lbs. per head.

Great Britain and America are the largest consumers of sugar. In other countries, as France, where the duty is higher, the consumption is proportionally less.

An article of diet so largely consumed merits as much attention from the physiologist and scientific physician as it has already received from the chemist.

The large employment of sugar in these times is no doubt a very important factor in the causation of dyspepsia. Our ancestors were much less troubled with indigestion than the present race, and the increase of this malady is commonly ascribed to increased civilisation and to the multiplication of sedentary occupations. Perhaps there is some truth in these ideas, but I have not found this disease more common among our hard brain workers than amongst our manual labourers. I believe the prevalence of indigestion mainly arises from the greater complexity of the diet now used, compared with the plain fare formerly consumed. Many dyspeptics have at an early period of their trouble to abandon saccharine foods, since they, soon after ingestion, cause much acidity, nausea, and heartburn. Why should this be so? Is cane sugar in itself so difficult of digestion, or is it because of its proneness to fermentative change that gastric disturbance is apt to arise? In what form is sugar absorbed into the blood? Is it as cane sugar, or is it as dextrose, lævulose, or maltose? How is cane sugar changed in digestion, and in what form is it absorbed? These are the questions I shall endeavour to answer.

Chemistry of Sugars.

1. *Cane Sugar.*—Let me briefly summarize some facts regarding the chemistry of sugars. When a solution of cane sugar or saccharose ($C_{12}H_{22}O_{11}$) is heated for a long time by itself, or for a short time in the presence of dilute mineral acid, it becomes "inverted." When yeast is added to a warm solution and a moderate temperature maintained, the cane sugar becomes first inverted and then suffers alcoholic fermentation. A solution of cane sugar is dextro-rotatory; after inversion, however, the solution rotates the polarized ray to the left. During inversion cane sugar takes up a molecule of water, and then splits into equal parts of dextrose and lævulose. Petit maintains that these do not occur in equal proportions; while Maumené believes that, in addition to these, inversion gives rise to other optically neutral bodies, and that the products are much more numerous than is generally believed.

The mineral acids are much more powerful and rapid in their inverting action than organic acids; and of the inorganic, sulphuric acid is the most potent of all. The rapidity of inversion increases with the temperature to which the mixture of acid and sugar is raised.

2. *Dextrose,* glucose or grape sugar, is a crystallizable sugar. It is not so sweet as cane sugar, and is much less soluble in water. It rotates the plane of polarized light to the right.

3. *Lævulose,* or fructose, on the other hand, is a colourless syrup as sweet as cane sugar. It has also been obtained in colourless acicular crystals. It turns the plane of polarization to the left, but its specific rotatory power is far greater than that of glucose, and hence, even though these two sugars may exist in equal amounts in invert sugar, the plane of polarization lies to the left.

The suboxide of copper is not precipitated from an alkaline solution of tartrate of copper by boiling with a solution of pure cane sugar, unless the ebullition be carried on for a long time; but if invert sugar be used, the copper oxide is at once reduced.

I. Digestion of Cane Sugar.

Action of Saliva on Cane Sugar.

It has been affirmed by some writers that saliva has an inversive action on cane sugar, while this is denied by others. I have sought to determine this point.

I have already stated that when a solution of cane sugar is heated alone it undergoes a slow inversion. To estimate the amount of this inversion I kept a 20 per cent. solution of pure cane sugar in a water-bath at a constant temperature of 38° C.

This solution was made by dissolving 200 grammes of pure dry cane sugar in distilled water and diluting to one litre. After being kept at this temperature for one hour, invert sugar amounting to 0·19 per cent. was produced. At the end of two hours this had increased to 0·252 per cent. This constitutes the control experiment, and shows the amount of inversion which a 20 per cent. solution of cane sugar undergoes after one and two hours' exposure to the normal temperature of the body.

To determine whether saliva had a greater inversive action on cane sugar than distilled water, I performed the following experiment:—

Equal volumes of human saliva and cane sugar solution (of strength equal to 40 per cent.) were mixed together to give a 20 per cent. solution of sugar. Several beakers containing this solution were placed in the water bath at 38° C. After thirty minutes no recognisable inversion had occurred. In forty-five minutes traces of invert sugar appeared, as shown by the reduction of copper oxide, and in one hour the invert sugar amounted to 0·2 per cent.; while in two hours it reached 0·27 per cent.

I. Cane Sugar, 20 per cent. at 38° C.	Invert Sugar.	
	In one hour.	In two hours.
1. Solution in distilled water, .	0·19%	0·252%
2. „ „ saliva, ...	0·2	0·27
Difference, ...	·01	·018

The amount of inversion in presence of saliva is so nearly the same as in its absence, that we may safely conclude that normal human saliva has practically no influence in hastening or retarding the inversion of cane sugar. In fact, it seems to be perfectly passive in this respect. The results given in the above experiment were practically identical with those obtained in other experiments conducted on similar lines.

II. Gastric Digestion of Cane Sugar.

Cane sugar reaches the stomach unchanged. Does it undergo any digestion in this organ, or does it require any?

It is thought by some that cane sugar is absorbed unchanged, and that after its entrance into the portal vessels it is transformed into glucose through the agency of a ferment in the blood. Pavy is of opinion that it does not require to be changed by digestion to aid its absorption, but merely requires solution to enable it to pass into the bloodvessels. He is inclined to believe, however, that, as a matter of fact, it is at all events partially converted into grape sugar before absorption from the alimentary canal. Bouchardat and Sandras state that, under the influence of the gastric juice and of the lining membranes, cane sugar is changed into invert sugar and lactic acid, and absorbed as such, and that it must undergo inversion before it can be absorbed and used up in the blood.

The gastric juice contains, besides pepsin, a milk-curdling ferment; and, according to Hammersten, there is also a lactic acid ferment that acts on milk sugar. But in opposition to this last statement, it is a fact that a pure solution of lactose does not undergo fermentation when acted on by the gastric juice.

The acidity of the gastric secretion is now universally believed to be due to free hydrochloric acid (as was first conclusively proved by Bidder and Schmidt), which amounts usually to 0·17 to 0·3 per cent. During the first stage of digestion, even though the contents of the stomach are acid, no free hydrochloric acid is found. The period when it appears varies in different individuals, and also varies with the diet. After breakfast it may not be found until 45–60 minutes have elapsed, while after a full dinner it is not evident until after the lapse of two hours.

Lactic acid is said by some to exist normally in gastric juice, though it never reaches an amount exceeding 1 per mille. Free hydrochloric or lactic acid can seldom be detected in the stomach of infants.

Of the total acidity which one estimates in the gastric juice during digestion, only a very small amount may be due to free hydrochloric acid, the greater part being caused by the presence of acetic, butyric, and lactic acids.

Action of Gastric Secretion on Cane Sugar.

Dalton, Leube, and others state that outside the body the gastric juice slowly changes cane sugar into glucose. Laborde, however, affirms that the inversive power of the gastric juice is less than that of a solution of hydrochloric acid of the same strength; but if a trace of hydrochloric acid be added to the gastric juice, its inversive power becomes greater than that of the dilute solution of hydrochloric acid alone. Leube makes an exactly opposite statement. Brown-Séquard, Schiff, and Smith say that cane sugar is inverted in the stomach, and Bourquelot thinks that it is partly inverted in the stomach, but that part passes directly into the blood and is there inverted by the carbonic acid. Hay could find no inversive ferment in the gastric mucous membrane. Frerichs states that cane sugar is not inverted even if left in the gastric juice for twelve to thirty-six hours; and Blondlot believes that the sugar undergoes no change while in the stomach. Richet found that unless he added hydrochloric acid to gastric juice, there was no inversion of cane sugar; and asserts, in explanation of this, that there is really no free hydrochloric acid in the gastric juice, but that it is always combined with organic bodies. He states that under normal conditions the gastric juice in the stomach does not act on sugars.

According to Dalton, it cannot be shown that cane sugar undergoes any inversion during ordinary digestion, and that if taken along with other food there is probably no conversion of it into glucose in the stomach. Kühne and Hermann make similar statements, and Leube comes to the same conclusion. In the healthy stomach, he says, no inversion of cane sugar occurs; but if there be dilatation, then there is a considerable amount of inversion.

Inversion of Cane Sugar by Dilute Hydrochloric Acid.

To estimate the amount of inversion caused by a dilute acid in a solution of cane sugar, I performed the following experiments:—

To 100 c. c. of a 20 per cent. solution of cane sugar I added 0·2 c. c. of hydrochloric acid, and placed it in a water-bath at 38° C. After the lapse of one hour it was removed, and was found to contain 0·37 per cent. of invert sugar. After being heated thus for two hours, the invert sugar had increased to 0·45 per cent. Subtracting the amount of sugar which is inverted when the 20 per cent. cane sugar solution is heated alone, we find that after one hour the hydrochloric acid has caused an increased inversion of 0·18 per cent., and after two hours 0·198 per cent., or nearly $\frac{1}{5}$th per cent. more.

Cane Sugar, 20 per cent. solution, at 38° C.	Invert Sugar.	
	In one hour.	In two hours.
1. Alone, ...	0·19 per cent.	0·252 per cent.
2. With 0·2 per cent. HCl,	0·37 „ „	0·45 „ „

This comparison shows that the presence of the acid in the solution of cane sugar nearly doubles the amount of invert sugar produced. At the end of two hours, only about $\frac{1}{45}$th part of the cane sugar had undergone inversion in the presence of acid similar in amount to that of the gastric juice and at the temperature of the stomach.

Inversion of Cane Sugar by Gastric Secretion.

I then continued the experiment with the gastric secretion from a man with a perfectly normal digestion. At 8 A.M. he had breakfast of porridge and milk. At 10 A.M. I washed out his stomach thoroughly, and then injected three ounces of dilute *Liquor Carnis*

(*Caffyn*). (This extract has no reducing action on the alkaline solution of copper.) Introducing the stomach-tube one hour later, I drew off the gastric contents, and used this, after filtration, in the same way as I had formerly used the 0·2 per cent. solution of hydrochloric acid. The initial acidity of this fluid, estimated as free hydrochloric acid, amounted to 0·15 per cent. Into a vessel I placed 10 c. c. of each of the following, viz., the gastric fluid, water, and 20 per cent. solution of cane sugar. The acidity of this mixture was 0·05 per cent. hydrochloric acid, and the sugar in this mixture was reduced by the dilution to about 6·6 per cent. After having been kept for two hours at a temperature of 38° C., it contained 0·83 per cent. of invert sugar.

10 c. c. healthy gastric fluid 10 c. c. water 10 c. c. 20 p. c. cane sugar solution	= 0·05 p. c. HCl =	Invert sugar after 2 hours— 0·83 p. c.

To determine whether the gastric juice had a greater or less effect in inverting cane sugar than a pure acid solution of similar strength, I made a solution of hydrochloric acid of strength equal to that of this gastric fluid which I had just employed, and used it in place of the gastric secretion in a similar experiment. After being kept at a temperature of 38° C. for two hours, the invert sugar in the mixture amounted to 0·66 per cent.

10 c. c. solution of HCl = 0·15 p. c. 10 c. c. water 10 c. c. 20 p. c. cane sugar solution	= 0·05 p. c. HCl =	Invert sugar after 2 hours— 0·66 p. c.

The amount of invert sugar formed in the latter experiment being only 0·66 per cent., as compared with 0·83 per cent. when diluted gastric juice was used, seems to demonstrate that healthy gastric juice has a greater inverting power than a solution of hydrochloric acid of similar strength, and thus corroborates Leube's statement that sugar inversion is less rapid and less energetic with a pure acid solution than with gastric juice, but is opposed to what Laborde affirms, that the inverting power of gastric juice is less than that of hydrochloric acid diluted to the same degree of acidity.

It has been definitely stated that there is a sugar-inverting ferment in the gastric secretion. To determine whether the inversive action of the acid is aided by such a ferment, I proceeded as follows:—

I mixed equal volumes of healthy gastric fluid, water, and 20 per cent. solution of cane sugar, and then carefully neutralized the acidity with potassium hydrate. I used specially prepared and very sensitive litmus paper to test the reaction. After keeping the mixture at 38° C. for one hour, there was no trace of invert sugar; after two hours, a faint trace of invert sugar had appeared, but too minute for quantitative estimation.

10 c. c. healthy gastric fluid 10 c. c. water 10 c. c. 20 p. c. solution of cane sugar	Carefully neutralized	Invert sugar after 2 hours—mere trace.

Therefore, when the acidity of gastric juice is neutralized no inversion of cane sugar occurs. I conclude that there is practically no sugar-inverting ferment in gastric juice, otherwise an appreciable amount of invert sugar would have been formed in the above mentioned experiment.

It is evident from these experiments that the acidity of the gastric juice is the only factor in causing inversion of cane sugar.

The preceding experiments were performed in the laboratory with fresh human gastric juice. I desired to investigate the changes, if any, which cane sugar undergoes *in the stomach.* I experimented on a healthy man by the following method:—At 8 A.M. he had breakfast of porridge and milk. Two hours later I washed out his stomach thoroughly by means of a syphon elastic tube, and then poured 250 c. c. of a warm 20 per cent. solution of pure cane sugar into the stomach, the patient being thus quite ignorant of the nature of the fluid which was introduced. At intervals of from half an hour to two hours after the injection I passed the stomach tube and removed some of the gastric contents. Each sample of the gastric fluid so obtained was measured and filtered, and the reducing sugar in it estimated by Fehling's solution. The total acidity was estimated by titration with a centinormal solution of caustic soda, and expressed in terms of anhydrous hydrochloric acid. I did not estimate the amount of free hydrochloric acid, as it was unnecessary, but I always tested for the presence of inorganic (of which hydrochloric is the chief) and organic acids qualitatively.

Having estimated the acidity and the amount of invert sugar present, I then inverted the unchanged cane sugar in a definite amount of the gastric fluid by heating it for two hours with a few drops of dilute sulphuric acid (1 c. c. ordinary acid to 9 c. c. water). At the end of this time, any cane sugar present in the fluid had undergone complete inversion.

Normal Healthy Gastric Digestion.

In the first place, it was necessary to investigate the general character of this healthy man's gastric secretion; so, after washing out his stomach, he was allowed to eat quickly 250 c. c. of cooked minced steak.

(1.) One hour later, 60 c. c. of muddy dark brownish-red fluid were drawn off. This contained much swollen and softened muscular tissue; fat in very small masses; total acidity was equal to 0·211 per cent. hydrochloric acid; inorganic acids were present, and a large quantity of organic acid; peptones were present in large amount, and fibrin soon dissolved in it on adding a trace of hydrochloric acid.

(2.) After two hours, 35 c. c. of turbid brown fluid were drawn off. The muscular tissue was further broken down, and fat occurred in larger masses; the total acidity was equal to 0·185 per cent. hydrochloric acid; inorganic acid was present in large amount, and organic acid also. The peptone reaction was hardly so marked as in the first case, and fibrin, as before, was quickly dissolved.

As another control experiment, I washed out this healthy man's stomach and then injected 250 c. c. of normal saline solution (=0·7 per cent. Na Cl.)

(1.) After one hour I drew off 140 c. c. slightly turbid fluid. Total acidity was equal to 0·075 per cent. hydrochloric acid; inorganic acids were alone present. Polariscope gave —1°·2. It contained no substance that had any reducing effect on Fehling's solution. After acidifying this fluid and heating it in a water-bath for two hours there was no chemical change.

(2.) After two hours 60 c. c. were drawn off. The acidity was equal to 0·178 per cent. hydrochloric acid; inorganic acids were alone present; the polariscope showed —0°·7, and the fluid contained no reducing substance.

In this case the polariscope shows a rotation of the polarized ray to the left, although no sugar was present. All proteids are lævo-rotatory, and there are peptones in the gastric fluid after injecting saline solution.

This, then, is the character of the gastric fluid with which we have to deal in the case of this healthy digestion.

Normal Gastric Digestion of Cane Sugar.

In each experiment 250 c. c. of 20 per cent. cane sugar solution were injected into the empty stomach, and samples of this were drawn off at varying intervals. The following Table gives the results of these observations:—

Series.	Time during which Cane Sugar was in Stomach.	Number of Cubic Centimetres drawn off.	Total Acidity as HCl per cent.	Presence of Inorganic Acids.	Presence of Organic Acids.	Per cent. of Invert Sugar formed in Stomach.	Total Amount of Reducing Sugar when Inverted outside.	Remarks.
	Minutes							
I.	30	160	0·09	+	+	0·25	2·44	No lactic acid.
II.	60	36·5	0·124	+	+	0·81	1·28	Trace of lactic acid.
III.	60	90	0·115	+	+	0·42	1·7	Trace of lactic acid.
IV.	90	40	0·125	+	+	0·13	0·495	...
V.	120	41	0·1428	++	+	0·68	0·934	Trace of lactic acid.
VI.	120	85	0·185	++	+	0·41	0·65	No lactic acid

These experiments show—

1. That inversion of cane sugar really takes place in the healthy stomach.

2. That as digestion proceeds the proportion of invert sugar to the whole sugar increases.

3. That the amount of invert sugar formed is proportional to the acidity of the gastric juice.

4. That the total amount of sugar diminishes as digestion proceeds.

III. Normal Gastric Digestion of Invert Sugar.

I prepared the invert sugar in the following manner:—One litre of the 20 per cent. solution of pure dry cane sugar was placed in a flask, and to it was added one cubic centimetre of dilute sulphuric acid (1 c. c. ordinary commercial acid to 9 c. c. water). The flask was then placed in a water-bath, and heated for two hours at a temperature of 170°–180° F. After allowing it to cool, it was made up to its original volume by adding water. This 20 per cent. solution of invert sugar gives a rotation of —10° by the polariscope of Zeiss.

I proceeded to experiment with this in the same way as I had done with the cane sugar solution, introducing 250 c. c. of the 20 per cent. solution of invert sugar into the previously emptied stomach, and passing the syphon tube after an interval of one and two hours, and withdrawing some of the gastric contents.

Digestion of Invert Sugar in the Healthy Stomach.

Series.	Numbers of c.c. withdrawn after being 1 or 2 hours in Stomach.		Total acidity as per cent. HCl		Per cent. Invert Sugar remaining in fluid withdrawn.		Remarks.
	1 hour.	2 hours.	1 hour.	2 hours.	1 hour.	2 hours.	
I.	100	24	0·176	·1276	1·8	1·25	
II.	100	0	0·172	0	2·77	0	Stomach empty at second hour.
III.	100	66	0·229	0·164	2·27	0·44	No lactic acid, but other acids present.
IV.	120	11	0·182	0·175	3·3	0	No lactic acid.
V.	75	0	0·156	0	4·5	0	No lactic acid. Stomach empty at second hour.

If we compare this table with that of the digestion of cane sugar, we see that there is a very great difference as regards the behaviour of these two sugars in the stomach.

First, As regards the quantity of fluid in the stomach. In the case of cane sugar there was always much fluid in the stomach, even after the lapse of two hours. In no case was it less than 86 c. c. It is very different with invert sugar, however. When it was injected much fluid could be withdrawn up to the end of the first hour, but after two hours the stomach was entirely or almost empty, as only in one or two cases could a few cubic centimetres be extracted. The stomach therefore becomes quickly emptied of invert sugar.

Second, If we compare the columns in the table after one and two hours, we see what a reduction has taken place in the amount of sugar. What has become of this invert sugar? It must either have been rapidly absorbed through the walls of the stomach, or have been passed on through the pylorus into the duodenum. Probably both of these processes go on at the same time.

IV. Intestinal Digestion of Cane Sugar.

Neither the biliary nor the pancreatic secretions seem to have any inversive action on cane sugar. Béchamp thought that the pancreas had a slight inversive action, but the change which he saw was in all probability due to bacteria causing decomposition, and not to any ferment.

The mucous membrane of the small intestine, however, secretes a ferment which has been named "invertin," and which causes cane sugar to become hydrated and split up into glucose and lævulose. This fermentative action of the succus entericus was first described by Claud Bernard. The ferment can be isolated, and then acts on cane sugar, but much more slowly than when in contact with the mucous membrane of the small intestine. Bernard found that it was present in every part of the small, but not in the large intestine. Sir William Roberts also describes this ferment, and has extracted it from the small intestine of the pig, fowl, and hare. It will not, he finds, pass through a filter, and its inversive action is very slow, usually requiring two hours at 38° C. before any reduction of copper takes place. Hoppe-Seyler does not think that this is a true ferment of the intestinal mucous membrane, but believes that it is one introduced from without, and Busch could not find that cane sugar underwent any change during its stay in the bowels. Hay, however, found this ferment constantly present in every part of the small intestine of the fœtus, and in such a case it could not have been introduced from without. Demant has also described this *invertin* ferment, and also a diastatic one in the small intestine, but he finds that they require to act on the sugar or starch for four or five hours before any inversion of sugar or conversion of starch occurs. Brown and Heron have also studied this question, and find that a watery infusion of the small intestine possessed no inversive action on cane sugar, but when they used the dried and powdered mucous membrane of the small intestine they found a marked inversion. They say that this property lies chiefly in the agminated glands of the small intestine.

To observe for myself whether this inversive ferment was active, and in what localities it was to be found, I made the following experiments:—

A healthy young rabbit was starved for thirty-six hours. It then received a full meal, and was killed two hours subsequently, so that the various digestive processes might then be in full activity. I had previously prepared a 5 per cent. solution of pure cane sugar, and having placed 50 c. c. into separate flasks, I heated all to 38° C. Having carefully but gently washed the contents from the alimentary canal of the animal with a stream of normal salt solution, I then placed 5 grammes of different parts of the intestinal tract and other organs into separate flasks containing the sugar solution, and kept them at 38° C. for two hours. They were then allowed to cool, and the amount of inversion (if any) which had taken place estimated. The following Table shows what tissues were employed, and is arranged in the order of greatest inversive power of the tissues.

Rabbit: 5 grms. each of—	Per cent. Invert Sugar formed.
1. Lower part of small intestine, .	1·14
2. Upper part of small intestine, .	·961
3. Vermiform appendix, lower part, .	·362
4. Liver, ...	·297
5. Vermiform appendix, upper part, .	·233
6. Central part of stomach, . .	·233
7. Pancreas, ...	·217
8. Large intestine, ...	·148
9. Cardiac end of stomach, . .	·144
10. Pyloric end of stomach, . .	·143
11. Spleen, ...	·133
12. Thyroid, ...	·084
13. Salivary glands, ...	·068
14. Muscle, ...	·065
15. Kidney, ...	·062
16. Œsophagus, ...	·061
17. Bile, ...	0

This certainly shows that there is a very decided inversive action in the small intestine of the rabbit, and also an action to a very much smaller extent with the other parts of the digestive tract.

I then performed exactly the same experiments with tissues of an infant which had lived three days, and had been fed on the breast during this period. The salivary glands were too small to be worth while removing. The following Table is also arranged in the order of the greatest inversive power of the tissues.

Infant: 5 grms. each of—	Per cent. Invert Sugar formed.
1. Small intestine, ...	·543
2. Large intestine, ...	·384
3. Stomach, central part, ...	·032
4. Œsophagus, ...	·012
5. Stomach, pyloric end, ...	0
6. Stomach, cardiac end, ...	0
7. Pancreas, ...	0
8. Liver, ...	0
9. Thyroid, ...	0
10. Kidney, ...	0
11. Bile, ...	0
12. Thymus, ...	0
13. Spleen, ...	0

A comparison of these two tables shows that the chief inversive action, both in the infant and in the rabbit, lies in the small intestine. It is a relatively powerful ferment, and, distributed as it is throughout the whole extent of the small intestine, will easily suffice to invert all the assimilable cane sugar which is ingested.

Recapitulating, therefore, we have seen that cane sugar is—

1. Unchanged by saliva.
2. Inverted to a certain small extent in the stomach, depending entirely on the degree and nature of the acidity of gastric fluid.
3. Inverted completely in the small intestine by the action of the ferment "invertin."

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DIGESTION OF SUGARS IN SOME DISEASED CONDITIONS OF THE BODY.

In my preceding paper I endeavoured to show the manner in which cane and invert sugar are digested and fitted for absorption in healthy individuals. In the present paper the results of an experimental investigation regarding the digestion of these sugars in some diseased conditions of the body, either general or local, are given.

I. Chronic Gastric Catarrh (*Gastritis glandularis chronica*).

The patient who suffered from this complaint was a blacksmith, aged 47. For two years he had been much troubled with heaviness, flatulence, and drowsiness after partaking of food. In his case there was no dilatation of the stomach.

Nature of the Gastric Secretion.—In the first place I examined the normal condition of his gastric secretion, by giving him 250 c. c. of cooked minced steak, after thoroughly washing out the stomach.

(1.) One hour subsequently I drew off 57 c. c. of turbid brownish-red fluid. The total acidity of this was equal to 0·3 per cent. hydrochloric acid. This acidity consisted of inorganic acid chiefly, though organic acids were also present. Peptones were present in large amount, and fibrin was digested by this fluid in three-quarters of an hour without the addition of any acid. The polariscope showed a rotation of —4°.

(2.) Two hours after the injection 84 c. c. of fluid similar to that just described were drawn off. The patient felt great relief after his stomach had been washed out, and experienced but little discomfort from the minced meat which he had eaten.

The total acidity was equal to 0·32 per cent. hydrochloric acid, and consisted of inorganic and organic acids in large amount; polariscope gave —2·6°; peptones were present, but the reaction was not so marked as after the first hour. Fibrin was digested in sixty-five minutes without the addition of any acid.

Inversion of Cane Sugar by Gastric Secretion.

It is said that in unhealthy stomachs containing much mucus the gastric juice is very active in changing cane sugar into glucose, and that this power seems to be due to a special ferment existing in the mucus. In order to see if this were so, I performed a set of experiments on this patient similar to that on the healthy individual. At 8 A.M. he had breakfast of bread and milk. At 10 A.M. the stomach was thoroughly washed out, and three ounces of dilute Liquor Caffyn were injected. One hour later a specimen of his gastric contents was drawn off and filtered. Its initial acidity was equal to 0·06 per cent. hydrochloric acid, I then placed in a warm bath equal volumes of this gastric fluid. water, and 20 per cent. cane sugar solution, and kept all at 38° C. In one hour invert sugar was present, and at the end of two hours it amounted to 0·35 per cent.

10 c. c. gastric fluid 10 c. c. water 10 c. c. 20 p. c cane sugar solution	At 38° C. = 0·02 p. c. HCl	In 2 hours— 0·35 p. c. invert sugar.

To determine whether this unhealthy gastric secretion was more active in causing the inversion of cane sugar than a pure acid solution of similar strength, I made a solution of hydrochloric acid of a strength equal to that of this gastric fluid, viz., 0·06 per cent. Equal volumes of this, water and cane sugar solution, were kept at 38° C. There was a good reduction of copper in one hour, and after two hours at 38° C. Fehling's solution showed that there was 0·434 per cent. of reducing sugar present.

10 c. c. solution of HCl = 0·06 p. c. 10 c. c. water 10 c. c. 20 p. c. cane sugar solution	At 38° C. = 0·02 p. c. HCl	After 2 hours— 0·434 p. c. invert sugar.

This last experiment shows that with the fluid from a case of chronic gastric catarrh there is less inversion of cane sugar than with a solution of hydrochloric acid of the same degree of acidity. This would agree with Foster's statement, but then it has happened with abnormal gastric juice and not with normal, as he implies. Still less does it show that in cases of gastric catarrh there is an increased inversion, as Schiff states.

Absence of Inversive Ferment from Gastric Secretion.

In order to confirm my denial of the presence of an inversive ferment in the gastric mucus, I modified the preceding experiment as follows:—To kill any inversive ferment which might be present, I boiled the gastric fluid for a few minutes. I then took as before equal volumes of this fluid, water, and cane sugar solution, and kept all at 38° C. There was a reduction of copper in one hour, and after two hours it amounted to 0·35 per cent.

10 c. c. boiled gastric juice = 0·06 p. c. HCl 10 c. c. water 10 c. c. 20 p. c. cane sugar solution	At 38° C. = 0·02 p. c. HCl	In 2 hours— 0·35 p. c. invert sugar.

The amount of invert sugar produced in this experiment is exactly the same as when unboiled gastric fluid was used. This and the following experiment prove undoubtedly, I think, that the inversion of cane sugar which takes place outside the body is not due to the presence of ferments, for the amount of invert sugar produced is the same before and after boiling the gastric fluid. There is no more inversion than can be accounted for by the acidity.

I then neutralized carefully a similar mixture of catarrhal gastric fluid, water, and cane sugar solution, and heated all on the water-bath at 38° C. There was no reduction produced in the copper solution after one hour's heating, while after two hours there was a slight reduction, but too faint to be estimated quantitatively.

10 c. c. catarrhal gastric fluid 10 c. c. water 10 c. c. 20 per cent. cane sugar solution	At 38° C. carefully neutralized.	After 2 hours— faint trace of invert sugar.

These results are similar to those obtained with healthy gastric fluid.

Digestion of Cane Sugar in Chronic Gastric Catarrh.

In the first place, I would remark that the nature of the fluid which was injected into the stomach was quite unknown to the patient, and therefore it is the more necessary to pay attention to his statements regarding pain or discomfort, or the reverse, after the reception of the sugary solutions.

(*a.*) Having washed out the stomach thoroughly, I then injected 250 c. c. of a 20 per cent. solution of cane sugar (= 50 grammes cane sugar). One hour afterwards 70 c. c. of thick whitish fluid were drawn off. This filtered with difficulty, as it was mixed with much mucus. The total acidity amounted to 0·2 per cent. hydrochloric acid. Organic and inorganic acids were present, including lactic acid. Fehling's solution showed that the sugar inverted in the stomach amounted to 0·98 per cent.

After inverting artificially 25 c. c. of this gastric fluid by heating it for two hours on a water-bath, the invert sugar present amounted to 2 per cent. Soon after receiving this sugary solution into his stomach the patient felt very sick, and vomited several times during the day. The vomit was very acid, putting his teeth "on edge," and rendering his tongue and gums tender. Pain over the region of the stomach was severe, while heartburn and flatulence were much worse than usual.

(*b.*) *Same Patient.*—At 10 A.M., on a subsequent day, I washed out his stomach. He had partaken of no food since 5 A.M., when he had some milk; yet much white curdy material came through the elastic syphon tube. This shows how slow the processes of digestion are in such cases, and for how long a time food remains in the stomach. I then injected 250 c. c. of 20 per cent. cane sugar solution.

(1.) One hour afterwards 83 c. c. of viscid white fluid, containing shreds of mucus, were drawn off. The total acidity, estimated as hydrochloric acid, was 0·133 per cent., and was due chiefly to inorganic acids; organic acids also present, lactic acid included. Invert sugar amounted to 1·47 per cent. Twenty-five c. c. of this gastric fluid were heated for two hours, to invert any cane sugar remaining. At the end of this time much of the organic acid had been driven off by the heat. The reducing sugar then amounted to 5·9 per cent.

(2.) Two hours after receiving the injection 130 c. c. of whitish fluid were drawn off. This was not so viscid as after the first hour. The total acidity was equal to 0·175 per cent. There was much more inorganic acid present than after the first hour, and lactic acid was also present. Sugar inverted in the stomach formed 1·7 per cent. After artificial inversion the invert sugar had increased to 4·3 per cent.

The patient suffered much after this fluid was injected from pain in the stomach, and heartburn, with much flatulence, and was not relieved till he had produced emesis by thrusting his finger down his throat.

(*c.*) *Same Patient.*—250 c. c. 20 per cent. solution of cane sugar injected into empty stomach.

(1.) One hour afterwards 65 c. c. of turbid white fluid were drawn off. A much greater quantity came through the tube, but I returned at once much of it back to the stomach. Total acidity equal to 0·07 per cent. HCl, chiefly inorganic; no lactic acid reaction. Invert sugar present in the stomach, 1·04 per cent. After inversion on water-bath, the invert sugar had increased to 6·6 per cent.

(2.) Two hours after injection 125 c. c. of fluid similar to the last were drawn off. Total acidity = 0·131 per cent. HCl, and was almost wholly due to inorganic acids; no lactic acid was present. Sugar inverted in stomach amounted to 0·9 per cent. After inversion outside, 4·3 per cent. of invert sugar was present.

(*d.*) *Same Patient.*—250 c. c. 20 per cent. cane sugar solution injected into empty stomach.

(1.) One hour after 72 c. c. turbid white fluid were drawn off. Total acidity = 0·09 per cent. HCl, chiefly inorganic. Small amount of organic acids, but no lactic acid present. Sugar inverted in stomach formed 0·56 per cent. After inversion by heating, the invert sugar had increased to 3·57 per cent.

(2.) Two hours after injection 83 c. c. of fluid similar in character to the preceding were drawn off. Total acidity as HCl = 0·134 per cent. Inorganic and organic acids were present in nearly equal amounts. No lactic acid. Sugar inverted in stomach amounted to 0·56 per cent., while after inversion outside, invert sugar formed 3·44 per cent.

(*e.*) *Same Patient.*—He says that he has felt very ill for the last three days, or since this treatment was commenced (*i.e.*, washing out stomach and injection of cane sugar solution). He had had only milk and bread for breakfast, yet on washing out the stomach there was much evolution of sulphuretted hydrogen. 250 c. c. of 20 per cent. cane sugar solution were injected.

(1.) One hour later 75 c. c. of turbid white fluid were drawn off. Total acidity, estimated as HCl, formed 0·109 per cent. A large amount of mineral acid was present; organic acid in small amount. No lactic acid reaction. The amount of sugar inverted in stomach was 0·392 per cent. After inversion outside, invert sugar formed 5·26 per cent.

(2.) Two hours after injection, 100 c. c. of thick fluid were drawn off. Total acidity now equal to 0·094 per cent., due chiefly to inorganic acids; no lactic acid present. Sugar inverted in stomach formed 0·9 per cent.; after inversion outside, invert sugar increased to 5 per cent.

He suffered much pain till he induced emesis.

(*f.*) *Same Patient.*—Injected 250 c. c. cane sugar solution.

(1.) One hour later 100 c. c. thick white fluid drawn off. Total acidity = 0·105 per cent., principally mineral; no lactic acid. Sugar inverted in stomach, 1 per cent.; after inversion outside, invert sugar 5·5 per cent.

(2.) Two hours afterwards 75 c. c. of fluid similar in character were drawn off. Total acidity, 0·116 per cent. as HCl; trace of organic but no lactic acid. Sugar inverted in stomach 0·6 per cent. After inversion on water-bath, invert sugar 2·3 per cent.

Digestion of Cane Sugar in Chronic Gastric Catarrh.

Series.	Time during which Cane Sugar was in the Stomach.	Number of Cubic Centimetres syphoned off.	Total Acidity as per cent. HCl.	Presence of Inorganic Acids.	Presence of Organic Acids.	Invert Sugar. Per cent. formed in Stomach.	Per cent. formed outside Body.	Remarks.
	Hours.							
I.	1	70	0·2	+	+	·98	2·	Had much pain; acid vomit; heartburn; flatulence.
II.	1	83	0·133	++	+	1·47	5·9	Pain; heartburn; flatulence severe, not relieved till emesis produced.
	2	130	0·175	+++	+	1·7	4·3	
III.	1	65	·07	++	+	1·04	6·6	Pain severe.
	2	125	0·131	+++	+	0·9	4·3	
IV.	1	72	0·09	++	+	0·56	3·57	Pain severe.
	2	83	0·134	++	++	0·56	3·44	
V.	1	75	0·109	++	+	0·392	5·26	Much pain till he vomited.
	2	100	0·094	+++	+	0·9	5·	
VI.	1	100	0·105	++	+	1·	5·5	...
	2	75	0·116	++	+	0·6	2·3	

If we compare this table with that of the healthy digestion of cane sugar, we see that the acidity is very much alike in both. There has been a tolerably large amount of inversion in the case of this dyspeptic, but the sugar has been retained in the stomach along with a large amount of fluid, and has not been absorbed or passed on as in the healthy individual. This case demonstrates well the tardy nature of the digestive and absorptive processes in catarrhal conditions of the gastric mucous membrane.

The patient made constant complaint of pain, heartburn, and flatulence after the injection of the cane sugar solution; while the healthy man only once mentioned that he had very slight pyrosis.

Digestion of Invert Sugar in Chronic Gastric Catarrh.

The next set of experiments deals with the gastric digestion of *invert sugar* in the same patient suffering from chronic gastric catarrh.

(*g.*) 250 c. c. 20 per cent. solution of invert sugar injected into stomach.

(1.) One hour later 80 c. c. of thick viscid fluid resembling saliva were syphoned off. Total acidity equal to 0·153 per cent. as HCl. Inorganic acids form the largest part of the acidity, though organic acids also are present. Invert sugar 5·26 per cent.

(2.) Two hours after injection 120 c. c. fluid, not so viscid as before, were drawn off. Total acidity 0·094 per cent., principally inorganic; no lactic acid. Invert sugar 1·54 per cent.

He made no compaint of pain, nor had heartburn or flatulence after receiving this injection, till about 4 P.M., or six hours after the invert sugar solution had been introduced, and obviously not at all due to the saccharine fluid.

(*h.*) *Same Patient.*—250 c. c. 20 per cent. solution of invert sugar injected.

(1.) One hour afterwards 65 c. c. thick whitish fluid were drawn off. The total acidity amounted to 0·091 per cent. as HCl; small amount of organic acid present (no lactic acid), but much inorganic. Invert sugar 5 per cent.

(2.) Two hours after injection 62 c. c. fluid drawn off. Total acidity equal to 0·138 per cent. HCl; characters similar. Invert sugar 2·6 per cent.

Patient had no discomfort of any kind.

(*i.*) *Same Patient.*—250 c. c. invert sugar introduced.

(1.) One hour later 52 c. c. turbid thick fluid obtained. Total acidity 0·122 per cent. HCl, due chiefly to inorganic acid. Invert sugar 5·5 per cent.

(2.) Two hours after injection 42 c. c. of fluid similar in character to the preceding were drawn off. Total acidity, estimated as HCl, 0·113 per cent., chiefly inorganic; no lactic acid. Invert sugar 1·2 per cent.

Patient felt very comfortable.

(*j.*) *Same Patient.*—250 c. c. invert sugar injected.

(1.) One hour later I drew off 68 c. c. turbid white fluid. Total acidity equal to 0·116 per cent.; small amount of organic acid present, but chiefly inorganic; no lactic acid. Invert sugar 4·76 per cent.

(2.) Two hours afterwards 100 c. c. of similar fluid drawn off. Total acidity equal to 0·102 per cent. HCl, chiefly inorganic; no lactic acid. Invert sugar 3·7 per cent.

(*k.*) *Same Patient.*—250 c. c. 20 per cent. invert sugar injected.

(1.) One hour afterwards 75 c. c. of turbid fluid were drawn off. Total acidity 0·109 per cent., due chiefly to inorganic acids; no lactic acid. Invert sugar 4·35 per cent.

(2.) Two hours after injection I drew off with difficulty 30 c. c., the stomach being almost empty. Total acidity equal to 0·07 per cent. as HCl, chiefly inorganic. Invert sugar 0·8 per cent.

On neither of the two latter occasions did the patient make any complaint, but said that he had felt better during the last few days, or during the time he had been getting invert sugar. It is interesting to compare this with the statement made by him after the cane sugar injections.

These results may be tabulated as follows:—

Digestion of Invert Sugar in Chronic Gastric Catarrh.

Series.	Time during which Invert Sugar was left in Stomach.	Number of Cubic Centimetres drawn off.	Total acidity as HCl per cent.	Presence of Inorganic Acids.	Presence of Organic Acids.	Invert Sugar per cent.	Remarks.
	Hours						
I.	1	80	0·153	+++	+	5·26	No discomfort.
	2	120	0·094	+++	+	1·54	
II.	1	65	·091	+++	+	5·5	...
	2	62	0·138	+++	+	2·6	
III.	1	52	0·122	+++	+	5·5	...
	2	42	0·113	+++	+	1·2	
IV.	1	68	0·116	+++	+	4·76	...
	2	100	0·102	+++	+	3·7	
V.	1	75	0·109	+++	+	4·35	...
	2	30	0·07	+++	+	0·8	

This table shows how great a reduction has taken place in the percentage of invert sugar during the second hour as contrasted with the first. If we compare this with the digestion of the same sugar in health (see *Edinburgh Medical Journal* for September, page 208), we are struck by the fact that in the healthy stomach there is very little invert sugar left after two hours, while in the dyspeptic, though the amount has been greatly reduced, there is still a large proportional amount. The absorption or emptying of the stomach is much less rapid in this catarrhal condition than in health, but the difference in behaviour of the sugars experimented with—cane and invert sugar—is strikingly evident on looking over the two tables showing the digestion of cane and invert sugar in the case of this patient with catarrhal dyspepsia. In the first table we see how large an amount of unchanged sugar was still in the stomach even at the end of two hours, while in the case of invert sugar the amount still retained at the end of this period was proportionally very small. The great and important clinical point to note, however, is that with invert sugar there was no pain or discomfort, while with cane sugar on nearly every occasion the patient suffered much from heartburn, flatulence, or even actual pain over the stomach. It is evident that in this case invert sugar was much more easily borne than cane sugar.

II. Digestion of Cane Sugar in Pernicious Anæmia.

The next patient in whom I carried on a similar set of experiments was a labourer, aged 45, suffering from pernicious anæmia. Six months previously his symptoms began by him experiencing a heavy, dull weight over the stomach after taking food. This increased in severity, till at the time when I had him under observation, this pain was very intense; he suffered severe headache soon after taking food, with waterbrash and even vomiting.

What was the nature of the gastric juice in such a case, and how would it behave towards sugar?

Nature of the Gastric Secretion.—To investigate the first of these questions, I gave him 250 c. c. of cooked minced steak to eat, after having first washed out his stomach thoroughly.

(1.) One hour afterwards I drew off 76 c. c. of muddy light yellow fluid containing very small fragments of muscular tissue, which formed an almost amorphous deposit. Fat was floating on the surface in tolerably large round masses. The total acidity equalled 0·016 per cent. hydrochloric acid; no lactic acid was present. The acidity was so feeble that we might almost have said it was neutral in reaction. No peptone reaction. Fibrin was soon digested after adding dilute hydrochloric acid.

(2.) Two hours after eating the mince-meat 30 c. c. of pale yellow fluid were drawn off. It also contained a fine powder of muscular fibre. On the surface the fat floated in one large mass. Total acidity was equal to 0·006 per cent.; faint trace of lactic acid present. Polariscope —1·1 per cent. No peptone reaction. Fibrin was soon digested after acidification with hydrochloric acid.

This gastric secretion has, therefore, hardly any acidity. There is no lack of pepsin, as is shown by the ready digestion of fibrin after the fluid has been acidified.

Gastric Digestion of Cane Sugar in Pernicious Anæmia.

(*a.*) 250 c. c. of a 20 per cent. solution of cane sugar were injected into the empty stomach.

(1.) One hour later I drew off 25 c. c. yellow coloured fluid. The total acidity as hydrochloric acid amounted to 0·0018 per cent.; no lactic acid present.

None of the cane sugar had undergone any inversion in the stomach, as evidenced by the inability of the secretion to reduce Fehling's solution. After inversion outside of the body the fluid contained 0·43 per cent. invert sugar.

(2.) Two hours after injection 38 c. c. of fluid, paler in colour than the previous, were drawn off. The total acidity was practically *nil* —being 0·0007 per cent. as hydrochloric acid. Invert sugar was absent from the fluid when withdrawn, and also after having been acidified and heated for two hours. In fact, after the lapse of two hours the stomach contained absolutely no sugar of any kind.

This patient had been accustomed to have his stomach washed out, and he told me that hitherto after such treatment he felt "light" and comfortable, but this time (after having the solution of cane sugar injected) he had felt very heavy and had a "gone feeling" over the region of the stomach, similar to what he experienced after taking a good meat diet.

(*b.*) *Same Patient.*—250 c. c. of a 20 per cent. solution of cane sugar injected.

(1.) One hour after I drew off 50 c. c. of yellow fluid with many mucous flocculi in it. The total acidity amounted to 0·021 per cent. HCl. Sugar inverted in stomach, none; after inversion on water-bath, invert sugar amounted to 4·17 per cent.

The patient stated that he felt "very bad indeed," and headache was severe.

(2.) Two hours after injection there was no fluid in the stomach, and when it was rinsed out with pure water the rinsings contained no sugar of any kind.

Gastric Digestion of Cane Sugar in Pernicious Anæmia.

Series.	Time during which Cane Sugar was in Stomach.	Number of Cubic Centimetres syphoned off.	Total Acidity as per cent. HCl.	Per cent. Invert Sugar formed in Stomach.	Per cent. Invert Sugar formed outside.	Remarks.
	Hours.					
I.	1	25	0·0018	0	0·43	Much pain and discomfort.
II.	2	38	0·0007	0	0	
III.	1	50	0·021	0	4·17	Felt very ill.
IV.	2	0	0	0	0	

Practically the gastric juice of this patient had no acidity. This accounts for there being no inversion of the cane sugar during its stay in the stomach. The probability is that after staying in the stomach unchanged for some time the cane sugar was simply passed on through the pyloric orifice into the duodenum.

Behaviour of Invert Sugar in the Stomach in case of Pernicious Anæmia.

(*c.*) *Same Patient.*—250 c. c. of 20 per cent. invert sugar solution introduced into stomach. Fifteen minutes afterwards 150 c. c. syphoned off. Total acidity equalled 0·0036 per cent. HCl; invert sugar 18·2 per cent.

(*d.*) *Same Patient.*—250 c. c. invert sugar solution given.

(1.) One hour later 52 c. c. greenish yellow fluid drawn off. Total acidity amounted to 0·0145 per cent. HCl. No lactic acid present. Invert sugar was present to 8·7 per cent.

Patient stated that he felt no discomfort that day, and that he experienced the same "light" feeling which he formerly had after having his stomach washed out. He had no flatulence or water-brash.

(2.) Second hour after injection 54 c. c. pale fluid drawn off. Acidity *nil*—it being neutral in reaction. No invert sugar was present.

(*e.*) *Same Patient.*—250 c. c. invert sugar introduced.

(1.) One hour later 23 c. c. drawn off. Total acidity equalled 0·01 per cent. as HCl. Invert sugar 3·7 per cent.

(2.) Two hours after injection there was no fluid in the stomach, and when rinsed out, no sugar was detected in the rinsings.

Behaviour of Invert Sugar in Pernicious Anæmia.

Series.	Time during which the Invert Sugar was left in Stomach.	Number of Cubic Centimetres drawn off.	Total Acidity as per cent. HCl.	Per cent. Invert Sugar.	Remarks.
	Hours.				
I.	1	52	0·0145	8·7	No discomfort.
II.	2	54	0	0	...
III.	1	23	0·01	3·7	...
IV.	2	0	0	0	...

In this patient the conduct of the stomach to both cane and invert sugar has been similar. It has simply emptied itself very quickly. There may have been some absorption of invert sugar through the gastric walls, but more probably the greater part has simply been passed through the pyloric orifice into the duodenum.

III. Digestion of Cane Sugar in Alcoholic Dyspepsia.

This patient was a seafaring man, aged 54. His complaints were morning vomiting, weight, fulness and uneasiness over stomach; very troublesome flatulence, and want of appetite.

(*a.*) 250 c. c. cane sugar solution (20 per cent.) were injected into his empty stomach.

(1.) One hour later 45 c. c. of turbid ropy fluid, containing much mucus, were drawn off. Much flatus escaped also through the tube. Total acidity amounted to 0·0145 per cent. as HCl. Traces of lactic acid were present. The amount of sugar inverted in stomach was 0·208 per cent. After inversion on water-bath the invert sugar had increased to 5 per cent.

He stated that flatulence became very severe after the injection of the cane sugar.

(2.) Two hours after injection 30 c. c. of thick viscid fluid were drawn off. The total acidity was equal to 0·0036 per cent. HCl. Sugar inverted in stomach amounted to 0·089 per cent. After inversion outside, invert sugar formed 0·213 per cent.

(*b.*) *Same Patient.*—250 c. c. cane sugar solution injected. One hour later 50 c. c. thick viscid blood-stained fluid syphoned off. The total acidity was here 0·01 per cent. as HCl; no lactic acid was present. Fehling's test showed that the cane sugar had undergone no inversion in the stomach. After inversion on water-bath the invert sugar formed 1·56 per cent.

Gastric Digestion of Cane Sugar in Alcoholic Gastric Catarrh.

Series.	Time during which Cane Sugar was in the Stomach.	Number of Cubic Centimetres syphoned off.	Total Acidity as per cent. HCl.	Per cent. Invert Sugar formed in Stomach.	Per cent. Invert Sugar formed outside.	Remarks.
	Hours.					
I.	1	45	0·0145	·208	5·	Flatulence severe.
II.	2	30	0·0036	·089	·213	...
III.	1	50	0·01	0	1·56	...

In this case the acidity is very slight, and the amount of inversion in the stomach proportionally small. This experience is quite opposed to the usual statement that in diseased conditions of the mucous membrane of the stomach, with the secretion of much mucus there is a great inversion of cane sugar, due to a special ferment which is said to exist in the mucus, and which is allied to ptyalin.

The preceding experiments show that in certain diseases invert sugar is very quickly passed on into the duodenum, and that the absorption of this sugar through the walls of the stomach seems to be very slight. That this is so is shown by the table of the events in the digestion of cane sugar in cases of chronic gastric catarrh. From it we see that the relation which the amount of invert sugar bears to cane sugar remains very much the same at the end of the first or second hour. Had there been much absorption through the gastric walls this relation would have been changed.

In all cases we find that invert sugar has been much more easily borne than cane sugar, and this appears to me a most important point clinically. In almost every case those patients made complaint of weight, pain, heartburn, flatulence, etc., after the solution of cane sugar had been introduced into the stomach, while there was an almost entire absence of disagreeable sensations after the same amount of invert sugar had been injected.

In the cases of chronic gastric catarrh cane sugar was retained in the stomach for a lengthened period, but did not undergo any marked degree of inversion. When invert sugar was, however, given to these patients it very rapidly disappeared from the stomach, though not so quickly as in the case of normal digestion. In the case of pernicious anæmia, owing to the want of acidity of the gastric juice, cane sugar underwent no inversion while in the stomach, even after an interval of two hours. It caused, likewise, much pain and discomfort. The solution of invert sugar, on the contrary, caused no such symptoms, and disappeared rapidly from the stomach.

I am convinced, from these experiments, that cane sugar lingers in the stomach for a much longer period than invert sugar, and is consequently much more liable to undergo fermentative changes. It is, however, an easy matter to give invert sugar instead of cane sugar to persons in whom digestion proceeds slowly or is deranged.

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DIGESTION OF STARCH IN THE STOMACH.

PTYALIN is the ferment in the salivary secretion which converts starch granules into achroodextrin, maltose, and glucose. Through the continued action of this ferment maltose is slowly split up into glucose. The amylolytic action of saliva is destroyed by high temperatures, as by boiling; while at low temperatures conversion becomes slow, and ceases entirely at 0° C. At the normal blood-heat (38° C.) starch is converted by ptyalin very rapidly in an alkaline solution. It is said that small quantities of hydrochloric acid suspend and rapidly kill the ferment. On the other hand, it is affirmed that its action goes on in neutral as well as in slightly acid solutions. In strongly alkaline or acid solutions its action very soon ceases.

The question as to the activity of the salivary ferment in acid solutions is of great importance as regards the digestion of starch in the stomach. The ingestion of food into the stomach leads to the secretion of gastric juice. If then hydrochloric acid be poured out early in digestion, the alkalinity of the saliva swallowed will be soon neutralized, and the activity of the ptyalin must soon come to an end in the acid medium.

It is almost certain, however, that the hydrochloric acid secreted in the stomach combines at once with the proteids during the earlier stages of digestion, and so, no free acid remaining, saliva still continues its converting action on starch. This condition lasts for a period varying from three-quarters to two hours; when, the proteids having combined with as much hydrochloric acid as they require, free hydrochloric acid appears in the gastric secretion. The conversion of starch in the stomach then ceases, as ptyalin is destroyed by the acids of the gastric juice in full digestion. There are thus two periods in gastric digestion—(1), when saliva still acts; (2), when pepsin alone is active.

What degree of acidity hinders or kills the ferment ptyalin? Do the various acids differ in their power of destroying ptyalin?

During the earlier stages of mixed digestion, though no free hydrochloric acid is present, the gastric secretion is acid, and this may be due to the presence of lactic acid and acid salts. Does ptyalin still act during this time? If it only acts in alkaline or neutral solutions, then its action will be limited to the time during which food is being masticated and swallowed, and in the stomach only till the alkalinity of the saliva is fully neutralized.

Effect of Normal Gastric Secretion on Amylolysis by Ptyalin.

The following experiments were performed with normal human gastric secretion. After washing out thoroughly the stomach of a healthy man, several ounces of a dilute solution of Caffyn's Liquor Carnis were introduced into it. After the lapse of an hour the contents of the stomach were drawn off, filtered, and used instead of the pure acid solutions in other experiments. The acidity of this gastric fluid was due to inorganic acid, and amounted to 0·15 per cent. hydrochloric acid.

10 c. c. gastric secretion 10 c. c. 1 per cent. starch solution 10 c. c. saliva	At 38° C. = 0·05 per cent. HCl	Starch unchanged after two hours.

This experiment shows that in the stomach with an acidity of the contents less than that even normally present in the gastric secretion, the action of ptyalin is wholly restrained.

Was the ferment merely inhibited from action by the acid, or was it destroyed? To determine this I took equal volumes of this gastric fluid, 1 per cent. starch solution and saliva, and having mixed them, neutralized the mixture carefully with a solution of caustic potash, using very delicate test papers to show the neutral point.

10 c. c. healthy gastric fluid 10 c. c. 1 per cent. starch solution 10 c. c. saliva	At 38° C., carefully neutralized	Starch wholly converted within ten minutes.

On examining the mixture shortly after neutralization the whole of the starch was found to have undergone conversion. It reduced Fehling's solution strongly, and contained 0·22 per cent. of reducing substance. This demonstrates that, with an acidity equal to 0·05 per cent. hydrochloric acid in the gastric contents, the action of ptyalin is restrained.

I performed similar experiments with the gastric fluid from a case of *chronic gastric catarrh*, the acidity of which was equal to 0·067 per cent. hydrochloric acid.

10 c. c. unhealthy gastric secretion 10 c. c. 1 per cent. starch solution 10 c. c. saliva	At 38° C. = 0·022 per cent. HCl	Starch unchanged after two hours.

After being neutralized:—

10 c. c. unhealthy gastric secretion 10 c. c. 1 per cent. starch solution 10 c. c. saliva	At 38° C., carefully neutralized	Starch completely converted within ten minutes.

After ten minutes the starch was wholly converted, and the reducing substances amounted to 0·23 per cent.

In this case also the acidity of the secretion was clearly the restraining agent. Does the acid merely restrain, or does it actually kill the ptyalin ferment if exposed long enough to its influence? By some authors it is affirmed that the former alone occurs, and that the conversive action of ptyalin again becomes potent on the gastric contents becoming alkaline after passing into the intestine. Others, again, state that ptyalin is actually killed during its stay in the stomach.

Outside of the body I found that the following takes place. I placed in a vessel—

10 c. c. gastric fluid (of an acidity equal to 0·102 per cent. hydrochloric acid) 10 c. c. 1 per cent. starch solution 10 c. c. saliva	At 38° C. for one hour,

and kept all at a temperature of 38° C. for one hour. At the end of this time the starch had undergone no conversion. I then neutralized the mixture carefully, and kept it at 38° C. for thirty minutes, when it was found to contain much erythrodextrin and soluble starch, some unchanged starch, and substances reducing Fehling's solution amounted to 0·19 per cent.

In another experiment I left a similar mixture at a temperature of 38° C. for twenty-four hours before neutralizing it. The starch had, of course, undergone no conversion. After being neutralized, it was kept at the same temperature for thirty minutes, at the end of which time it contained much unchanged starch, some soluble starch and erythrodextrin, and 0·09 per cent. of reducing substance. After having been kept for two hours in the warm chamber it gave no coloration with iodine (showing that the starch had been changed into the higher or achroodextrins), and contained 0·138 per cent. reducing substance.

These experiments show that with that degree of acidity found in the above secretions the ferment ptyalin is not killed, but its converting action is prevented. The diastatic action of the saliva seems also to become weaker the longer it is exposed to the influence of the acid, as is shown in the second case, where the ptyalin was exposed to the action of the acid for twenty-four hours. In this case the converting action was feeble and very slow, compared with its action when exposed to the influence of the acid for one hour only.

I am inclined to think, therefore, that as the acidity of the gastric contents increases during digestion, so is the power of the ferment ptyalin diminished, till at the end of digestion it must be almost, if not entirely destroyed, and, I believe, incapable of resuming its function in the small intestine.

The Digestion of Starch in the Stomach.

If to a solution of starch we add a dilute acid and keep the mixture at a high temperature, the starch becomes changed into dextrin and glucose. Are the conditions under which starch is subjected in the stomach favourable to conversion in this manner?

A priori one would not expect that starch could undergo any conversion in the stomach, as the degree of acidity is so feeble and the temperature comparatively low.

From his experiments on Alexis St Martin, however, Smith concluded that starchy food was digested in the stomach independently of saliva, and Brown-Séquard, from his own experience, came to a similar conclusion. Munk and Haycraft have even described a ferment which is sometimes found in the gastric mucous membrane of the pig, and which changes starch into sugar. Brücke found that soluble starch was formed in the stomach to a large extent, and thinks that it is due to the acidity, while the erythrodextrin formed from starch is due to the lactic acid fermentation. The saliva of dogs has only a very slight diastatic action, yet when fed on starch, dextrin and sugar is found in the stomach along with free hydrochloric acid.

On the other hand, Dalton, Kühne, Duclaux, and Schiff deny that starchy matters are digested in the stomach. Foster states that the gastric juice *per se* has no effect on starch whatever. Bouchardat and Sandras found that starch underwent no change in the stomach of rodents. It was only in the small intestines of these animals that dextrin and glucose were formed from starch. In birds they found that starch was much more completely digested, and so in the gizzard dextrin and glucose are found. They think, however, that in the human stomach cooked starch begins to be dissolved. Laborde found that gastric juice had not the same power of converting starch as a solution of hydrochloric acid of the same degree of acidity, and thinks that the acid in the stomach was therefore lactic acid.

If the reaction of the gastric contents be neutral or alkaline, achroodextrin may be formed through the continued action of the saliva. If acid, however (and this only to a small extent), then the conversion which has begun is rapidly brought to a conclusion, and so erythrodextrin may be alone formed.

Von den Velden states that ptyalin acts in the stomach only in presence of weak organic acids, but not if free hydrochloric acid be present also. It has been found, however, that when starchy food is received into the stomach the secretion of hydrochloric acid takes place very early and in a not inconsiderable amount, and remains so till the food passes out of the stomach.

To determine if the gastric secretion *per se* had any effect on starch, I performed the following experiment:—

I. *Healthy Gastric Secretion.*—

I placed 30 c. c. of a 1 per cent. solution of starch in a vessel with 10 c. c. of gastric secretion from a healthy individual (the acidity of the latter was equal to 0·211 per cent. hydrochloric acid), and kept all at a temperature of 38° C. There was absolutely no change in the starch even after the lapse of two hours.

30 c. c. 1 per cent. starch solution 10 c. c. healthy gastric secretion (=0·211 per cent. HCl)	At 38° C.	Two hours later no conversion.

II. *Chronic Gastric Catarrh.*—

With the secretion from an individual suffering from chronic gastric catarrh I performed a similar experiment, and with a similar result.

30 c. c. 1 per cent. starch solution 10 c. c. unhealthy gastric fluid (of acidity=0·30 per cent. HCl)	At 38° C.	No change after lapse of two hours.

III. *Pernicious Anæmia.*—

A similar experiment was tried in this case, but with different results.

30 c. c. 1 per cent. starch solution 10 c. c. unhealthy gastric secretion (acidity=0·016 per cent. HCl)	At 38° C	After one hour 0·6 per cent. reducing substance present.

On testing the fluid one hour after, 0·6 per cent. of reducing sugar was present, and this appeared to be the maximum conversion, as the figure remained the same at the end of the second hour. We note, however, that in this last case there was practically no acidity, and the conversion was probably due to saliva swallowed accidentally.

The next experiments were made with starch in the *living stomach.*

I. *Healthy Digestion.*—

After having washed out thoroughly the stomach of a healthy man, 250 c. c. of a 5 per cent. mucilage of starch were injected into his stomach, taking care that saliva was excluded.

After the lapse of one hour the elastic tube was passed, and 72 c. c. of a turbid whitish fluid were withdrawn. The total acidity was equal to 0·22 per cent. HCl, and was composed almost entirely of inorganic acid. The contents consisted of unchanged starch in large amount, tolerable quantities of soluble starch and erythrodextrin, with a trace of reducing sugar—too small in amount for quantitative analysis.

After the lapse of two hours, 56 c. c. of a clear viscid fluid were syphoned off. The acidity was chiefly inorganic, and amounted to 0·17 per cent. There was very little starch present, and no erythrodextrin or sugar. The erythrodextrin and sugar which were present at the end of the first hour had either been absorbed through the walls of the stomach or been passed on through the pylorus.

II. *Chronic Gastric Catarrh.*—

As before, 250 c.c. of the 5 per cent. starch mucilage were injected into the empty stomach.

One hour later 96 c.c. of a whitish fluid were drawn off. The total acidity was equal to 0·127 per cent. hydrochloric acid, and was due chiefly to this acid. Much unchanged starch was present in the fluid, erythrodextrin and soluble starch in small amount, and a mere trace of sugar.

After an interval of two hours, 100 c.c. of a thick whitish-yellow fluid were obtained from the stomach. Organic and mineral acids were present in nearly equal amounts—the total acidity amounting to 0·225 per cent. Here, again, much unchanged starch was present, a small amount of erythrodextrin, and a trace of sugar. The patient felt no discomfort of any kind from this injection of starch solution.

III. *Pernicious Anæmia.*—

250 c.c. of the 5 per cent. starch solution were injected into the stomach of this patient with the same precautions as in the preceding cases.

After the lapse of one hour 41 c.c. of clear thin fluid were withdrawn. The total acidity amounted to 0·01 per cent. as hydrochloric acid. Small amounts of unchanged and soluble starch were present, but no erythrodextrin, and reducing sugar amounted to 1 per cent.

After the lapse of two hours 67 c.c. of thin yellowish fluid were obtained. The acidity was almost *nil*—amounting to 0·0036 per cent. A trace of starch was present, but erythrodextrin and sugar were both absent. Patient had been very comfortable.

Gastric Digestion of Starch.

	Healthy.		Chronic Gastric Catarrh.		Pernicious Anæmia.	
Hours.	1	2	1	2	1	2
Number of c. c. withdrawn.	72	56	96	100	41	67
Total acidity.	0·22	0·17	0·127	0·225	0·01	0·0036
Unchanged starch.	Much.	Little.	Much.	Much.	Small amt.	Small amt.
Erythrodextrin.	Plenty.	None.	Small amt.	Small amt.	None.	None.
Sugar, per cent.	Trace.	None.	Trace.	Trace.	1	None.
Remarks.	Turbid.	Viscid.	Whitish.	Thick.	Thin fluid.	Thin fluid.

A glance at this Table shows that with the acidity of the healthy stomach, or in pathological conditions where the acidity is not diminished, conversion of starch is soon brought to an end in the stomach; whereas in those conditions where the gastric juice has a feeble degree of acidity, the conversion of starch is carried on to a great extent in the stomach, as is shown in the case of pernicious anæmia, where probably amylolysis was carried to its full limit, and the products either at once absorbed or passed on.

In these experiments the starch was introduced directly into the stomach by means of the stomach tube. In this way there was no admixture of saliva except what was swallowed subsequently. The Table shows that in cases where the normal acidity was not lessened, this swallowed saliva had little conversive action on the starch. It likewise shows that even a pure starch solution introduced into the stomach promotes the secretion of hydrochloric acid,—a fact which, on *à priori* grounds, we should not have expected as being inimical to the digestion of amylaceous substances.

From the high degree of conversion which the starch has undergone in the stomach of the patient with pernicious anæmia, I should be inclined to think that this was either due to swallowed saliva or to a conversive ferment secreted by the gastric mucous membrane, as has been described in the stomach of the pig.

The above, however, is not the normal condition in which starchy food is received into the stomach, for it is always mixed up with and accompanied by the products of salivary secretion.

In order to see what changes occur in starch solutions received into the stomach under such conditions, I experimented as follows:—

Combined Effect of Salivary and Gastric Digestion on Starch.

Having thoroughly washed out the stomach, I allowed the following patients to eat slowly a fluid mucilage of boiled starch.

I. *Healthy Digestion.*—

250 c. c. boiled starch solution eaten slowly. Fifteen minutes later I drew off 40 c. c. The total acidity was equal to 0·061 per cent. Starch and erythrodextrin were present in large amount, and reducing sugar amounted to 0·16 per cent.

I carefully neutralized this fluid, and kept it at a temperature of 38° C. to see if any further conversion would take place. After being kept thus for forty-five minutes, no further change had occurred. The ptyalin ferment had therefore in this case been killed by this degree of acidity of the gastric contents, viz., 0·061 per cent. hydrochloric acid.

One hour after the ingestion of the starch solution other 45 c. c. were syphoned off. The total acidity equalled 0·102 per cent.; much unchanged starch was present, with traces of erythrodextrin and sugar.

This also was neutralized and kept at 38° C. for forty-five minutes, and in this case also no further change occurred. These examples demonstrate that the normal acidity of the healthy gastric secretion not only restrains, but soon kills the salivary ferment.

II. *Chronic Gastric Catarrh.*—

1. Patient slowly supped 250 c. c. boiled starch solution. Fifteen minutes later 45 c. c. were withdrawn. Total acidity amounted to 0·138 per cent. Much starch and erythrodextrin were present, along with a faint trace of sugar.

This fluid was also neutralized and kept at 38° C. for three-quarters of an hour, but underwent no further change.

One hour after the injection 38 c. c. were obtained. Total acidity equalled 0·196 per cent. A very small amount of starch was present, but no erythrodextrin or sugar. It underwent no further change after being neutralized and kept at 38° C. for forty-five minutes.

2. Same patient. 250 c. c. starch mucilage supped. After the lapse of ten minutes 80 c. c. of thin white fluid were syphoned off. The total acidity reached 0·102 per cent. Much starch was present, some erythrodextrin, and sugar amounted to 0·4 per cent. When neutralized and kept for three-quarters of an hour at 38° C., the sugar increased to 0·63 per cent.

One hour after the injection 100 c. c. of turbid fluid were obtained. The total acidity was equal to 0·175 per cent. hydrochloric acid. Much starch remained; erythrodextrin was present, and 0·153 per cent. of sugar. After being neutralized and kept warm for forty-five minutes, the sugar remained almost identical in amount (0·154 per cent.).

Combined Digestion of Starch by Saliva and Gastric Juice.

	Healthy Digestion.		Chronic Gastric Catarrh.			
Time, in minutes, of stay in stomach.	15	60	15	60	10	60
Number of c. c. withdrawn.	40	45	45	38	80	100
Total acidity as HCl.	0·061	0·102	0·138	0·196	0·102	0·175
Starch.	Much.	Much.	Much.	Small amount.	Much.	Much.
Erythrodextrin.	Much.	Traces.	Much.	None.	Some.	Some.
Sugar, percentage.	0·16	Traces.	Trace.	None.	0·4	0·153
After neutralization and heating at 38° C. for 45 minutes.	No change.	No change.	No change.	No change.	0·63	0·154

From this we learn that even a short stay in the stomach during the digestion of a simple carbohydrate suffices to kill the ferment ptyalin. This ferment acts with great rapidity, and the amount of starch which was found in the stomach converted into dextrins and sugar had probably undergone this change during the process of mastication and swallowing, and for a very short period after its entrance into the stomach. In the case of the dyspeptic, the ferment was not killed after a stay of ten minutes in the stomach, and was still able to continue its amylolytic action in a less acid medium. A stay of five minutes longer, however, in the stomach, during which time the amount of acid had increased, was enough to kill the ferment, as after being neutralized no further amylolytic action took place.

We may therefore state that the diastatic ferment of the saliva is killed by a certain degree of acidity of the gastric contents (varying from 0·06 to 0·1 per cent. hydrochloric acid), and, depending on the rapidity of the production of this acid, it continues active in the stomach till this limit is reached.

The sugar formed from starch during this period must be at once absorbed in health, as it is not found in the stomach at a later stage in digestion.

Had proteids been present the free acidity would have taken a much longer time to develop, and consequently starch proteolysis would have advanced much further.

This shows, then, that unless starch undergoes the process of mastication most thoroughly, it is not so well digested in the stomach as when it is accompanied by proteid matters. My experiments show that free acidity is soon developed on a purely carbohydrate diet, whereas it is much later when a mixed diet is partaken of.

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THE RÔLE OF THE CARBOHYDRATES IN DIETETICS, Etc.

General Considerations regarding Diet.

Diet Tables.

1. Full or ordinary diet, Royal Infirmary, Edinburgh.

Meat,	8	ounces (= 1½ oz. water-free albumin).
Vegetables,	8	"
Bread,	16	"
Barley, rice, or peas,	1½	ounce.
Sugar,	1¼	"
Salt,	¾	"
Butter,	1	"

Porridge and milk if desired.

2. Public diet (Moleschott).

Proteids,	130	grams.
Fats,	84	"
Carbohydrates,	404	"
Salts,	30	"
Water,	2800	"

3. Diet of European armies.—Water-free food in ounces.

	English.	French.	Russian.	Austrian.
Albuminates,	3·86	4·33	4·02	3·73
Fats,	1·30	1·27	1·09	1·64
Carbohydrates,	17·43	18·04	19·62	17·0
Salts,	0·81	1·0	1·50	1·0

4. Sailor in British Navy.

Salt meat,	9	ounces.
or		
Fresh meat,	4½	"
Carbohydrates,	26½	"

5. Prisoners at hard work, and confined for more than three months;
   36 ounces of food daily. Butcher's meat forms only a small proportion of this, amounting to 16 ounces per week.

6. The diet of the Trappist monks is vegetarian, and consists daily of—

Bread,	17½ ounces.	=	Proteids,	2·186 ounces.
Beer,	17½ „		Fats	0·35 „
Vegetable soup,	2 plates.		Carbohydrates,	15·08 „
Green vegetables,	1 plate.			

From these tables it is manifest that the chief element in all dietaries is the carbohydrate one, the proteids forming but a small proportion, the fats and salts holding a still lower place.

While proteids are of first importance in building up the active tissues, the carbohydrates form, through their combustion, the energy or heat-producing agencies, or are stored up as reserves of such.

Proteids are notoriously less easily digested than carbohydrates, and it is affirmed that vegetable proteids are even less digestible than animal proteids. It is a matter of common observation that, unless we take active exercise when living on a diet rich in animal food, we soon get out of sorts, and become bilious or dyspeptic. In all likelihood this is due to accumulation of many extractives in the body. Where do the most of the proteids come from which we consume in our food?

Looking at the percentage composition of flesh, we see how little proteid material it contains, and one can easily calculate the small quantity of nitrogenous matter which is obtained in consuming the ordinary amount of meat.

Composition of Flesh.

	Ox.	Fowl.
Water,	77·50	77·30
Solids,	22·50	22·7
Soluble albumin,	2·20	3·0
Insoluble albumin,	17·50	16·5
Fat, etc.,	2·30	3·2

It is obvious, therefore, that in ordinary diets the nitrogenous matters are chiefly of vegetable origin, and so are usually consumed along with the carbohydrates in the form of bread, farinaceous materials, or vegetables.

While a mixed diet in which animal food is present may be, and probably is, useful, we see that it is by no means absolutely necessary.

The proteids contained in farinaceous foods and vegetables are amply sufficient in most cases to replace the animal proteids, and I believe that when the organism becomes accustomed to the vegetable proteid there is little greater difficulty in digesting it than there is with the animal proteid. There could hardly be found stronger men than Scotch ploughmen of a century ago, and their staple food consisted of porridge and milk. The prisoner's diet of to-day would be much improved did it contain more of the quondam ploughman's food, and many would leave prison in better health than is the case at present. Native Indians eat scarcely anything but rice, to which a little butter (usually rancid) is added, and rice is almost the poorest in proteids of any farinaceous food which we have (7·40 per cent.).

It is usually stated that when a food stuff so rich in one element is used alone very large quantities of it must be consumed, so as to get a sufficiency of that element in which it is poorest. Theoretically this is true, but in practice it is seldom observed. The Chinese or Indian eats by no means an extravagant quantity of rice; in fact, we should be inclined to call it very moderate. Then we have always the extreme and historical examples (like Alexis St Martin in questions of digestion) of Cornaro, who lived healthily and well for fifty-eight years, or till he attained the age of 103, on 12 ounces of food, chiefly vegetable, and 14 ounces of light wine daily; or of the still more abstemious Thomas Wood, a miller of Belaricoy, who lived happily for nearly twenty years on a daily pudding made of a pound of flour with water, no other fluid being taken.

I have no intention of posing as an advocate of vegetarianism, though I think there is a very great deal to be said in its favour. Of course, we know well the oft-alleged assertion that, owing to the structure of the digestive tract in man, he is capable of digesting both animal and vegetable foods, and therefore ought to make use of both. The capacity for digesting both of these varieties implies, however, that each can be perfectly used up in the human economy. We know of many hardy races who are almost, if not entirely, vegetable eaters. Dr Parkes remarks that the meat eater and the man who lives on corn, peas, or rice are equally well nourished, and that the well-fed vegetable eater shows, when in training, no inferiority to the meat eater. Then, amongst animals, the largest and most powerful, either domestic or wild, are purely vegetable eaters,—as the horse, ox, elephant.

I think these facts are sufficient to show that perfect health may easily be enjoyed while animal food is excluded from the dietary; and at the same time they may serve to direct attention to one of the most important elements in a proper diet, viz., the *carbohydrates.* We have seen that they form the largest part in any scheme of dieting, and we remember that they form the staple food of young children and invalids. They thus merit, in my opinion, a greater regard than as yet they seem to have received from the clinician or physiologist.

Digestive troubles form the most potent factors in swelling the mortality tables of children dying under one year. This fact is more strikingly brought home to us when we recall that the mortality of children is greatest from the fourth to the sixth month, and this period corresponds to the time when "hand-feeding" is usually begun, with its dire results in too many cases.

Again, in towns this practice of artificial feeding of children is far more general than in country districts, and this is well shown in the Registrar-General's Returns. For instance, the death-rate per 1000 from diarrhœa in 1887 was, in rural districts 0·50; while in London it amounted to 0·90; and in the twenty-eight "great towns" together it formed 0·97. In 10,000 deaths amongst children in the city of Berlin it was found that 7646 had been artificially fed.

Apart from the question of infant mortality as the result of mismanaged feeding, there is the immense importance of this branch of dietetics in the many forms of indigestion and diseases of the alimentary organs in adults.

Statistics of hospitals and dispensaries prove that affections of the alimentary tract form by far the largest proportion of all diseases occurring during adult life, and these are only too frequently induced by unsuitability of food or irregularity in feeding.

In this paper I shall only deal with one branch of the carbo-hydrate group, viz., the digestion of starches (I have already in other papers treated of the digestion of sugars), though incidentally we may have to speak of sugars also.

Résumé of the Chemistry of Starch.

The chemical constitution of starch may be represented in its simplest form by $C_6H_{10}O_5$. More probably, however, it is a multiple of this, and n $(C_{12}H_{20}O_{10})$ would represent it more accurately, n being unknown, though probably never less than five or six.

When starch is heated by itself, or, as mucilage, if boiled with dilute acids, or when acted on by diastase, it becomes changed into an isomeric body—dextrin.

There are many varieties of dextrin. That which is formed earliest is termed soluble starch or amylodextrin. As dextrination proceeds erythrodextrin is formed, and still later the achroo-dextrins. If ebullition with acids be continued, or if diastase be allowed to act for a long enough time on the dextrin, it becomes hydrated and changed into maltose, which in its turn becomes converted into glucose ($C_6H_{12}O_6$) through the continued action of diastase or of dilute acids.

When a solution of iodine is added to starch, a deep blue colour is produced. Soluble starch in solution gives a violet colour with iodine. If dry, however, the colour produced is yellow, violet, or brown.

As the starch undergoes conversion this violet becomes a purplish-red and then a red colour with iodine, showing that the stage of erythrodextrin formation has been reached.

Still later this red colour becomes lighter, till at length no coloration results from adding iodine solution. This is the stage of the achroodextrins. Of these there are many varieties differing from each other in their rotatory and reducing powers. The first to be formed,—achroodextrin α,—can still by the action of diastase be changed into maltose and glucose, as happens with amylodextrin and erythrodextrin.

The formation of dextrins has been explained thus. The constitution of soluble starch is probably represented by the formula $C_{120}H_{200}O_{100}$. Under the influence of the diastase of malt it assimilates a molecule of water, and so forms a molecule of maltose, the rest going to form erythrodextrin α.

$$\underset{\text{(soluble starch)}}{C_{120}H_{200}O_{100}} + H_2O = \underset{\text{(maltose)}}{C_{12}H_{22}O_{11}} + \underset{\text{(erythrodextrin } \alpha).}{C_{108}H_{180}O_{90}}$$

On further hydration another molecule of maltose is formed, and erythrodextrin β, which has a less molecular weight.

$$\underset{\text{(erythro. } \alpha)}{C_{108}H_{180}O_{90}} + H_2O = \underset{\text{(maltose)}}{C_{12}H_{22}O_{11}} + \underset{\text{(erythrodextrin } \beta).}{C_{96}H_{160}O_{80}}$$

By a similar process achroodextrin results—

$$\underset{\text{(erythro. } \beta)}{C_{96}H_{160}O_{80}} + H_2O = \underset{\text{(maltose)}}{C_{12}H_{22}O_{11}} + \underset{\text{(achroodextrin).}}{C_{84}H_{140}O_{70}}$$

There is a difference of opinion between chemists as regards the further changes which occur. The most recent and careful investigations seem to leave no doubt, however, but that the hydration process goes on till only maltose is left. Each of its molecules in turn takes up a molecule of water through the continued action of diastase or dilute acids, and splits up into two molecules of grape sugar—

$$\underset{\text{(maltose)}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{(grape sugar).}}{2\ C_6H_{12}O_6}$$

Digestion of Starch.

Ptyalin is the ferment in the salivary secretion which converts the starch granules into achroodextrin, maltose and glucose. Through the continued action of this ferment maltose is slowly split up into glucose. The amylolytic action of saliva is destroyed by high temperatures, as by boiling; while at low temperatures conversion becomes slow, and ceases at 0° C. At the normal blood heat (38° C.) starch is converted by ptyalin very rapidly in an alkaline solution. It is said that small quantities of hydrochloric acid suspend and rapidly kill the ferment. On the other hand, it is affirmed that its action goes on in neutral as well as in slightly acid solutions. In strongly acid or alkaline solutions its action soon ceases.

The question as to the activity of the salivary ferment in acid solutions is of great importance as regards the digestion of starch in the stomach. If hydrochloric acid be poured out early in digestion, the alkalinity of the swallowed saliva will be soon neutralized, and the activity of the ptyalin must soon come to an end. It is almost certain, however, that the hydrochloric acid in the stomach combines at once with the proteids during the earlier stages of digestion, and so, no free acid remaining, saliva still continues its conversive action on starch. This condition lasts for a time varying from three-quarters to two hours. At the end of this period the proteids have combined with as much acid as they require, and now free hydrochloric acid appears in the gastric secretion. The conversion of starch in the stomach then ceases, as ptyalin is destroyed by the acidity of the gastric juice in full digestion. There are thus two periods in gastric digestion—(1), when saliva still acts; and (2), when pepsin is alone active.

What degree of acidity hinders or kills the ferment ptyalin? Do the various acids differ in their power of destroying ptyalin?

These questions seem to me of great importance. During the earlier stages of digestion, though no free hydrochloric acid is present, the gastric secretion is often acid from the presence of lactic, acetic, malic, or tartaric acids, or from acid salts, taken along with the food.

Does ptyalin still act during this period? If it only acts in alkaline or neutral solutions, then its action will be limited to the time during which food is being masticated and swallowed; or if the food be itself acid, its converting action ought to be entirely inhibited. In the stomach its action will only go on till the alkalinity of the saliva is fully neutralized.

In nearly all cases, therefore, ptyalin must be entirely destroyed before the contents of the stomach escape into the duodenum. Only in these cases where the acid has been so deficient that conversion of starch has gone on uninterruptedly in the stomach, can ptyalin escape destruction. Nor, indeed, is it necessary that ptyalin should be preserved in normal conditions, for soon after the contents of the stomach escape into the duodenum their acidity becomes neutralized, and they then encounter the pancreatic secretion, which is very much more powerful than the saliva in its diastatic action on starch, as it transforms it almost immediately into maltose and glucose. This converting ferment of the pancreas, amylopsin, can act on raw starch at the temperature of the body, giving rise to the production of several dextrins which have a reducing power on alkaline solutions of copper as well as maltose and glucose. The pancreatic secretion further changes maltose and dextrins into glucose. This hydration process is slow, however, and is much assisted by the action of the *succus entericus.*

The *succus entericus* has only a very slight action on starch (it is even denied that it possesses any), and it takes many hours' digestion with it even to produce a small amount of erythro-dextrin and soluble starch. The small intestine possesses, however, a powerful hydrolytic action on maltose, much more so than on soluble starch, dextrins, or even cane sugar. This property is chiefly resident in the agminated and solitary glands of the small intestine. The physiological actions of the pancreas and *succus entericus* are consequently mutually dependent. Starch under pancreatic proteolysis becomes changed for the most part into maltose and glucose. The former then encounters the intestinal secretion and undergoes hydration and splitting up to form glucose. In this way the whole of the starch is at length changed into glucose.

A starch-converting ferment is, however, widely diffused throughout the tissues of the body, and Magendie long ago showed that blood serum possesses this amylolytic power. It has also been recently shown that if solutions of starch be slowly injected into the tissues they are soon converted and entirely absorbed.

Digestion of Starch during Infancy.

Are the digestive processes of the young child materially different from those found in the adult? Can infants fully digest and absorb amylaceous matters?

This question has been carefully investigated, and it has been found that though starch can in very small amount be digested from the earliest period of life, yet it is a slow process. For the first two months of the child's life the amount of saliva secreted is very small, and we have all noticed how dry the mouth is in healthy infants. During the first month of the child's life the total secretion of mixed saliva is only about 1 c.c. in twenty minutes. The secretion rapidly increases after the first month: till at the third month the rate is about 1 c.c. in two minutes. Along with this scantiness in secretion of saliva, its proteolytic action is slow, and in a child seven days old, starch solution only showed a commencing conversion after it had been acted on for four minutes by the saliva. Because of this scanty secretion and slow action, many have thought that the salivary secretion in infants possessed no diastatic action on starch.

Ptyalin does not appear in the saliva to any marked extent till the sixth month; that is to say, till the eruption of teeth begins. At this time also saliva is secreted in great abundance, though there is a larger admixture of mucus, probably from the irritation, than at other times.

It is not, however, till nearly at the end of the child's first year that the amylolytic action of the saliva reaches its full amount and power. There is no essential difference between the gastric digestion of infants and adults.

The pancreatic secretion possesses no conversive action on starch during the first month of life. During the second month this power is developed, and is well marked at the third month. But, as with the salivary glands, so here: the full development of the diastatic action is not reached until the end of the child's first year.

At an early period of life, moreover, the number of glands in the intestinal canal is relatively small. As the child grows older, so does the number of glands increase. The development of the glandular system advances *pari passu* while the lymph vascular system decreases in importance.

THE CONSTITUTION AND USE OF INFANTS' FOODS.

Infants' or Invalids' Food.

We come now to consider foods designed for the special use of infants or invalids.

Condensed Milk.

This is by no means a starchy food, yet I may be pardoned for mentioning it, as it is undoubtedly by far the most universally used form of infants' food. It is easy to see why this is so, for owing to its small bulk, and consequent convenience in carriage, the length of time which it keeps, and the ease with which it can be made ready, its use is made general.

It is certainly for many children a good substitute for mother's or even for fresh cow's milk, and specially so for children during the first month or two after birth, with whom it nearly always seems to do well. But still this does not warrant us in recommending its general use, for many children assimilate with impunity food which is most deleterious to infants as a class.

This milk is prepared in two forms—

(1.) Simply condensed and unsweetened.

(2.) Condensed and with cane sugar added to preserve it.

The first consists in merely evaporating ordinary cow's milk down to one-third or one-fourth its original volume. In only too many cases, however, the milk has previously undergone a partial, or even an entire, skimming to remove the cream before it has been concentrated.

This forms a thick, syrupy, pale-yellow fluid, and merely requires the addition of water to restore it to its "original condition" (?) it is said. This preparation is not so largely used as the second, as, on account of there being no preservative added, it does not keep sweet for more than two or three days after the tin is opened. If kept longer than this, or in warm weather when organic fluids decompose rapidly, there are all the risks of giving the infant a fluid which is beginning to undergo fermentative changes, and we know how common a cause of infantile diarrhœa tainted cow's milk is during summer or autumn.

The sweetened variety is the one so universally used. It is a generally accepted fact that many infants fed on this variety rapidly put on fat. Many of these children are flabby and soon show signs of rickets. Gastric and intestinal catarrhs frequently occur in them, and it is rare to find that they have uninterrupted good health. My own experience agrees with the usual opinion that such feeding makes children less able to withstand the usual diseases of infancy, or renders the convalescence from them slow and unsatisfactory.

Of the large number of rickety children found in all large towns, a very great proportion occurs amongst those who have been brought up on artificial food, such as condensed milk. In rapidly growing children the need of nitrogen must be satisfied in order to obtain proper development; but while in cow's milk the proportion of nitrogen to carbon is as 1 to 12, in preserved milk it is 1 to 20. The large amount of carbon given in such food explains why there is such a rapid deposition of fat, but the needs of bone and muscle must remain unsatisfied by such a food.

I examined several specimens of condensed and sweetened milks as they were found in the market, and subjoin the figures found in a few.

1. This was found to contain 13·13 per cent. of milk sugar. I then estimated the amount of cane sugar present by the method described by Pavy, and found it present to 41·6 per cent.

2. In another specimen of condensed milk I found the reaction to be acid, and that it contained 11·7 per cent. lactose and 43 per cent. cane sugar.

3. Another was said to be partially peptonized and condensed. It contained 12·63 per cent. lactose, and 33·84 per cent. of a substance having a reducing action on Fehling's solution and which was probably maltose. It contained, likewise, dextrins and fat, but no unchanged starch.

The first two of these preparations contain, therefore, a very large amount—nearly one-half of the total constituents—of a substance so difficult of absorption as cane sugar. This improper food is also increased in amount as the child grows older, not only by lessening the dilution of the milk but by giving him more of it, and thus the risks of this sugary food increase *pari passu* with the age of the infant.

In spite, therefore, of the general use of such sweetened condensed milks, I have no hesitation in stating that their use constitutes a form of injudicious feeding. The proportions of the food constituents are so altered that it has little resemblance to ordinary breast milk. Simple condensed and unsweetened milk is not in itself to be condemned, though certainly far inferior to fresh cow's milk, for the relative proportion of the constituents remain pretty much as they were originally on again diluting the milk. The constant use of the variety sweetened with cane sugar is, however, to be strongly deprecated.

It is a common practice amongst the poor to add starchy materials—as corn-flour, arrow-root, pounded biscuit, bread, etc.—to the milk which is given to the child. This is done with the idea of thickening the milk and making it thus more nutritious, for it is a popular idea that cow's milk is in itself not a sufficient food. They forget, meanwhile, that if the child were fed from the breast it would receive no other added food.

The physiological processes in the infant show that starchy matters must be very imperfectly digested by it, owing to the extreme feebleness and the scantiness of secretion of the diastatic ferments at an early period of life. All authorities agree in stating that farinaceous materials are quite unadapted and hurtful to the young child.

The only carbohydrate which a naturally-fed child receives is sugar of milk. There is no substance in milk which in the least corresponds to starch. It is only at the sixth month that the diastatic ferments of the saliva and pancreas are secreted to any extent, and certainly no pure starchy food ought to be given before this age. The full action of the saliva and pancreatic secretions on starch is not attained till the end of the first year, and it is only then that we may allow ordinary farinaceous food, as rice, corn-flour, etc., to be given. If we permit the use of such food before this age, then assuredly the starch should be predigested. By this I mean that unchanged starch must be rigidly excluded from the dietary and only given in a readily assimilable form, as after partial or complete conversion into dextrins, maltose, and glucose. I have already shown that glucose and some dextrins are directly absorbed, while maltose is not so, but requires to be changed into glucose first. Starch should be wholly converted into dextrins and dextrose when added to milk for infants of from five to six months.

At an early age it is sometimes found to be advantageous to add a carbohydrate to the dietary when the child is not thriving on milk alone, or in those cases where cow's milk sets into too firm a curd even when diluted with water. This firm curd is not well acted on by the gastric juice, and is rejected by vomiting. When a farinaceous material is added, however, the density of the curd is lessened, and so its digestion is rendered easier. In such conditions only the easily assimilated carbohydrates should be used, and I would recommend dextrins and dextrose, which, being easily absorbed, afford small opportunity for fermentative changes to occur.

As the diastatic power of the saliva and pancreatic secretions increases, we ought gradually to lessen the degree of starch conversion so as to stimulate more the secretion of these ferments. Thus, after the age of six months, I would only partially convert the starch, so giving a mixture of dextrins, maltose, and glucose. As the child grows older the degree of conversion ought to be still further gradually lessened, thus reducing the amount of glucose, while the quantities of dextrins (of lower variety) and maltose are increased relatively, till, at the end of the first year, we may allow almost natural well-cooked starchy foods to be given. To corroborate this, it has been shown by analysis that as lactation proceeds the amount of albumin in human milk diminishes, while the amount of carbohydrate increases, the amount of fat remaining the same. This goes to prove that as development proceeds the need for nitrogen becomes less, while the necessity for carbon increases.

This leads us, therefore, to the consideration of the so-called "infants' food." The food which is suitable for the young child is unsuitable for the same child at a later period, and so in order to be able to direct the dietary of the infant we must know of what these foods are composed.

Many different preparations are sold to the public under the name of "babies'" or "infants' food." Some, through their own merit, but more through judicious or persistent advertising, have become widely known and largely employed as additions to, or substitutes for, cow's milk.

The foods in themselves may be good enough, but may be unsuited to the age or condition of the children to whom they are given. The infant may thrive on a certain food for a time, but afterwards begins to fall off, even though it is taking the same food readily. If so, there must be some dietetic error, and we will probably find that it is in the character of the artificial food. This, though it nourished the infant well enough at an earlier period, does not form a sufficiently nourishing food for the same child when older.

Again, if we continue to give predigested food for too long a time, the secretions of the alimentary canal lose their distinctive digestive properties to a large extent through disuse of the glands. Thus on changing the food to one not previously digested, rapid emaciation follows, because the digestive secretory glands, having been out of action for some time, require an interval during which to regain their functions.

The constitution of some of these foods we know, but of many the nature of the ingredients is kept secret. In medicine anything which savours of quackery is eschewed. Why should it not be so likewise in dietetics, especially when they concern infancy? The whole after-life may be made or marred by the nature of the food partaken of during the active development of the child.

In all foods designed for the use of infants we must have the four elementary principles—proteids, fats, carbohydrates, and mineral matters. These must be combined in certain relative proportions so that the child may get a sufficiency of each and yet not an excess of any one. Too small or too great a relative amount of any leads ultimately to ill-health. In the first case some of the tissues are starved, while in the second all cannot be absorbed, and so intestinal irritation and general ill-health result.

It is, however, to the carbohydrate constituent of these foods that I desire now to devote attention, as this forms by far their most important element, and, as I have pointed out, requires the greatest care in administration.

Examination of Infants' Foods.

In most of the analyses of these foods the results refer to them as they occur in commerce, and not to the food as it exists after being prepared for use. These two analyses are very different in many cases. My investigations were made in order to determine in what condition the starch was after the food had undergone the process of cooking.

In preparing these for examination I followed the directions given with each food, only instead of using milk as the menstruum (which is sometimes recommended), I used ordinary water.

I generally made a 5 per cent. solution of the food, but when this gave too thick a mucilage I reduced it to a 2 or even to a 1 per cent. solution. Having allowed it to cool, I then tested the mixture for the presence of unchanged or soluble starch, erythrodextrin, achroodextrins, or sugar. I have named all those matters which have a reducing effect on Fehling's solution for brevity "glucose," but which may be glucose, levulose, maltose, lactose, or reducing dextrins. In each case I have calculated them as dextrose.

A definite amount of the solution was then heated on the water-bath for two hours at 140° F., five minims of a dilute solution (1 in 10) of sulphuric acid having previously been added to it. By this proceeding any cane sugar present in the food underwent inversion. This solution was again allowed to cool, any loss from evaporation made up, filtered, the condition of the starch again examined, and the amount of reducing substance again estimated.

In those cases where malt or malt extract was supposed to be present, instead of boiling (which would have destroyed the diastase) I simply warmed the solution, and having set it aside in a warm place for half an hour, examined the condition of the starch and estimated the "glucose" in it.

For obvious reasons I have refrained from mentioning the foods by name.

1. *A Milk Food* (N. M. F.).—This food is in the form of a yellow powder, extremely difficult to mix with cold water, and when so giving a muddy solution, having a faintly acid reaction. It has a very sweet taste, resembling that of ground biscuit.

The directions bear that it should be mixed with cold water and then boiled for a few minutes with continuous stirring.

Having made according to the directions a 2 per cent. solution of—

(1.) Boiled food, I found that it contained unchanged starch, soluble starch, some erythrodextrin, and 4·5 per cent. of glucose.

(2.) Having acidified and heated the solution for two hours, it then contained much unchanged starch, erythrodextrin in large amount, and glucose to 38·5 per cent. Lest there should have been malt or malt extract in this food, and which the boiling would have destroyed, I prepared a solution but only heated it to 100° F.

(3.) Solution only heated, not boiled—unchanged starch, trace of erythrodextrin and glucose, 6·65 per cent.

(4.) This solution, kept hot for thirty minutes, gave similar results.

(5.) A cold extract of the milk shows the presence of unchanged starch, traces of erythrodextrin and glucose 4·35 per cent.

This food clearly contains a large amount of cane sugar (34 per cent.), which must, by the method of preparation, be administered as such. The acidity was too feeble and the heat insufficient to have converted entirely the starch, except perhaps into some early formed dextrins; nor did there appear to be, after boiling, any dextrins present which might have been converted more readily. We must conclude, therefore, that this food contains much unchanged starch and cane sugar.

2. *A Soluble Food for Infants* (C. F.).—This is in the form of a very fine light yellow powder, freely soluble in water, and having a neutral reaction. It is said that this food is partially predigested by pancreatinine.

Directions.—The food is to be dissolved in a definite amount of cold water; then it is to be gradually added to an equal amount of boiling water, stirred till it boils, and boiled for two minutes.

Having made a 2 per cent. solution of—

(1.) Boiled food, it contained unchanged starch only, and glucose 20 per cent.

(2.) Acidified and heated at 140° F. for two hours. Unchanged starch and soluble starch, erythrodextrin in large amount; glucose now 23 per cent.

To see if the pancreatic ferment were active, or if invertible sugar were present, I prepared a solution, but did not boil it.

(3.) Solution made with hot water (not boiled), and examined at once, showed only unchanged starch; glucose 18·5 per cent.

(4.) Same solution kept warm (100° F.) for thirty minutes, showed unchanged starch, small amount of erythrodextrin, and glucose increased to 25·6 per cent.

(5.) A cold extract shows unchanged starch, erythrodextrin in traces, and glucose.

This food contains, therefore, only a very small amount of invertible substance, but the pancreatic ferment appears to be still active, though by following the directions the full advantage of this is not obtained. When merely heated for thirty minutes we get 25·6 per cent of glucose, but when boiled it forms only 20 per cent. This food would thus yield a more assimilable product if it were simply heated and not boiled. The starch is either unchanged or present as soluble starch when made according to the directions, but by heating it for long a large amount becomes dextrinized. Owing to the presence of the dried milk, however, this cannot be done, for then the pancreatic ferment would act for too long a time, and render it bitter. Thus the presence of milk in this food does not allow of us obtaining the full advantage of the amylopsin, and, besides this, the milk is predigested, and this is unnecessary in a food designed generally for the use of infants. This food would be valuable in acute diseases.

3. *A Non-Farinaceous Food* (M. F.).—This is in the form of a yellow powder possessing a sweet malt taste. It dissolves in water, giving a muddy yellow solution, and possessing a neutral reaction.

It is directed to be prepared by dissolving the food in cold water, then adding milk and water, and heating gently.

Having made a 2 per cent. solution, I examined it.

(1.) Prepared by dissolving in warm water. There is no unchanged starch present. No coloration results from the addition of iodine, so that any starch originally present has been converted into achroodextrins, maltose, or glucose. Glucose forms 29·8 per cent. of the food.

(2.) When acidified and heated for two hours, glucose forms 30·4 per cent. This is almost exactly the same as before, and so this food contains no invertible substance.

(3.) When heated alone for thirty minutes the same results were obtained.

The amount of reducing substance is the same after simply dissolving the powder as after heating with the addition of an acid. There is thus no cane sugar or other easily invertible substance present. The slight increase in the amount of glucose is probably due to conversion of some non-reducing dextrins into those capable of reducing copper from its solution, through the prolonged action of heat. Any starch which was originally present has been during manufacture converted into achroodextrins, maltose, or glucose.

This food contains, therefore, carbohydrates in their most easily assimilable condition.

4. *The same, with Desiccated Milk added* (M. L. G.).—This is in the form of a brownish-yellow powder having a sweetish taste of malt. It dissolves in cold water, forming a turbid fluid, and has an alkaline reaction.

It is prepared by dissolving in warm water. A 2 per cent. solution was made with warm water.

(1.) Solution made by heating only. Small amount of erythrodextrin present. Glucose forms 32·7 per cent.

(2.) After being acidified and heated for two hours, it gives no reaction with a solution of iodine. Glucose forms 33·6 per cent.

This is almost exactly the same as before inversion. There is, therefore, only a trace of invertible substance present, or rather, and more probably, convertible substance, for the erythodextrins have become achroodextrins and reducing dextrins, so increasing the glucose nearly 1 per cent.

This food closely resembles the preceding in its composition, containing in addition desiccated milk. The carbohydrates are all in a very easily assimilable condition.

5. *A Pancreatized Food* (B. F.).—This is a dry white powder, resembling wheaten flour.

In preparing it for the use of infants, we are directed to mix it into a paste with one-third cold milk, then to add two-thirds boiling milk or milk and water, and set it aside in a warm place. In fifteen minutes it will have been sufficiently digested, and should then be slowly heated till it boils, when it is ready for use.

(1.) Mixed with cold water it has a slightly alkaline reaction, gives the starch reaction with iodine, and shows a trace of erythrodextrin. It causes no reduction when boiled with Fehling's solution.

(2.) A 2 per cent. solution made with hot water, and examined at once, shows starch abundantly; erythrodextrin in greater amount than when made with cold water. Glucose is present to 7·8 per cent.

(3.) Prepared according to the directions; kept warm for a quarter of an hour, and then boiled. Starch reaction is not so marked; soluble starch and erythrodextrin in much larger amounts, and glucose forms 17·2 per cent.

(4.) A solution prepared according to the directions and heated, after being acidified, for two hours, shows only a very small amount of starch to be present. Much erythrodextrin is present, and glucose 13·9 per cent.

After this prolonged heating, the amount of reducing material has diminished. I do not know how to account for this, unless the pancreatic ferment has split up the products of digestion during the lengthened time during which it has acted. I repeated this and similar experiments several times, but always with the same result. This would seem to prove that there is a ferment, as has already been described, in the pancreas which is destructive to grape sugar.

This food contains, therefore, in its original state no substances which have a reducing action. It has undergone no previous treatment with malt. During its preparation, however, the pancreatic ferment which it contains acts on the starch, and in this way we have a large amount of dextrin and glucose formed, though, even after all, there is yet a small amount of unchanged starch left unacted on. The food seems to consist of flour chiefly, mixed with some pancreatic ferment. When milk is used in the preparation of this food it also, of necessity, will undergo digestion by the same ferment.

6. *A Food designed for the use of Infants during the first Three Months.*—This occurs as a gritty yellow powder having a slight cheesy smell, and with a sweet milky taste. It leaves a saline sensation in the mouth.

It is prepared by dissolving to a smooth paste in hot water, then adding a sufficiency of hot water.

(1.) Mixed with cold water it gives no reaction with iodine, and contains 34·7 per cent. of reducing sugar (glucose).

(2.) Made according to the directions, there is no change from the preceding.

(3.) Made with warm water and kept at 38° C. for thirty minutes, still same results.

(4.) Heated on water bath for two hours after acidification, the sugar has increased to 44·6 per cent.

This food contains, therefore, no unchanged or soluble starch, or even dextrins capable of higher transformation. Nor does it contain erythrodextrin. It seems to be what is affirmed, dried cow's milk from which has been abstracted the excess of casein; while cream, soluble albumin, and milk sugar have been added, to make it resemble ordinary mother's milk. The increase in the amount of sugar seen after heating with acid is probably due to the splitting up of lactose into glucose and galactose.

7. *A Food for Infants up to their Seventh Month.*—This is also in the form of a fine yellow gritty powder with sweet milky taste. It also leaves a saline taste in the mouth. It possesses a faint odour of cheese and malt

It is prepared by mixing with hot water and then adding a sufficiency of hot or boiling water.

(1.) A cold extract gives no reaction for starch. It contains 36·2 per cent. of sugar (as glucose).

(2.) Prepared according to the directions, the constituents remain in the same proportion.

(3.) Prepared with warm water, and kept for thirty minutes at 38° C., the sugar has increased to 39·05 per cent.

(4.) Heated on water bath for two hours after acidification, the sugar now amounts to 39·65 per cent.

There is no starch of any kind present, but only dextrins and sugar. There is, however, some malt present, as the amount of sugar has increased during the period of simple heating. Some of the lower non-reducing dextrins have been changed into higher and reducing dextrins or into sugar through the action of this malt. This food thus resembles the preceding, except that it possesses originally more sugar, dextrins, and malt.

8. *A Malted Food* (A. H. F.)—This appears as a cream-coloured powder, having a sweet taste of flour and malt.

It is prepared by adding boiling milk and water to the food, which has previously been mixed to a paste with cold water, and to which cane sugar has been added.

(1.) Mixed with cold water it shows the presence of unchanged starch, but no soluble starch, and contains 10·85 per cent. of reducing substance.

(2.) Made according to directions, and examined at once. Unchanged starch is present along with erythrodextrin, and reducing substances form 12·4 per cent.

(3.) Prepared as directed, and kept warm for thirty minutes. Trace of unchanged starch. No soluble starch, or mere trace. Erythrodextrin in large amount, along with achroodextrins. Reducing substances form 12·85 per cent.

(4.) Heated for two hours on water bath after acidification. Shows the presence of trace of unchanged starch. Soluble starch. Much erythrodextrin. Reducing substances, 14 per cent.

These three latter preparations are intended to form a continuous diet for the infant from birth up to the end of the first year.

The first (No. 6) consists merely of ordinary cow's milk so treated as to resemble closely human milk. It is then sterilized and dried in vacuo.

The second (No. 7) consists in an addition to the first of maltose, dextrins and malt, together with soluble salts.

While the third (No. 8) consists of starch which has undergone a partial conversion through the action of malt. During the process of preparation the degree of conversion is still further advanced.

The *first food* is designed for infants up to three months of age the *second* from three to seven months, and the *third* (along with ordinary cow's milk) from this age onwards.

9. *A Malt Food for Infants* (S. M. F.).—This is a fine cream-coloured powder, closely resembling and having the taste of heated flour. Directions for preparing the food: It is to be mixed with cold milk, or milk and water, into a thin paste. Then boiling milk or milk and water is to be added till the food thickens (at 140° F.). It then rapidly becomes fluid, and is ready for use.

(1.) When mixed with cold water its reaction is faintly alkaline, and it shows the presence of unchanged starch, but no sugar.

(2.) A 2 per cent. solution prepared according to the directions, but with water only. Starch is present in small amount. Much erythrodextrin and achroodextrin. Glucose 9·25 per cent.

(3.) Part of this solution kept at 100° F. for thirty minutes. Starch in very small amount. Much soluble starch and erythrodextrin. Glucose 11·1 per cent.

(4.) A solution acidified and heated at 140° F. for two hours shows only a trace of unchanged and soluble starch, erythrodextrin in very large amount, as also achroodextrin. Glucose amounts to 15·6 per cent.

(5.) A solution prepared by adding the food to tepid water, and keeping it at 80° F. for thirty minutes, showed very little unchanged or soluble starch, much erythro- and achroodextrin. Glucose forms 5·3 per cent.

This is clearly one of the malt foods, consisting of flour and malt. Under the influence of heat and solution, the latter acts on the former to cause its conversion into dextrins, maltose, and glucose. We see that the conversion is more complete the longer the mixture is kept warm. If, however, the temperature is never raised high (as in 5), the diastase of the malt converts the starch merely into dextrins, and but little reaches the condition of sugar. If kept for long, however, even at this temperature, all the starch ultimately becomes changed into maltose and glucose.

10. *A Self-Digesting Whole-Meal Food.*—This is a fine yellowish powder with brown particles in it, and possessing a strong taste of malt. It is cooked in exactly the same way as the preceding.

(1.) Mixed with cold water, its reaction is faintly alkaline, and it consists solely of unchanged starch with the merest trace of sugar.

(2.) Prepared according to directions. Much erythrodextrin, achroodextrin, soluble starch, and unchanged starch. Reducing substances form 7·35 per cent.

(3.) When kept at 120° F. for thirty minutes the erythro- and achroodextrins have increased at the expense of the starches, and reducing substances form 8·3 per cent.

(4.) Acidified and heated for two hours. Still more dextrins present, and reducing substances 11 per cent.

This food does not differ from the preceding except that apparently whole meal has been used instead of flour.

11. *A Malted Food* (H. M. F.).—This is a granular, gritty yellow powder, having a sweet milky taste.

It is prepared simply by dissolving in hot water. The amount of the powder used is regulated by the age and condition of the child.

(1.) Five per cent. solution made with warm water. Alkaline reaction. There is no unchanged or soluble starch, and no erythrodextrin. No precipitate is formed on adding acetic acid. Glucose amounts to 23·25 per cent. of the food.

(2.) Part of this solution kept at 100° F. for thirty minutes showed an increase of the glucose to 25 per cent.

(3.) Acidified and heated for two hours. Glucose forms 31·25 per cent.

This preparation is said to consist of desiccated cows' milk, malted flour, and alkaline carbonates to neutralize the acidity of the milk.

It contains no starch or early-formed dextrins. It has been almost completely malted already. The length of time it is heated by itself increases but little the amount of sugar. The increase in reducing substance by the prolonged heating with acidification is not likely due to added cane sugar, but most probably to the more complete conversion of some of the higher dextrins (achroodextrins) into reducing dextrins and sugars.

This preparation contains, therefore, dextrins, maltose, glucose, albuminous materials, and mineral salts.

12. *A Patent Cooked Food for Infants* (R. F.)—This is a cream-coloured powder, looking and tasting like heated flour. Directions: Mix the food with water or milk to form a cream; add hot water or milk, "stirring briskly while boiling." It is then ready.

(1.) Prepared with cold water it has a faint acidity, and consists of unchanged starch with no sugar.

(2.) Prepared according to directions, but not boiled, only kept at 120° F. for thirty minutes. It gives only unchanged starch reaction, along with the faintest trace of reducing sugar.

(3.) Prepared by boiling—starch alone is present; no sugar. Even if kept for thirty minutes at 120°, no further change results.

(4.) Acidified and heated at 140° F. for two hours, a large amount of erythrodextrin is present, along with soluble and unchanged starch. Glucose forms 5·4 per cent. of the food.

This food contains apparently only flour; and if prepared according to the directions, we only get a paste containing no dextrins nor sugar. At best the starch is only present in its soluble form. Prolonged heating after acidification converts a good deal of the starch into dextrins and into a small amount of sugar.

13. *A Farinaceous Food* (F. N.)—This appears in the form of a light cream-coloured powder, with a taste of heated flour. Directions: Mix the food with cold water to form a thin paste; add boiling water, and boil gently for five or seven minutes. Then milk and sugar are added and it is ready.

(1.) Mixed with cold water it has a neutral reaction, contains unchanged starch and no sugar.

(2.) A 2 per cent. solution made as directed, but not raised above a temperature of 140° F., and kept at this for half an hour, shows only the presence of unchanged starch. Glucose forms 1·65 per cent.

(3.) Prepared according to the directions, no sugar or dextrins, but only unchanged starch.

(4.) Part of this solution (No. 3) kept at 100° F. for thirty minutes shows a trace of sugar.

(5.) Acidified and heated for two hours. Nearly all the starch has been converted, only a trace being left unchanged. Erythrodextrin is present in large amount. Glucose forms 6·88 per cent. of the food.

This food is very similar to the last. Prepared in its usual way, the starch remains almost unchanged. If heated for long, however, a large amount of conversion takes place, and more especially if rendered acid.

14. *Another Farinaceous Food* (F. H.)—This is a fine powder, closely resembling ordinary flour. It is prepared by mixing with a little cold water. Boiling water is then added, and it is boiled for eight minutes. Milk and sugar are added to make it agreeable.

(1.) Mixed with cold water it has a neutral reaction; contains no sugar or dextrin, but only unchanged starch.

(2.) A solution made with warm water and kept at 140° F. for thirty minutes, but not boiled, shows the presence of dextrin in small amount, much unchanged starch, and glucose forms 2·27 per cent.

(3.) Prepared as directed, only unchanged starch is present; no sugar or dextrins.

(4.) Boiled and kept warm for thirty minutes, gives results similar to No. 3.

(5.) Acidified and heated for two hours, shows very little unchanged starch, much erythrodextrin and achroodextrin. Glucose forms 6·25 per cent. of the food.

This food also closely resembles the two preceding. If made as indicated we get only a flour paste, but if heated for long a large amount of conversion results.

15. *Another Farinaceous Food* (F. N. H.)—This appears as a coarse white powder, with which are mixed small hard brown scales like bran. For infants' use it is prepared by pouring equal parts of boiling milk and water over the food which has previously been slightly moistened. It then is boiled for five minutes.

(1.) Mixed with cold water it has a faintly acid reaction, and shows only the presence of unchanged starch.

(2.) A solution prepared with hot water and kept at 120° F. for thirty minutes shows much unchanged starch; small amounts of dextrins. Glucose forms 5·2 per cent.

(3.) Prepared according to the instructions, only unchanged starch; no sugar or dextrins.

(4.) Part of the latter mixture heated for thirty minutes shows a trace of sugar.

(5.) Acidified and heated for two hours, much unchanged and soluble starch; erythrodextrin in small amount; glucose 2·32 per cent. of the food.

It is evident that the boiling which the food is directed to have destroys the small amount of power of the converting ferment which it seems to possess. When simply made with warm water and kept warm, it develops 5·2 per cent. of glucose, whereas if boiled there is none.

General Conclusions regarding Infants' Foods.

We gather from the preceding analyses of the principal varieties of infants' foods the following:—

1. Most of these consist of wheaten flour mixed with malt or extract of malt. The latter is supposed to act on the starch of the flour during the process of cooking, and by the diastase which it contains to convert the starch into maltose and glucose.

I have shown, however, that in several of these varieties, if prepared according to the directions accompanying each, only a very small conversion of starch occurs. A temperature of 140°-150° F. is most suitable for the action of diastase; while if carried to 212° F. the ferment is killed or its action arrested. Now, several of these foods are prepared by adding boiling milk or water, and then boiling for from five to ten minutes. Such treatment effectually prevents the starch from undergoing any conversion, or soon brings to an end any that is going on already. I have shown that if some of these foods be prepared by adding warm water, and be then kept warm for half an hour, the temperature not being allowed to rise much above 150° F., part of the starch undergoes conversion, and we then find dextrin, maltose, and glucose, with or without unchanged starch, depending on the time allowed and on the strength of the ferment.

Some of the foods composed of flour and malt are directed to be prepared thus, and with these no fault can be found. Those, however, which are directed to be boiled, I have no hesitation in saying, are quite unsuitable as foods for young infants. Not that the food is in itself bad, but owing to the mode of preparation which renders it so. If properly cooked, some of these would make fairly good foods.

Those containing ground malt should always be used in preference to those which contain the extract, as the former is much more active in its converting power.

It is to the mixtures of malt and flour that I look to the greatest improvement in the feeding of infants. By varying the time during which such mixtures are heated, we may convert the starch to any degree we desire, and so make it suitable for the child at different ages or according to its condition of health. We may either wholly convert the starch by prolonged heating, so making it suitable as a food in addition to milk for young infants; or the conversion may be only partial, leaving still soluble starch, dextrins, and maltose. As the child grows older the amount of conversion is proportionally lessened, till when it has arrived at a suitable age or condition unchanged starch may be given alone.

In a few of these foods cane sugar is also added; but this is an addition to infants' or invalids' food which I have elsewhere sufficiently condemned.

2. Instead of malt, some contain the pancreatic ferments. These act both on the starch and on the milk with which the foods are prepared, and so both are predigested.

Such foods must be most valuable in conditions of great debility, inanition, or exhaustion in infants or invalids. In an ordinary food for children, however, we do not wish to digest the milk, which is the natural food of the child, and which usually can be digested well enough. Proteids are generally well digested by infants, and we take advantage of this to feed them on meat infusions when there is great debility. As a general rule, therefore, we do not desire to predigest the proteids of milk, but only the carbohydrate element which the infant cannot properly, or only partially, digest. It has been shown that kittens fed on fully predigested milk did not, for a time, thrive so well when this was replaced by only partially predigested milk as their brothers and sisters who were fed on ordinary milk. The use of predigested foods lessens the activity of the glands which ought to secrete the digestive fluids. We ought not, therefore, to give artificially digested food for a longer time than is absolutely necessary.

3. In some of the foods the starch has been converted previously through the action of the diastase of malt. In these we find no unchanged starch, or at most mere traces of it; erythrodextrins and achroodextrins are found in varying amount; while maltose and glucose occur usually in large amount.

Nearly all of these are made from flour, and so contain, besides, the vegetable albumins and mineral matters. In some foods an alkaline carbonate is added in order to neutralize the acidity of ordinary cow's milk.

Such foods as these are very easily absorbed. The starch is almost wholly changed into easily absorbable dextrins and glucose, and so they require little or no digestion. This is manifestly of the greatest importance to the child, in whom the power of digesting carbohydrates is at the minimum.

4. Combinations of dextrins and starch are often met with, and are highly vaunted as valuable foods for infants. Such foods consist simply of flour which has been subjected to a high temperature, and has thus been baked. The starch during this heating becomes changed into soluble dextrins. If the flour has been carefully heated, and for a long enough time, the starch becomes wholly dextrinized. In the usual foods, however, such treatment has rarely been carried sufficiently far; thus only a part, and usually a small part, of the starch has undergone conversion even into the early formed or low dextrins. They contain usually much unchanged starch, along with the albuminous constituents and salts of the grain. Domestically this is known as the "flour-ball," and is prepared by boiling flour in a cloth for about twenty-four hours. It then forms a hard ball, which, after the translucent outside skin has been pared off, consists of a dense white substance, made up of dextrinized starch. This is then ground down and mixed with milk for the infant's use. Used in this manner it forms an easily assimilated carbohydrate, and, acting as a mechanical diluent, helps to prevent the milk from coagulating in large or firm clots in the stomach.

If these dextrinized foods are thoroughly well prepared they form valuable additions to the milk. If imperfectly dextrinized, however, the large amount of unchanged starch which is also given forms a great drawback to their use as safe articles of diet.

5. Many preparations sold as food for infants consist simply of flour or unchanged starchy matter.

Such foods ought never to be given, as only a small part can be digested by the infant. We find that many of these, besides, are very coarsely prepared, and show, when examined by the microscope, the presence of husks, spiculæ, etc., which must prove most irritating to the delicate intestinal mucous membrane, and which form a sufficient cause in many cases for the diarrhœa which ensues after such food is administered.

Owing to the relatively small number of glands in the intestinal tract in the young child, and to the immaturity of those which are present, the infant is unable to assimilate carbohydrates which require extensive change.

As the child grows older greater liberties may be taken with his digestion; but at an early period of his life it is culpable ignorance to tamper with the delicate machinery of digestion by giving any or the first food which may present itself to the parents or to the seller.

It seems to me that the general and unrestricted sale of such preparations as food for infants ought to be prohibited; or that, at least, they should only be sold by qualified chemists who would first inquire as to the age and condition of the child, and who would thus know whether the food were suitable or not. A still safer plan would be that none of these foods should be supplied unless prescribed by a medical practitioner,—in fact, dispensed in the usual manner in which drugs are sold. In order to do this, however, the method of manufacture and composition of each food, both before and after being cooked, would require to be made public and printed on each packet.

It is the wholesale vending, nay, the intrusion, of such foods on people that renders their use so general. It is a fact that so soon as a birth is advertised in the newspapers, many of the manufacturers of these foods send samples of their preparations to the parents, and, of course, each is accompanied by its own laudatory literature. The parents, knowing little regarding the proper feeding of their child, select one which they think is best, and so, unguided by experience and ignorant of physiological processes, they usually choose that which is most highly vaunted or is accompanied by portraits of the fattest babies reared on such food.

It is on account of the incalculable harm which is thus done—unwittingly in many cases—to the infantile population, that I would put the sale of such foods under a restriction. For this purpose a special clause might be introduced into the "Sale of Foods and Drugs Act," so as to make the indiscriminate sale of infants' foods penal.

Almost all the forms of infants' foods are directed to be made with milk or with a mixture of milk and water, except those which already contain desiccated milk.

In those which contain malt the starch becomes converted in large part during the preparation of the food. Now it has been shown that if malt be added to milk, and if this mixture be kept at 100° F. for some time, the casein of the milk undergoes such a change that it becomes uncoagulable by acids. I have verified this, and find that when acetic acid is added to milk which has been heated with malt no curdling takes place. This fact must be of great importance as regards the digestion of milk, for one great cause of indigestion is the formation of large clots of milk in the stomach. In foods containing malt the milk is also acted on during the process of cooking, and so rendered uncoagulable by the acid of the stomach. Might this not prove serviceable in the treatment of some forms of indigestion following the use of cow's milk? Instead of mixing the milk with any starchy food, would it not be preferable to keep it in contact with a solution of malt for some time so as to prevent the formation of dense coagula in the stomach?

Such foods containing malt, when the cooking causes an almost complete conversion of starch, or those which are already entirely converted, when added to diluted cow's milk, and with a little cream added (for nearly all these foods are deficient in fat, and the dilution of the milk reduces the percentage of fat much too far), make, in my opinion, the most suitable substitute for mother's milk, or for infants with whom ordinary cow's milk does not agree, or who are not thriving on it.

Not only are these foods good as adjuvants to milk, but they are sometimes the only food which the child can digest. After once that fermentative changes have taken place in the gastric and intestinal contents, with consequent vomiting and diarrhœa, the bacteria which have caused these remain, and cause milk to become acid as soon almost as it has been taken. Under such circumstances the use of milk must be stopped, and we have then recourse to such foods as the above, along with infusions of meat, as veal or chicken broth.

At a later date also they are of great value, when we are beginning to add other food materials to the milk. What better can we begin with than some of the easily digested carbohydrates?

It would be improper in me to specify by name the particular foods which I would recommend in feeding infants of various ages. After what I have said, however, there can be little difficulty in choosing the particular food for the particular age and condition of the child. I have shown what I consider to be the most easily assimilated forms of the carbohydrate group, and from the analyses of the carbohydrate constituents of the most widely-known foods for infants now on the market which I have given, it will be easy to select those which would form desirable additions to, or substitutes for, a purely milk diet.

What I have stated regarding the kind of carbohydrate food which may be given to the infant applies, and in some cases with even greater force, to the dyspeptic and invalid, or during senescence, when the digestive organs are feeble and assimilation is less active than formerly.

In such diseases as chronic gastric catarrh, dilatation of stomach with concomitant atrophy of the gastric glands, acid dyspepsia, cancer of stomach, congestion of the gastric and intestinal mucous membrane from heart or lung disease, I would forbid the use of ordinary farinaceous food, unless in very small amount; while I would advocate the use of partially or completely converted starch. In ascites or dropsy such food would act most beneficially and even therapeutically, for glucose and even dextrins form powerful diuretics, and act without raising the blood pressure.

In many febrile conditions the amylolytic action of the salivary and pancreatic secretions is greatly lessened, and only harm can be done by the administration of ordinary starchy foods; whereas if predigested they act as valuable and easily assimilated foods. Again, in those cases where there is great deficiency of hydrochloric acid in the gastric juice, as, for example, in anæmia, simple and pernicious, cancer of the stomach, etc., where proteid matters are not digested well, starchy food ought to bulk largely in the diet, as the amylolytic action of the saliva continues for long in the stomach, there being little or no acidity to cause its cessation.

The carbohydrates, when either partially, or specially when wholly converted, form easily assimilated articles of diet, and give rise to no inconvenience, unless when, like any other food, they are taken in excess. They are quickly absorbed, and thus form a most valuable addition to our fat-producing or energy-saving foods.

It is by attending to such points as I have drawn attention to in managing the dietary of infants and invalids, along with an improved hygiene, that we may in the future with confidence expect a greatly diminished rate in infantile mortality, and a much improved condition in the general health amongst the new members of our population.

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THE SALIVARY DIGESTION OF STARCH IN SIMPLE AND MIXED DIETS: AN EXPERIMENTAL INQUIRY. By W. G. Aitchison Robertson, M.D. (Edin.), D.Sc., F.R.S.E.

The following investigation was pursued in furtherance of previous studies in the same field. It has reference chiefly to the normal physiological processes which take place in starch proteolysis, as induced by the ferment of ordinary mixed human saliva.

The effect of ptyalin on starch alone has been for long well known. Hitherto, however, no extensive series of observations have been made on amylolysis by ptyalin in mixed diets. To determine the question whether the digestion of starch is affected favourably or unfavourably by its admixture with other articles of food, seems to me to be of immense importance as regards the selection of a proper diet for invalids and infants.

To know which is the most easily digested form of bread; whether it is more easily digested when taken alone or along with some other article of food or drink; in what forms potatoes, rice, etc., are most digestible, and other like questions, appear to be dietetic problems of the utmost importance.

It is of interest to remember that the largest proportion of proteid matter which we consume is of vegetable origin. We are thus compelled to eat a large amount of carbohydrate material along with the proteid.

The following table shows how little proteid matter is present in flesh; and consequently the smallness of the amount of nitrogenous matter which we obtain in consuming the ordinary quantity of flesh is evident.

Composition of Flesh.

	Ox.	Fowl.
Water, ...	77·50	77·30
Solids, ...	22·50	22·7
Soluble albumin, ...	2·20	3·
Insoluble albumin, ...	17·50	16·5
Fat, etc., ...	2·30	3·2

It is a common observation that starchy matters are frequently badly digested by certain individuals. In the treatment of this, which is termed 'amylaceous dyspepsia,' many forms of diastase are employed as digestive agents, viz.—malt, maltine, malt extracts, taka-diastase, etc. Those, it is said, convert, much more energetically than ptyalin, starchy matters present in the stomach. Even if this is so (and it is extremely doubtful whether many of the forms of malt extract have any diastatic action on starch), it is certainly most undesirable to have large quantities of sugar produced at once in the debilitated stomach. By such means it is not unlikely that we disturb the equilibrium of digestion and absorption, and render the advent of fermentative changes easy. If, on the other hand, as happens normally in nature, the starch is less rapidly converted, the sugar thus produced is absorbed slowly into the portal circulation. The artificially separated diastase of malt to a very large extent converts starch into dextrins and maltose, and hardly any into glucose. Such a proceeding is not a normal physiological result, and we could hardly imagine that the salivary ferment would have much effect on such products.

At best, however, these agents separated from malt form poor substitutes for those produced in the body during the act of digestion, and which doubtless vary their composition according to the requirements of the ingested material.

Besides this, it is well known that malt has a retarding influence on proteid digestion. Thus, in partaking of a mixed diet, what we might gain in rapidity of starch conversion through the agency of malt diastase (a doubtful advantage), we lose in the delay of proteid digestion.

In many cases, also, where such preparations of malt are given, not on account of their digestive action, but as foods in constitutional debility, etc., they give rise to acidity, nausea, with very frequently persistent and troublesome itching of the skin. On leaving off these malt preparations, these symptoms soon disappear.

Instead of this (in many cases) experimental use of an artificial digestant for starch, it is surely far better to study the precise action of the salivary ferment itself on starchy foods in their simplest form, as well as in more complex combinations. In this way an exact dietary could be drawn out for each case of 'amylaceous dyspepsia.'

In other papers I have very fully entered into the question of the digestion of starch during its stay in the stomach and intestines: I therefore pass by this subject of the digestion of starch by the gastric juice entirely, merely stating that the amount of starch which undergoes conversion by the normal acidity of the gastric juice must be exceedingly limited, and that the gastric juice can be in no way considered as a digesting agent for starch.

Secretion of Saliva.—This is said to amount to from 200 to 1500 grammes per twenty-four hours. Bidder and Schmidt, however, put the minimum at 1000 grammes, and the maximum at 2000.

I have investigated this in my own case, and the following are averages got from many observations.

Method of investigation.—I carefully weighed the quantity of food which I would have eaten at the various meals, and then proceeded to masticate it. Instead of swallowing it, however, it was put out, and when all had been masticated, again carefully weighed. The increase in weight, of course, corresponded to the amount of saliva added during the process of mastication.

During the intervals between meals the saliva which would naturally have been swallowed was carefully collected and measured.

No two days give corresponding results; and this is easily accounted for, because different foods stimulate to a greater or less degree salivary secretion: not only so, but different occupations affect it,—manual labour or outdoor exercise lessening the secretion, while sedentary occupations increase it. The varying mental conditions also markedly modify the amount secreted.

Breakfast.—Supping 6 oz. of porridge along with milk leads only to a small salivary secretion, not amounting to more than 3 or 4 grammes. The porridge is quickly swallowed, and thus little opportunity is given for a larger admixture of saliva.

After eating the porridge, bread, butter, and cold meat to the amount of $5\frac{1}{4}$ oz. (=148·8 grammes) were chewed. After mastication it was again weighed, and showed that on an average 46·5 to 50 grammes saliva had been secreted.

Between breakfast and dinner (taken at 1·30 P.M.), the amount of saliva secreted during four and a half hours amounted to from 50 to 60 cubic centimetres.

Dinner.—As happened with porridge, little saliva is added during the supping of soup. During the mastication of $7\frac{1}{2}$ ounces of meat, potatoes and rice, 10 to 15 grammes saliva were added; a similar amount was added during the mastication of 5 ounces of milk pudding.

Between dinner and tea less saliva was secreted than between breakfast and dinner, and the amount seldom rose above 50 grammes.

Tea.—The process of masticating bread and butter along with tea produces a copious secretion of saliva. When $2\frac{3}{4}$ ounces of such bread and butter (toast) were masticated, from 47 to 53 grammes saliva were added,—very much the same as at breakfast.

Between tea and supper—sitting reading or writing—from 60 to 70 grammes of saliva were secreted.

Supper.—$2\frac{1}{4}$ ounces of plain bread and butter (=63·78 grammes) and 5 grammes cheese, when masticated, led to a production of from 40 to 45 grammes of saliva.

Between supper and bedtime (9–11.15 P.M.), from 30 to 40 grammes were secreted.

The *total amount* secreted was therefore, on an average, in my own case, as follows :—

Breakfast,	49·5	to	54	grammes.
Interval,	50	,,	60	,,
Dinner,	20	,,	30	,,
Interval,	35	,,	55	,,
Tea,	47	,,	53	,,
Interval,	60	,,	70	,,
Supper,	40	,,	45	,,
Interval,	30	,,	40	,,
	331·5		407	

Making all allowances for any loss, we find, therefore, that the amount of saliva secreted per twenty-four hours, in my own case, seldom exceeded 400 grammes.

To show how much saliva is secreted and unconsciously swallowed, I made the following observations on myself.

The salivary secretion was collected and measured during half an hour's reading after partaking of breakfast (of porridge, milk, tea, and fish), and it amounted to 35 grammes. On other occasions it varied slightly, but never fell below 30 grammes.

The amount collected after dinner is not nearly so copious, amounting to from 35 to 55 grammes in two and a half to three hours.

After tea, on the contrary, the secretion is much more copious, varying from 45 to 55 grammes per hour.

After supper (cocoa, toast, biscuit) the salivary secretion was also copious, and varied from 30 to 40 grammes per hour in many cases.

Agents which stimulate Salivary Secretion.

Hot water.—I have found that rinsing out the mouth with tepid water greatly promotes the flow of saliva. Within certain limits, the warmer the food or drink which we consume, the greater is the flow of saliva. The effect of this, as regards the physiological digestion of starch in the stomach, is, of course, apparent. We cannot swallow liquids which are too hot; and as starch proteolysis is most effective at a temperature of 38° C., it is readily seen how rapidly and extensively starch must be converted when the amount of ptyalin is increased.[1] Thus, though tea be a great hindrance to starch proteolysis, from the presence of tannin, yet, from the copious flow of saliva which it induces, we rarely meet with amylaceous dyspepsia as a result of its use.

[1] As an objection to this, it may be said that in those cases of copious salivary secretion, it is only the watery constituent which is increased, the ferment, ptyalin, being in very small amount. As a result of many experiments on the amylolytic power of saliva collected as a result of stimulation by different forms of food and drugs, I cannot find that the amount of ptyalin is at any time diminished to any appreciable extent either in quantity or amylolytic power. The details of these experiments cannot, however, be given here.

Alcohol.—In the form of brandy or whisky, alcohol forms a powerful stimulating agent in promoting the flow of saliva. Even in weak dilution, it acts energetically; but the stronger the alcohol, the more powerful it is as a sialogogue.

Wines.—Contrary to expectation, these do not promote the flow of saliva; sherry produces a more abundant secretion of mucus.

Beer.—Bitter beer forms a powerful sialogogue.

Sugar.—In the form of sweets, this produces a copious flow of saliva. No doubt this is in part due to mechanical stimulation of the buccal mucous membrane. It is also, however, largely the result of stimulation of the sensory nerves of taste.

Mechanical irritation of the buccal mucous membrane by insoluble substances (*e.g.*, quill, pin, etc.) forms also a powerful sialogogue.

Employment.—During reading or writing the secretion is much more abundant than while performing any ordinary mechanical work or walking.

The following table (compiled from several sources) is of interest in showing the relative proportions of food elements present in the chief forms of carbohydrate food:—

	Water.	Albumin.	Carbohyd.	Fats.	Salts.
Wheaten flour, .	15	11	70·3	2	1·7
Oatmeal, . .	15	12·6	63	5·6	3
Barley, . . .	15	6·3	74·3	2·4	2
Rice, . . .	12·4	7·4	79·4	0·4	0·4
Rye, . . .	15	8	73·2	2	1·8
Maize, . . .	13·5	10	64·5	6·7	1·4
Arrowroot, . .	16·5	0·8	82·4	...	0·19
Potatoes, . .	74	1·5	23·4	...	1·1
Bread (white), .	40	8	49·2	1·5	1·3
Biscuit, . . .	8	15·6	73·4	1·3	1·7
Peas, . . .	12·3	26·7	56·4	1·7	2·9
Beans, . . .	12·6	23·1	59·2	2	3·1
Tapioca, . . .	2	0·63	97·8	...	0·2
Macaroni, . .	13·1	9	76·8	0·3	0·8
Sago, . . .	12·8	0·81	86·1	...	0·19
Chocolate, .	12	20	10	50	4
Apples (canned), .	83·2	0·2	15·9	0·4	0·3
Pears, . . .	83	0·36	16·3	...	0·31
Bananas, . .	...	...	23·3	...	.
Turnips, . .	85	2·95	6·9	0·2	1·2
Carrots, . . .	87·05	1·04	10·1	0·21	0·9
Cabbage, . .	89·9	1·89	6·2	0·2	1·2
Melon, . . .	...	...	2·5	...	...

As regards the richness of these in starch, the following is the order :—

	Per cent.
1. Tapioca,	97·8
2. Sago,	86·1
3. Arrowroot,	82·4
4. Rice,	79·4
5. Macaroni,	76·8
6. Barley,	74·3
7. Biscuit,	73·4
8. Rye,	73·2
9. Flour (wheat),	70·3

Method of Investigation.

I investigated how far and in what kind of manner salivary digestion proceeded in the various starchy foods after they were cooked and prepared for the table.

Ten grammes of each of the various foods were accurately weighed out, placed in a large test-tube, heated to 38° C.; 2 cubic centimetres of mixed human saliva[1] (filtered to remove mucus) were added. A series of these tubes was prepared, and the whole was placed on a water-bath kept at a uniform temperature of 38° C. At frequent intervals the tubes were well shaken, so as to ensure thorough mixing of the starchy material with the saliva. At intervals of 5, 10, 20, 30, 45, 60, 90, 120, 150, 180 minutes a tube was removed, and the condition of its contents noted. The contents of the tube were then rapidly boiled, to prevent any further amylolytic action of the saliva. The sugar was then extracted by repeated washing with water and filtering. The filtrate was made up to a definite volume and the sugar estimated quantitatively as dextrose, so as to be comparable with the dextrose obtained by boiling the starchy material with dilute acid. Actually, maltose is the sugar produced in greatest amount as a result of salivary proteolysis, and it has a far feebler effect in reducing Fehling's solution than has dextrose (the proportion being 65 : 100). For ease in comparison all the sugar produced has been calculated, however, as dextrose.

[1] The collection of saliva was always made in the evening, as Hofbauer has shown that there is great variation in the composition of saliva at different hours of the day (*Archiv für die gesammte Physiologie*, 1896–7, Bd. 65, p. 503–15).

I. *Ordinary Whole Rice.*

This was prepared in the ordinary way by boiling until quite soft. A watery extract showed that it consisted solely of unchanged starch, with practically no sugar. Ten grammes of this boiled rice were mixed with 2 c.c. saliva, kept at 38° C., and examined at intervals up to the end of three hours.

When 10 grammes of the rice were slowly masticated, the weight was increased to 11·16 grammes, showing an addition of 1·16 gramme saliva. This was examined at once, as also after being kept at 38° C. for thirty minutes.

When 10 grammes of this boiled rice were boiled for ten hours with dilute sulphuric acid, in order to convert the whole of the starch into glucose, it was found that 2·92 grammes of this sugar were present. We may therefore take this figure as the standard with which to compare the degree of salivary digestion during the various periods of exposure.

The results of these experiments are shown in the following table:—

TABLE I.—*Salivary Digestion of Cooked Rice*—10 *grammes.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold-water extract, . .	all	0	0	0	0
Converted wholly, . .	0	0	0	0	2·92
Masticated, ...	nearly all	little	trace	0	0·357
Masticated, then 30 min. at 38° C., ...	,,	much	fair amt.	little	0·361
2 cc. saliva at 38° C. 5 min.,	,,	some	small amt.	0	0·156
,, ,, 10 ,,	much	much	,,	trace	0·156
,, ,, 20 ,,	,,	,,	little	,,	0·315
,, ,, 30 ,,	,,	still more	good amt.	more	0·322
,, ,, 45 ,,	,,	much	much	much	0·344
,, ,, 60 ,,	,,	not so much	still more	still more	0·393
,, ,, 90 ,,	,,	,,	,,	,,	0·454
,, ,, 120 ,,	not so much	still less	,,	much	0·520

From this table it is evident that the action of mastication has, as one would have thought, caused a greater degree of conversion of the rice than when saliva acted on the whole rice. In the process of chewing, little more than 1 gramme of saliva was added, whilst in the artificial digestion 2 grammes were added. The degree of subdivision of the grains has been in this case the cause of the hastened proteolysis.

After half an hour's exposure to the action of ptyalin in the test-tube, only about one-ninth of the rice starch has been changed completely into sugar: this is within the usual time during which the salivary ferment is active in the stomach. Of course, besides the sugar, soluble starch and dextrins have been produced likewise.

II. *Ordinary well-boiled Porridge.*

1. A cold-water extract shows it to consist of unchanged starch, with practically no sugar.

Ten grammes of porridge were mixed with 2 c.c. saliva, kept at 38°, and examined at varying intervals, as shown in the table.

When masticated slowly, 1·11 gramme saliva is added to each 10 grammes porridge.

Ten grammes porridge, boiled for ten hours with dilute sulphuric acid to convert all the starch, contains 1·03 grammes dextrose. (This is equal to 0·927 gramme starch which has undergone complete conversion.)

Table II.—*Salivary Digestion of Porridge*—10 *grammes.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold-water extract, . .	all	0	0	0	0
Converted wholly, . .	0	0	0	0	1·03
Masticated, ...	nearly all	little	little	0	0·149
Masticated, then 30 min. at 38°, ...	,,	much	much	trace	0·265
2 c.c. saliva at 38° for 5 min.,	,,	much	traces	0	0·115
,, ,, 10 ,,	much	,,	more	0	·128
,, ,, 20 ,,	less	not so much	much	traces	·158
,, ,, 30 ,,	some	little	,,	much	·188
,, ,, 45 ,,	,,	,,	,,	,,	·194
,, ,, 60 ,,	,,	,,	,,	,,	·2
,, ,, 90 ,,	little	,,	more	more	·211
,, ,, 120 ,,	very little	very little	,,	,,	·226

In this case, also, mastication has been productive of a larger amount of sugar from the starch than the artificial method. The amount of soluble starch begins to diminish after twenty minutes' digestion, and it is just at this period that the amount of dextrins increases greatly.

Before proceeding to investigate the effect which the addition of milk might have in influencing amylolysis, I made the following experiments with added water.

Does the degree of dilution of the starchy medium have any effect in hastening or retarding the proteolysis of starch ?

III. *Porridge with an equal volume of Water added, corresponding to thick Gruel.*

Ten grammes porridge—10 c.c. water—thoroughly mixed.

A cold-water extract shows only the presence of unchanged starch.

Two c.c. saliva were added to 10 c.c. water and 10 grammes porridge, placed at 38° C., and examined at intervals.

TABLE III.—*Salivary Digestion of Porridge with an equal volume of Water added—10 grms. of each.*

	Unchanged Starch.	Soluble Starch.	Eythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold extract, . . .	all	0	0	0	0
Totally converted, . .	0	0	0	0	1·03
Masticated, ...	all	0	0	0	0·172
Masticated, and at 38° for 30 min., ...	some	much	small amt.	0	0·308
2 c.c. saliva at 38° for 5 min.,	nearly all	,,	,,	0	0·153
,, ,, 10 ,,	much	,,	larger amt.	0	0·26
,, ,, 20 ,,	,,	,,	still more	traces	0·263
,, ,, 30 ,,	,,	,,	good amt.	,,	0·294
,, ,, 45 ,,	,,	still more	,,	,,	0·303
,, ,, 60 ,,	,,	,,	,,	fair amt.	8·312
,, ,, 90 ,,	little	,,	still larger	,,	0·335
,, ,, 120 ,,	,,	not so much	,,	much	0·357

Evidently the dilution of the porridge has allowed the salivary ferment to act more readily on the starch contained in the oatmeal; for, in every case, the amount of sugar formed is greater than when saliva acts on porridge alone. There is an increase in every case of about 0·12 gramme. Greater quantities of erythro- and achroo-dextrins are also formed in the dilute solution than in the case of porridge itself. With porridge alone the formation of soluble starch began to lessen after twenty minutes' exposure to the conversive ferment; while in the case of the watery porridge, soluble starch was formed up to the end of the first ninety minutes. The digestion of starch began more rapidly in the latter case also; for, after exposure to ptyalin for ten minutes, 0·26 gramme dextrose was formed, while with simple porridge only, 0·128 gramme was formed during this period. The after progress in the dilute solution, however, is not so marked as with porridge alone; for in the present case the amount of dextrose formed between the intervals of five and one hundred and twenty minutes is only 0·09 gramme, while during the same interval, in the porridge alone 0·109 gramme has been formed.

IV. *Porridge with equal volume Milk.*

Ten grammes porridge were thoroughly mixed with 10 c.c. fresh milk, heated to 38° C., and then 2 c.c. saliva added. The mixture was then kept at a uniform temperature of 38° C. for varying periods. At the expiry of these, the condition of the starch was investigated, and the fluid boiled to stop further amylolytic action. The casein was coagulated by adding one or two drops of acetic acid, and the sugar washed out by repeated washing with water on a filter.

The amount of milk-sugar normally present in 10 c.c. milk was carefully estimated, and deducted from the total amount of sugar found in each observation. The lactose present in each 10 c.c. of milk amounted to 0·406 gramme, or if calculated as dextrose, 0·303.

[Table IV.

Table IV.—*Salivary Digestion of Porridge and Milk—equal volumes.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold water, . . .	all	0	0	0	0
Wholly converted, . .	0	0	0	0	1·03
Masticated, ...	all	trace	0	0	0·021
Masticated, and at 38° for 30 min., ...	much	much	fair amt.	0	0·247
2 c.c. saliva at 38° for 5 min.,	,,	,,	little	0	0·151
,, ,, 10 ,,	,,	,,	good deal	trace	0·197
,, ,, 20 ,,	,,	little	much	much	0·247
,, ,, 30 ,,	not so much	less	still more	still more	0·258
,, ,, 45 ,,	,,	very little	large amt.	large amt.	0·265
,, ,, 60 ,,	,,	traces	almost all	,,	0·292
,, ,, 90 ,,	,,	,,	,,	,,	0·322
,, ,, 120 ,,	,,	,,	,,	,,	0·365

Dilution of the porridge with milk has in this case also furthered the action of the salivary ferment. Up to the expiry of ninety minutes, however, the amount of the complete conversion into sugar is not so great as with the simple dilution with water. With the porridge and milk the conversion of starch into dextrins is much more rapid than in the watered porridge. Before the lapse of twenty minutes, the formation of soluble starch decreases, while the higher dextrins are rapidly and increasingly produced.

Towards the end of the second hour, sugar begins to be formed much more rapidly than in the case of simple dilution with water.

If we compare this table with that of the digestion of porridge alone, we note that the addition of milk has favoured an increased degree of conversion of starch. In both, the amount of soluble starch begins to show a decrease after the twentieth minute.

Erythrodextrin, which up to this period has been much the same in both cases in point of quantity, now rapidly increases in the case of porridge + milk, and reaches a much higher amount than in the case of porridge alone. The same occurs with achroodextrin; and in the case of dextrose, even from the first five minutes there is an excess of 0·036 gramme over the porridge alone. This excess gradually and steadily increases, until at the end of the second hour the porridge + milk has an advantage of 0·139 gramme dextrose over the simple porridge.

V. *Salivary Digestion of Corn Flour.*

The corn flour was boiled with water for eight minutes; a firm, transparent jelly resulted.

TABLE V.—*Salivary Digestion of Corn Flour.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold extract,	all	0	0	0	0
Wholly converted,	0	0	0	0	0·902
Masticated,	much	much	very little	0	0·25
Masticated, and at 38° for 30 min.,	trace	,,	much	trace	0·344
2 c.c. saliva at 38° for 5 min.,	much	some	0	0	0·25
,, ,, 10 ,,	,,	much	little	0	0·256
,, ,, 20 ,,	,,	,,	,,	trace	0·263
,, ,, 30 ,,	,,	,,	much	more	0·277
,, ,, 45 ,,	less	,,	still more	,,	0·290
,, ,, 60 ,,	,,	,,	,,	,,	0·310
,, ,, 90 ,,	,,	,,	,,	much	0·33
,, ,, 120 ,,	still less	,,	,,	,,	0·378
,, ,, 150 ,,	small amt.	less	large amt.	large amt.	0·384
,, ,, 180 ,,	trace	very little	,,	,,	0·406

At the end of three hours' artificial digestion not one-half of the available starch has undergone complete conversion into sugar, though at this time what remains has been almost wholly converted into dextrins. The process of mastication has greatly hastened conversion, as after being masticated and kept at 38° C. for thirty minutes, more sugar was formed than was produced by ninety minutes' artificial digestion.

Corn flour undergoes a rapid and fairly complete digestion within even the first three-quarters of an hour; and were it diluted further with water or milk, the rate and degree of conversion would be increased.

VI. *Salivary Digestion of Boiled and Powdered Potatoes.*

The potatoes were boiled, then forced through a potato-masher having fine holes. They were thus brought into a much finer state of subdivision than is usual even after the mastication of a potato. In this way the saliva had ready access to the starch.

TABLE VI.—*Salivary Digestion of Boiled and Powdered Potato—10 grammes.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold-water extract, . .	all	0	0	0	0·03
Wholly converted, . .	0	0	0	0	3·04
Masticated, . . .	much	fair amt.	0	0	0·520
Masticated, and at 38° for 30 min., ...	little	0	0	much	0·617
2 c.c. saliva at 38° for 5 min.,	much	fair amt.	fair amt.	0	0·423
,, ,, 10 ,,	,,	much	very much	much	0·427
,, ,, 20 ,,	some	,,	much	,,	0·657
,, ,, 30 ,,	,,	small amt.	,,	,,	0·657
,, ,, 45 ,,	,,	,,	small amt.	,,	0·757
,, ,, 60 ,,	,,	very little	very little	good amt.	0·757
,, ,, 90 ,,	little	trace	trace	fair amt.	0·833
,, ,, 120 ,,	,,	,,	,,	,,	0·877
,, ,, 150 ,,	very little	merest tr.	none	,,	0·892
,, ,, 180 ,,	,,	,,	,,	,,	0·892

At the expiry of three hours' artificial digestion, a little more than one-quarter of the starch normally present in cooked potato has been wholly changed into sugar. In the case of potato, the process of mastication has had a little advantage over simple digestion on the water-bath; but, as prepared, the potato was finely powdered, and so freely acted upon by the added saliva. No more intimate mixing could be produced by chewing. That the starch of the potato thus prepared is easily and rapidly acted upon by the saliva, is shown by the fact that after having been simply masticated, a fair amount is rendered soluble, and 0·520 gramme, or more than one-sixth of the total starch, changed into sugar.

The limit of possible conversion in this experiment seems to have been reached in from two to two and a half hours. After this period no further change has taken place either in the amount of sugar formed or in the condition of the starch or dextrins.

VII. *Salivary Digestion of Boiled Potatoes merely broken into fragments, to represent what might happen during mastication.*

TABLE VII.—*Salivary Digestion of Boiled Potato (in fragments).*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold-water extract, . .	all	0	0	0	0
Wholly converted, . .	0	0	0	0	3·04
Masticated, ...	much	much	faint trace	0	0·298
Masticated, and at 38° for 30 min., ...	0	0	0	much	0·657
2 c.c. saliva at 38° for 5 min.,	much	much	present	0	0·277
,, ,, 10 ,,	,,	,,	little	trace	0·45
,, ,, 20 ,,	,,	,,	,,	,,	0·454
,, ,, 30 ,,	,,	,,	much	much	0·460
,, ,, 45 ,,	,,	,,	,,	,,	0·494
,, ,, 60 ,,	only in lumps	0	,,	,,	0·476
,, ,, 90 ,,	,,	0	,,	,,	0·520
,, ,, 120 ,,	,,	0	,,	,,	0·543
,, ,, 150 ,,	,,	,,	,,	,,	0·55
,, ,, 180 ,,	,,	,,	,,	,,	0·561

In this set of experiments we find the iodine starch reaction soon giving negative results. That is to say, that the saliva has acted on the smaller particles, and has converted them wholly into achroodextrin and sugar. The same had occurred on the surface of the larger masses, but the saliva has been unable to penetrate the larger pieces and convert the starch inside them. Thus we have at an early period all the easily accessible starch changed into achroodextrin and sugar.

Looking over the column showing the amounts of sugar produced by the artificial digestion by saliva, we note that the figures are not perfectly progressive with the length of time digested. This irregularity is easily explained, however. The size of the potato fragments was by no means uniform in the different test-tubes. The larger fragments were consequently less acted on than the smaller, as they presented a relatively smaller surface to the digestive fluid. Thus the amount of sugar produced was less in some tubes than in others. On the whole, however, we note a steady enough increase in the amount of sugar produced.

It is more interesting to compare this table with the preceding. We notice that the amount of starch converted in the present set of experiments is much less than it was in the preceding set. Thus, after twenty minutes' heating, the powdered potato has produced 0·657 gramme sugar, while the potato in fragments has only produced 0·454 gramme. At the end of the third hour the figures are 0·892 against 0·561 gramme. In the case of powdered potato the starch has almost entirely disappeared, while in the present case it is yet unconverted in the interior of the larger fragments.

This shows how very important the mode of preparation of such an article of food as potato is. There can be no doubt but that the fineness of division of the potato hastens its digestion. Nor is it practically possible to masticate an ordinary potato sufficiently to render it as digestible as it is when powdered artificially. In proof of this, we find that the chewed whole potato when examined at once possessed only 0·298 gramme sugar, while the chewed but previously powdered potato had 0·520 gramme. We see that, after having been kept at 38° C. for thirty minutes, the ordinary masticated potato possesses 0·657 gramme sugar in contrast with 0·617 gramme sugar in the powdered potato treated in the same way. This apparent contradiction is, however, explained by the fact that I purposely chewed the ordinary whole potato more thoroughly, and for a long time, in order to observe how much sugar could be produced by the admixture with saliva during simple mastication.

Even at the end of three hours we cannot say that the potato (in fragments merely) has been digested. The smaller fragments have, however, been dissolved, but the larger ones have only had their surface acted on by the amylolytic ferment. This, then, is a good example for the beneficial results which follow from a proper preparation of food for the table.

VIII. *Salivary Digestion of Bread.*

This was ordinary plain bread without the crust, the second day after baking, and crumbled into small fragments.

Ten grammes of this formed too bulky a quantity to deal with. I therefore used 5 grammes only, and to this 2 c.c. saliva were added. Even with this reduction, the bread is really only moistened at one spot, and at the end of three hours' heating at 38° C., a large part was quite dry and unacted upon, while the fragments which were moistened had become quite pulpy. The results of this series of experiments are consequently so irregular that I need not detail them, merely stating that the irregularity was due to the unequal and localised action of the saliva on the bread crumb.

1. When 5 grammes bread are thoroughly well chewed, the weight increases to 7·74 grammes, showing that 2·74 grammes saliva have been secreted during the process. The bread then shows the presence of much unchanged starch, along with some soluble starch and erythrodextrin, while 0·26 gramme sugar is present.

2. When 5 grammes bread are chewed thoroughly, and then kept at 38° C. for thirty minutes, the sugar increases to 0·854 gramme, and while much unchanged starch is yet present, soluble starch and erythrodextrin are present in much larger amounts.

3. A cold watery extract of 5 grammes bread shows that only unchanged starch is present, along with a very small amount of soluble starch, and sugar amounts to 0·042 gramme.

TABLE VIII.—*Ordinary White Bread—5 grm. + 2 c.c. saliva.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Dextrose. grammes.
Cold-water extract, . .	nearly all	little	?	0·042
Masticated, ...	much	some	little	0·26
Masticated, and at 38° C. for 30 min., ...	much	much	much	0·854
Totally converted, . .	0	0	0	2·174

This shows that more than one-fifth of a gramme of starch has been converted by simply chewing the bread. I must, however, again draw attention to the fact that the mastication was most complete and deliberate, and not the incomplete operation which it usually is. If it be kept at the body temperature for half an hour after being well masticated, about two-fifths of the whole undergo conversion into sugar.

It is, however, a very unusual occurrence to eat dry bread alone. It is nearly always accompanied by some fluid or beverage. As the simplest, I experimented with water in the first instance.

IX. *Salivary Digestion of Bread Crumb with Water.*

Ten c.c. of water (previously heated to 38° C.) were mixed with 2 c.c. of ordinary mixed saliva and poured over 5 grammes bread crumb (also at temperature of 38° C.). This amount of fluid moistened the bread thoroughly.

TABLE IX.—*Salivary Digestion of Bread* (5 *grms.*) *along with Water* (10 *c.c.*).

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold-water extract, . .	nearly all	little	?	0	0·042
Totally converted, . .	0	0	0	0	2·174
Masticated, +10 c.c. water, .	much	much	present	?	0·505
Masticated, and at 38° for 30 min., ...	little	,,	much	much	0·706
2 c.c. saliva at 38° for 5 min.,	much	present	trace	?	0·289
,, ,, 10 ,,	much	much	trace	?	0·382
,, ,, 20 ,,	,,	,,	present	?	0·476
,, ,, 30 ,,	,,	,,	good amt.	present	0·574
,, ,, 45 ,,	,,	,,	more	,,	0·639
,, ,, 60 ,,	decreasing	very much	large amt.	,,	0·704
,, ,, 90 ,,	present	,,	,,	,,	0·726
,, ,, 120 ,,	,,	,,	,,	,,	0·746
,, ,, 150 ,,	,,	,,	,,	large amt.	0·769
,, ,, 180 ,,	little	,,	very ,, ,,	very ,, ,,	0·849

As preceding examples have demonstrated, so does this experiment, that a proper dilution greatly hastens salivary proteolysis. In the case of bread chewed alone, only 0·26 gramme dextrose resulted; while when chewed with 10 c.c. water, 0·505 grammes are produced, or almost exactly double the amount. Evidently the dilution and general moistening of the bread produces a marked rapidity in the action of ptyalin, for after having been chewed and kept at 38° C. for thirty minutes, the dilute saliva has produced 0·706 gramme, while during the same period the bread chewed alone showed that the pure saliva had produced 0·854 gramme dextrose. This is to say, that the dilute saliva acted more rapidly on the starch of the bread, but that its ultimate effect was feebler than that of the pure saliva when allowed to act for a certain time. Though dilution hastens amylolysis, yet it would seem that the process does not go so far in the production of sugar as when pure saliva acts on the starch of bread; for example, at the end of three hours' artificial digestion, 0·849 gramme sugar has been produced in the dilute solution, while 1·33 grammes dextrose (or more than one-half of the total starch present) were produced by the action of 2 c.c. saliva on 5 grammes bread alone. In the dilute saliva, however, very little unchanged starch remains at the end of three hours, for nearly all has been converted into soluble starch or dextrins.

It is well known that newly-baked bread is indigestible. Is this shown in its action to the salivary ferment?

X. *Salivary Digestion of Newly-baked Bread Crumb.*

Five grammes newly-baked bread crumb; 10 c.c. water and 2 c.c. saliva; at 38° C.

TABLE X.—*Salivary Digestion of Newly-baked Bread along with 10 c.c. Water.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Dextrose. grammes.
Cold-water extract, . .	nearly all	little	?	?	0·042
Wholly converted, . .	0	0	0	0	2·174
Masticated, ...	much	present	present	0	0·384
Masticated, and at 38° C. for 30 min., ...	much	much	much	present	0·742
2 c.c. saliva at 38° for 5 min.,	,,	present	mere trace	0	0·384
,, ,, 10 ,,	,,	fair amt.	little	0	0·510
,, ,, 20 ,,	much	much	little	?	0·537
,, ,, 30 ,,	,,	,,	,,	trace	0·568
,, ,, 45 ,,	,,	,,	fair amt.	present	0·704
,, ,, 60 ,,	,,	,,	good amt.	,,	0·735
,, ,, 90 ,,	not so much	,,	much	,,	0·83
,, ,, 120 ,,	,,	,,	,,	,,	0·851
,, ,, 150 ,,	,,	,,	,,	much	0·857
,, ,, 180 ,,	still less	not so much	very large amount	very large amount	0·927

Did we look merely at the result of chewing on this freshly-baked bread (examined immediately) we would say that certainly it was less easily digested than stale bread; for only 0·384 gramme dextrose results in the one case, as compared with 0·505 gramme in the other. This is, however, not borne out by a further consideration of the process of salivary digestion. In fact, all through we find that the newly-baked bread has undergone a more rapid and extensive change than the staler bread. In the freshly-baked bread the starch granules will still be in a moist condition, and so more readily acted upon by the saliva than in the second day's bread, which has undergone a partial drying, so rendering the starch granules less easy of amylolysis.

We can easily account for the apparent difficulty in reconciling the fact that less sugar is produced by chewing the fresh bread than by chewing the old. When we try to crumble freshly-baked bread it will hardly do so, but becomes sodden and doughy. The same results appear during the process of mastication. Thus the saliva acts less rapidly on this doughy mass than on the separate crumbs of stale bread. This sodden condition does not persist long when the bread is exposed to moisture. It soon swells up and starch digestion proceeds rapidly, as is shown by the fact that when chewed and exposed to the action of saliva for 30 minutes, 0·742 gramme sugar is produced from the newly-baked bread, as compared with 0·706 gramme from the stale bread.

The bread crumb of newly-baked bread, though more compact than that of stale bread, rapidly absorbs the fluid, and swelling up, the still moist starch granules become easily acted upon by the proteolytic ferment. In this way we have a rapid and extensive change of starch.

It therefore does not appear as a result of these experiments that newly-baked bread is less easily digested than stale bread. They rather prove the reverse, so far as salivary digestion alone is concerned.

XI. *Salivary Digestion of the Outside Crust of Stale Bread.*

The crust of bread is popularly believed to be more nutritious and easily digested than the crumb, as the starch has undergone dextrinisation through the heat? Is this borne out in its behaviour to the salivary ferment?

TABLE XI.—*Salivary Digestion of Crust of Bread—5 grammes crust, 10 cc. water, 2 cc. saliva.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grammes.
Cold-water extract, . .	much	much	trace	...	0·066
Wholly converted, . .	0	0	0	0	3·03
Masticated, ...	much	much	trace	...	0·744
Masticated, and at 38° for 30 min., ...	,,	,,	fair amount	?	1·0
2 cc. saliva at 38° for 5 min.,	,,	,,	good amt.	trace	0·267
,, ,, 10 ,,	,,	,,	,,	,,	0·275
,, ,, 20 ,,	,,	,,	much	present	0·316
,, ,, 30 ,,	,,	,,	,,	fair amt.	0·474
,, ,, 45 ,,	,,	,,	,,	,,	0·5
,, ,, 60 ,,	,,	less	,,	,,	0·542
,, ,, 90 ,,	less	little	,,	much	0·588
,, ,, 120 ,,	present	,,	not so much	,,	0·649
,, ,, 150 ,,	,,	very little	less	,,	0·681
,, ,, 180 ,,	,,	,,	trace	,,	0·713

These products of digestion filtered with extreme difficulty, owing to the amount of gummy dextrin present.

The crust of bread does contain a large amount of dextrin, but it does not seem to undergo much higher conversion under the influence of ptyalin. After three hours' artificial digestion not one-quarter of the available sugar has been formed from starch in the case of crust; while, in the same period, with newly-baked bread almost one-half of the available sugar was formed from starch. During the process of digestion soluble starch and erythrodextrin have been converted into achroo-dextrin to a large extent, but little of the latter becomes changed into reducing sugar. On account of the presence of so much soluble starch and dextrins and to their easy transformation into higher varieties, the crust of bread is thus perhaps more easily assimilated than ordinary bread crumb.

Does the structure of bread modify its reaction to the salivary ferment? That is to say, if the bread is lighter in consistence or more porous, is it more easily digested?

In order to determine this, I took a very spongy variety of bread, known as Vienna bread, and subjected it to the same set of experiments as had previously been carried out with ordinary stale bread. It is not usual to eat this bread stale, but for purposes of comparison it was tried.

XII. *Salivary Digestion of Stale Vienna Bread*—5 *grammes bread*, 10 *cc. water*, 2 *cc. saliva, at* 38° *C.*

TABLE XII.—*Salivary Digestion of Stale Vienna Bread compared with stale ordinary bread in respect to amount of Sugar formed.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grammes	Stale Ordinary Bread. Sugar.
Masticated, ...	much	much	much	fair amt.	0·595	0·505
Masticated, and at 38° for 30 min., ...	,,	,,	,,	much	0·764	0·706
2 cc. saliva in . 5 min.,	,,	,,	fair amt.	present	0·55	0·289
,, ,, 10 ,,	,,	,,	much	,,	0·572	8·382
,, ,, 30 ,,	,,	,,	,,	,,	0·595	0·574
,, ,, 60 ,,	,,	,,	,,	,,	0·73	0·704
,, ,, 120 ,,	,,	,,	,,	much	0·781	0·746
,, ,, 180 ,,	,,	,,	,,	,,	0·835	0·849

Before making any remark, I will give the results of experiments with new, freshly-baked Vienna bread. This is very light in texture, and even when chewed does not become sodden like ordinary bread.

XIII. *Salivary Digestion of New Vienna Bread*—5 *grammes bread*, 10 *cc. water*, 2 *cc. saliva, at* 38° *C.*

New Vienna Bread.—As was to be expected, there was a greatly increased degree of conversion in the case of this spongy bread. This is shown both as a result of chewing and also of simple artificial digestion by ptyalin. We note, however, that this increased degree of conversion persists only during the first two hours. At the end of the second hour more sugar has been formed from the ordinary bread than from the Vienna, and this goes on increasing during the third hour.

Table XIII.—*Salivary Digestion of New Vienna Bread compared with stale ordinary bread in respect of amount of Sugar formed.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Ordinary New Bread. Sugar.
Masticated, ...	much	much	fair amt.	...	0·70	0·384
Masticated, and at 38° for 30 min., ...	,,	,,	much	much	0·847	0·742
2 c.c. saliva at 38° for 5 min.,	,,	,,	some	?	0·455	0·384
,, ,, 10 ,,	,,	,,	,,	?	0·579	0·510
,, ,, 30 ,,	,,	,,	much	much	0·704	0·568
,, ,, 60 ,,	,,	,,	,,	,,	0·746	0·735
,, ,, 120 ,,	,,	,,	,,	,,	0·770	0·851
,, ,, 180 ,,	,,	,,	,,	,,	0·833	0·927

Stale Vienna Bread.—The results in this case are very similar to those found in the new Vienna bread, excepting that it is not until the end of the third hour that the ordinary bread (stale) gains on the porous bread in respect to the amount of sugar produced.

The lightness of the bread, therefore, is only of use in increasing the rapidity of starch conversion, and not in helping to increase the total amount of sugar formed.

What effect, if any, have some of the usual concomitants of bread, as butter or cheese, on amylolysis of starch by ptyalin? This seemed an interesting question to solve. I therefore give the results of these experiments.

XIV. *Salivary Digestion of Bread and Butter.*

Three grammes of salt butter were thoroughly mixed with five grammes of stale bread crumb; 10 c.c. water + 2 c.c. saliva were added, and all was kept at 38° C.

TABLE XIV.—*Salivary Digestion of Bread and Butter—5 grms. bread, 3 grms. butter, 10 c.c. water.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water alone.
Watery extract, . . .	nearly all	little	0	0	0·042	
Totally converted, . .	0	0	0	0	2·174	
Masticated, ...	much	much	some	?	0·428	0·505
Masticated, and at 38° for 30 min., ...	,,	,,	much	much	0·68	0·706
2 c.c. saliva at 38° for 60 min.,	,,	,,	?	0	0·694	0·704
,, ,, 120 ,,	,,	,,	fair amt.	present	0·724	0·769
,, ,, 180 ,,	,,	,,	,,	,,	0·845	0·849

There is a close parallelism between the results of this experiment and those obtained from plain bread and water. Butter is not at all a stimulus to salivary secretion, and so the amount of starch conversion is even less in the case of bread and butter than it is in the case of plain bread and water.

The addition of butter, therefore, to bread has little or no effect on amylolysis by ptyalin.

XV. *Salivary Digestion of Bread and Cheese.*

Four grammes of ordinary cheese in small fragments were mixed with 5 grammes of stale bread crumb and 10 c.c. water, together with 2 c.c. saliva, and kept at 38° C.

TABLE XV.—*Salivary Digestion of Bread and Cheese—cheese 4 grms., bread 5 grms., water 10 c.c.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water alone.
Cold-water extract, . .	nearly all	little	0	0	0·042	
Wholly converted, . .	0	0	0	0	2·174	
Masticated, ...	much	much	some	some	0·755	0·505
Masticated, and at 38° for 30 min., ...	,,	,,	much	much	0·808	0·706
2 c.c. saliva at 38° for 60 min.,	,,	,,	some	?	0·644	0·704
,, ,, 150 ,,	,,	,,	fair amt.	some	0·737	0·769
,, ,, 180 ,,	,,	,,	much	much	0·83	0·849

As regards artificial digestion, the addition of cheese seems to have had little or no effect on salivary amylolysis. If we had expected a more rapid conversion of starch as a result of chewing, we have not been disappointed. The cheese has caused an increased flow of saliva, and as a result an increased conversion of starch. Apart, therefore, from the consideration of its digestibility, cheese has a helpful action in promoting starch proteolysis, owing to its directly stimulating effect on the salivary glands.

Effect of Fluid Foods on Digestion of Starch by Saliva.

In order to investigate this I took as examples of very common foods milk and broth, and noted the reaction of the starch to ptyalin when either of these was added.

XVI. *Salivary Digestion of Bread and Milk.*

Five grammes of stale bread crumb were added to 10 c.c. fresh milk together with 2 c.c. saliva. This was kept at 38° C.

TABLE XVI.—*Salivary Digestion of Bread and Milk—5 grms. bread, 10 c.c. milk, 2 c.c. saliva.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water. Sugar.
Masticated, ...	much	much	some	?	0·152	0·505
Masticated, and at 38° for 30 min., ...	,,	,,	much	some	0·621	0·706
2 c.c. saliva at 38° for 5 min.,	nearly all	some	traces	0	0	0·289
,, ,, 10 ,,	much	more	more	?	0·083	0·382
,, ,, 30 ,,	,,	much	fair amt.	,,	0·197	0·574
,, ,, 60 ,,	,,	,,	,,	,,	0·492	0·704
,, ,, 120 ,,	,,	,,	,,	,,	0·551	0·746
,, ,, 180 ,,	,,	,,	,,	,,	0·671	0·849

In arriving at the above estimations of sugar, the amount of lactose present in 10 c.c. milk was first determined, and this amount was subtracted from the subsequent estimations.

The addition of milk to bread causes a remarkable enfeeblement of the salivary ferment. During practically the first twenty minutes no conversion of starch takes place. After this period, however, the change goes on fairly rapidly, though it never by any means attains to that produced when water alone is taken along with bread.

Milk has therefore a retarding effect on the salivary ferment, and at the same time lessens its converting power.

XVII. *Salivary Digestion of Broth and Bread.*

Amongst our working-class population this is a very common (very often the sole midday) article of diet. It consequently seemed an interesting experiment to investigate in what manner the addition of broth might affect the digestion of starch by ptyalin.

The broth was made of meat and rice, but only the clear fluid was used in the experiments.

Ten c.c. of broth fluid along with 2 c.c. saliva were poured over 5 grammes stale bread crumbs. This was kept at 38° C.

TABLE XVII.—*Salivary Digestion of Bread and Broth—5 grms. stale bread,* 10 *c.c. broth fluid,* 2 *c.c. saliva.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water Plain.	Differ-ence.
Masticated, . .	much	much	much	present	0·467	0·505	·038
Masticated, and at 38° for 30 min., .	,,	,,	,,	,,	0·73	0·706	·024
2 c.c. saliva at 38° for 5 min.,	,,	,,	some	?	0·320	0·289	·031
,, 10 ,,	,,	,,	,,	,,	0·323	0·382	·061
,, 30 ,,	,,	,,	good deal	,,	0·542	0·574	·032
,, 60 ,,	,,	,,	,,	,,	0·698	0·704	·006
,, 120 ,,	,,	,,	much	,,	0·769	0·746	– ·023
,, 180 ,,	,,	,,	,,	present	0·802	0·849	·047

Throughout this series of experiments (with one exception) the degree of starch conversion is less than in the case of bread and water alone. Evidently, either the saline or proteid matters present in the broth have had a slight restraining influence on the salivary ferment.

The retarding influence is, however, very slight as compared with that caused by milk.

XVIII. *Salivary Digestion of Bread and Tea.*

As we have seen, bread is seldom eaten alone. It is usually eaten along with some fluid, none being more used than tea infusion.

What effect on the salivary digestion of bread has an infusion of tea?

The tea used was an ordinary good household tea, with a slight addition of Pekoe as flavouring. It was infused for ten minutes, and the infusion had an acidity equal to 0·86 per cent. tannic acid.

Ten c.c. of this infusion at 38° C. were mixed with 2 c.c. saliva and poured over 5 grammes stale bread crumb (2nd day).

We have to compare this table with that showing the digestion of bread along with water (Table IX.).

These experiments show that an infusion of tea hinders, though by no means inhibits, the action of ptyalin. Up to the end of the second hour, less sugar is formed from starch when in the presence of tea infusion than is formed in its absence. After this time-limit, however, no difference is noted either with or without tea infusion.

TABLE XVIII.—*Salivary Digestion of Bread along with Tea—5 grms. bread, 10 c.c. tea infusion, 2 c.c. saliva.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water Plain.	Differ-ence.
Cold-water extract,	all	little	...	...	0·042		
Wholly converted by acid, . . .	0	0	0	0	2·174		
Chewed, and at once examined, . .	much	much	some	?	0·256	0·505	·249
Chewed, and at 38° for 30 min., . .	little	much	much	present	0·5	0·706	·206
2 c.c. saliva at 38° for 5 min.,	much	much	trace	?	0·161	0·289	·128
,, 10 ,,	,,	,,	present	present	0·273	0·382	·109
,, 20 ,,	,,	,,	fair amt.	,,	0·359	0·476	·117
,, 30 ,,	,,	,,	,,	,,	0·412	0·574	·162
,, 45 ,,	,,	,,	,,	,,	0·596	0·639	·043
,, 60 ,,	,,	,,	much	more	0·602	0·704	·102
,, 90 ,,	not so much	not so much	grt. amt.	grt.amt.	0·653	0·726	·073
,, 120 ,,	,,	,,	,,	,,	0·714	0·746	·032
,, 150 ,,	,,	,,	,,	,,	0·769	0·769	
,, 180 ,,	little	little	,,	,,	0·845	0·849	·004

When bread is chewed along with tea infusion, only about one-half the amount of sugar is formed compared to the same proceeding with bread and water alone. After being chewed, if it be kept at 38° C. for half an hour, only half a gramme of sugar is formed, as compared with 0·706 gramme produced in the presence of water alone. During the early stages of digestion, therefore, there is a marked retardation produced by infusions of tea.

XIX. *Salivary Digestion of Bread and Coffee.*

Five grammes bread crumb were mixed with 10 c.c. ordinary decoction of coffee, along with 2 c.c. saliva, at 38° C.

TABLE XIX.—*Salivary Digestion of Bread and Coffee—5 grms. bread, 10 c.c. coffee, 2 c.c. saliva.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Plain Water.	Differ-ence.
Cold extract, . .	nearly all	little	0	0	0·042		
Totally converted, .	0	0	0	0	2·174		
Chewed, and at once examined, . .	much	lge. amt.	lge. amt.	0	0·36	0·505	0·145
Chewed, and at 38° for 30 min., . .	,,	,,	,,	,,	0·637	0·706	0·069
2 c.c. saliva at 38° for 5 min.,	much	fair amt.	trace	0	0·263	0·289	·026
,, 10 ,,	much	much	fair amt.	?	0·343	0·382	·039
,, 20 ,,	,,	,,	,,	,,	0·435	0·476	·041
,, 30 ,,	,,	,,	much	,,	0·531	0·574	·043
,, 45 ,,	,,	,,	,,	,,	0·570	0·639	·069
,, 60 ,,	,,	,,	,,	,,	0·670	0·704	·034
,, 90 ,,	,,	,,	,,	,,	0·719	0·726	·007
,, 120 ,,	,,	,,	,,	,,	0·722	0·746	·024
,, 150 ,,	,,	,,	,,	,,	0·750	0·769	·019
,, 180 ,,	,,	,,	,,	,,	0·753	0·849	·096

In the case of coffee, starch conversion commences early, and goes on steadily progressing. The maximum amount of sugar produced falls far short of that produced along with tea infusion. On comparing these tables it is well shown how strongly an inhibiting agent tea is. The figures in the "difference" column are striking. We find, then, that coffee has no great effect in hindering or slowing starch proteolysis.

XX. *Salivary Digestion of Bread and Cocoa.*

Five grms. of bread crumb were mixed with 10 c.c. of cocoa solution and 2 c.c. saliva. The cocoa used was Van Houten's. An extract of this, made with boiling water, contains the merest traces of sugar, too small to be regarded, and when digested alone with 2 c.c. saliva for thirty minutes, no reaction with iodine is obtained, and no appreciable amount of sugar is formed.

The above mixture was kept at 38° C.

TABLE XX.—*Salivary Digestion of Bread and Cocoa.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar, grms.	Bread and Plain Water.	Differ-ence.
Cold-water extract, .	nearly all	little	0	0	0·042		
Totally converted, .	0	0	0	0	2·174		
Chewed, and at once examined, . .	much	much	traces	traces	0·526	·505	·021 +
Chewed, and at 38° C. for 30 min., .	,,	,,	present	present	0·866	·706	·160 +
2 c.c. saliva at 38° 5 min.	,,	,,	,,	0	0·281	·289	·008 −
,, 10 ,,	,,	,,	good amt	0	0·433	·382	·051 +
,, 20 ,,	,,	,,	much	?	0·590	·476	·114 +
,, 30 ,,	,,	,,	,,	present	0·610	·574	·036 +
,, 45 ,,	,,	,,	,,	,,	0·630	·639	·009 −
,, 60 ,,	,,	,,	,,	,,	0·711	·704	·007 +
,, 90 ,,	,,	,,	,,	,,	0·756	·726	·030 +
,, 120 ,,	,,	,,	,,	,,	0·762	·746	·016 +
,, 150 ,,	,,	,,	,,	much	0·788	·769	·019 +
,, 180 ,,	,,	,,	not so much	much	0·814	·849	·035 −

Naturally, we compare these results with those obtained in the case of tea and coffee. In the case of cocoa, we find there is little or no restraining action. Starch conversion begins early and proceeds steadily.

In the case of tea, conversion was at first restrained; later on, however, amylolysis proceeded more rapidly, until, at the end of two and a half hours, we find that the starch has undergone a greater conversion relatively to what we find in the case of cocoa. Even from the first the starch undergoes solution almost as readily as it does when water alone is used.

Comparing cocoa with coffee, though the differences are not so marked as in the case of tea, yet the advantage rests with cocoa; there is less inhibition of ptyalin in the present case than in the case of coffee.

What effect have our ordinary stimulants on the salivary digestion of starch?

XXI. *Salivary Digestion of Bread along with Beer.*

Five grms. bread crumbs were mixed with 2 c.c. saliva and 10 c.c. Prestonpans beer (there is practically no sugar in 10 c.c. of this beer).

This mixture was kept at 38° C.

Table XXI.—*Salivary Digestion of Bread and Beer.*

	Un-changed Starch.	Soluble Starch.	Erythro dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water.	Differ-ence.
Cold-water extract, .	all	0	0	0	0		
Totally converted, .	0	0	0	0	2·174		
Chewed, and at once examined, . .	much	much	fair amt.	0	0·366	·505	·139 –
Chewed, and at 38° for 30 min., .	,,	,,	much	much	·671	·706	·135 –
2 c.c. saliva at 38° for 5 min.	,,	,,	some	0	·314	·289	·025 +
,, 10 ,,	,,	,,	more	0	·411	·382	·029 +
,, 20 ,,	,,	,,	much	traces	·576	·476	·100 +
,, 30 ,,	,,	,,	,,	,,	·607	·574	·133 +
,, 45 ,,	,,	,,	,,	more	·614	·639	·025 –
,, 60 ,,	,,	,,	,,	,,	·619	·704	·085 –
,, 90 ,,	less	,,	,,	,,	·703	·726	·023 –
,, 120 ,,	,,	,,	,,	much	·745	·746	·001 –
,, 150 ,,	,,	,,	,,	,,	·784	·769	·015 +
,, 180 ,,	,,	,,	,,	,,	·787	·849	·062 –

If we compare this with the digestion of starch by saliva in the presence of water, what do we find?—that an increased degree of conversion up to the end of the first 150 minutes is evident. Instead of a restraining effect on ptyalin, the beer seems to have exerted a stimulating action, and even from the earliest period the amount of sugar formed is in excess of that produced in the presence of water alone. Being more energetic in the earlier periods, there is a falling off in the amount of sugar converted from starch after two and a half hours. Conversion begins at once, and goes a far length in the case of beer.

It might be thought that the bitterness of the beer would promote an increased salivary flow, and consequently a greater amylolysis. If it does promote a greater secretion of saliva, however, the degree of starch conversion is not hastened, as we see from the two experiments after mastication. In these the amount of sugar produced is much smaller than with water alone. The probability is that no greater secretion of saliva does take place.

XXII. *Salivary Digestion of Bread and Dilute Whisky.*

Whisky and water form one of the commonest of beverages in Great Britain, and its consumption is steadily increasing over the globe.

What effect has it on salivary digestion?

In the first set of experiments, ordinary good Scotch whisky (Talisker) was used, diluted with water in the proportion of 1 part whisky to 2 of water.

Five grm. bread crumb were mixed with 10 c.c. dilute spirit and 2 c.c. saliva (all at 38° C.) and kept at this temperature.

Table XXII.—*Salivary Digestion of Bread and Dilute Whisky.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water.	Differ-ence.
Cold-water extract, .	nearly all	little	0	0	0·042		
Totally converted, .	...	...	...	...	2·174		
Chewed, and at once examined, . .	much	little	present	?	·328	·505	·177 −
Chewed, and at 38° for 30 min., .	much	much	much	present	·762	·706	·056 +
2 c.c. saliva at 38° 5 min.	,,	vy. little	0	0	·189	·289	·100 −
,, 10 ,,	,,	,,	0	0	·291	·382	·091 −
,, 20 ,,	,,	much	trace	trace	·473	·476	·003 −
,, 30 ,,	,,	,,	,,	,,	·495	·574	·079 −
,, 45 ,,	,,	,,	much	present	·619	·639	·020 −
,, 60 ,,	,,	,,	,,	,,	·71	·704	·006 +
,, 90 ,,	,,	,,	,,	,,	·724	·726	·002 −
,, 120 ,,	not so much	,,	,,	much	·737	·746	·009 −
,, 150 ,,	,,	,,	,,	,,	·741	·769	·028 −
,, 180 ,,	,,	,,	,,	,,	·75	·849	·099 −

These experiments show that weak spirit has permanently lessened the activity of ptyalin. At the end of the third hour there is still much unchanged starch present, while soluble starch and dextrins form 'much' of what remains, and sugar 0·75 gramme.

In the case of bread and water, very little unchanged starch remains at the end of the third hour, and soluble starch and dextrins are present in 'very large amounts'; while sugar forms 0·849 gramme.

Then, in the mastication of the bread, in spite of the very large (5 grammes) addition of saliva, only 0·326 grm. sugar has been formed, as compared with 0·505 grm. with water alone. After this chewed mass has been kept at 38° C. for thirty minutes, much unchanged starch is yet present and 0·762 grm. sugar, as compared with the presence of little unchanged starch and 0·706 grm. sugar in the chewed bread and water.

On the contrary, if we compare the effect of dilute whisky with that of tea, we find that the balance of favour goes to the spirit. Up till the end of the second hour, dilute whisky has a less restraining effect on ptyalin than has an infusion of tea.

XXIII.—*Salivary Digestion of Bread and Pure Whisky.*

	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water.	Differ-ence.
Cold-water extract, .	nearly all	little	0	0	·042		
Totally converted, .	0	0	0	0	2·174		
Chewed, and at once examined, . .	chiefly	some	little	0	·45	·505	·055 –
Chewed, and at 38° C. for 30 min., .	much	much	little	present	·684	·706	·022 –
2 cc. saliva at 38° for 5 min.,	chiefly	trace	indic.	0	·166	·289	·123 –
" 10 "	much	much	trace	0	·227	·382	·155 –
" 20 "	"	"	"	"	·301	·476	·175 –
" 30 "	"	"	much	?	·384	·574	·190 –
" 45 "	"	"	"	"	·423	·639	·216 –
" 60 "	"	"	"	present	·508	·704	·196 –
" 90 "	"	not so much	"	much	·568	·726	·158 –
" 120 "	"	"	"	"	·633	·746	·113 –
" 150 "	"	"	"	"	·661	·769	·108 –
" 180 "	"	"	not nearly so much	"	·673	·849	·176 –

XXIII. *Salivary Digestion of Bread and Pure Whisky.*

Ten c.c. undiluted whisky were mixed with 2 c.c. saliva and poured over 5 grms. bread. All were at 38° C., and kept at this temperature.

If we compare this table with the preceding, we note that pure whisky exerts a much greater action in weakening the salivary ferment than when it is diluted. In spite of 7 grammes saliva having been added during mastication, only 0·45 gramme sugar was formed, and after being kept at 38° C. for half an hour this only increased to 0·684 gramme, as compared with 0·762 gramme in the case of dilute whisky.

At the end of the first hour only 0·508 gramme sugar has been formed in the present case, as compared with 0·71 gramme in the preceding. At the end of the third hour these figures are 0·673 and 0·75 gramme. Manifestly, therefore, pure whisky has a still greater destructive action than the same when diluted.

XXIV. *Salivary Digestion of Bread and Sherry.*

The acidity of this wine was equal to 0·547 per cent., calculated as tartaric acid. The wine contained likewise 2·84 grammes sugar per cent. (=0·284 gramme per 10 c.c. wine, and this amount has been subtracted from each observation).

In this case the inhibition of amylolysis is almost complete. Starch remains entirely unconverted up to the end of the first hour, when the merest traces of soluble starch appear. Only at the expiry of two and a half hours do we find erythrodextrin appearing, and even after three hours' digestion only 0·240 gramme sugar has been formed.

When 5 grammes bread is chewed with 10 c.c. sherry the starch undergoes no change, and the amount of sugar formed, even after such is kept at 38° C. for thirty minutes, is only 0·147 gramme.

That this inhibition of starch proteolysis is entirely due to the acid present in the wine is shown by the fact that when the sherry is neutralised and kept for one hour at 38° C. much soluble starch is present, along with tolerable amounts of erythrodextrin and achroodextrin, while sugar forms 0·681 gramme.

On being kept at 38° C. for three hours after neutralisation, though much starch remains unaffected, there are yet large quantities of soluble starch and dextrins, and sugar forms 0·730 gramme. It is needless to state, however, that such neutralisation entirely changes the character of the wine, rendering it a nauseous turbid fluid with a semen-like odour.

XXV. *Salivary Digestion of Bread and Claret—5 grammes bread,* 10 *c.c. good claret* (*Medoc*), 2 *c.c. saliva.*

This claret possessed practically no sugar. Its acidity was equal to 0·75 per cent., calculated as tartaric acid.

The experiments showed that claret had even a greater restrianing effect on salivary proteolysis than sherry. Even after three hours' digestion, the starch had undergone no conversion into soluble starch or dextrins. After ten minutes' digestion the sugar formed only amounted to 0·095 grammes; in ninety minutes 0·120 gramme, and at the end of the third hour 0·143 gramme.

The process of masticating bread with claret promotes a large flow of saliva. On examining the result, however, only a small amount of soluble starch was present, and sugar to 0·089 gramme. After keeping the same mixture at 38° C. for thirty minutes, the sugar only increased to 0·179 gramme.

Claret has therefore a most powerful effect in inhibiting salivary digestion.

On neutralising the acidity of the claret and keeping it along with bread and saliva at 38° C. for one hour, we find that much soluble starch and dextrins are present, while sugar forms 0·684 gramme. After three hours' digestion thus at 38° C. the sugar has increased to 0·73 gramme, as compared with 0·143 gramme in the case of ordinary claret.

XXVI. *Salivary Digestion of Bread and Port Wine—5 grammes bread,* 10 *c.c. port wine,* 2 *c.c. saliva.*

The acidity of this wine was equal to 0·427 per cent., calculated as tartaric acid. It contained 4·80 grammes sugar per cent. (0·480 gramme per 10 c.c. wine).

Of all the beverages thus examined, port wine has the greatest effect in inhibiting starch proteolysis, with the exception of claret and sherry.

TABLE XXVI.—*Salivary Digestion of Bread and Port Wine.*

	Unchanged Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Sugar. grms.	Bread and Water.	Difference.
Cold-water extract, .	nearly all	little	0	0	·042		
Totally converted, .	0	0	0	0	2·174		
Chewed, and at once examined, . .	nearly all	0	0	0	0	·505	·505 –
Chewed, and at 38° C. for 30 min., .	much	much	fair amt.	fair amt.	·289	·706	·417 –
2 c.c. saliva at 38° 10 min.,	nearly all	some	0	0	·020	·382	·362 –
,, 20 ,,	,,	,,	0	0	·052	·476	·424 –
,, 30 ,,	much	much	traces	0	·116	·574	·458 –
,, 45 ,,	,,	,,	,,	,,	·120	·639	·519 –
,, 60 ,,	,,	,,	tolerable amount	traces	·159	·704	·545 –
,, 90 ,,	,,	,,	,,	,,	·228	·726	·498 –
,, 120 ,,	,,	,,	,,	,,	·231	·746	·515 –
,, 150 ,,	,,	,,	,,	fair amt	·233	·769	·536 –
,, 180 ,,	,,	,,	,,	,,	·245	·849	·604 –

Inhibition is most marked throughout the whole experiments.

When chewed, the ferment in the saliva seems to be rendered almost inactive, there being no sugar produced during the process. If, after being masticated, it be kept at 38° C. for thirty minutes, 0·289 gramme sugar is formed, and this is greater than that produced by adding two c.c saliva, and allowing it to act on the bread in presence of the wine for three hours.

That this inhibition is also due to the organic acids present in the wine is manifest on neutralising it, a marked and fairly rapid conversion of starch then occurring.

In order to make a general comparison, I have drawn up the following table, which shows the results of masticating definite amounts of each of the starchy substances, and then keeping the masticated mass at 38° C. for half an hour. The sugar which has been formed from the starch by salivary proteolysis has been calculated as a percentage of the total sugar which was obtained by actual artificial conversion of the starch by acid and boiling.

TABLE XXVII.—*Comparison between Different Starchy Foods masticated, then kept at 38° C. for thirty minutes.*

Food.	Un-changed Starch.	Soluble Starch.	Erythro-dextrin.	Achroo-dextrin.	Per-centage Sugar formed.
1. White bread alone, . .	much	much	much	much	39·28
2. Bread + water, . . .	little	,,	,,	,,	32·47
3. Newly-baked bread + water,	much	,,	,,	present	34·13
4. Bread crust + water, . .	,,	,,	fair amt.	,,	33·0
5. Vienna bread (stale) + water,	,,	,,	much	much	35·14
6. ,, (new) + water,	,,	,,	,,	,,	38·96
7. Bread + butter, . .	,,	,,	,,	,,	31·27
8. ,, + cheese, . .	,,	,,	,,	,,	37·16
9. ,, + milk, . . .	,,	,,	,,	some	28·56
10. ,, + broth, . . .	,,	,,	,,	,,	33·57
11. ,, + tea, . . .	,,	,,	,,	,,	22·99
12. ,, + coffee, . . .	,,	,,	,,	–	29·30
13. ,, + cocoa, . . .	,,	,,	present	present	39·83
14. ,, + beer, . . .	,,	,,	much	much	30·86
15. ,, + dilute spirits, .	,,	,,	,,	present	35·05
16. ,, + strong spirits, .	,,	,,	,,	,,	31·46
17. ,, + sherry, . .	nearly all	–	–	–	6·76
18. ,, + claret, . . .	,,	sm. amt.	–	–	8·23
19. ,, + port wine, . .	much	much	fair amt.	fair amt.	13·29
20. Potato, boiled and powdered,	little	–	–	much	20·28
21. ,, in fragments, .	–	–	–	–	21·28
22. Porridge, alone, . .	nearly all	much	much	trace	25·72
23. ,, + water, . .	some	,,	sm. amt.	–	29·9
24. ,, + milk, . .	much	,,	fair amt.	–	23·88
25. Rice, boiled, . . .	,,	,,	,,	little	12·36
26. Corn flour, boiled, . .	trace	,,	much	,,	38·13

CONCLUSIONS.

In order to bring this to a conclusion, attention may be drawn to the following points (which are gathered from the individual tables, and not from the concluding one):—

1. Porridge along with milk forms a more digestible compound, as far as amylolysis by saliva is concerned, than other combinations of oatmeal.

2. The more dense, the less broken down, or the firmer the jelly in which the starchy food is when undergoing salivary digestion, the less rapid and extensive is the proteolysis.

3. Some forms of starchy food undergo a certain amount of digestion by saliva, but at a certain stage this process stops, and

no matter how long they may be exposed to the action of ptyalin, no further amylolysis by saliva takes place (we must remember, however, the restraining effects which the products of digestion exert).

4. Amylaceous substances are more easily acted on by saliva when thoroughly moist than when more or less dry.

5. Bread in a light and spongy condition is more rapidly acted upon by saliva than when less spongy. Such bread, however, does not ultimately undergo any more complete digestion than does ordinary bread.

6. Milk has a retarding influence on the salivary digestion of starch in bread, while broth has little or no effect.

7. Tea has a markedly inhibitory influence on amylolysis by saliva. Coffee has this property also to a less extent. Cocoa has hardly any restraining effect.

8. Beer promotes the salivary digestion of starch.

9. Alchol, even in dilute solution, retards salivary digestion of starch, but the action is much less marked than in the case of infusions of tea.

10. Wines have a very marked inhibitory influence on the digestion of starch by saliva, and this is almost wholly due to their acidity.

THE VALUE OF SACCHARINE FOODS AS ARTICLES OF DIET

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In view of the general attention which is now being given to carbohydrates (sugars and starches) as forming one of the most important of the food elements, a brief consideration of the food value of some of the usual saccharine substances may not be uninteresting.

Farinaceous matters and sugars are readily digested as a rule, and very completely absorbed. Whether they are simply burned up within the body and so preserve the amount of fat already formed, thus lessening the amount of proteid change, or whether they become transformed into fat themselves, are questions which do not concern us now. It is sufficient to remember that they act as heat and energy-producing agents, and thus form most important constituents of a normal diet. Practically, we know that all so-called "fattening foods" contain much sugar and starch.

The kind of sugar which is present in the saccharine food is, however, of the greatest importance as regards its ease of assimilation. Cane sugar is not absorbed as such, but requires to undergo *inversion*, and is thus split up into dextrose and levulose, which are then directly absorbed. This change does not take place to any extent in the stomach, but only in the small intestine. Maltose likewise readily undergoes a change in its molecular constitution, and so forms a readily assimilable sugar. Many physicians now recognise the great value of these easily absorbed sugars, and recommend that in extreme exhaustion or in acute diseases (as in typhoid fever), glucose, levulose, or milk sugar should be administered, or as maltose, by acting on starchy food with extract of malt. These are even given as enemata, and are found very useful in those conditions where food cannot be introduced into the stomach.

Apart from this, however, sugar forms such a large and important part in ordinary diet that the dyspeptic finds he can hardly avoid consuming some, and besides this, to many people it is a necessity in order to render other articles of food pleasant.

Some sugary foods are much more easily borne by the stomach than others, or more of one kind may be taken with impunity than another. Why is this? I have already stated that some sugars are more easily assimilated than others. Does the ease or difficulty of digestibility of certain sugary foods depend on the nature of the sugars which they contain?

In order to answer this question we require to know the kind or kinds of sugar which are present in some of the common articles of diet.

I. Preserved Fruits.

JAMS AND FRUIT JELLIES.

Owing to the wholesale manufacture of these and to their consequent cheapness, these now form in this country at least, very largely used articles of diet and so merit our consideration.

Jams are usually made by boiling the fruit with from one half to its own weight of cane sugar. The natural acid of the fruit inverts a large quantity of this sugar into dextrose and levulose. If the jam has been boiled for a considerable time, nearly the whole of the cane sugar undergoes inversion. This is particularly the case with home-made jams, which are always well boiled in order to make sure that they will keep.

In the case of commercially made jams, on the contrary, the percentage of cane sugar which remains is high. Such jams are not subjected to long boiling, as this would cause a great loss in their volume by escape of vapour, and as the output would be lessened consequently, the profit would be correspondingly decreased.

In such jams, cane sugar may form 10 to 50 per cent. of the whole, while in home-made jams cane sugar rarely exceeds 20 per cent.

Fruit jellies have a composition very similar to those of jams. The gelatinous property of fruits depends on the presence of a gummy substance named pectin. This undergoes destruction if the fruit be boiled too energetically or for too long a period, and instead of forming a jelly a syrupy fluid results. In many of the commercially made jellies, however, gelatine is added to increase their degree of firmness—and lessen the amount of fruit used.

The following figures were obtained by estimating the amounts of the different sugars present in some home-made jams.

Watery extracts (2 per cent.) of the jams were made and the sugar present was estimated by the saccharometer and also by titration against Fehling's solution. The cane sugar remaining in them was then inverted by prolonged heating (after acidification) and the invert sugar resulting was again estimated.

1. *Strawberry Jam.*—This had an acidity corresponding to 0·049 per cent. acetic acid; cane sugar was present to 23·6 per cent.; and invert sugar to 18 per cent.

This means that nearly one half of the cane sugar has undergone inversion during the process of manufacture.

2. *Marmalade.*—The acidity corresponded to 0·072 per cent. acetic acid; cane sugar amounted to 10 per cent.; invert sugar to 51 per cent., showing that almost all the cane sugar had undergone inversion during the process of boiling.

3. *Bramble Jam.*—Acidity corresponded to 0·056 per cent. acetic acid; cane sugar was present to 11·8 per cent.; invert sugar 47·6 per cent.

4. *Raspberry Jam.*—Acidity = 0·051 per cent. acetic acid; cane sugar 16·56 per cent.; invert sugar 26·12 per cent.

5. *Plum Jam.*—Acidity = 0·12 per cent.; cane sugar 8 per cent.; invert sugar 50 per cent.

SUGAR IN JAMS.

	Acidity.	Cane Sugar.	Invert Sugar.	Proportion of Cane Sugar inverted.
	°/ₒ Acetic Acid.			
Strawberry .	0·049	23·6	18·	2/5
Marmalade .	·072	10·	51·	5/6
Bramble . .	·056	11·8	47·6	4/5
Raspberry .	·051	16·56	26·12	3/5
Plum . . .	·12	8·	50·	6/7

In these different jams the acidity is distinct and the amount of cane sugar which has undergone inversion has been somewhat proportional to the degree of acidity—the greater the acidity the greater the inversion. This is not quite carried out in the above examples, but then the length of time that the jams were boiled is not known.

Jams are considered to be very wholesome and form a pleasant way in which to take a large amount of concentrated carbohydrate food along with the valuable organic acids—citrates, tartrates, malates—which the fruit contains.

Marmalade forms a very common addition to the breakfast or tea, and one half of it consists of invert sugar.

I feel convinced that the large amount of invert sugar which these preserves contain is the cause of their easy digestibility. Many chronic dyspeptics are found who still eat such preserves along with other articles of food and suffer no discomfort from doing so.

FRUITS.

All ordinary ripe fruits contain a good deal of sugar, and it is to this chiefly, along with the organic acids, that they owe their value in dietetics. The sugar is chiefly present in the uncrystallisable form (levulose) with a small proportion of glucose. In some cases also cane sugar is present in small amount. The glucose and levulose present in fruits are not the results of any natural inversion of cane sugar, for they do not occur in their usual proportion, and in many fruits the proportion of cane sugar increases during the process of ripening. In even so acid a fruit as the lemon, we find four parts of cane sugar to every ten parts of invert sugar. In the case of the sugar cane itself, much invert sugar occurs in the young leaves, which is gradually replaced by cane sugar as the leaves ripen. The acidity of the fruit is often so marked that sugar has to be added to counteract this. It would, however, be better from a health point of view to neutralise the acidity by adding an alkali than to sweeten it by means of cane sugar, but the flavour is by no means improved by this procedure. When cane sugar is added to acid fruits, in cooking them much becomes inverted. Invert sugar is not so sweet as cane sugar, and so the cook is frequently at a loss to understand why the fruit is so sour although she had added an ample quantity. As, however, invert sugar is much more easily absorbed, it is an advantage to add cane sugar to the fruit while cooking, so that it may become inverted.

Stewed fruits form a valuable and nutritious addition to our food stuffs.

CRYSTALLISED OR CANDIED FRUITS.

Those are made in the following manner. A clear syrup of cane sugar is prepared. The fruit, either whole or cut up into small pieces, is then boiled in this syrup until it is thoroughly permeated. The fruit is then removed from the syrup and dried by the aid of gentle heat.

An infusion of several varieties of these had an acidity equal to 0·054 per cent. acetic acid. Cane sugar constituted 20·5 per cent. and invert sugar 29·5 per cent. Such fruits are hard, dense, and difficult of disintegration, and are well known to be indigestible. They form, however, a very small part of ordinary diet.

HONEY.

Before the sugar cane was so largely cultivated as it is at present, honey was generally employed as the sweetening agent in this and in other countries. Since the great fall in the price of sugar, however, the industry of bee-keeping has largely fallen into desuetude in this country at least.

The chief constituents of run honey are dextrose and levulose, with a certain amount of less well-known sugars (said by some to be cane sugars), mannite, etc., along with organic acids of which formic acid is the chief. The reducing sugars amount on an average to 67·85 per cent. In one specimen of honey examined as to its sugars, dextrose amounted to 35 per cent. and levulose to 38 per cent.

This natural product then consists of those easily assimilated sugars, and it would form a very important and easily obtainable article of diet.

TREACLE (MOLASSES), GOLDEN SYRUP.

These may be termed the refuse products got in sugar refining. They consist of cane sugar (present in an uncrystallisable form) and invert sugar in nearly equal amounts. There is also about 20 per cent. of water present.

These are much used by the poorer classes instead of preserves.

II. Confections.

Very many sweetmeats consist of finely-ground cane sugar made into a paste with gum mucilage, albumin or gelatine, and with a flavouring agent added. This mixture is either rolled out and cut into lozenges or coloured and moulded into various shapes. These are then dried in a warm room, but at no time are such sweets subjected to any degree of heat.

The various lozenges, French crêmes, icing for cakes, etc., consist almost entirely of pure cane sugar.

Inverted sugar resulting from prolonged boiling alone or from the addition of some organic acid, is found in such sweets as toffy, and various clear sweets technically known as "boilings." Most of these are made by adding a little water to a quantity of sugar and heating until dissolved. A quantity of cream of tartar, acetic acid or vinegar is added during the boiling, and the candy is boiled until "high," that is, until a quantity of it when dropped on a cold surface becomes brittle. The addition of the acid and the prolonged boiling prevent the sugar crystallising again on cooling. In this way a tolerably large amount of cane sugar undergoes inversion. If it have been insufficiently inverted, on cooling the whole mass crystallises and the candy is spoiled.

It is well known in the nursery that clear sweets and toffy are much less harmful to children than crystallised sweets. A mother will allow her child to eat much more of the former than of the latter, as she has observed that "they do not harm the stomach so much." Is this not owing to the large amount of invert sugar which they contain?

To determine in what proportions cane and invert sugar exist in different sweets I examined the following:—

1. *French Crême Sweets.*—A 2 per cent. solution of these was made, and the amount of invert sugar which they contained was estimated. The cane sugar was then inverted by prolonged heating with dilute sulphuric acid and again estimated. These sweets contained 71·3 per cent. of cane sugar and 7·7 per cent. of invert sugar.

2. *Chocolate.*—I found that ordinary chocolate contains no invert sugar. Cane is the only sugar present, and it forms 45 per cent. of the whole; cocoa and mucilage forming the larger half.

This is considered a very wholesome confection, and naturally so. Even though the sugar is wholly present as cane sugar, it does not amount to one half of the total, the major part consisting of the highly nutritious cocoa (made up of fat, albuminous matter and theobromine).

Owing to its mode of manufacture, invert sugar is not formed. Cane sugar is merely ground in along with the warm cocoa paste and then turned into moulds.

3. *Chocolate Crême.*—This confection naturally contains 8·6 per cent. of invert sugar, and 53·9 per cent. of cane sugar. The invert sugar which naturally occurs in this sweet, is confined to the white crême in the interior. If this white part be isolated from the surrounding chocolate, the same amount of reducing sugar is found to be present, viz., 8·6 per cent.; whereas the chocolate contains only cane sugar.

4. *Acid Drops.*—The acidity of these corresponds to 0·1 per cent. of tartaric acid. These contain 55·5 per cent. cane sugar, and 27·5 per cent. invert sugar. We might have expected to find a greater amount of invert sugar present in these sweets, especially as the acidity is relatively high. The method of manufacture explains this, however. The candy from which they are made is prepared in the same manner as for other clear-boiled sweets; that is to say, that acetic acid or cream of tartar is added, and it is boiled to "candy high." All these sweets are prepared, in the first instance, in exactly the same way; it is only the subsequent treatment which differs, and which gives rise to the varieties of clear sweets. In this case, after being boiled high, the candy is poured on to a slab, and, when sufficiently cool, a definite quantity of acid tartrate of potassium is kneaded in to give it the desired acidity of taste.

5. *Clear Transparent Sweets.*—Cane sugar amounts to 71·2 per cent.; invert sugar 13·8 per cent.

6. *Extract of Malt Lozenges.*—These have practically no acidity. Cane sugar forms 70·3 per cent. and invert sugar 14·7 per cent. These correspond closely to ordinary lozenges in the amount of cane sugar which they contain.

7. *Everton Toffy.*—The acidity was equal to 0·007 per cent. tartaric acid. It contains 34·8 per cent. of cane sugar, and 27·7 per cent. of invert sugar. Invert sugar is present in almost the same amount as in the case of No. 4, though here

the degree of acidity is feeble. The candy, however, is subjected to long boiling. Besides invert and cane sugar, it also contains much fat in the shape of butter, which is added when the candy is removed from the fire.

Curiously enough, this sweet is universally known to be very wholesome, and one frequently observes that it is given to delicate children who are forbidden to eat other sweets. Dr Milner Fothergill even recommended its use, instead of cod-liver oil, for strumous children, and remarks that he has saved many children from death by its use.

This high recommendation is no doubt based on the fact that it contains a large amount of fat, which is eagerly taken in this form by delicate children, who would refuse it in its natural state, or as butter or cod-liver oil. I doubt not but that its good effects are, to a very great extent, also due to the large amount of easily assimilated carbohydrate which it contains as invert sugar.

Our contention, then, seems to be proved, both by the results of the foregoing analyses and by clinical observation.

In all cases where such saccharine food is readily and easily digested, we find that the sugar is in the form of levulose or glucose, or mixtures of these in various proportions.

In giving directions for a dietary, we ought to consider the ease of digestibility of the saccharine elements, and make a selection accordingly.

THE ACTIVITY OF THE SALIVA IN DISEASED CONDITIONS OF THE BODY.

THE ACTIVITY OF THE SALIVA IN DISEASED CONDITIONS OF THE BODY.

By W. G. Aitchison Robertson, M.D., D.Sc., F.R.C.P.Ed., F.R.S.E.

Before coming to the subject of this paper, I desire to point out a fact which is too often overlooked, and which has been erroneously taught in the past. This is the all-important and primary action of saliva, that of transforming starch into maltose. Many teachers have been in the habit of stating that the amylolytic power of saliva is feeble, and that any slight transforming action which it possesses is soon brought to an end by reason of the acidity of the gastric secretion. Now, it cannot be sufficiently insisted upon that the converting power of ptyalin is extremely active, and transforms a relatively enormous proportion of starch into sugar, and this within a very brief period. It has been calculated that 120 grs. of ptyalin are secreted each day as compared with 40 grs. of pancreatin. When we think of the immense quantity of starchy food taken into the stomach each day, is it likely that nature intended that this large amount of so active a ferment as ptyalin should be lost? It has been shown over and over again (as by von den Velden, Ewald, Sohlern, and others) that no free acid appears in the stomach until, at earliest, three-quarters of an hour after a mixed diet has been eaten. Consequently, during this period, the salivary ferment can exert its uncontrolled influence on starch in the stomach.

Not only so, but saliva has an alkaline reaction, due most probably to the presence of alkaline phosphates and bicarbonates, while ptyalin acts most energetically in a neutral medium (neutralised saliva is more active than normal saliva, Chittenden and Ely). The neutralisation of the alkalinity of the saliva must therefore hinder the production of free acid. It has also been proved that the presence of a minute trace of free acid still further increases the activity of ptyalin. During the first period of gastric digestion the only free acids which are produced are lactic or acetic, and these have a much feebler inhibitory effect on salivary proteolysis than hydrochloric acid. It is evident, therefore, that amylaceous matters must, under normal conditions, undergo a very thorough digestion while in the stomach.

The salivary ferment is, however, destroyed by the gastric juice during the period of full proteid digestion. Thus, only the more resistant portions of starchy food—as, for example, lumps of imperfectly masticated potato, under-cooked vegetables, rice, sago, tapioca, etc.—may require a further disintegration and solution than they receive in the stomach. This they will obtain when they pass into the small intestine and come under the action of the amylopsin of the pancreatic secretion.

These facts dispose of the too prevalent idea that salivary digestion takes place only in the mouth, and for a few minutes afterwards in the stomach.

Secretion of Saliva.

It has been demonstrated by several observers, as by Hofbauer, that there is a daily variation in the diastatic action of saliva. Thus, on rising in the morning, the converting power of saliva is strong. It falls towards and after breakfast, then rises slowly and reaches the maximum before the mid-day meal. After this it again falls rapidly, and remains low for two hours subsequently. Towards the evening meal it rises slowly, and this is succeeded by a gradual fall. So as to eliminate this variation in my experiments, the saliva was always collected at the same period during the evening.

Method of Investigation.

The experiments were performed in the following manner:—Each individual was instructed to wash out his mouth thoroughly with luke-warm water, and during the succeeding half-hour all the saliva which he secreted was received into a vessel, and its quantity measured. Two c.c. of the saliva were then mixed with 10 c.c. of starch mucilage, at a temperature of 38° C., and the mixture was kept at this temperature for ten minutes. At the end of this period the condition of the starch present was noted, and further action of the ferment was prevented by rapidly boiling the mixture. The amount of sugar which had been formed by the ptyalin was then estimated by titration against standard Fehling's solution.

In Healthy Adults.

The activity of the salivary ferment was investigated in ten healthy adults. If we take 0·080 grm. of sugar, produced by the action of 2 c.c. saliva on 10 c.c. starch solution for ten minutes, as a low average, and as a means of estimating the intensity of salivary proteolytic action, we find that in healthy adults the amount of sugar produced has only in a single instance been below this figure.

In almost every instance the amount of sugar produced has reached about 0·1 grm., and in some cases this figure has been greatly exceeded.

In Children.

Under the age of 5 years the average amount of sugar formed is 0·077 grm.; from the ages of 5 to 13 it is 0·078 grm. The average figure all over, from the ages of 16 months to 13 years, is 0·078, the difference between the highest and lowest amounts being only 0·010 grm. During childhood the activity of the salivary ferment remains remarkably uniform.

In Diseased Conditions.

Above 100 cases of disease of various kinds were investigated, in order to see if the activity of the salivary ferment was altered. A glance over the figures shows us that the amount of sugar formed in such cases varied from 0 to 0·128 grm. If we analyse the table a little more closely we find that in

1. *Gastro-intestinal disorders* twenty-one cases were investigated. The average amount of sugar formed in these was 0·089 grm. In chronic gastric catarrh this figure varied from 0·078 to 0·1 grm. In acid dyspepsia the amount of sugar formed is above the healthy average. In ulceration of the stomach the amount of sugar formed is generally only slightly below the normal average. These general observations agree in the main with the conclusions arrived at by two Italian investigators, Petterutti and Ferro, who state that the greater number of gastro-intestinal disorders are associated with a decrease in the amount of ptyalin.

In one case of great dilatation of the stomach, the salivary ferment proved to be almost absent, or at least inactive in the saliva. In cirrhosis of the liver the amount of sugar is by no means reduced, and in some cases it is even greatly increased.

2. *Pulmonary diseases.*—In the group of lung diseases, generally the salivary ferment is fairly active, and on an average 0·087 grm. of sugar is formed. In the cases of phthisis which were examined ptyalin seems to be present in normal amount, as the sugar formed almost always reached the standard quantity. The cases of pneumonia which I examined furnished results similar to those obtained by Jawein. These cases showed that the amylolytic action of the saliva is higher than the normal during the period preceding the crisis, but lower after the crisis.

3. *Heart diseases.*—In the large group of heart cases the saliva retains its usual composition, and the amount of sugar formed in my experiments hovered at or about the normal limits.

4. *Nervous diseases.*—A larger proportion of subnormal cases were

met with in the group of nervous diseases (41 per cent. giving a proportion of sugar lower than the normal average). In one case of cerebral tumour the saliva, though copious in amount, contained practically no converting ferment, whereas in a case of locomotor ataxia, though the secretion was equally copious, the converting ferment produced the large amount of 0·111 grm. sugar.

5. *Hæmopoietic system.*—Of three cases of Addison's disease examined, the saliva of two showed marked deficiency in their power of starch digestion, while the third exceeded the normal limit.

6. *Renal diseases.*—Taken all over, the group of renal diseases shows a lower average than the normal. In 55·5 per cent. the quantity of sugar formed was considerably below the average.

In diabetes, on the other hand, the saliva has a very active converting action. In three out of four cases examined, the average proportion of sugar formed was much above the standard figure. The saliva in these cases contained no traces of sugar. In simple anæmia the converting ferment seems to be present in the saliva in its normal amount. If, however, the anæmia be associated with dyspepsia the average is subnormal. In subacute and chronic rheumatism the ferment shows no great variations from the normal. In general febrile conditions the secretion of saliva is greatly reduced in amount, and this reduction increases, *pari passu*, with the increase in temperature. It is important to note that this scanty secretion seems to be possessed of enhanced amylolytic power. This same fact has also been noted by Jawein.

Quantity of Saliva Secreted.

If we pass now to the consideration of the amount of saliva secreted in the various diseased conditions of the body, and taking as the normal amount secreted by healthy adults as from 10 to 15 c.c., in half an hour we note first, that in infants and children the amount of saliva poured out is relatively much greater than it is in adults. For example, in five children under the ages of 3 years, who could not be made to understand properly how to collect their saliva, from 7 to 9 c.c. were obtained in thirty minutes. In two girls, æt. 4 years, the amounts were respectively 12 and 14 c.c. In another girl, æt. 5, 20 c.c. were secreted, and so on. In the case of females the secretion seems to be generally a little more copious than in males.

In Diseased Conditions.

Gastric disorders.—In most cases of acid dyspepsia the secretion is above the normal in amount. This may be due to reflex irritation of the salivary glands. One authority has recommended patients suffering from this affection to further stimulate the secretion of saliva by sucking gelatin lozenges. He thinks that the large amount of alkaline saliva thus introduced into the stomach neutralises to a great extent the hyperacidity of the gastric secretion. In chronic gastric catarrh the amount secreted is hardly, as a rule, up to the average. In ulceration of the stomach the same deficiency of secretion is met with. In those cases where we find diarrhœa or ascites the secretion of saliva is in many cases far below the normal amount.

Pulmonary diseases.—In the group of diseases of the lungs we find that in bronchitis and in the early stages of pneumonia the volume of saliva which is secreted is generally up to the full average, and may even be beyond it. In the course of chronic phthisis, on the other hand, the secretion of saliva is always very scanty.

Cardiac diseases.—In the large class of heart affections of a grave nature there is an almost constant diminution in the secretion.

Nervous diseases.—In affections of the cord, the amount of saliva secreted reaches the highest average and even surpasses it, as, for example, in locomotor ataxia. In hemiplegia the same excess is found. The reverse is found generally in the class of cerebral tumours, where the saliva is very small in amount.

Renal diseases.—In chronic Bright's disease, as a rule, we see that the salivary secretion is scanty. This may account for the very fœtid odour of the breath so often present in such cases. In diabetes, of course, the saliva is very scantily secreted. In simple anæmia, in the chronic forms of rheumatism, and in three cases of Addison's disease examined, the amount of saliva was subnormal. In fevers generally, when the temperature is at all high, the secretion of saliva is lessened in amount, but (as has already been noted) its amylolytic power is increased. In very slight degrees of fever, however, the normal amount may be produced.

It might be thought that where a large amount of liquid saliva is secreted, the ferment would not be present in so large an amount as it would be in an equal volume of saliva where its secretion was scanty. Such an opinion, though true in the main, is not in all cases borne out by a consideration of the facts observed, either in the healthy or in diseased conditions. In many cases where the secretion is scanty, the diastatic action is likewise feeble, and on the contrary, where the secretion is copious, its proteolytic power is also great.

It is an easy matter for anyone to satisfy himself at once by a simple examination of the saliva as to whether unchanged starchy food ought to be given to an invalid or not. Of course, if the secretion be very scanty—as, for example, in pyrexia—it would be quite out of the question to think of administering such a food, and practically we know that such fever cases are usually nourished on milk, meat infusions, or jellies, alcohol, or predigested starchy foods.

If, on the other hand, the secretion be present, but there is doubt as to its amylolytic power, the following experiment may be readily performed. A small quantity (about 10 c.c.) of starch mucilage is mixed with 1 or 2 c.c. of the saliva in a test tube, and the whole is kept at a temperature of 100° C. for a few minutes (five to ten). This can readily be accomplished by immersing the tube in a large body of warm water, and taking the temperature of this by means of a clinical thermometer. At the end of this period the mixture is boiled. If a few drops of this be now poured on to a plate, and a drop of a weak solution of iodine be added, the degree of starch conversion will be at once shown. If the ptyalin has had no action, the starch is merely coloured purple; but if the ferment has been active, a reddish-purple or red-pink colour is produced, depending on the intensity of the action. If the ferment has been energetic no colour is produced, the whole of the starch having been converted into the colourless form of dextrin (achroo-dextrin). The latter result is seldom obtained, and we generally find a more or less red-purple colour, indicating that only part of the starch has undergone conversion. The redder or pinker the colour the greater has been the power of the ptyalin.

Next, a small quantity of Fehling's solution is boiled in a test tube, and one drop of the mixture is added. If no precipitation of the suboxide of copper takes place a second drop is added, and so on until a precipitate is produced. Such a proceeding gives a very rough estimate of the amount of maltose produced, and consequently of the intensity of the salivary ferment. These two tests are so simple and easily performed that no one need neglect the examination of the saliva in a doubtful case.

It is evident that a full appreciation of the amylolytic power of saliva is of immense value when we consider the dietetics of disease. In those cases where the salivary secretion is extremely scanty or even in abeyance—as, for example, general pyrexia, the exanthemata, etc., or in such cases as dilatation of the stomach, where the saliva contains almost no ptyalin, or again in cases where the secretion has been inhibited by drugs (*e.g.* morphine, atropine)—it is evident that ordinary starchy foods ought not to be allowed. If they are administered at all, the starch must be, in the first place, rendered soluble by treatment with some of the artificial digestants, as zymine, taka diastase, or extract of malt. Such facts are, of course, insisted on in every reliable work on dietetics, but in spite of this they are generally ignored in practice. One authority, for example, recommends the giving of farinaceous foods in dilatation of the stomach, and in this disease we have seen that the proteolytic action of the saliva is very feeble, or even absent.

In conclusion, I would advocate a systematic examination of the saliva in all diseases of the gastro-intestinal tract, as also in other diseases where ordinary starchy food is found to disagree with the patient.

Amount and Converting Power of Saliva.

TABLE I.—HEALTHY ADULTS.

No.	Sex.	Age.	No. c.c. Secreted.	2 c.c. Saliva and 10 c.c. Starch solution at 38° C. for Ten Minutes.	
				Changes in Starch.	Amount of Sugar Formed.
1	Male .	34 years	12	Soluble starch, much; erythro-dextrine and achroodextrine, some.	0·076 grm.
2	,,	20 ,,	10	,, ,,	0·094 ,,
3	,,	22 ,,	12	,, ,,	0·094 ,,
4	,,	34 ,,	16	,, ,,	0·121 ,,
5	,,	21 ,,	5	,, ,,	0·092 ,,
6	,,	19 ,,	5	,, ,,	0·1 ,,
7	,,	22 ,,	3	,, ,,	0·113 ,,
8	,,	20 ,,	4	,, ,,	0·080 ,,
9	Female	32 ,,	16	,, ,,	0·067 ,,

Amount and Converting Power of Saliva.

TABLE II.—HEALTHY CHILDREN.

No.	Sex.	Age.	No. c.c. Secreted.	2 c.c. Saliva and 10 c.c. Starch solution at 38° C. for Ten Minutes.	
				Changes in Starch.	Amount of Sugar Formed.
1	Female	16 months	7	Soluble starch, erythro-dextrine, and achroo-dextrine.	0·081 grm.
2	,,	17 ,,	7	,, ,,	0·073 ,
3	Male .	19 ,,	9	,, ,,	0·078 ,,
4	Female	2 years	8	,, ,,	0·079 ,,
5	Male .	3 ,,	8	,, ,,	0·075 ,,
6	Female	4 ,,	12	,, ,,	0·080 ,,
7	,,	4 ,,	14	,, ,,	0·075 ,,
8	,,	5 ,,	20	,, ,,	0·078 ,,
9	,,	7 ,,	12	,, ,,	0·080 ,,
10	Male .	7 ,,	12	,, ,,	0·073 ,,
11	Female	8 ,,	7	,, ,,	0·083 ,,
12	,,	10 ,,	8	,, ,,	0·080 ,,
13	Male .	12 ,,	16	,, ,,	0·081 ,,
14	Female	12 ,,	12	,, ,,	0·080 ,,
15	,,	13 ,,	14	,, ,,	0·075 ,,

[Table III.

Amount and Converting Power of Saliva.

TABLE III.—DISEASED CONDITIONS.

No.	Disease.	Sex.	Age.	No. c.c. Secreted.	2 c.c. Saliva and 10 c.c. Starch solution, at 38° C. for Ten Minutes. Changes in Starch.	Amount of Sugar Formed.
						Grm.
1	Acid dyspepsia . .	F.	50	17 Acid reaction	Soluble starch, much; erythro-dextrine, some.	0·108
2	,, ,,	M.	22	4	Soluble starch only.	0·106
3	Chronic gastric catarrh	,,	71	8	Soluble and erythro., much.	0·078
4	,, ,, .	,,	47	10	,, ,,	0·086
5	,, ,, .	,,	44	9	Much soluble, some erythro.	0·087
6	,, ,, . with fermentation.	,,	40	4	Much soluble, little erythro.	0·10
7	Dilatation of stomach, great.	,,	45	8	Soluble starch only.	0·008
8	Gastric ulcer, with hæmoptysis.	,,	27	10	Soluble and erythro.	0·079
9	,, ,, .	F.	30	6	Soluble, much.	0·078
10	Simple gastric ulcer, with anæmia.	,,	17	10	,, ,,	0·073
11	Gastric ulcer . .	,,	23	9	,, ,,	0·083
12	Diarrhœa (nervous).	M.	33	6	Soluble and erythro.	0·073
13	Tuberculous disease of the bowels.	,,	13	...	Mouth perfectly dry.	...
14	Peritonitis . . .	F.	20	11	Soluble and erythro.	0·113
15	Ascites from cancer of liver.	,,	42	10	Soluble, much; erythro., little.	0·086
16	Ascites	M.	39	2	Soluble, erythro- and achroo-dextrine.	0·113
17	Ascites from cirrhosis of liver.	,,	63	8	,, ,,	0·108
18	,, ,, .	,,	34	3	,, ,,	0·080
19	Ascites . . .	,,	38	3	,, ,,	0·113
20	Ascites with cirrhotic liver.	,,	36	14	,, ,,	0·080
21	,, ,, .	,,	40	10	,, ,,	0·096
22	Gallstones . . .	,,	30	8	,, ,,	0·113
23	Bronchitis . . .	M.	44	9	Much soluble and erythro-dextrine.	0·092
24	,, with some pneumonia.	,,	24	21	,, ,,	0·094
25	Pleurisy and bronchitis	,,	26	20	,, ,,	0·084
26	Pneumonia . .	,,	24	21	,, ,,	0·104
27	,, after crisis	,,	48	6	,, ,,	0·081
28	Phthisis . . .	,,	41	4	Much soluble, little erythro- or achroo-dextrine.	0·074
29	,, ...	,,	20	12	,, ,,	0·098
30	,, ...	,,	49	2	,, ,,	0·104
31	,, ...	F.	21	8	,, ,,	0·067
32	,, ...	M.	36	2	,, ,,	0·080
33	Cardiac weakness .	M.	54	4	Soluble, erythro- and achroo-dextrine.	0·092
34	Cardiac weakness—dropsy.	,,	59	2	,, ,,	0·086
35	Mitral heart disease .	,,	51	4	,, ,,	0·102
36	,, ,, (temp. 102° F.)	F.	25	5	Soluble, erythro., much; and achroo.	0·092
37	,, ,,	M.	18	26	Soluble, erythro., much.	0·064
38	,, ,, (advanced).	,,	26	5	,, ,, ,,	0·080

TABLE III.—DISEASED CONDITIONS—*continued.*

No.	Disease.	Sex.	Age.	No. c.c. Secreted.	2 c.c. Saliva and 10 c.c. Starch, soluble at 38° C. for Ten Minutes. Changes in Starch.	Amount of Sugar Formed.
						Grm.
39	Mitral heart disease .	M.	20	16	Soluble, erythro-dextrine, much.	0·075
40	Double mitral disease with nephritis.	,,	30	6	Soluble, much ; erythro.	0·078
41	Mitral disease . .	F.	56	5	,, ,, ,,	0·083
42	,, stenosis . .	M.	32	12	Soluble, much.	0·080
43	,, ,, with bronchitis.	F.	19	11	,, ,,	0·070
44	Double mitral and aortic disease—dropsy.	M.	20	6	,, ,,	0·083
45	Mitral heart disease—dropsy.	,,	39	12	,, ,,	0·086
46	Double aortic disease .	,,	41	21	,, ,,	0·080
47	Aortic aneurysm .	,,	36	5	,, ,, erythro.	0·078
48	General debility .	,,	55	4	,, ,,	0·086
49	Chorea . . .	F.	12	8	Soluble, much.	0·080
50	,, (chronic) .	M.	20	6	,, ,,	0·075
51	Sciatica (severe) .	,,	44	5	,, ,,	0·062
52	,, with great debility.	,,	62	7	,, ,, erythro-dextrine.	0·083
53	Hysteria . . .	F.	18	5	Soluble, much.	...
54	Neuritis ; myelitis .	M.	56	17	,, ,,	0·083
55	Progressive muscular atrophy.	,,	19	17	,, ,, ,,	0·080
56	Paraplegia . . .	,,	44	18	,, ,, ,,	0·082
57	,, ...	,,	57	24	,, ,,	0·68
58	Spastic paralysis .	,,	38	9	,, ,, ,,	0·075
59	Hemiplegia . .	,,	40	17	,, ,, ,,	0·083
60	,, . . .	,,	26	15	,, ,, ,,	0·073
61	Locomotor ataxia .	,,	32	22	,, ,,	0·111
62	Cerebral tumour .	F.	27	8	,, ,,	0·096
63	,, . . .	,,	30	3	,, ,,	0·10
64	,, . . .	M.	32	15	Soluble only.	0·001
65	,, . . .	F.	19	12	Soluble, much.	0·084
66	Exophthalmic goitre .	,,	27	6	,, ,,	0·083
67	Purpura hæmorrhagica (Henoch's).	M.	13	22	Soluble, erythro- and achroo-dextrine.	0·10
68	Addison's disease .	,,	17	11	,, ,,	0·104
69	,, . . .	,,	30	12	Soluble and erythro.	0·067
70	,, . . .	F.	23	3	,, ,,	0·064
71	Solid œdema of face .	M.	28	12	,, ,,	0·078
72	Nephritis (acute) .	M.	50	14	Soluble, much ; erythro-dextrine.	0·086
73	,, ,, .	,,	33	7	Soluble and erythro.	0·089
74	,, ,, .	,,	21	4	,, ,,	0·096
75	,, ,, .	,,	8	12	Soluble, much.	0·069
76	,, ,, .	,,	46	6	Soluble and erythro.	0·083
77	Nephritis (chronic) .	,,	19	4	Soluble, much.	0·066
78	,, ,, .	F.	24	10	,, ,,	0·076
79	,, ,, .	,,	64	2	,, ,,	0·078
80	,, ,, with bronchitis.	M.	64	14	,, ,,	0·060
81	Diabetes mellitus .	F.	50	6	Soluble, erythro- and achroo-dextrine.	0·108
82	,, . . .	M.	44	8	,, ,,	0·104
83	,, . . .	,,	46	2	,, ,,	0·104

TABLE III.—DISEASED CONDITIONS—*continued.*

No.	Disease.	Sex.	Age.	No. c.c. Secreted.	2 c.c. Saliva and 10 c.c. Starch, soluble at 38° C. for Ten Minutes.	
					Changes in Starch.	Amount of Sugar Formed.
						Grm.
84	Diabetes mellitus .	M.	23	6	Soluble, much.	0·083
85	Anæmia . . .	F.	18	6	Soluble and erythro-dextrine.	0·089
86	,, ...	,,	17	4	,, ,,	0·081
87	,, with dyspepsia	,,	21	8	Soluble, much.	0·069
88	,, ,, .	,,	18	5	,, ,,	0·064
89	Rheumatism . .	,,	33	2	Soluble and erythro.	0·086
90	,, . .	,,	47	3	...	...
91	Rheumatic fever .	,,	15	7	Soluble and erythro.	0·094
92	,, ,, subacute	,,	27	6	,, ,,	0·086
93	,, ,, ,, .	,,	24	2	,, ,,	0·078
94	,, ,, ,, .	,,	25	13	Soluble, erythro- and achroo-dextrine.	0·089
95	Influenza . . .	M.	56	4	,, ,,	0·128
96	,, . . .	,,	29	5	Soluble and erythro.	0·098
97	Quinsy . . .	F.	18	4	Soluble, erythro- and achroo-dextrine.	0·083
98	Suppurating hip-joint	M.	24	16	Soluble and erythro.	0·089
99	Chronic suppuration; waxy disease.	,,	21	6	,, ,,	0·075
100	Eczema; acute, wide-spread.	,,	37	16	Soluble, erythro- and achroo-dextrine.	0·098
101	Acromegaly . .	F.	33	12	,, ,,	0·102

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SIALOGOGUES:

THEIR THERAPEUTIC EMPLOYMENT

BY

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SIALOGOGUES: THEIR THERAPEUTIC EMPLOYMENT[1]

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THE term "sialogogue" has a quaint, old-fashioned sound about it, like that of "emmenogogue," or "galactogogue," and we are apt to think that the value of such agents as stimulate the flow of saliva, though made use of by former generations of practitioners, is practically nil, and that the members of this group of drugs ought to be relegated to the period of the stone pill or the powdered spider.

I hope, however, to be able to show that these drugs have a very distinct pharmacological action, and that we may take advantage therapeutically of the increased flow of saliva which they stimulate.

I would, however, by no means laud the virtues of saliva to the extent that a near namesake of mine did in a work which ran through many editions, and which was entitled "A treatise on the virtues and efficacy of a crust of bread eat early in the morning fasting; to which are added some particular remarks concerning the great cures accomplished by the saliva

[1] Read before the Edinburgh Medico-Chirurgical Society.

or fasting spittle, as well when externally applied as when internally given in the scurvy, gravel, stone, rheumatism, and divers other diseases arising from obstruction, etc. By a Physician" (8vo, London, 1756-1821-1844; N. Robinson, author).

I do not intend to speak of the employment of drugs given to increase the salivary flow in those rare cases where the secretion is greatly reduced, or even entirely absent. Such a case of complicated xerostomia has been very carefully recorded by Sir Thomas R. Fraser, and where the oral condition was successfully palliated by the topical application of a dilute solution of the nitrate of pilocarpin to the buccal mucous membrane. I should think that in this instance pilocarpin could hardly be called a sialogogue. After its application, the patient's mouth became slightly moist, due most probably to stimulation of the buccal glands. That the moisture did not originate in the salivary glands is evident, I think, from the fact that it had no influence in converting starch mucilage into dextrine or maltose.

Nor do I mean to treat of ptyalism induced by the internal administration of such drugs as mercury, pilocarpin, iodine, salts of copper, etc. I shall only refer to those substances which, by their local action, exert a sialocinetic influence, and to the therapeutic exhibition of such agents.

It is stated in some works on physiology that the salivary secretion varies in chemical composition as well as in physiological activity, according to the nature of the peripheral stimulus which has provoked it; that in some cases the secretion is copious, watery, faintly alkaline in reaction, with a low percentage of ptyalin; while, as a result of other stimuli, the secretion may be scanty in amount, but possessing alkalinity and amylolytic power to an intensely high degree.

This inquiry was directed to the elucidation of those agents or drugs which, when locally applied, were really provocative of true salivary secretion, and to find whether the secretion thus induced varied in its amount, alkalinity, or starch-converting power.

First, as regards the amount of saliva secreted.

Certain substances, and especially those which are warm or pungent to the taste, when chewed cause a rapid flow of a watery fluid into the mouth. Does this secretion result from a temporary stimulation of the special nerves of taste or of the sensory nerves supplying the mucous membrane of the tongue, palate, mouth and lips, and does this stimulation induce a rapid, transient, or continuous secretion from the salivary glands ?

To observe this, I masticated a portion of each of the substances noted below, for a period of thirty minutes, collecting and measuring the quantity of saliva so secreted every two minutes. In this way it was noted whether the flow was constant and uniform during the period under observation, or whether the flow was copious at first under the initial stimulus of the drug, but fell off in amount later, or *vice versa*. The experiments were invariably made in the evening, as Hofbauer has shown (*Archiv. f. die gesammt. Physiologie*, 1896-7, p. 513) that there is a very great variation in the composition of the saliva during different hours of the day.

The alkalinity of the saliva was estimated in each case by means of very sensitive litmus paper. When the sialocinetic agent was itself alkaline or acid, the amount of this was deducted.

The amylolytic or starch-converting power of the saliva secreted under these conditions was estimated in the following manner :—

A starch mucilage was made by boiling 10 grammes of powdered starch in half a litre of water for five minutes. Then 10 c.c. of this in a test-tube were placed in a water bath kept at a constant temperature of 38° C. When the mucilage had taken this temperature, 2 c.c. of the saliva secreted under the stimulation of each particular agent were added to the tube, thoroughly mixed and then kept at 38° C. for ten minutes. At the end of this interval the contents of each tube were rapidly boiled to prevent further amylolysis. The condition of the contents was then determined as regards its dextrinisation. The sugar was next washed out with numerous additions of water, and, after filtration, was estimated by titration against a standard Fehling's solution.

The following table gives the results of these experiments. The degrees of dextrinisation of the starch is not noted, as these are of little use in a table of comparisons :—

Stimulating Agent.	Amount of saliva secreted in 30 minutes.	Rate of secretion.	Amount of sugar formed by acting on 10 c.c. starch mucilage with 2 c.c. saliva for 10 minutes.
Normally secreted	11 to 18 c.c.	Uniform	0·12 gramme
Hot water rinsing	18	Not uniform	0·086 ,,
Bitter beer	18	,,	0·125 ,,
Juniper gum	21	Uniform	0·116 ,,
Rhubarb root	21	,,	0·03 ,,
Whisky and water	22	Not uniform	0·113 ,,
Mustard seeds	22	,,	0·120 ,,
Sarsaparilla root	23	Uniform	0·104 ,,
Bael fruit	23	,,	0·113 ,,
Coriander seeds	24	,,	0·089 ,,
Pimenta	25	,,	0·11 ,,
Catechu	25	,,	0 ,,
Orris root	26	,,	0·11 ,,
Cinnamon bark	26	,,	0·113 ,,
Althæa radix	26	,,	0·104 ,,
Carraway seeds	26	,,	0·104 ,,
Ipecacuanha root	26	Not uniform	0·113 ,,
Anise seed	27	Uniform	0·118 ,,
Calumba	28	,,	0·125 ,,
Orange peel	28	,,	0·108 ,,
Squill root	28	,,	0·116 ,,
Gentian root	30	,,	0·108 ,,
Chamomile	30	,,	0·121 ,,
Cinchona bark	30	,,	0·106 ,,
Pine wood	32	,,	0·113 ,,
Cusparia	32	,,	0·120 ,,
Krameria	33	,,	0·108 ,,
Pyrethrum	36	,,	0·09 ,,
Colchicum corm	36	,,	0·108 ,,
Ginger root	37	,,	0·113 ,,
Horse radish	42	,,	0·10 ,,
Piper nigrum	46	Not uniform	0·119 ,,
Potasii Tartras Acida	17	Not uniform	0·116 ,,
Borax	21	Uniform	0·04 ,,
Sulphide of Calcium	22	,,	0·113 ,,
Nitroglycerine	24	,,	0·119 ,,
Magnesium Sulphite	25	,,	0·10 ,,
Alum	27	,,	0 ,,
Ammonium Chloride	27	Not uniform	0·119 ,,
Soda Mint	31	Uniform	0·052 ,,
,, (after neutralisation)			0·108 ,,
Potasii Chloras	32	,,	0·090 ,,
Potasii Nitras	32	,,	0·114 ,,
Acidum Tartaricum	42	,,	0 ,,
,, (neutralised)			0·024 ,,
Acidum Citricum	50	,,	0 ,,
,, (neutralised)			0·113 ,,
Smoking tobacco	15	,,	0·113 ,,

Quantity of Saliva secreted.—Under ordinary circumstances and without the local stimulation of any foreign substance, from 11 to 18 c.c. of mixed saliva are secreted every 30 minutes. The mere presence of an insoluble substance (as, for example, Juniper gum) in the mouth causes an increase in the flow of saliva. That it is chiefly the watery constituent which undergoes augmentation in such a case is evident from the lessened diastatic power of the secretion.

Rhubarb root can hardly be termed a sialocinetic, as its presence in the mouth calls forth but a scanty secretion.

Mustard is usually classed amongst the sialogogues, yet we find that it possesses but feeble properties in this direction, inducing a flow of but 22 c.c. Sarsaparilla root stands in a very similar position.

That there is some sialogogic property in pine wood is shown by the fact that its mastication induces a copious secretion of saliva.

Such bitter substances as calumba, cusparia, gentian, cinchona, exert a distinctly stimulating action on the salivary glands, while pyrethrum, ginger and colchicum stand still higher in the scale of sialocinetics.

Horse radish and black pepper hold the foremost place however, in promoting the flow of saliva, producing respectively 42 and 46 c.c.

It is surprising to find that substances so reputedly astringent as catechu and Bael fruit should stimulate a relatively large flow of saliva.

Passing to the action of the *non-vegetable* group we find that acid substances possess the greatest sialocinetic power. Citric acid leads to the production of 50 c.c. and tartaric acid to 42 c.c. Further down the scale we find chlorate of potassium and nitrate of potassium each with 32 c.c. Most of the other inorganic substances experimented with seem to act more as mechanical than as specific stimulants.

Alkalinity of the Saliva secreted under Stimulation.—In the whole series of experiments the alkalinity of the saliva secreted under the action of the different stimulating agents was found to vary within very small limits. It may therefore be stated that the alkalinity remained practically the same throughout all the experiments.

Starch-converting Power of Saliva secreted under the stimulation of various agents.—As a standard of comparison I took the amount of sugar formed by acting on 10 c.c. of starch mucilage with 2 c.c. of normal saliva secreted without any mechanical stimulation. The amount of sugar thus formed was 0·12 gramme.

A survey of the table shows that (with a few exceptions) there are no great divergences from this standard figure. The amount of sugar formed by the different examples of saliva varied from 0·09 to 0·125 gramme. Let us look at some of the exceptions.

(1) *Catechu.*—The catechu-tannic acid has precipitated the ferment and has prevented it from acting. Such saliva has no amylolytic power.

(2) *Rhubarb Root.*—This contains both chrysophanic and tannic acids, and these have also inhibited the ptyalin from acting.

(3) *Alum* has likewise restrained the action of the salivary ferment.

(4) *Borax*, as is well known, checks the action of such other ferments as diastase, yeast, myrosine and emulsine. In this case it has checked the converting action of ptyalin.

(5) *Soda.*—Alkaline salts are not nearly so energetic in their inhibitory effects on starch conversion as are acids. In this case, though the saliva was rendered highly alkaline by the soda-mint, yet 0·05 gramme of sugar was produced. On carefully neutralising the secretion with dilute acid and warming to 38° C. the amount of sugar soon doubled itself.

(6) *Hot Water.*—The saliva in this case was probably dilute from admixture with the hot water used in rinsing the mouth and so only 0·086 gramme of sugar was formed.

Turning now to the agents which induce a copious flow of saliva and glancing first at the organic substances we see that—

(7) *Piper Nigrum*, with 46 c.c. of saliva secreted, has a sugar-producing power of 0·119 gramme; and

(8) *Horse Radish* with 42 c.c. of secretion, produced in each experiment 0·10 gramme of sugar. Such agents act powerfully in increasing the flow of what is really normal saliva. They stimulate the secretion of a digestive fluid of normal composition.

Other agents which act as sialocinetics, though not quite so powerfully, are ginger, pyrethrum, colchicum, krameria, cusparia, pine wood, gentian, chamomile, cinchona, etc.

It is of interest to observe that krameria, though acting usually as an astringent from the tannin present, exerts a stimulating effect on the secretion of saliva, and this without lessening to any extent the normal proportion of the active ferment.

Many other vegetable substances have a very distinct action as sialogogues, though it is hardly so well marked as in the examples given.

Some advantage may even be gained by the sipping of whisky and water, in that it increases the flow of a saliva rich in ptyalin. Doubtless the more slowly it were sipped the larger would be the production of active saliva. On all grounds, however, it may perhaps be wisest not to include this agent in a list of sialogogues.

I have already shown that acid substances are the most potent in provoking salivary secretion. Thus citric acid induces a flow of 50 c.c., but the ferment is restrained from acting by the acid present. That it is not, however, destroyed, is shown by the fact that when the acidity is neutralised by the addition of a dilute solution of caustic soda, the amount of sugar produced from the starch mucilage is well up to the standard.

With tartaric acid, however, the case is different. Either the saliva secreted under its stimulation is very deficient in ptyalin, or the ferment is almost destroyed by the acid, for even after neutralisation hardly any starch is converted into sugar.

For practical purposes, it may be considered that the useful sialocinetic substances are confined to the vegetable kingdom.

The Therapeutic Employment of Sialogogues.—The above experiments were performed some years ago, and since then I have endeavoured to carry out in clinical practice the results then obtained.

When a digestive secretion fails either in amount or in one or more of its active constituents, then one's endeavours ought rather to lie in the direction of so stimulating the secreting glands as to promote a more normal action in them, rather than in the administration of preparations which contain artificially-prepared digestive agents. Apart from other considerations, it is a self-evident fact that the long-continued employment of such digestants leads to a more or less permanent impairment of the secretory power of the glands thus vicariously re-inforced.

In the case of deficiency in the secretion of saliva, we find that certain authorities advocate the administration of some one of the numerous preparations of malt or extract of malt (many specimens of which are almost devoid of diastatic action), taka-diastase or even the dried parotid or submaxillary gland substance. Apart from being adventitious products, some of these substances act prejudicially on the organism, and frequently exert a disturbing influence on the processes of digestion and assimilation—malt, for example, has a very distinct retarding action on the digestion of proteid matters.

It appeared to me that in such conditions some of the substances which we have seen to be powerful stimulants to the salivary glands might be employed with good effect. A fairly large number of individuals find more or less difficulty in the comfortable digestion of starchy materials. Such persons are commonly said to suffer from amylaceous dyspepsia. Great benefit and even cure can be obtained in many of these cases by enforcing a properly slow mastication of such starchy food after the manner of the herbivorous animals. It is the usual practice to swallow soft, pulpy food without any mastication whatever, but it is of much less importance to masticate animal substances thoroughly than it is to properly insalivate amylaceous materials.

In the more aggravated examples of such dyspepsia I have found that the patients derived the greatest benefit from the slow chewing of some one of these vegetable agents which exert a distinct sialocinetic influence. The dyspeptic is advised to masticate the food slowly, and after the meal to chew for ten minutes or so one or other of the more potent and palatable sialogogues. I have never found in such cases that it was at all necessary to invert the order of the usual courses of one's meal. In the treatment of dyspepsia we find some authors advocating that proteid food should be taken quite apart and at different times from starchy food. Others again suggest that the dyspeptic ought to commence the meal with the dessert, which is usually largely composed of starchy material. If care be taken to promote the flow of saliva, it is really unnecessary to subject the patient to such discomfort in feeding. When we remember that the period during which ptyalin remains active in the stomach is usually from forty-five to sixty minutes, or until free hydrochloric acid is distinctly present in the gastric contents, we see that there is abundance of time during which all the starch which has been consumed may be converted into dextrins and sugar and so absorbed.[1] Besides this, and as I have shown in a former paper ("Digestion of Starch in the Stomach," *Edinburgh Medical Journal*, May 1896), starchy matters undergo a more complete digestion in the stomach when they are accompanied by proteid matters.

Fifteen grammes of water-free starch form a fairly large amount for an ordinary meal. If this quantity be boiled in water for ten minutes, and when cool enough if 20 c.c. of saliva be added and the whole be kept at a temperature of 38° C. for an hour, it will be found that about one-third of the starch has undergone entire conversion into sugar, and a very large part of the remainder into soluble dextrines. If this degree of conversion takes place outside of the body, then we may reasonably suppose that a far larger percentage of starch would undergo entire conversion during its stay in the stomach.

In cases of hyperchlorhydria the onset of pain is usually delayed until some time after partaking of a meal. The greater the amount of carbohydrate and the less proteid food consumed, the more rapid is the onset of pain and discomfort. In ordinary cases of hyperchlorhydria the digestion of starch is soon brought to an end in the stomach, but Pawlow has demonstrated that the increased acidity of the gastric contents in such cases stimulates the pancreas to an increased activity, and thus a very complete and rapid amylolysis takes place in the intestine. Mathieu (*Maladies de l'Estomac*, Paris, 1901, page 195) has proved that in cases of hyperchlorhydria, micro-

[1] A recent series of observations has indeed shown that at the end of an hour free hydrochloric acid is either absent or is present in deficient amount. (Muller: *Verhand. d. physikal.-medicin Gesellsch. zu Wurzburg*, xxxv. 4, 1903.)

organisms are most numerous, and that the hydrochloric acid, even when present in large amount, is unable to restrain fermentations in the stomach.

Are we justified, therefore, in leaving starchy matters in the stomach to undergo decompositions induced by bacteria or fungi? Decompositions such as the following may result:—

$$C_6H_{10}O_5 + H_2O = C_4H_8O_2 + 2CO_2 + 2H_2$$
(starch) (butyric acid)

$$C_6H_{12}O_6 = 2(C_3H_6O_3)$$
(glucose) (lactic acid)

$$C_6H_{12}O_6 = 2(C_2H_5OH) + 2CO_2$$
(glucose) (alcohol)

The products of these and of other fermentative processes, not only by their local, but even more by their general toxic effects, frequently give rise to grave symptoms. That disordered states of the mind depend very largely on disorders of the digestive system is now well recognised, and the melancholia incident to dyspepsia is in reality an autointoxication.

In cases of hyperchlorhydria, our aim ought to be to secure the digestion of the amylaceous constituents of the meal before the free acidity has had time to check proteolysis. This we can do by increasing the flow of normal saliva. Besides this, the alkalinity of the saliva swallowed delays the period when free acid appears in the stomach, and so still furthers the action of the ferment ptyalin. Such a method of treating gastric acidity was advocated many years ago by Sir William Roberts, who suggested that patients suffering from hyperacidity ought to suck gelatine lozenges in order to promote the flow of saliva, whose alkalinity would neutralise the acid in the stomach. The amount of carbonic acid gas given off in this neutralisation is quite inconsiderable, and could not give rise to the gaseous eructations which some writers have ascribed to this process. The gases which develop in the stomach arise from bacterial fermentation.

In many cases of feeble gastric digestion the fault is due merely to a diminished activity in the gastric juice, both hydrochloric acid and pepsin being present in less than their normal amounts. When saliva is introduced into such a stomach it has the effect of stimulating a more copious and also a stronger secretion, and so the more saliva which is introduced the larger is the amount of gastric fluid which is secreted.

In many cases such as I have described, I have found that a stimulation of the salivary secretion by means of palatable and pleasant vegetable sialogogues, as, for example, ginger, gentian, peppercorns, cusparia, etc., has been of the greatest benefit to the patient. By their employment patients have been enabled to partake of and to digest with impunity many amylaceous articles of diet which they previously had been obliged to forego.

In certain cases other means of treatment must first be employed, as, for example, multiple fermentations in the stomach must be treated by lavage and the exhibition of antiseptic agents, as salol, salicylate of bismuth, naphthol, etc. In cases of defective motility of the stomach, stimulation by massage, electricity and lavage must be employed in the first place, together with the internal administration of nerve tonics, as strychnine. Having by suitable means cured what may be termed these grosser affections, our simpler remedies may then be employed with benefit.

Such bitter agents as cusparia, calumba, gentian, chamomile, etc., which are powerfully sialocinetic, exert also a very beneficial effect on the gastric mucous membrane. Other salivary stimulants are at the same time carminatives, as pimenta, ginger, pepper, etc. We can thus obtain both actions from the same drug and employ them therapeutically.

There is rather a tendency at the present time to administer drugs in tabloid or palatinoid form. We ought not to forget, however, that in the exhibition of many drugs it is their local action which is most beneficial; thus the stimulating effect on the appetite induced by a bitter tonic is almost lost when the drug is given in pill or tabloid form.

I have found but few patients who did not persevere in the simple method of treatment which I have indicated, and the benefit obtained is usually remarkable.

I have ventured to bring this method of medication under notice, as I have not seen any allusion to it in the usual works on therapeutics, and I think that it will appeal to many both on account of its simplicity and relative pleasantness to the patient.

RATE OF FERMENTATION OF SUGARS.

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Most of the sugars undergo certain fermentations, the chief of these being the lactic, butyric, and the alcoholic or vinous.

In order to determine the rate at which fermentation occurs in the commoner varieties of sugar, I performed the following series of experiments:—I made 5 per cent. solutions in distilled water of chemically pure samples of cane sugar, invert sugar,[1] lactose, dextrose, maltose, and lævulose. 100 c.c. of each of the above solutions were placed in separate flasks, and a measured quantity of the fermenting agent having been added to each, they were placed in a warm chamber and kept at a uniform temperature of 38° C. The solutions were tested at definite intervals, and the amount of fermentation that had taken place in each was estimated.

I. Lactic Acid Fermentation.

To each of the flasks containing 100 c.c. of the solution of sugar, 10 c.c. of sour skim-milk filtrate were added. Skimmed milk was employed, to obtain as pure a lactic fermentation as possible. When ordinary unskimmed milk becomes sour, the fat of the milk is apt to undergo butyric fermentation. The fermentative process is thus less simple with unskimmed than with skimmed milk. Even with this precaution, however, lactic fermentation gives rise to the production of small quantities of butyric and carbonic acids, showing that it is not a simple splitting of the milk sugar into lactic acid; not simply $C_6H_{12}O_6 = 2C_3H_6O_3$.

Immediately after the addition of the sour-milk filtrate to each

[1] The invert sugar was made by rendering the 5 per cent. solution of pure cane sugar slightly acid by the addition of sulphuric acid (the most powerful acid in causing inversion). The mixture was then kept at a temperature of 170-180° F. in a water bath for three hours. After allowing it to cool the loss of bulk through evaporation was replaced, and it was rendered neutral by adding a few drops of caustic potash solution. Invert sugar is said to consist solely of equal parts of dextrose and lævulose; this is denied by other observers, however.

of the saccharine solutions I estimated the degree of acidity. I calculated it as lactic acid, and have termed it the *initial acidity.* During the succeeding four days, the flasks were kept at a constant temperature of 38° C., which has been found the most suitable for promoting the growth of *bacterium lactis.* The percentage of acid produced in each saccharine solution was estimated at intervals, and the results are given in Table I.

Lactic Acid Fermentation.

Table I.—*Percentage Amounts of Acid formed in Stated Periods.*

Hours.	Cane Sugar.	Invert Sugar.	Lactose.	Dextrose.	Maltose.	Lævulose.
Initial Acidity	0·0639	0·0639	0·0639	0·0639	0·0657	0·0684
2	0·0639	0·0657	0·0648	0·0657	0·0666	0·0702
4	0·0639	0·0670	0·0657	0·0675	0·0669	0·0711
8	0·0702	0·0729	0·0666	0·0684	0·0693	0·0738
24	0·0711	0·0774	0·0684	0·0693	0·0702	0·0756
30	0·0738	0·0954	0·0756	0·0765	0·0756	0·0873
72	0·1044	0·1062	0·1242	0·1152	0·0972	0·3375
96	0·1386	0·135		0·189	0·1233	0·8181

In Table II. the amounts of lactic acid formed in each solution in definite periods are enumerated.

Table II.—*Total Percentage Amount of Acid formed in Stated Periods.*

Hours.	Cane Sugar.	Invert Sugar.	Lactose.	Dextrose.	Maltose.	Lævulose.
2	0	0·0018	0·0009	0·0018	0·0009	0·0018
4	0	0·0031	0·0018	0·0036	0·0012	0·0027
8	0·0063	0·0090	0·0027	0·0045	0·0036	0·0054
24	0·0072	0·0135	0·0045	0·0054	0·0045	0·0072
30	0·0099	0·0315	0·0117	0·0126	0·0099	0·0189
72	0·0405	0·0423	0·0603	0·0512	0·0315	0·2691
96	0·0747	0·0711	—	0·1251	0·0576	0·7497

These experiments show the following results:—

1. *Cane Sugar.*—A considerable time elapses before the commencement of its change into lactic acid. During this period it is probably undergoing inversion. Thus, until the end of the fourth

hour there is no increase of acidity. The fermentation then begins and proceeds slowly until the thirtieth hour, when it becomes rapid, and a large amount of acid is produced.

2. *Invert Sugar* resembles dextrose in soon undergoing lactic fermentation. Like the sugars mentioned below, it has no resting period such as that observed in the case of cane sugar, but begins to ferment at once. Up to the thirtieth hour the fermentation is much more rapid than in the case of cane sugar, but after that period they nearly correspond in the change they undergo.

3. *Lactose.*—This sugar begins to ferment at once, but only a small percentage of acid is formed up to the end of the twenty-fourth hour, after which the change becomes very rapid. Probably the sugar splits up into glucose and galactose during the early hours, and these in turn undergo lactic fermentation, as happens with cane sugar.

Milk sugar and maltose seem to undergo an equal degree of fermentation up to the twenty-fourth hour. By the seventy-second hour, however, the lactose has yielded almost twice as much lactic acid as the maltose.

4. *Dextrose* undergoes a slowly progressive fermentation during the early hours. After the thirtieth hour, however, the change becomes rapid, and at the fourth day this sugar is found to have undergone a greater degree of change than any of the others, with the exception of lævulose.

5. *Maltose* is apparently less easily and less rapidly fermented than dextrose.

6. *Lævulose* very soon undergoes a marked conversion into lactic acid. Up to the twenty-fourth hour it yields as much lactic acid as cane sugar does. When dextrose undergoes alcoholic fermentation induced by yeast it is more rapidly fermented than lævulose. It is precisely the reverse when these two sugars are subjected to lactic acid fermentation; in that case, the lævulose ferments much more rapidly and to a much greater extent than dextrose. The fermentation of lævulose by the lactic acid ferment is remarkable, inasmuch as it yields about five times as much lactic acid as is yielded by any of the other sugars in the same period of time.

At the end of the third day the sugars may be arranged in the following order as regards the amount of fermentation which they have undergone:—1. Lævulose; 2. Lactose; 3. Dextrose; 4. Invert Sugar; 5. Cane Sugar; 6. Maltose.

II. Butyric Acid Fermentation of Sugars.

In order to induce this fermentation, I added two grammes of well-pounded and thoroughly mixed old cheese (free from mould) to each of the flasks containing 100 c.c. of the five per cent. solutions of the sugars. The initial acidity was first estimated, and they were then placed in the warm chamber and kept at 38° C. as before.

The butyric ferment acts best at a temperature of 35–40° C. The change resulting from the addition of cheese to saccharine solutions is not pure butyric fermentation, but also, to a lesser extent, lactic fermentation, and this is specially true as regards the earlier part of the process. The change, however, results in the production of large quantities of butyric acid, and for practical purposes it may therefore be regarded essentially and almost entirely as butyric fermentation.

The results of these experiments are shown in the two following tables:—

Butyric Acid Fermentation.

Table III.—*Percentage Amounts of Acid formed in Stated Periods.*

Hours.	Cane Sugar.	Invert Sugar.	Lactose.	Dextrose.	Maltose.	Lævulose.
Initial.	0·014	0·0264	0·0308	0·026	0·0255	0·044
2	0·0536	0·0545	0·0598	0·0572	0·066	0·0809
4	0·0589	0·0616	0·0668	0·0624	0·0686	0·0862
24	0·114	0·139	0·1082	0·1364	0·1399	0·232
48	0·227	0·2657	0·2024	0·387	0·4347	0·6652
72	0·447	0·440	0·3256	1·490		

Table IV.—*Total Percentage Amounts of Acid formed in Stated Periods.*

Hours.	Cane Sugar.	Invert Sugar.	Lactose.	Dextrose.	Maltose.	Lævulose.
2	0·0396	0·0281	0·029	0·0312	0·0405	0·0369
4	0·0449	0·0352	0·036	0·0364	0·0431	0·0422
24	0·100	0·1126	0·0774	0·1104	0·1144	0·188
48	0·213	0·2393	0·1716	0·361	0·4092	0·6212
72	0·433	0·4136	0·2948	1·464		

1. *Cane Sugar* appears in this case to undergo rapid inversion and subsequent fermentation, for, at the end of the second hour, a considerable amount of butyric acid has been formed (0·0396 per cent.). This sugar had undergone no change by the end of the second hour in the lactic fermentation. At the end of the third day more butyric acid had been formed from cane sugar than from invert sugar.

2. *Invert Sugar* begins at once to undergo butyric fermentation, but more slowly, and to a less extent than cane sugar.

3. *Lactose.*—In this sugar also the change seems to begin at once, but the after-progress is slow and never reaches a great amount,—the acid forming at the seventy-second hour only 0·2948 per cent. At the same period the cane sugar solution has been fermented to the extent of 0·433 per cent., and dextrose 1·46 per cent.

4. *Dextrose* begins to ferment at once, and the change proceeds slowly until the end of the second day, when the further progress becomes greatly accelerated.

5. *Maltose* begins to ferment at once, and, up to the end of the fourth hour, it suffers change to a greater extent than any of the other sugars, with the exception of cane sugar.

6. *Lævulose* also begins to ferment at once, and until the end of the fourth hour the rapidity of its butyric change runs somewhat equally with that of cane sugar. After this period, however, the production of butyric acid from lævulose proceeds at a great rate, till, at the end of the second day, it far exceeds the amount produced from any of the other sugars.

At the end of the second day the sugars may be arranged in the following order as regards the amount of change they undergo when acted on by the butyric ferment:—1. Lævulose; 2. Maltose; 3. Dextrose; 4. Invert sugar; 5. Cane sugar; 6. Lactose.

III. Alcoholic Fermentation of Sugars.

This was induced by adding 2 c.c. of fresh beer yeast to each flask containing 100 c.c. of the 5 per cent. solutions of the sugars.

The specific gravity of each solution was determined, and all were kept at 38° C. for the next three days. The specific gravity of each solution was taken with a hydrometer (and also by the method of weighing) at intervals during the next three days, care being taken to previously cool them to a temperature of 15°·5 C.

The following table gives the results:—

Alcoholic Fermentation.

Table V.—*Alcoholic Fermentation of Sugars as indicated by the Specific Gravity.*

Hours.	Cane Sugar.	Invert Sugar.	Lactose.	Dextrose.	Maltose.	Lævulose.
Initial Sp. Gr.	1017	1020	1017·5	1017·5	1017·7	1013
2	1014·7	1016	1017·2	1014·5	1015	1008·3
4	1014	1014	1017	1013·5	1012·5	1006
24	1008·7	1008·7	1017	1006·7	1005·8	1000·46
48	1003·2	1005·2	1017	1003·5	1000	1000·092
72	1002·2	1002·3	1017	1003	1000	1000·092

Table VI.—*Degrees of Specific Gravity lost during the Alcoholic Fermentation.*

Hours.	Cane Sugar.	Invert Sugar.	Lactose.	Dextrose.	Maltose.	Lævulose.
2	2·3	4	0·3	3	2·7	5·3
4	3	6	0·5	4	5·2	7
24	8·3	11·3	0·5	10·8	11·9	12·54
48	13·8	14·8	0·5	14	17·7	12·908
72	14·8	17·7	0·5	14·5	17·7	12·908

1. *Cane Sugar* undergoes a rapid inversion, and the resulting products ferment quickly,—the solution having lost 2°·3 of specific gravity in the course of the first two hours. At the end of the third day, however, it has not undergone so great a degree of fermentation as the solution of invert sugar. On testing the solution 120 hours after the beginning of the experiment, the specific gravity was 1000·2, and gave only the faintest trace of reduction of the cupric oxide from its alkaline solution.

2. *Invert Sugar* being ready to undergo immediate fermentation, the fall in specific gravity begins at once, and steadily progresses, the loss in specific gravity being greatest in the case of this sugar. Maltose is very similar to invert sugar in its rate of fermentation, and both have suffered an equal loss in specific gravity at the seventy-second hour.

The invert sugar solution caused a very faint reduction of cupric oxide when tested 120 hours after the observation began, but the amount was insufficient for quantitative estimation.

3. *Lactose* did not undergo alcoholic fermentation at all, there being only a few bubbles of carbonic acid gas evolved during the first hour or two of the experiment. The trifling loss in specific gravity observed in the experiment probably resulted from some impurity in the sugar. When tested after the lapse of 120 hours, it was found still to contain as much as 4·82 per cent. milk sugar.

4. *Dextrose.*—This sugar resembles cane sugar as regards its proneness to undergo alcoholic fermentation. No sugar was found in the solution when tested by Fehling's solution 120 hours after the beginning of the experiment.

5. *Maltose* undergoes a rapid and high degree of fermentation. It reaches its highest limit (loss of 17°·7) in 48 hours. All sugar had disappeared from the solution when tested 120 hours after the initial specific gravity had been taken.

6. *Lævulose.*—This sugar begins to ferment more rapidly than any of the others. It falls far short of some of the other sugars, however, in the extent to which it undergoes fermentation. The

solution contained no sugar when tested 120 hours after the beginning of the experiment.

The following is the order as regards the amount of alcoholic fermentation which the above sugars were found to have undergone at the end of the third day:—1. Maltose; 2. Invert sugar; 3. Cane sugar; 4. Dextrose; 5. Lævulose; 6. Lactose (scarcely changed).

Practical Deductions.

The practical deductions from these experiments may be briefly stated.

In cases of dyspepsia there is usually much delay in the absorption of carbohydrates, even when digested. They are consequently exceedingly prone to undergo fermentation, and this is specially apt to occur if the carbohydrate be in slight excess.

In that variety of dyspepsia accompanied by lactic fermentation, the use of those sugars which rapidly undergo the lactic change, viz., dextrose, lævulose, and invert sugar, is contra-indicated, while the moderate use of cane sugar, maltose, and lactose may be allowed.

In those cases of dyspepsia where butyric fermentation is prominent, milk sugar would seem to be the most suitable, as it is least easily changed by ferment. On the other hand, maltose is very readily changed, as the other sugars also are to a lesser degree.

Lastly, in dyspepsia associated with the alcoholic and acetic acid fermentations, cane sugar, dextrose, maltose, and lactose may be allowed in small amounts; while invert sugar and lævulose should be forbidden. Lactose, however, is the sugar to give in this condition, as it is not at all acted on by the alcoholic ferment.

These theoretical deductions have been supported by clinical observation in the case of cane and invert sugar. I leave it for future investigation to show whether they are true as regards the other sugars.

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