

# THE MECHANISM OF AMYLASE SECRETION IN THE DOG'S INTESTINAL JUICE FOLLOWING THE EXCLUSION OF PANCREATIC SECRETION

O. I. Shvetzova

Laboratory of Digestive Physiology (Head - Professor. G. K. Shlygin), Institute of Nutrition AMN SSSR, Moscow

(Presented by Active Member of AMN SSSR V. N. Chernigovskii)

Translated from *Byulleten' Éksperimental'noi Biologii i Meditsiny* Vol. 49, No. 4, pp. 28-32, April, 1960

Original article submitted February 27, 1959

In a number of publications G. K. Shlygin and co-workers of the Laboratory of Digestive Physiology [2-3] have shown that the characteristic intestinal enzymes - enterokinase, alkaline phosphates, saccharase, and others, are secreted into the intestine in the form of "mucous" globules. The "mucous" globules (the so-called solid portion of intestinal juice) are formed during the secretory process by the sloughed-off intestinal epithelial cells. After the breaking up of the globules, the enzymes are found in the liquid portion of the secretion. Due to this secretory mechanism the concentration of a number of characteristic intestinal enzymes in the solid portion of the juice is much greater than in the liquid portion.

In contrast to the above, amylase that is found in the dog's intestinal juice in very small quantities shows particular properties. It is found in liquid and solid portions of intestinal secretion in either the same quantities, or in the solid portion one and one-half or sometimes twice as much as in the liquid portion.

A supposition was advanced [4] concerning the possibility of transfer of varying quantities of dog amylase from blood into the intestinal juice. Investigation of dog salivary amylase [1] has established that when pancreatic ducts are ligated pancreatic amylase can be transferred into the saliva.

We have undertaken the problem of clarifying whether the presence of amylase in the intestinal secretion is the result of its active synthesis by intestinal glands, or whether it is due to transfer from the blood.

In order to solve this question we investigated the amylase content of blood and intestinal secretions of dogs with intact pancreas and in dogs without exocrine pancreatic secretions. In the dog, pancreatic juice is a very potent source of amylase; thus, after its exclusion one would anticipate a shift toward compensatory intestinal production of amylase, that is, if the intestines can produce it. If the intestines cannot produce it, then one can anticipate that the increase in blood amylase will render its transfer into the intestinal secretions, and in the latter case the amylase content of the intestinal juice should be closely related to blood amylase content.

## METHOD

The experiments were conducted on 12 dogs, each one of which had two loops of small and large intestine isolated, according to the method of Thiry. Eight of these animals were given a common ration, sufficiently rich in carbohydrates, four were given a predominantly protein ration poor in carbohydrates. The caloric content of both rations was 90 calories per kilogram of animal weight. Supplementation with vitamins and mineral salts was conducted in relation to the dog's requirements [5]. Intestinal juice was collected for 18 hours of periodic secretion after five hours of feeding. We recorded the weight of solid and liquid fractions, the amylase content, and likewise the content of enterokinase, alkaline phosphatase, lipase, peptidase, and saccharase. The amylase content of the juice and blood serum was determined by the modified method of Volgemut and the photometric method of Smith and Roe [6]. For the determination of other intestinal enzymes the methods accepted and partially worked out by the Digestive Physiology Laboratory of the Nutrition Institute of the Academy of Medical Sciences of the USSR [3] were used.

After the determination of the starting enzyme levels in the intestinal juice and in the blood of these animals, the exocrine pancreatic secretions were removed by means of ligating and cutting the efferent glandular ducts and by the isolation of the gland from the intestine by the omentum. The insulin secretory apparatus was not disturbed; this was ascertained by morphological investigations and through the determination of blood sugar.

## RESULTS

Comparison of the amylase content of both portions of intestinal secretions with blood serum has shown that the blood of a dog with intact pancreas is almost twice as rich in amylase as is the intestinal juice.

After ligation of the efferent pancreatic ducts (Fig. 1), one day after operation there is already observed an extraordinarily sharp increase in the blood amylase content (20 to 30 fold). At the same time there is a rapid increase (10 to 20 fold) in the amylase content of intestinal juice

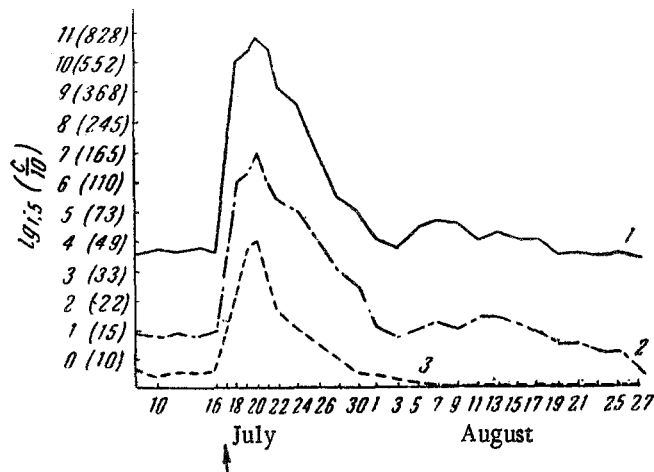


Fig. 1. Changes in amylase concentration after ligation of pancreatic ducts. 1) In blood; 2) in duodenal secretion; 3) in secretion of the large intestine. The arrow points to the time of duct ligation.

from the isolated loops of the duodenum and the large intestines. Gradually during one and one-half to two and a half weeks the content of amylase in blood and intestinal secretions becomes decreased, holds steady for 30-45 days, and then is decreased gradually. After four to five months, as a result of atrophy of the exocrine elements of the pancreas, the amylase content of blood and juice is 30-35% lower than before ligation. However, even at the end of the observations (eight to ten months after ligation) the concentration of blood amylase amounts to 40-45% of the starting level. The duodenal amylase content at the same interval after ligation is found to be a very low level. In the secretion of the isolated loop of the large intestine after one to one and one-half months after duct ligation, amylase can not be determined.

In Fig. 2, together with the changes in concentration of intestinal juice amylase, the contents of other enzymes are presented: enterokinase, alkaline phosphatase, peptidase, and saccharase. The heights of the starting levels of the given enzymes in the juice prior to ligation are taken as 100%.

Ten days after ligation of the ducts, when amylase concentration in the juice is still at an elevated level, the content of other enzymes is still unchanged. Two months after ligation of the ducts the amylase content of intestinal juice approaches the starting level; the content of other intestinal enzymes begins to increase.

At longer intervals, six to eight months after ligation, the amylase content in the juice is only one third, or less, of the starting level, whereas the content of enterokinase

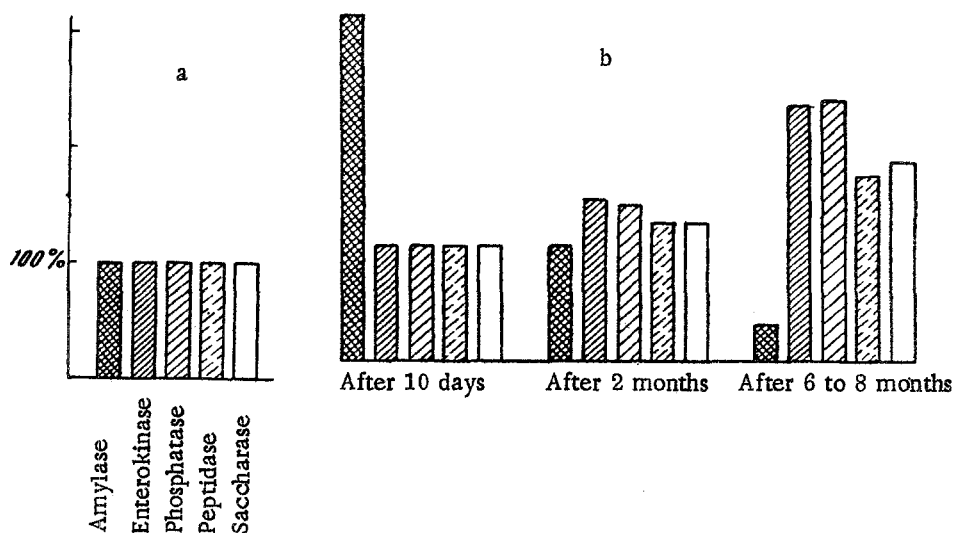


Fig. 2. Enzyme content of duodenal secretion (isolated loop). a) Prior to ligation; b) after ligation of pancreatic ducts.

and phosphatase is markedly increased and is two to two and one-half fold higher than the starting level. The peptidase and saccharase contents are also increased, approximately one and one-half fold higher than the original level prior to ligation. The increase in the production of a number of characteristic intestinal enzymes (enterokinase, phosphatase, peptidase, saccharase) can be looked upon as a compensatory change in activity of intestinal glands.

The steadfast decrease of amylase in the digestive juice and in blood (as a result of pancreatic atrophy) leads to a drastic deficit of amylase in the digestive tract.

Naturally, a common ration that is generally rich in carbohydrate is unfavorable. Dogs receiving this ration lose more weight more rapidly than animals maintained on a carbohydrate poor and predominantly protein ration. Sharp deficit of amylase in the digestive tract after ligation of the glandular ducts leads to gastrointestinal disturbances in carbohydrate digestion, which is supported by coprological investigations. In feces of dogs maintained on sufficiently rich carbohydrate rations there are observed many undigested starch granules.

Further experiments were directed toward clarification of the mechanism of increase in digestive juice amylase immediately after ligation. The question was raised whether or not the increase is connected with active production of the enzyme by intestinal glands. It is known that the secretion of enzymes in the intestines is regulated by the neural system. It was shown that denervation of an intestinal loop results in drastic decrease in production of a number of its enzymes [2]. In relation to amylase such investigations have not been conducted.

Intestinal denervation was performed by two methods. In two dogs one of the intestinal loops was isolated by Thiry's method, and the other was denervated by cutting the branches of mesenteric nerves; in the third dog one of the intestinal loops was isolated by Thiry's method, and the other was denervated by transplanting it under the skin and subsequently cutting the vascular-neural bundle. The starting secretory level was determined for both loops.

In agreement with previous literature [2], it was shown that the enterokinase and phosphatase content in juice from the denervated loop was sharply decreased. Denervation had no noticeable influence on the amylase content. The amylase concentration in juice from the denervated intestinal loop was not decreased; it remained at the same level as the Thiry loop.

After ligation of the glandular ducts the amylase content of the secretions from the denervated loop as well as from the Thiry loop was sharply increased (Fig. 3). During the first few days after operation juice from the denervated loop contained less amylase than the juice from the Thiry loop. On the third and fourth day the content was increased and surpassed the amylase content of the Thiry loop.

Subsequently, the amylase concentration in juice from both loops gradually decreases and in one and one-half to two weeks it returns to the starting level and thereafter it decreases further. These changes are correlated with blood amylase content.

Separate determinations of amylase in the solid and liquid portions of the juice, after ligation of the ducts,

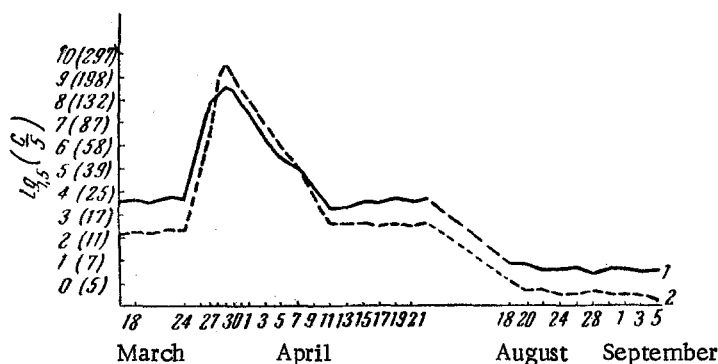


Fig. 3. Amylase production in the liquid portion of intestinal juice. 1) Isolated intestinal loop (Thiry); 2) Transplanted intestinal loop. The arrow (↑) points to the time of duct ligation and sectioning of the vascular-neural bundle of the loop.

In order to clarify the role of the neural system in the development of the above mentioned change in amylase production following ligation of pancreatic ducts, experiments were conducted with the denervated intestinal loop. In these experiments the same dog served as the source of intestinal juice from isolated Thiry loop and from a denervated intestinal loop. The humoral medium of both of the loops was the same.

have shown that with the sharp increase of amylase, the relative contents of amylase in both portions remained the same as prior to ligation, i.e., approximately in the same quantities or in the solid portion one and one-half to two fold greater than in the liquid portion. The same relationships are observed in the secretions from the denervated loop.

Thus the deficiency of amylase in the digestive tract

resulting from exclusion of exocrine pancreatic secretion does not lead to active production of this enzyme by intestinal glands, and compensatory increase of amylase does not occur (even in animals kept on a common, carbohydrate rich ration).

The increased output of amylase in intestinal juice after pancreatic duct ligation does not depend on the increase in its secretions from the intestinal glands.

The data showing the same amylase content in the liquid and solid juice portions, correlating changes in the blood and intestinal juice after duct ligation, and likewise the absence of changes after denervation, allow the conclusion to be made that in dogs, after exclusion of the exocrine pancreatic secretions, the increase in amylase concentration of the intestinal juice depends on the transfer of this enzyme from the blood into the intestinal secretions.

It may be supposed that in the dog under normal conditions, the small amount of amylase found in the intestinal juice is similarly dependent on its transfer from the blood.

#### SUMMARY

Both pancreatic ducts were ligated in dogs with the isolated (according to Thiery) and denervated intestinal

loop. The following was established: The presence of almost the same amylase content in the fluid and thick portions of the intestinal juice, its correlating changes in the blood and intestinal juice after ligation of the ducts, the absence any changes of its content in denervation by way of section of the mesenteric nerves. A suggestion is made that the presence of amylase in the dog's intestine depends mainly upon the fact that this ferment is conveyed from the blood into the intestinal secretion. The intestinal enzymes enterokinase, alkaline phosphatase, lipase, peptidase and saccharase were also investigated.

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