XXX. THE RELATION OF SALIVARY TO GASTRIC SECRETION.

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SALIVA, besides its main functions in assisting deglutition and exercising some amylolytic action, has other functions of secondary importance which also play a certain rôle in digestive processes. Maxwell [1915] found that boiled starch has a marked inhibitory action on peptic digestion, but that the products of amylolytic hydrolysis have not this effect. Thus the amylolytic ferment of the saliva acquires a new importance by removing the inhibitory factor and thus indirectly assisting in the gastric digestion. Maxwell, in all his experiments, used commercial pepsin. The object of the experiments described in this communication was to repeat Maxwell's experiments with natural gastric juice and to extend them to the rennet action of gastric juice.

A. SALIVA AND PEPTIC DIGESTION.

Pure gastric juice was collected by "sham feeding" from a dog which had a gastric fistula and an oesophagostomy. Fresh samples were used for each experiment. Mett's method was found to be sufficiently accurate for the purpose of these experiments and was used throughout the research. The Mett's tubes were left to digest for ten hours at 40°. All the experiments were repeated a considerable number of times, and those given in this communication serve only as examples.

Exp. 1. The seven small flasks containing the solutions named in Table I were kept at 40° for one hour; at the end of this time 5 cc. of gastric juice were added to each flask, and after another half hour the Mett's tubes were placed in each sample. In ten hours the readings of the digested tubes given in Table I were observed.

Table I.

						Digestion of Mett's tubes in mm.
1.	3 cc. of 2 %	boiled potato starch	+ 1 cc. fresh	human saliva		5.3
2.	" "	" "	+ "	boiled "	" "	3.9
3.	" "	raw "	+ "	" "	" "	5.4
4.	" "	soluble starch	+ "	" "	" "	5.3
5.	" "	erythrodestrin	+ "	" "	" "	5.2
6.	" "	maltose	+ "	" "	" "	5.4
7.	" "	glucose	+ "	" "	" "	5.5

The figure for flask 2 is the only one that shows a deviation from the rest. This flask was also the only one that contained the starch in a colloidal form. The hydrolysis of the starch in flask 1 was carried to the achromic point.

Exp. 2. In this experiment the actions of hydrolysed and unhydrolysed starches of different origin were compared. The different pairs given in Table II must not be compared with each other, because, although the hydrolysis was carried on for the same length of time, it reached a different stage with each starch as determined by the iodine reaction.

Table II.

		Digestion of Mett's tubes in mm.
1.	Potato starch hydrolysed	5.3
	„ „ unhydrolysed	3.9
2.	Maize „ hydrolysed	3.0
	„ „ unhydrolysed	2.2
3.	Wheat „ hydrolysed	3.3
	„ „ unhydrolysed	2.6
4.	Rice „ hydrolysed	5.2
	„ „ unhydrolysed	4.2

In each case 1 cc. of saliva, boiled or unboiled, was added to 3 cc. of the 2 % solution, kept in the thermostat for one hour, and then mixed with 5 cc. of gastric juice. The readings were taken at the end of ten hours.

Maxwell's observations made with commercial pepsin are extended in these experiments to normal gastric juice.

The theory of adsorption of the pepsin by the colloidal starch advanced by Maxwell seems to be the most probable explanation of the experiments described. There is one factor of general interest which should be mentioned. As has been described by several observers, the gastric juice secreted on a carbohydrate food is always the richest in pepsin. On the other hand, carbohydrates, when in a colloidal form, hinder peptic digestion. This seems to be another case of a delicate adaptation of the organism in providing more ferment when its action meets with difficulties.

B. SALIVA AND MILK CLOTTING.

We have seen that the carbohydrates in a colloidal form behave towards normal gastric juice and the commercial preparation of pepsin in the same manner. We now proceeded to determine whether the carbohydrates behave in the same way towards the rennet of gastric juice.

The experiments with milk clotting were performed in the same way as those with peptic digestion, but instead of the Mett's tubes, 5 cc. of cow's milk were added to each test tube and the time required for clotting noted.

The action of the boiled starch on milk clotting was found to be the opposite to its action on peptic digestion. In each experiment the addition of starch in a colloidal form produced a considerable acceleration of the clotting. *Exp. 3* serves as an example.

Exp. 3. The seven test tubes containing the solutions were placed in a thermostat at 40°. After one hour 0.3 cc. of gastric juice was added to each test tube and after a further 30 minutes 5 cc. of cow's milk. The time of clotting of each sample is given in Table III.

Table III.

				Time of clotting in mins.
1.	3 cc. boiled potato starch	+ 1 cc. fresh human saliva		15
2.	" " " "	+ " boiled " "		3
3.	" raw " "	+ " " " "		15
4.	" soluble starch	+ " " " "		14
5.	" erythrodestrin	+ " " " "		14
6.	" maltose	+ " " " "		15
7.	" glucose	+ " " " "		16

As in the first experiment, the only figure which deviates from the others is the one corresponding to the test tube containing the starch in a colloidal form. But in this experiment the difference is in the opposite direction, showing a marked acceleration.

Exp. 4. Some other starches (beans, sago, barley, oats, etc.) were tried, and always with the result that the starch in a colloidal form produced an acceleration of milk clotting. Table IV gives some of the figures obtained.

Table IV.

				1 cc. saliva	Gastric juice	Milk cc.	Time of clotting mins.
3 cc. boiled potato starch				fresh	0.3	5	9
" " " "				boiled	"	"	3
" " bean "				fresh	"	"	8
" " " "				boiled	"	"	3
" " rice "				fresh	"	"	8
" " " "				boiled	"	"	5
" " maize "				fresh	"	"	6
" " " "				boiled	"	"	4

In all the above experiments human filtered saliva was used. The filtered saliva was quite watery and contained hardly any mucin as determined by precipitation with acetic acid. The result of the experiments with milk clotting indicates that the amylolytic action of saliva indirectly slows the clotting of the milk in the presence of colloidal starch. The experiments provide one more example of the difference in behaviour of pepsin and rennin.

Under normal conditions it is rather exceptional for saliva to have this effect on milk clotting, and it certainly never occurs in animals deprived of the salivary amylase. It is of some interest, however, that even in such animals (dog) a fair amount of saliva is secreted on milk although it is of no use for its deglutition and has no direct relation to its digestion. In the dog the submaxillary saliva secreted on milk is richer in mucin than the saliva secreted on any other food. In sucklings there is a profuse secretion of viscid saliva. These facts suggest that saliva itself, besides its indirect action described above, has some importance in the digestion of milk. Borisov [1914] has shown that in dogs with gastric fistula milk gives finer clots when mixed with saliva, and ascribes it to the physical action of the viscous saliva. Allaria [1912] found occasionally a slight slowing in milk clotting when mixed saliva from an infant was added.

The following experiments were performed in order to determine whether saliva has any direct effect on milk clotting.

Parotid and submaxillary saliva were collected from a dog having salivary

fistulae of the two glands. The saliva was diluted ten times with thrice distilled water. To each 5 cc. of the diluted saliva 5 cc. of milk were added and then mixed with 0.5 cc. of gastric juice. The time required for milk clotting in the thermostat at 40° is given below.

Table V.

					Time of clotting in mins.
1.	{	5 cc. tap water + 5 cc. milk	...	...	2
		ordinary distilled water + 5 cc. milk	...	...	2
		parotid saliva + 5 cc. milk	...	...	3
		submaxillary saliva + 5 cc. milk	...	...	6
2.	{	submaxillary saliva (10 times diluted) + 5 cc. milk	...	...	5
		tap water + 5 cc. milk	...	...	2
3.	{	pure submaxillary saliva (undiluted) + 5 cc. milk	...	...	∞
		tap water + 5 cc. milk	...	...	2

The sample of parotid saliva used in this experiment did not contain any mucin, which is often present in dog's parotid secretion.

Brennemann [1917] showed that in rapid clotting larger curds are formed than when the clotting of milk is slow. As the presence of the viscid saliva delays the clotting of the milk, this explains the observations of Borisov quoted above. It is certain that this effect of the submaxillary saliva does not depend on a change in the reaction. The addition of colloidal starch as used in the above experiments to acid solutions did not change their p_H as determined colorimetrically. Parotid saliva, being not less alkaline than submaxillary, has no such delaying effect on milk clotting. The action of the viscid saliva seems to be better explained by ascribing a protective action to the mucin.

CONCLUSIONS.

1. Maxwell's experiments on the inhibitory effect of colloidal starch on peptic digestion are confirmed and extended to natural gastric juice.

2. The amylase of saliva hydrolysing the starch removes its inhibitory effect on gastric digestion.

3. Pepsin and rennin behave towards colloidal starch differently—the action of the pepsin is inhibited by colloidal starch and the action of the rennin accelerated.

4. The amylase of saliva hydrolysing the starch removes its accelerating action on rennin.

5. The saliva has a delaying action of its own on milk clotting; this action was found to be due to the protective action of mucin.

6. The secretion of saliva in sucklings is important because it delays the milk clotting and thus produces finer and more easily digested curds.

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