PROTEOLYTIC PROPERTIES OF GASTRIC JUICE WITH RESPECT TO PLANT AND ANIMAL PROTEINS CONTAINED IN QUALITATIVELY DIFFERENT DIETS FED FOR SHORT OR LONG PERIODS OF TIME

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The effects of the nature of foodstuffs on the activities of the digestive glands are manifested in different ways, depending on the nature of the basic diet (B. P. Babkin [1], I. P. Pavlov [4], I. P. Razenkov [5], Knok, Auerbach and Lin [10], and others).

We have shown in our previous papers [6, 7] that the gastric juice secreted by a healthy animal in response to single applications of such alimentary stimulants as meat and bread is best adapted to digest the proteins present in the particular kind of food which is present at the given time in the alimentary tract. We have applied the terms "zoolytic" to the proteolytic activity of gastric juice with respect to animal proteins, and "phytolytic" to activity on plant proteins. The quotient of these two activities (index Ph/ Z) characterizes the "spectrum" of activity of gastric juice: if the index exceeds unity, the juice is adapted to the digestion of plant proteins, while if it is less than unity it is adapted to digestion of animal proteins.

In our earlier communications we studied the course of these processes of adaptation of the digestive properties of gastric juice during a single digestive act. The present paper is devoted to the study of the digestive power of gastric juice of animals maintained for short and long periods of time on different diets, and during the transition periods between changes of diet.

EXPERIMENTAL METHODS

The chronic experiments were performed on 5 dogs provided with an anterior wall stomach pouch, according to our procedure [8]. Samples of juice were taken at hourly or half-hourly intervals. In each such portion we determined the proteolytic power of the gastric juice with respect to plant protein (gluten) and to animal proteins (a mixture of denatured muscle proteins), from the rise in free tyrosine content (Anson and Mirsky's method).

We first estimated the adaptive power of the gastric glands of each animal , by giving a single meat or bread meal after a period of mixed foods, after which they were kept for 2-6 days on a vegetarian or milk-meat diet,* and then for the same length of time on the opposite diets. In addition, we examined the effect of prolonged (2 months or more) meat or cereal feeding.

EXPERIMENTAL RESULTS

Our control experiments, applying single bread or meat meals, gave results in agreement with our earlier findings: the zoolytic properties of the juice preponderated after a meat meal, and the phytolytic ones after a

* On the former diet the dogs were given 0.8 liters of milk and ad. lib. amounts of cereal and black bread daily. The latter diet consisted of 0.5 liters of milk and 1 kg of meat per diem.

bread meal. Adaptation developed with great speed in most cases. The effect was only slightly more pronounced when cereal feeding was continued for 3-4 days. If the animal was then put on a meat diet, some of the specific features of the preceding diet persisted, even if it had been applied for a short time only.

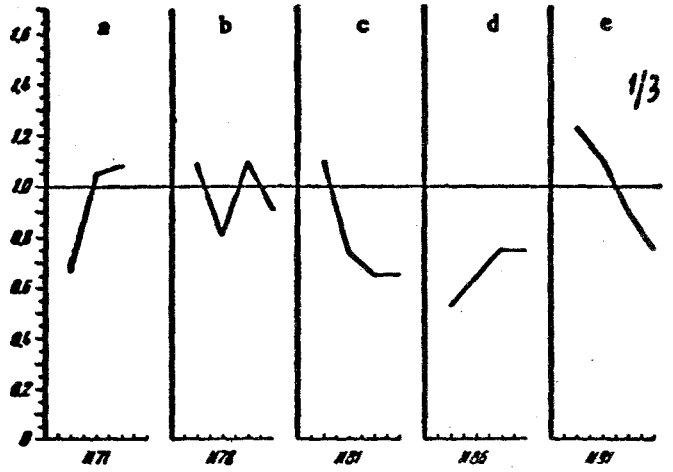

Fig. 1. Ratio of phytolytic to zoolytic activity of gastric juice in short-term dieting experiments. The ordinate axis represents values of the Ph/ Z index (when Ph/ Z = 1 animal and plant proteins are digested to an equal extent; when Ph/ Z > 1 plant proteins are more readily attacked, and when Ph/ Z < 1 animal proteins are more readily broken down). The abscissae represent time in hours from the beginning of the experiment.
a) Gastric juice secreted in response to a meat meal, first day of a meat diet following a vegetarian one; b) the same on the second day; c) the same, third day; d) the same, fourth day; e) gastric juice secreted in response to a cereal meal, on the first day of cereal feeding after a short meat diet.

We found that when meat was first given after a brief period of cereal feeding the juice secreted during the first 1-2 hours was adapted to digestion of meat proteins, but during the subsequent few hours its properties changed to those characteristic of plant protein feeding (Fig. 1, a). As meat feeding was continued, all the portions of gastric juice began to show uniform properties, on the 2nd, 3rd, or 4th days (variously for different animals). Fig. 1 shows how gradual adaptation to a meat diet developed over 4 days, after a preliminary meatless diet.

When the animals were transferred back to a meatless diet we again observed a slow and gradual adaptation of the digestive properties of the juice to the new kind of food.

We consider that the effect of a diet differs from that of a single alimentary stimulation less in the amplitude of the adaptive reaction (very pronounced adaptation may be seen after a single meal) than in this adaptation becoming habitual, inert, and ingrained, not readily giving place to adaptation to a new diet.

This state of inertia of adaptive reactions of the glandular, and probably also of the regulatory apparatus of the experimental animals became established fairly rapidly (3-5 days). It seems that there exists a certain sequence in the process of conversion of the digestive properties of gastric juice in changing from one short period of dieting to another.

It might have been thought that if the animals are fed meat after being on a meatless diet the juice secreted during the first 1-2 hours would be appropriate to their former diet, and should then change its properties to those adapted to a meat diet. But, as appears from Fig. 1, the transformation was only complete on the 3rd day of meat feeding, although adaptation took place on the first day, but was of short duration only. When the animals were transferred to a meat diet the zoolytic properties of the juice began to predominate during the 1st-2nd hours (Fig. 1, a), and then disappeared. At later times after meat had been eaten the juice collected in most of the experiments showed adaptation to a cereal diet.

Thus the juice secreted during the first few hours after a meal was adapted to the given type of food eaten, after which it reverted to the type adapted to the past staple diet of the animal. To a certain extent, these effects correspond in time to the first reflex, and the second humoral-chemical, phases of gastric secretion, and they probably reflect the lability of the adaptive processes acting during the first phase, and the well known inertia of those acting during the second phase.

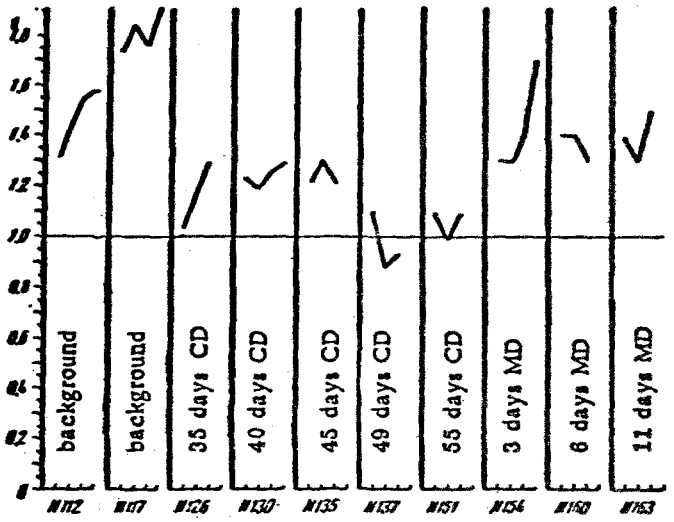

Fig. 2. Ratio of phytolytic to zoolytic activities of gastric juice secreted in response to bread, during prolonged meatless feeding. Background: mixed diet; CD: cereal diet; MD: mixed diet after a cereal diet.

The adaptation of the digestive properties of gastric juice to a given alimentary stimulus does not appear immediately after transfer to a new dietary regime in the second phase of secretion, but having once made its appearance it is distinguished by its considerable stability and inertia, as has been pointed out above.

We may thus assume the existence of two regulatory mechanisms. One of them, manifested during the first phase of secretion, is distinguished by the great lability of its process of adaptation to changes in the nature of the food eaten; the other, which makes its appearance during the second phase, is characterized by "habituation" to the given stereotype of food. These findings are to a certain extent in agreement with those obtained from the study of gastric juice collected from a Heidenhain pouch, and also from sham feeding experiments.

Our experiments on short-term dieting threw some light on the reason why so-called "unsuccessful" animals are encountered in studies on gastric digestion.

It is generally known that many animals provided with a classical or modified Pavlov pouch do not display the effects described by I.P. Pavlov [4] and P. P. Zhizhin [9], showing adaptation of the secretion to the nature of the food ingested. Such animals are traditionally excluded from the experiments, the reason for their rejection being specially discussed in each paper. The reason for the failure of such animals to adapt was usually put down to defective functioning of the stomach pouch, due either to operational injury, or to anomalies in its nerve supply.

Under our experimental conditions, such "unsuccessful" animals did not give reproducible classical secretory curves, and adaptation to a given type of food was slight, or was even totally abolished. In the latter case, the juice secreted in response to meat or cereal feeding had identical ratios of phytolytic to zoolytic properties.

When a given diet is continued for 2-4 days, such dogs show quite definite adaptation to a cereal or a meat diet. It follows that in such animals the process of adaptation of the digestive apparatus is distinguished by its high inertia, owing to which the organism does not have enough time to achieve adaptation to frequent changes of diet.

Although we cannot, within the limits of the present paper, enter into a more detailed discussion of our observations, we would like to draw attention to one paradoxical effect, which was observed during the late stages

of dieting (20-50th days). As has been pointed out above, when meat is fed against a mixed diet background, the juice secreted has a preponderance of zoolytic properties, whereas after cereal feeding phytolytic properties prevail. If, however, the animal had been kept on a cereal diet for 35-40 days a perceptible lowering of phytolytic, and a heighteining of zoolytic, properties of the gastric juice was seen when cereal was fed. In such cases, judging from the activity of the juice on protein substrates in vitro, it does not correspond to the nature of the diet (unlimited white and black bread, boiled potato, porridge, and 400 g of milk), or to that of the given alimentary stimulus (250 g of bread), inasmuch as it has a more zoolytic activity than the juice secreted on a mixed diet (Fig. 2). Conversely, the phytolytic activity of gastric juice secreted by animals maintained on a meat diet (meat, milk) for about the same length of time shows a definite rise. Continuation of a given dietary regime does not lead to the disappearance of this paradoxical effect, or to its weakening.

How can we explain this phenomenon?

It cannot be ascribed simply to loss of power of adaptation, and it cannot be considered to be a classical paradoxical phase. In the former case we would expect that, with the given dietary background, the activity of the juice should be the same irrespective of the nature of the alimentary stimulus given (meat or bread). In a paradoxical phase we would expect the juice secreted in response to meat to have a higher Ph/Z index than when bread is given (conversely to the normal reaction). In reality, however, we find the usual relative adaptation to bread or meat (the Ph/Z index of the juice secreted in response to meat is lower than that secreted in response to bread).

The digestive properties of gastric juice secreted during this phase are not, however, correlated with the nature of the given meal, but rather with that of the excluded dietary component. Is not the indigestibility of monotonous diets, recognized by most clinical physicians, due to this phenomenon, as well as the benefits of making radical changes from one to another form of long-term diet?

Judging from the literature, this phenomenon should not be regarded as being altogether unexpected. K. S. Zamychkina [2] has shown that when dogs are maintained on a carbohydrate diet for a long time, amylase makes it appearance in the saliva, and then disappears after 3-4 weeks of continued carbohydrate diet. Thus the initial adaptation has been lost. When the dogs were transferred to a meat diet, the amount and the acidity of the gastric juice rose abruptly at first, but fell thereafter, as meat feeding was continued [3, 5].

It thus appears that there exist many phenomena of the same sort as the one described, and taking place within about the same time period. We do not consider our paradoxical effect to be a consequence of some pathological changes in the secretory apparatus. The point is that we observe a well-defined tendency towards reversion to the initial functional state immediately after transfer from a mixed to a meat or a cereal diet. It might be supposed that the secretion of juice possessing pronounced zoolytic activity after prolonged maintenance on a cereal diet, and of the converse effect after a prolonged meat diet, could be due to exhaustion of the mechanisms which initially assured the secretion of juice having an activity appropriate to the given food. But if this is the case, it is not clear why, after much longer times, when inappropriate juice is secreted during the second dietary phase, exhaustion of the mechanisms assuring secretion of juice having the opposite properties does not take place.

Moreover, as we have shown in other experiments which will be reported elsewhere, special mechanisms assuring the secretion of zoolytic or phytolytic types of gastric juice do not appear to exist.

There is one other possible explanation. It is conceivable that after prolonged maintenance on a vegetarian or meat diet the organism somehow responds to deficiency in any particular dietary factor by a complex of adaptive reactions, involving also adaptations of the digestive system, tending towards the making good of the deficiency. From this viewpoint, the predominantly zoolytic properties of gastric juice secreted after prolonged feeding with plant products may be regarded as being an adaptation to whatever factor is missing from the diet. Under natural conditions, animals are to a certain extent free to select the food they eat, in which case the adaptive significance of the findings described by us becomes evident.

SUMMARY

It was shown that during short (3-4 day) vegetable and meat diets the adaptation of proteolytic properties of the gastric juice to the quality of food becomes, to a certain extent, inert. Immediately after the change from the meat diet to vegetable and vice versa, proteolytic properties of the gastric juice correspond to the quality of

the food, while in the following few hours – to the quality of the previous diet. Adaptation to the new diet is completely developed in 2 to 4 days. However, a paradoxical phenomenon on the 3th to 50th day of prolonged diet is noted, i.e. in meat diet – the phytolytic properties of the gastric juice become prevalent, while in vegetable – zoolytic.

LITERATURE CITED

[1] B. P. Babkin, External Secretion of the Digestive Glands,* Moscow-Leningrad, 1927.

[2] K. S. Zamychkina, Arkh. Biol. Nauk 34, Nos. 1-3, 105-112 (1934).

[3] Kh. S. Koshtoiants, Zhur. Eksptl. Med. 1, No. 1, 109-123 (1928).

[4] I. P. Pavlov, Lectures on the Work of the Chief Digestive Glands,* Leningrad, 1949.

[5] I. P. Razenkov, Nature of Nutrition, and the Functions of the Organism,* Moscow, 1946.

[6] A. M. Ugolev, Biull. Eksptl. Biol. i. Med. 44, No. 10, 29 (1957).**

[7] A. M. Ugolev, Adaptive Properties of gastric juice. Doklady Akad. Nauk SSSR 113, 1, 230 (1957).**

[8] A. M. Ugolev, Biull. Eksptl. Biol. i. Med. 44, No. 7, 108 (1957);**

[9] P. P. Zhizhin, Secretory Work of the Dog's Stomach,* Dissertation, St. Petersburg, 1896.

[10] W. E. Knok, V. H. Auerbach and E. C. Lin, Physiol. Rev. 1956, v. 36, No. 2, p. 164 - 254.

* In Russian.

** See C. B. Translation.