

Rates of Digestion, Gastric Emptying and Intestinal Absorption of Starch.

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We have shown in previous studies^{1,2,3} that the rates of gastric emptying and intestinal absorption of carbohydrates were closely related. Our work has also indicated, contrary to the findings of Cori,⁴ that the rate of intestinal absorption of carbohydrates depended, among other things, upon the amount of administered carbohydrate. Much of our earlier work has been done with dextrose administered by forced feeding. This method has been called unphysiological by some workers, and it must be admitted that few animals habitually obtain their nourishment by stomach tube. On the other hand, we found it quite impossible to study dextrose absorption in short time intervals by using any method other than forced feeding. Starch, either in pure form, or as part of some food product, lends itself to studies with voluntary feeding. We have shown in an earlier study that rats can be made to consume limited amounts of such starch in a relatively short period of time.

The present study was undertaken to obtain further information on the fate of voluntarily ingested starch, to extend our previous experiments to other cereal products, and to determine the role salivary digestion plays in the utilization of starch by the rat.

Methods. This investigation was carried out with 3 preparations—(1) corn starch added to boiling water in amounts giving a concentration of 10%; (2) a breakfast cereal

from which the free sugar was removed by washing with water, followed by drying at 70°C (Cereal I); and (3) a breakfast cereal which contained no free sugar (Cereal II). The two breakfast cereals were fed as a paste, water being added in sufficient amounts to give a starch concentration of 10%. All 3 preparations were analyzed for starch, protein, fat, fiber, ash and moisture. As experimental animals we used white rats weighing between 140 and 200 g. These animals were fed the 3 starch preparations in amounts containing 247 or 317 mg of starch. In all other respects the procedure was the same as described by Fenton and Pierce.³

An effort was made to determine the extent of digestion in the alimentary tract above the pylorus. Some information was obtained by carrying out the standard osazone tests on the gastric contents. Since the presence of dextrans gave rise to abnormal crystal shapes, solubility in hot and cold water and in glacial acetic acid was used as the chief criterion. Additional information was obtained from a combination of Barfoed's and Benedict's qualitative tests.

Results and Discussion. The qualitative tests performed on the gastric and intestinal contents support the conclusion that the free sugar present in greatest amounts in the stomach was maltose while dextrose was found in the intestines. We have, therefore, calculated our results on this basis.

All pertinent data have been assembled in Table I. In general the rates of hydrolysis, emptying and absorption were closely related. The only exception to this was noted in the group receiving corn starch at the low level (247 mg of starch) with an absorption period of one hour. With this one exception the rates of hydrolysis, emptying and absorption of Cereal II and of corn starch were of the

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¹ Fenton, P. F., *Am. J. Physiol.*, 1945, **144**, 609.

² Birchall, E. F., Fenton, P. F., and Pierce, H. B., *Am. J. Physiol.*, 1946, **146**, 610.

³ Fenton, P. F., and Pierce, H. B., *Am. J. Physiol.*, 1947, **148**, 296.

⁴ Cori, C. F., *J. Biol. Chem.*, 1925, **66**, 691.

TABLE I.
Summary of Results Obtained with Rats Fed 3 Starch Preparations Fed at 2 Levels.*

Amount of starch fed	247 mg		317 mg	
	1 hr mg	2 hr mg	1 hr mg	2 hr mg
Hydrolyzed				
Cereal I	137 ± 7.3†	179 ± 7.7	158 ± 8.5	213 ± 8.3
Cereal II	184 ± 3.8	222 ± 3.1	231 ± 5.2	258 ± 5.8
Corn starch	180 ± 5.8	222 ± 4.3	254 ± 5.2	281 ± 4.8
Emptied				
Cereal I	118 ± 8.8	170 ± 8.3	140 ± 10.0	198 ± 10.4
Cereal II	154 ± 3.8	210 ± 4.6	176 ± 6.2	226 ± 7.2
Corn starch	116 ± 8.2	197 ± 7.6	168 ± 9.6	248 ± 8.3
Absorbed				
Cereal I	117 ± 8.8	170 ± 8.3	130 ± 9.4	195 ± 10.1
Cereal II	148 ± 4.4	210 ± 4.6	158 ± 6.2	220 ± 7.8
Corn starch	115 ± 8.0	197 ± 7.6	165 ± 9.8	248 ± 8.3

* The data presented here were obtained on a total of 240 animals, each group containing from 15 to 30 animals. All values are expressed in terms of starch.

† Standard error

same order of magnitude. Cereal I was hydrolyzed, emptied and absorbed at a consistently slower rate.

The data presented here are in excellent agreement with our previous findings. It is again evident that increasing the size of the meal fed also increases the amount of starch hydrolyzed, emptied and absorbed. The fact that the rates of absorption decreased with time should not be emphasized too strongly since only relatively small amounts of carbohydrate remained unabsorbed during the second hour.

The intimate relationship of the rates of

hydrolysis, emptying and absorption and the effect of varying the size of the meal upon these rates support very well our earlier reports in connection with the utilization of dextrose. The results reported here were, however, obtained under conditions which permitted the elimination of forced feeding.

Conclusions. Three starch preparations were fed to a total of 240 animals. The rates of hydrolysis, emptying and absorption are closely related. Increasing the size of the test meal increases these rates. The data were obtained under conditions permitting the elimination of forced feeding.

16372

A Comparison of the Nutritive Value of Egg Proteins and Their Amino Acid Content.

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Since the early investigations of Osborne and Mendel¹ the high nutritive value of egg proteins has been recognized. Mitchell and Carman² found that whole egg protein fed at an 8% level in the diet had a biological value of 93 as compared with 74 for pork and 67 for wheat. Subsequently the same investi-

gators³ reported a biological value of 94 for the nitrogen of whole egg and 83 for the nitrogen of egg albumin. Sumner⁴ and others reported the biological value of whole egg protein as 94 when fed at a 5% level and 85 when fed at an 8% level and that the biological value was higher for young rats than