ANALYSIS OF MECHANISMS DETERMINING ADAPTATION OF GASTRIC JUICE PROPERTIES TO THE NATURE OF THE FOOD

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As has been previously shown [5], the secretory process in the normal organism occurs in such a way that the gastric juice secreted is best suited to the digestion of that sort of food which is at that time being subjected to digestion. Following ingestion of meat the gastric juice collected from a Pavlov pouch exerts a more pronounced action on proteins of animal origin than on proteins of vegetable origin. The reverse effect is seen upon ingestion of bread. Such fine adaptation is, apparently, aimed at ensuring the most effective treatment of the food in the stomach with the most economic use of the glandular apparatus. The intensity of animal protein digestion has been designated as zoolytic activity of the juice and plant protein digestion as phytolytic activity. In many animals this adaptation is sufficiently labile to become apparent 30-60 minutes after the beginning of feeding. This evidently has the reflex nature of initial adaptation, while adaptation of the gastric juice in subsequent hours can be explained in two ways: humoral adaptation mechanisms may be postulated but also long-acting nervous influences may be involved. The present work is devoted to an analysis of the regulatory mechanisms responsible for the adaptation of gastric juice to the type of food ingested.

EXPERIMENTAL METHODS

Chronic experiments were carried out on 2 dogs with esophagotomy and gastric fistula and on 2 dogs with isolated Heidenhain pouch. Experiments with "pseudo-feeding" were performed on animals, which had been on a mixed diet, 16-20 hours after the last feeding. The stomach was washed out with warm water; the digestive power and acidity of "spontaneous" portions of the juice were then determined. The animals were given meat in one lot of experiments and white bread in another lot of experiments. Ten to fifteen minute samples of the juice were examined. Animals with the Heidenhain pouches were on a mixed diet and following 16-18 hour fasting received 200 g meat or 250 g bread. The digestive power of the juice was determined on half-hourly and hourly samples.

The proteolytic properties of gastric juice were determined parallelly on proteins of animal origin (mixture of denatured muscle proteins) and on proteins of plant origin (gluten). To a weighed amount (50 mg) of each of the proteins was added 0.3, 0.5 or 1 ml of gastric juice obtained. Incubation at 35-38° was continued for 20-30 minutes. Enzyme activity was determined in the early experiments by the undissolved residue of protein, in the later ones it was mainly determined by the Anson-Mirsky [6] tyrosine method. Results obtained by the latter method are reported in the present work, although they do not differ qualitatively from those obtained by the former.

EXPERIMENTAL RESULTS

Excitation of the receptor elements of the oral cavity and, to a lesser extent, of the pharynx which occur during eating acts as a direct stimulus for the initial period of gastric secretion [1, 3]. The question arises whether this "ignition" secretion has definite adaptive features with respect to the nature of ingested food or whether it is, as it were, indifferent and adaptation is achieved at some other stage of the process ?

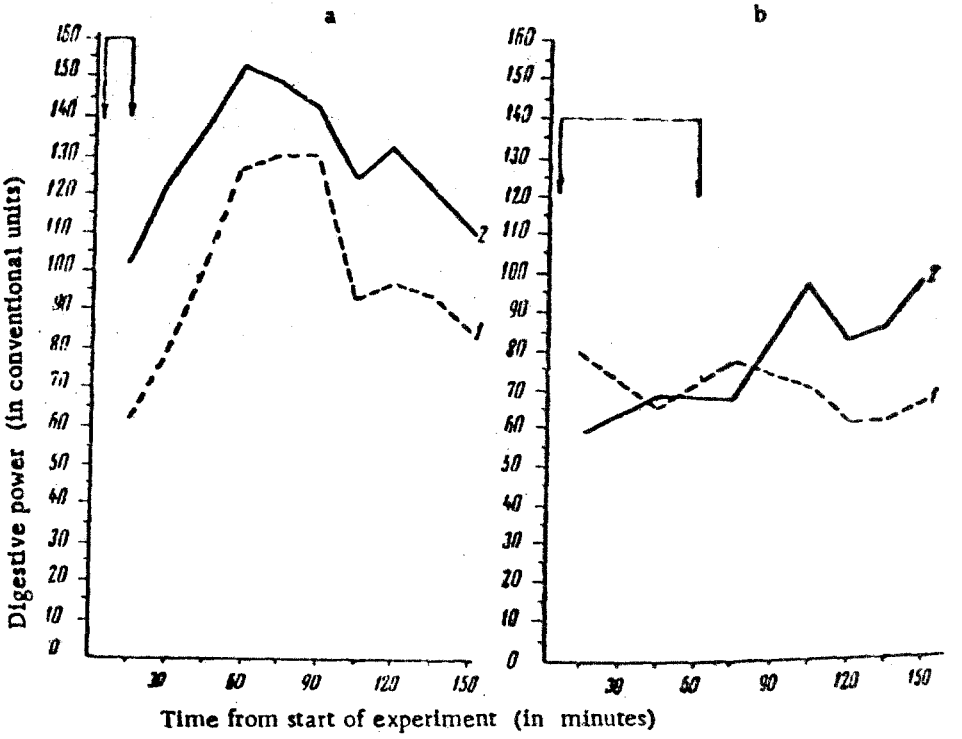

Fig. 1. Breakdown of plant (1) and animal (2) proteins in vitro by gastric juice of dogs upon "pseudo-feeding" with meat (a) and bread (b). Arrows indicate period of feeding.

The first experiments showed that with pseudo-feeding with meat the majority of samples collected during 1-1½ hours (each taken at 10-15 minute intervals) showed predominance of activity with respect to animal proteins. It is suggested that activity of enzyme or secretion toward substrates of animal origin be called zoolytic and toward substrates of plant origin – phytolytic or phytotropic. Thus, even excitation of the oral receptors only by food is sufficient not merely to initiate the secretory process but also for adaptive features to develop. In the final analysis this must mean that the receptor apparatus and central nervous mechanisms possess sufficiently specialized and differentiated properties to ensure reflex adaptation of the quality of gastric juice to the nature of the food.

If the times of feeding are noted carefully the following phenomenon becomes apparent (Fig. 1). Samples of juice collected during feeding and immediate y afterward show definite adaptation to the nature of the food stimulus, whereas subsequently the juice acquires intermediate properties although secretion remains fairly vigorous. This evidently signifies that there is less aftereffect on adaptation than on secretion as a whole, following stimulation.

Figure 1, a shows that when the animal is given meat, adaptation of gastric juice to the food is most marked in its first portions. The ratio of phytolytic activity to zoolytic activity (designated as an index P/Z) at this time is found to be low. On cessation of feeding the index rises until an indifferent level for the given animal is reached (0.7-0.8). Figure 1, b shows that the first samples of gastric juice, coinciding with feeding

of bread, break down plant proteins more readily than animal. On cessation of pseudo-feeding the relative plant protein break-down activity drops while break-down activity for animal proteins rises so that the P/Z index fairly quickly reaches a stable level of 0.7-0.8 (similar to that in the experiment with meat).

Statistical treatment (Fischer-Student) of the data obtained showed the whole of the results to be completely reliable as regards comparison of all samples of "meat" and "bread" juices during periods of pseudo-feeding (P less than 0.001). There is significant difference in the properties of those samples of "bread" or "meat" juices collected during the period of pseudo-feeding on the one hand and during reflex aftereffect on the other.

It has already been noted that indices for juice obtained in response to meat and bread outside the periods of pseudo-feeding are fairly close together. This is confirmed by statistical treatment of all the material showing lack of significance in the differences obtained. The following phenomena occurring upon pseudo-feeding should, therefore, be distinguished. Pseudo-feeding is associated not only with excitation of secretory activity of gastric glands but also with such modifications of the secretory process that the proteolytic activity of the secreted juice becomes adapted to the nature of the food ingested. Soon after cessation of pseudo-feeding, when intensive secretion still continues, the juice loses its qualitative adaptation to a particular type of food to such an extent that it becomes impossible at any rate using our technique to distinguish the juice obtained in response to meat from that obtained in response to bread.

The reflex arising in response to pseudo-feeding is therefore not simply secretory but adaptive secretory. This raises the question whether stimuli which evoke secretion also evoke adaptation or whether the two factors have a different structural basis. The material cited indicates that the two phenomena are distinct since secretory influences are maintained for considerably longer periods than adaptive ones.

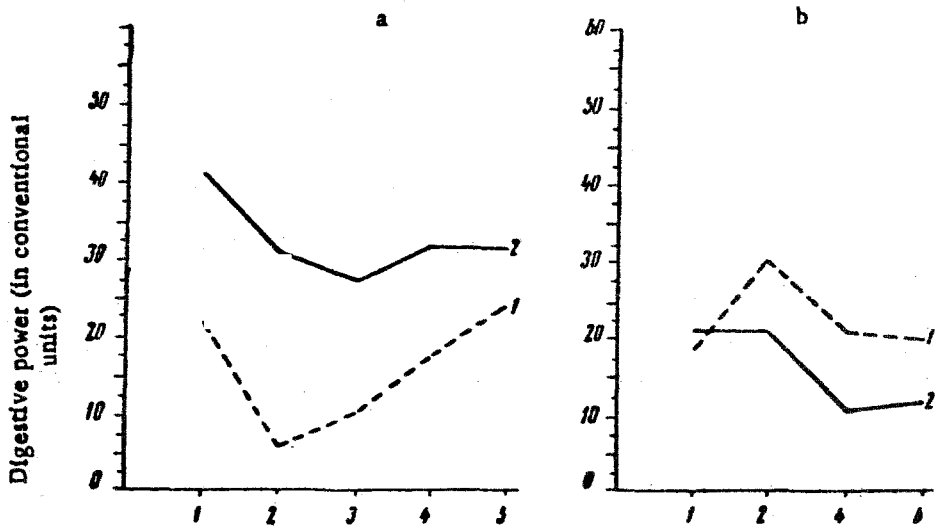

Fig. 2. Breakdown of plant (1) and animal (2) proteins by juice obtained from Heidenhain pouch in response to meat (a) and to bread (b).

Of some interest, from this point of view, are some other observations made by us. In those cases in which the animal consumed the food greedily adaptation of the digestive properties of the juice to the nature of the food was clear and definite, whereas the juice secreted in response either to meat or bread in cases in which the animal ate without desire was very close to indifferent.

It was noted previously that in juice obtained from a Pavlov pouch adaptation changes in the digestive properties of the juice could be detected very quickly; these changes persisted for a fairly long time including

that period which is known as the humoral-chemical phase of secretion. At the same time it was also shown that on pseudo-feeding adaptation occurred fairly rapidly but also disappeared rapidly. This leads naturally to speculation as to how would adaptation processes develop in a stomach completely or almost completely deprived of parasympathetic innervation. In this connection experiments were carried out on dogs with Heidenhain pouches.

As can be seen from Fig. 2, despite considerable changes in the secretory process typical for denervated pouch [2, 4] and appreciable lowering of digestive power as a whole, the adaptive capacity of the secretory apparatus is preserved. Although the amount of secretion is diminished, the ability of the Heidenhain pouch to secrete juice better able to digest meat proteins in response to meat and plant proteins in response to bread is maintained. The P/Z index provides no basis for suggesting that there is any reliable lowering of this ability.

At the same time it is impossible to neglect one detail which sharply distinguishes the gland adaptation process in the Pavlov [5] and the Heidenhain pouches. It has already been pointed out that adaptation of the digestive properties of juice from a Pavlov pouch can be detected in samples collected in the first 30-60 minutes after beginning of feeding; in the case of the Heidenhain pouch the latent period of secretion is 30-40 minutes so that the first determination of the digestive properties was made on samples of juice collected in the 2nd hour. Fairly frequently the ratio of phyto- and zoolytic activities was not commensurate with the nature of the food given (Fig. 2). Adaptation of digestive properties occurred at later periods.

The most noticeable difference in the process of adaptation in the denervated pouch is thus its inertness.

The material so far obtained gives positive evidence of adaptation in the Heidenhain pouch but does not as yet reveal the underlying mechanism. However, it can be asserted even now that adaptation is achieved in one of the following ways. Since denervation which occurs in the process of formation of a Heidenhain pouch is always incomplete it may be supposed that adaptation is preserved so long as parasympathetic innervation is present. It may also be supposed that parasympathetic innervation is practically entirely interrupted during the formation of a Heidenhain pouch. In that case adaptation may be mediated by the remaining sympathetic innervation. Finally, the possibility of the existence of specialized humoral mechanisms responsible for adaptation of gastric juice properties during the second phase of gastric secretion cannot be excluded.

In summarizing all the material presented in this paper it can be stated that reflex mechanisms which determine adaptation of gastric juice properties in the first phase of secretion do exist. Their activity is stimulated by excitation of receptors in the oral cavity upon intake of food. Prolonged maintenance of adaptation of digestive properties to the nature of the food is apparently ensured by a supplementary mechanism which is activated by food when it gains access to the stomach. This mechanism is found in sufficiently "pure" form on examination of juice obtained from a Heidenhain pouch.

SUMMARY

It was demonstrated that adaptive changes of the proteolytic properties of the stomach juice to the quality of food appear not only during the normal course of digestion, but, likewise, in pseudo-feeding. Thus, in pseudo-feeding by meat, there is a prevalence of the zoolytic activity of the gastric juice (the splitting of proteins of animal origin). In pseudo-feeding by bread, phytolytic (splitting of fats of vegetable nature). Adaptation of the proteolytic properties of the gastric juice disappears in 20-30 minutes after pseudo-feeding is discontinued, although the secretion still continues.

Adaptation of the properties of the gastric juice from the Heidenhain pouch is, likewise, pronounced and persists for several hours. However, its development is much slower than in the case of Pavlov pouch.

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