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STUDIES ON WATER DRINKING: X. FECAL OUTPUT AND ITS CARBOHYDRATE CONTENT UNDER THE INFLUENCE OF COPIOUS AND MODERATE WATER DRINKING WITH MEALS.

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Introduction.

It has been said that the amount of feces, as well as its nitrogen content, depends entirely upon the cellulose content of the food materials, the first being the result of the inability of the organism to digest cellulose, the second being due to the increased desquamation of intestinal epithelium as a result of heightened peristalsis and to an accompanying increase in the amount of digestive fluids secreted.

Aside from possible traces of the less common complex carbohydrates, the only carbohydrates ever present in normal feces under ordinary conditions are cellulose and starch. It has been shown by Lusk[1] that the decomposition of cellulose does not result in the formation of glucose, and its nutritive value is probably in the fatty acids formed from it. In a study of the digestibility of carbohydrate, therefore, a consideration of the possible digestion of cellulose is unnecessary.

The source of starch in the feces is ingested vegetable food, the cellulose envelopes of which, as a result of insufficient disintegration, have not become accessible to the action of the digestive juices. The manner of preparing the food has much to do with the extent of this disintegration; the efficiency of the mastication also plays a part, and the activity of the digestive juices and the extent of the churning to which the food is subjected in the intestin also have an influence. All other conditions remaining the same, the amount of carbohydrate found in the feces should furnish some indication as to the digestibility of carbohydrate in the organism, as well as to the extent of cellular disintegration by which it has become available. In the series of observations reported in the preceding papers on the utilization of protein and fat under the conditions of water drinking with meals attention was also paid to the comparative amounts of fecal dry matter and moisture, and to the utilization of carbohydrate, although the diet consisted of almost completely available food and contained little cellulose.

The early experiment of Ruzicka[2] previously referred to included certain data upon total fecal excretion. During the first 2-day period (no water with meals) the total fecal dry matter was 46.2 grams against 42.0 grams in the second 2-day period when water was taken with meals. The total dry matter ingested during the first (no water) period was 783.3 grams, while the dry matter ingested in the second period was 842.5 grams. The carbohydrate intake and excretion (obtained by difference) for the two periods were as follows:

	First period (no water). Grams.	Second period (water). Grams.
Ingesta	357.4	384.4
Excreta	6.9	6.3

It is thus seen that the ingestion both of total dry matter and of carbohydrate was larger in the water period than in the period when no water was taken with the meals, while the excretion both of total dry matter and of carbohydrate was smaller when water was taken with meals than when none was taken. The diet was one of bread and meat, and analyses are given which show that the feces were of relatively the same composition in both periods, 100 grams of the dry substance yielding 14.9 and 15.0 grams, respectively, of carbohydrate.

In the investigation of Fowler and Hawk[3] referred to in the previous paper the elimination of fecal dry matter and moisture during the period of water ingestion with meals was much less than during either the fore or after period. No data weie obtained on carbohydrate utilization.

Methods.—In the papei on fat utilization will be found a description of the method of collecting and preparing the sample. *Moisture.* Moisture was determined, during one experiment, in porcelain crucibles, during a second in lead caps. The latter method is much more satisfactory. The samples were first air-dried for two or three days, and then in an oven at 102°, for two or three days.

Carbohydrate.—Carbohydrate was determined by a modification of the method of Strasburger.[4] The procedure was as follows: Five to 10 grams of feces were weighed out into a 200 cc. Erlenmeyer flask, and 5–7 grams of bone-black were added along with 100 cc. of 2 per cent. hydrochloric acid. This mixture was boiled for one and one-half to two hours under a reflux condenser, allowed to cool, made alkaline with sodium hydroxide to precipitate calcium salts and filtered with suction. Ordinarily this took considerable time. The filtrate was clear and varied in color from a dark straw to entire absence of color. This solution was approximately neutralized and its reducing power was determined in an aliquot portion by the method of Benedict.[5] The procedure of Strasburger involves the determination of sugar by the copper thiocyanate method of Volhard-Pflüger, and the time and labor required in this method are considerably greater than for the method used in these experiments. In most cases, also, satisfactory duplicates were obtained. The solutions as prepared for the determination could never be allowed to stand any length of time with neutral or slightly alkaline reaction as the development of molds brought about decompositions and destruction of sugar. When they were left standing they were always acidified.

Experiments on Copious Water Drinking with Meals.

The routine of the experiment on Subjects H and W has been described in a preceding paper. The diet of both men contained carbohydrate as follows:

	Amount (per meal).	Carbohydrate.
Graham crackers	150.0 grams	108.8 grams
Peanut butter	20.0	3.2
Milk	450.0 (cc.)	25.7
Butter (carbohydrate negligible)	25.0	——
	Total,	137.7

For water ingestion see paper on fat utilization.

Discussion of Data from Subject W, Table I.—The average amount of

TABLE I.—SUBJECT W.

	Number of stool.	Weight. Grams.	Per cent. dry matter.	Amount dry matter. Grams.	Amount moisture. Grams.	Carbohydrate. Grams
Prel. period. 3 days	1	147.0	27.33	40.2	106.8	1.955
	2	182.5	25.86	47.2	135.3	2.71
	3	66.0	27.21	18.0	48.0	1.12
	4	138.0	23.67	32.7	105.3	1.78
Total		533.5	...	138.1	395.4	7.565
Average (per day)		177.8	25.9	46.0	131.8	2.52
Water period. 5 days	5	214.0	13.17	28.2	185.8	2.09
	6	25.2	23.24	5.9	19.3	0.26
	7	94.0	27.34	25.7	68.3	1.51
	8	102.8	28.85	29.7	73.1	1.56
	9	121.5	26.05	31.6	89.9	1.87
	10	39.0	29.83	11.6	27.4	0.47
Total		596.5	...	132.7	463.8	7.76
Average (per day)		119.3	22.2	26.5	92.8	1.55
Final period. 3 days	11	104.5	25.48	26.6	77.9	1.40
	12	134.0	25.83	34.6	99.4	2.09
	13	26.9	31.85	8.6	18.3	0.38
	14	98.0	26.10	25.6	72.4	1.55
Total		363.4	...	95.4	268.0	5.42
Average (per day)		121.1	26.3	31.8	89.3	1.81

feces passed per day during the preliminary period was 177.8 grams, during the water period 119.3 grams, and during the final period 121.1 grams. A similar variation is observed in the fecal dry matter which decreases from 46 grams per day in the preliminary to 26.5 grams in the water period and again rizes in the final to 31.8 grams. The average daily amount of water in the feces of the preliminary period was 131.8 grams, in the water period 92.8 grams and in the final period 89.3 grams. Notwithstanding the large amount of water passed into the intestin during the water period, there was less in the feces during that time than before; the amount of water excreted in the feces in the final period was slightly less than the amount in the water period. The total amount of feces and of dry matter for the final period were only slightly higher than those of the water period and not nearly as high as those of the preliminary.

Digestion and Absorption of Carbohydrate.—The average daily excretion of carbohydrate during the preliminary period was 2.52 grams, during the water period 1.55 grams, and during the final period 1.81 grams. It appears that the effect of the large amount of water was to secure a better digestion and more complete utilization of the ingested carbohydrate, and the influence of the water extended beyond the time in which it was used.

The amount of carbohydrate in Stool No. 5, the first of the water period is 2.09 grams, the largest amount during any day of the period. This is the more striking since the entire stool contained only 28.2 grams solid matter, of which 5.8 grams were fat. The total nitrogen was also above the average, and the bacterial and extractive or acid-alcohol-soluble portions were unusually low. All of these facts indicate incomplete digestion of the food. Stool No. 5 was passed immediately after breakfast on the morning of the second day of water. Before breakfast Stool No. 4 had been passed; this contained none of the charcoal that had been taken before breakfast on the morning of the day before, the first day of the water. Charcoal was found in No. 5. W records a feeling of pressure on the first day of water as well as on the second, but on the second it seemed to increase. Stool No. 5 gives evidence from its high content of water and of foodstuffs that it was forced out before the time necessary for satisfactory digestion and absorption. Notwithstanding that this, the first stool of the water period contained, undigested protein, fat and carbohydrate, nevertheless an examination of the data shows that the average daily output of those substances was markedly lowered under the influence of water ingestion.

Discussion of Data from Subject H, Table II.—The average daily amount of feces passed during the water period was less than that in either preliminary or final periods. The average amount in the period after the water is less than that in the period before the water. The average daily dry matter suffered a similar drop during the water period. The amount of water in the feces during the water period was also less than during the

TABLE II.—SUBJECT H.

	Number of stool.	Weight. Grams.	Per cent. dry matter.	Amount dry matter. Grams.	Amount moisture. Grams.	Carbohydrate. Grams.
Prel. period. 3 days	1	42.5	29.42	12.5	30.0	0.57
	2	87.0	26.54	23.1	63.9	1.20
	3	158.0	26.57	42.0	116.0	2.37
	4	104.0	26.21	27.3	76.7	1.80
Total		391.5	...	104.9	286.6	5.94
Average (per day)		130.5	26.8	35.0	95.5	1.98
Water period. 5 days	5	54.0	17.71	9.6	44.4	0.66
	6	81.7	27.95	22.8	58.9	1.45
	7	43.0	31.68	13.6	29.4	0.82
	8	269.5	24.33	65.6	203.9	3.89
	9	141.0	22.00	31.0	110.0	1.87
Total		589.2	...	142.6	446.6	8.69
Average (per day)		117.8	24.2	28.5	89.3	1.74
Final period. 3 days	10	101.0	23.90	24.1	76.9	1.06
	11	25.5	33.40	8.5	17.0	0.37
	12	112.0	27.90	31.3	80.7	1.71
	13	141.5	25.92	36.7	104.8	1.92
Total		380.0	...	100.6	279.4	5.06
Average (per day)		126.7	26.2	33.5	93.1	1.69

preliminary or final periods showing that even with the large amounts of water sent into the intestin the amount absorbed was actually more than the excess administered.

Carbohydrate.—The data from the carbohydrate determinations are not as striking as those from Subject W but the variations are in the same direction. The average daily excretion during the preliminary period, 1.98 grams, fell to 1.74 grams during the water period, and was still less, 1.69 grams per day, in the final period.

Summary.—The findings obtained in this experiment show that during the period when large amounts of water were taken with meals the total amounts of feces, of fecal dry matter and of fecal moisture were less than without the unusual amounts of water, and that a more or less permanently better utilization of carbohydrate accompanied the water drinking.

Experiments on Moderate Water Drinking.

Before considering the data obtained in the experiment on moderate water drinking a word of explanation should be given regarding Subject E. During the preceding year while he was serving as subject on another metabolism experiment and was on a uniform diet a pronounced intestinal fermentation made itself evident by a stool of high moisture content. Although he was subject to a condition of this kind even on an ordinary mixed diet he made no mention of this and was therefore accepted for the present metabolism study. The condition was one apparently peculiar to the organism and was not dependent upon such external conditions as could easily be determined and controlled. Subject W had served in the preceding experiment.

The diets of the two men were alike in composition but differed slightly in quantity.

SUBJECTS W.

	Amount (per meal).		Carbohydrate.
Graham crackers	125 grams		90.6 grams
Peanut butter	20		3.2
Milk	400 (cc.)		22.8
Butter (carbohydrate negligible)	25		——
		Total,	116.6

SUBJECT E.

	Amount.		Carbohydrate.
Graham crackers	150 grams		108.8 grams
Peanut butter	20		3.2
Milk	400 (cc.)		22.8
Butter (carbohydrate negligible)	25		——
		Total,	134.8

For water ingestion see paper on fat utilization.

In addition to the weights of feces, dry matter and moisture, the values for the daily excretion of dry bacteria are also given; the values have been calculated from the bacterial nitrogen values on the basis of a nitrogen content of dry bacteria equal to 10.96 per cent.; this is more fully explained by us in a recent paper on the method for determining bacterial nitrogen.*

Discussion of Data from Subject W, Table III.—The separation of the preliminary period of low water ingestion into two parts showed a condition for carbohydrate and for total fecal output similar to that noted for fat and protein. The average amount of feces passed per day during the first part of this period was 89.0 grams, as against 104.6 grams in the second. The average daily dry matter content during the first part of this period was 23.9 grams as against 27.3 grams during the second part. The differences are small but not inconsiderable. Carbohydrate also shows an increase from 2.15 grams per day in the first part to 2.31 grams in the second. Comparing this preliminary period with that of the first experiment, the average daily amount of feces in the first experiment was

* Mattill and Hawk: *J. Exp. Med.*, **14**, 433 (1911).

TABLE III.—SUBJECT W.

	Number of stool.	Weight. Grams.	Per cent. dry matter	Amount dry matter. Grams.	Amount moisture. Grams.	Bacterial dry substance. Grams.	Carbohydrate. Grams.
Prel. period I. 7 days	1......	155.5	25.94	40.3	115.2	...	3.16
	2......	39.2	31.57	12.4	26.8	...	1.14
	3......	63.7	27.78	17.7	46.0	...	1.92
	4......	72.0	28.92	20.8	51.2	...	1.89
	5......	201.8	27.04	54.6	147.2	...	5.22
	6......	90.9	23.50	21.4	69.5	...	1.74
Total......................		623.1	...	167.2	455.9	...	15.07
Average (per day)............		89.0	26.85	23.9	65.1	...	2.15
Prel. period II. 6 days	7......	62.8	25.61	16.1	46.7	4.40	1.52
	8......	98.8	26.72	26.4	72.4	6.32	2.08
	9......	109.8	27.50	30.2	79.6	7.21	3.05
	10......	185.8	24.10	44.8	141.0	10.10	3.58
	11......	41.8	31.23	13.1	28.7	2.62	1.03
	12......	104.9	24.28	25.5	79.4	5.38	2.15
	13......	24.0	32.87	7.9	16.1	1.78	0.45
Total......................		627.9	...	164.0	463.9	37.80	13.86
Average (per day)............		104.6	26.10	27.3	77.3	6.30	2.31
Water period. 10 days	14......	31.6	23.90	7.6	24.0	1.82	0.25
	15......	147.5	27.52	40.6	106.9	8.98	2.25
	16......	75.4	26.20	19.8	55.6	5.13	1.20
	17......	144.8	27.45	39.8	105.0	9.92	2.60
	18......	63.9	26.84	17.2	46.7	4.02	1.37
	19......	115.5	27.10	31.3	84.2	7.97	2.51
	20......	26.0	27.49	7.2	18.8	1.81	0.56
	21......	169.0	26.52	44.8	124.2	11.84	4.60
	22......	127.0	24.35	30.9	96.1	8.04	2.93
	23......	152.7	23.26	35.5	117.2	9.08	3.54
Total......................		1053.4	...	274.7	778.7	68.60	21.81
Average (per day)............		105.3	26.12	27.5	77.8	6.86	2.18
Final period. 5 days	24......	60.0	24.67	14.8	45.2	3.80	1.34
	25......	119.6	23.38	28.0	91.6	7.51	2.41
	26......	51.1	27.50	14.1	37.0	4.21	1.10
	27......	142.7	25.05	35.8	106.9	10.59	2.27
	28......	81.4	27.96	22.8	58.6	6.91	1.82
	29......	53.4	30.61	16.4	37.0	4.91	1.39
Total......................		508.2	...	131.9	376.3	37.92	10.33
Average (per day)............		101.6	25.90	26.3	75.3	7.59	2.07

177.8 grams as against 89.0 in the second; dry matter 46.0 grams in the first as against 23.9 in the second; carbohydrate 2.52 grams in the first as against 2.15 in the second.

Carbohydrate.—An examination of the data upon carbohydrate excretion during the ten-day water period reveals differences that are small but nevertheless in the same direction as noted in the experiment on copious water drinking. The daily average excretion in the preliminary period, 2.31 grams, fell to 2.18 grams in the water period, and was still lower, to 2.07 grams, in the final period.

Discussion of Data from Subject E, Table IV.—The findings upon the fecal output of Subject E during the three periods of this experiment show variations so small that they admit of no conclusions.

TABLE IV.—SUBJECT E.

	Number of stool.	Weight. Grams.	Per cent. dry matter.	Amount dry matter. Grams.	Amount moisture. Grams.	Bacterial dry substance. Grams.	Carbohydrate. Grams.
Prel. period. 7 days	1.	88.4	20.81	18.4	70.0	...	2.48
	2.	30.2	26.56	8.0	22.2	...	1.18
	3.	179.2	23.01	41.2	138.0	...	4.98
	4.	193.9	24.67	47.8	146.1	...	7.21
	5.	76.9	26.17	20.1	56.8	..	2.37
	6.	207.7	22.78	47.3	160.4	...	5.31
	7.	124.6	22.30	27.8	96.8	...	3.49
	8.	44.0	29.42	12.9	31.1	...	1.38
Total		944.9	...	223.7	721.2	...	28.40
Average (per day)		135.0	23.70	32.0	103.0	...	4.06
Water period. 10 days	9.	76.5	22.87	17.5	59.0	4.89	2.48
	10.	140.9	20.88	29.4	111.5	9.90	4.47
	11.	63.8	29.16	18.6	45.2	6.25	1.55
	12.	169.0	24.30	41.1	127.9	12.52	4.04
	13.	247.5	19.19	47.5	200.0	13.17	4.80
	14.	135.3	22.96	31.1	104.2	9.29	3.33
	15.	192.4	19.58	37.7	154.7	9.88	4.18
	16.	79.2	24.58	19.5	59.7	4.77	1.33
	17.	55.9	27.17	15.2	40.7	3.88	1.48
	18.	173.5	24.91	43.2	130.3	12.25	3.68
	19.	51.5	27.98	14.4	37.1	4.06	1.17
Total		1385.5	...	315.2	1070.3	90.85	32.51
Average (per day)		138.6	22.73	31.5	107.1	9.09	3.25
Final period. 4 days	20.	67.3	23.60	15.9	51.4	3.88	1.42
	21.	117.8	26.08	30.7	87.1	9.26	2.76
	22.	147.7	23.19	34.3	113.4	9.74	3.46
	23.	145.9	26.49	38.7	106.2	11.34	4.53
	24.	31.2	31.55	9.8	21.4	1.78	0.81
Total		509.9	...	129.4	380.5	36.0	12.98
Average (per day)		127.5	25.34	32.3	95.2	9.0	3.25

Carbohydrate.—The average daily excretion of carbohydrate dropped from 4.06 grams to 3.25 grams during the water period, and stayed at the same value in the final. This is a small difference to be significant but on a uniform diet the evidence is creditable; it points to the same conclusion for moderate water drinking that has been reached up to this time for copious water drinking.

On the basis of these data it appears that the effect of a moderate amount of water with meals is in the same direction as when large amounts are used, although the differences observed are much smaller and not as uniformly found as with the copious amounts of water. Absolutely no harmful results could be detected.

Copious Water Drinking by an Habitual Water Drinker.

The experiment of 14 days, during the 5-day water period of which Subject E took 1333 cc. of water additional with each meal, remains to be considered.

TABLE V.—SUBJECT E.

	Number of stool.	Weight. Grams.	Per cent. dry matter.	Amount dry matter. Grams.	Amount moisture. Grams.	Bacterial dry substance. Grams.	Carbohydrate. Grams.
Prel. period. 6 days	1	35.2	28.88	10.2	25.0	2.80	1.02
	2	66.0	28.48	18.8	47.2	6.32	2.03
	3	202.2	24.65	49.8	152.4	15.64	5.59
	4	129.2	24.89	32.2	97.0	9.92	3.17
	5	161.3	21.43	34.6	126.7	10.99	3.73
	6	171.8	22.61	38.8	133.0	11.54	4.43
	7	34.6	27.24	9.4	25.2	3.32	0.97
Total		800.3	...	193.8	606.5	60.52	20.94
Average (per day)		133.4	24.21	32.3	101.1	10.09	3.49
Water period. 5 days	8	90.3	20.15	18.2	72.1	5.83	2.14
	9	37.2	27.33	10.2	27.0	3.33	1.06
	10	249.4	23.57	58.8	190.6	18.61	7.72
	11	74.7	26.57	19.9	54.8	6.01	1.52
	12	258.0	14.81	38.2	219.8	9.86	6.42
	13	52.6	30.23	15.9	36.7	4.81	1.23
Total		762.2	...	161.1	601.1	48.47	20.12
Average (per day)		152.5	21.12	32.2	120.2	9.69	4.02
Final period. 3 days	14	128.3	23.09	29.6	98.7	9.50	3.07
	15	86.4	24.34	21.0	65.4	7.00	1.51
	16	206.5	21.56	44.5	162.0	14.19	3.06
	17	50.6	11.06	5.6	45.0	1.45	0.43
Total		471.8	...	100.8	371.0	32.14	8.07
Average (per day)		157.3	21.36	33.6	123.7	10.72	2.69

Discussion of Data from Subject E, Table V.—An examination of the data in Table V shows that the average amount of feces excreted per day was 133.4 grams during the preliminary period, 152.5 grams during the water period, and 157.3 grams in the final period. This marked increase during the water and final periods is not evident from the values for dry matter. During the preliminary period this averaged 32.3 grams per day, during the water period 32.2 grams per day, and during the final 33.6 grams per day, values which are strikingly uniform.

The apparent increase in the average daily amount of feces was thus due to water only, and it would seem that the absorption limit of water in the intestin had been reached. While no difficulty was experienced in drinking the large volume of water, the limit for its absorption had been passed. In the case of Subject W in the first experiment there was no evidence of having reached the absorption limit, while some difficulty was at first experienced in ingesting and disposing of the large quantity of water. This would lead to the conclusion that individuality and dietary habit are important factors.

Carbohydrate.—The average daily excretion of carbohydrate rose from 3.49 in the preliminary period to 4.02 in the water period, and fell to 2.69 in the final period. Stool No. 12 weighing 258 grams contained 6.42 grams of carbohydrate and only 38.2 grams of solid matter; there was pronounced evidence of fermentation. It was passed 15 hours before the usual time and was evidently the result of the intestinal conditions previously mentioned, to which E was subject at times. A larger amount of undigested material than was usual might therefore be expected, and its appearance could not be attributed to the effect of the water. The fall in excreted carbohydrate during the final period is marked, and shows rather conclusively that the high daily average output during the water period was not due to the fact that water interfered with the digestion of ingested carbohydrate but rather that the unusual finding during the water period may logically be explained as above.

Discussion.

The findings of decreased fecal output, both dry matter and moisture, and a decreased elimination of carbohydrate during the periods of water drinking indicate a more complete absorption of both water and dissolved material, with the exceptions noted above. It has been seen, in the preceding papers, that this decreased excretion of solid matter was the result also of a better utilization of the nitrogen (protein) and fat of the diet.

If drinking water with meals brought about a more rapid emptying of the stomach, the carbohydrates might reasonably be expected to give the first evidence of this fact because of all the foodstuffs carbohydrates are normally the first to leave the stomach and a shortening of the time of their sojourn there might mean incomplete hydrolysis of starch by salivary amylase. In experiments on dogs London and Polovzova[6] have shown that sucrose and erythrodextrin alone suffer a slight hydrolysis in the stomach, due not to enzymes but to hydrochloric acid, and that under no conditions are carbohydrates absorbed in the stomach. In the duodenum hydrolytic cleavage is very extensive but absorption does not begin until the upper ileum is reached where the greater portion of carbohydrate is absorbed. The great importance of the duodenal juices in carbohydrate digestion is hereby emphasized.

This evidence may be of less value because of the fact that the saliva of the dog has at most but a slight amylolytic power.[6a, 6b, 6c]

In this connection it should also be noted that certain experiments in this laboratory[7] have shown that the production of pancreatic amylase is increased under the influence of water drinking, as would be supposed, and this fact may account in part, for the better utilization of carbohydrate.

As to the absorptive activity of the stomach toward carbohydrates, von Mering[8] concluded from some of his observations that the various sugars could be absorbed in the stomach, absorption being dependent upon the concentration of the solution; that below 5 per cent. glucose was not sensibly absorbed.

The experiments upon the absorption of carbohydrate solutions of different concentrations in the intestin have been very clear in showing the acceleration of absorption by dilution. In experiments on dogs with intestinal fistulas Kaoru Omi[9] has found that in the absorption of solutions of sodium chloride and glucose the percentage of sodium chloride and glucose absorbed depends on the concentration of the solutions introduced and is maximum for isotonic solutions. The absorption of cane sugar is maximum at lower than isotonic concentration. The amount of water absorbed diminishes with increasing concentration of the solute and at slight hypertonicity absorption is checked.

London and Polovzova[10] have made similar experiments with solutions of glucose on dogs with intestinal fistulas and the following are their findings. With increasing concentrations of the glucose solutions introduced, absorption of water in the intestin diminishes progressively. With higher concentrations a diluting secretion begins to flow from the wall of the intestin; its amount runs parallel with increasing concentration of the glucose solution, and at its maximum it may amount to one-half the total quantity of blood in the animal. By this dilution and also by absorption of sugar the concentration of the solution is brought down to 6–8 per cent., a dilution at which absorption takes place very readily in the lower intestinal tract. The secretion of the diluting fluid begins with the coming in of the first glucose solution and continues fairly uniformly. Dilute glucose solutions seem better adapted to absorption than concentrated ones. In the lower portions of the intestinal tract the concentration tends toward a value that is lower than isotonic. The diluting secretion has a small amount of nitrogen (0.1 per cent.) and possesses a kinase, so that in part at least it represents an increased intestinal secretion. For concentrated solutions absorption seems to take place in two stages: in the proximal portion of the intestin the proper dilution is reached, in the distal portion absorption takes place. The intestinal wall differs from the stomach wall in that the latter does not dilute concentrated solutions. The absorption of water and of dissolved substances must be considered as two independent and distinct processes, brought about by different factors. The ability to regulate automatically the concentration of substances to be absorbed is believed to be a part of the function of the digestive juices.

Applying these findings to the experiments on water drinking with meals the explanation for the more complete digestion and absorption of carbohydrates during the period of water ingestion is facilitated. Increased dilution is the effective factor. While it would seem in these experiments that the water taken with a given meal is voided in the urine before the bulk of the food material of that meal has reached the intestin, nevertheless some of the food must be carried along with the water. And further, since absorption is going on more or less continuously in the intestin, the water taken with one meal aids in diluting the products of the previous meal which are in the intestin. Not only is enzyme action more complete in dilute solutions but such solutions are also better adapted to absorption. When the solutions to be absorbed are not dilute the organism must first make them so by pouring out a diluting secretion; if they have been made dilute, the organism is spared this task.

It has been shown by Mosenthal[11] that nitrogen to the amount of about 35 per cent. of the food nitrogen of a mixed diet is daily secreted in the succus entericus of dogs, and that of this quantity an amount equal to 10 per cent. of the food nitrogen is excreted in the feces and an amount equal to 25 per cent. of the food nitrogen is reabsorbed. The metabolic significance of this reabsorption is not understood, but it is probably of great importance. In cases of defective absorption the amount of fecal nitrogen may easily be increased from this source and thus lead to the drawing of wrong conclusions. It is obvious that for various reasons, this possibility need not be considered in connection with water drinking.

That secretion and absorption are exothermic in their nature and require energy has frequently been shown and again recently,[12, 13] and in their first report of observations on the stimulating action of water upon the gastric, mucous membrane, Foster and Lambert[14] suggest that a physiological basis for the objection to copious water drinking with meals may be found in the increased activity to which the glands are thus forced. If glandular activity requires as much energy as other forms of activity, this special and excessive secretion may be a form of extravagance leading to the weakening and premature death of the cells. In fact, they find that the juice excited by a meal following 5 or 6 hours after a meal with water and its greater demands is less in amount than a normal meal should excite. Whether this is a true gland fatigue, and whether or not such observations point to a premature death of the cells can be determined only by histological examinations.[1] Applying this reasoning to the secretory activity of the intestin a similar form of extravagance may be said to be caused in the intestin by insufficient water ingestion with meals. If there is a loss in energy in the increased flow of gastric juice by water drinking, this is more than compensated by better digestion and absorption of food in the intestin, while the needless energy used in preparing a diluting secretion for food which is too concentrated is a direct loss uncompensated by any subsequent factors making for better utilization of the food. The preservation of the digestive efficiency of the intestin is probably of much greater importance than that of the stomach, since it may be that the main offices of the stomach are not those of a digestive nature.[15]

Conclusions.

(1) It has been shown that in men living on a uniform diet the addition of 1000 cc. of water to each meal causes a decrease in the excretion of fecal material, both dry matter and moisture.

(2) Under the same conditions a decrease in excreted carbohydrate material was also observed.

(3) The better utilization of food material thus evident was not temporary but appeared to extend for some time following the use of water.

(4) The ingestion of a smaller amount of water (500 cc.) and the use of a large volume of water (1333 cc.) by one accustomed to drinking water with meals showed a similar but less marked reduction in the excretion of carbohydrate.

(5) The individual variations noted emphasize the fact that the findings on two or three men possessing different dietary habits and accustomed to ingesting varying volumes of water with meals may not be generalized.

(6) The beneficial effects noted are probably due to the stimulatory action of water upon the digestive secretions, to the increased dilution which facilitates enzyme action and materially aids in absorption, and to a conservation of the intestinal energy involved in the secretion of a diluting fluid which is necessary when insufficient water is ingested.

(7) The average daily output of dry bacterial substance for the 66 stools completely examined was 8.27 grams.

[1] Investigations of this character are contemplated.

(8) Many desirable and no undesirable effects were obtained by the use of water with meals, and in general, the more water taken the more pronounced were the benefits.

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STUDIES OF THE TRYPTIC DIGESTION OF SILK.[1]

FIRST PAPER.

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Introduction.

Städeler[2] in 1859 first demonstrated that silk was composed of two parts, fibroin and silk glue or sericin. The dissociation products of these parts were, however, first studied by Cramer,[3] who obtained serine from silk glue, and subsequently by Weyl,[4] Vignon,[5] Wetzel[6] and E. Fischer.[7]

Silk fibroin is insoluble in superheated water, dilute acids or alkalies. It has been shown by E. Fischer that fibroin may be heated with water for hours at 117–120°, if the reaction be exactly neutral; however, in the presence of acids or alkalies considerable change takes place under these conditions. According to Weyl it is not attacked by either pepsin or trypsin, a statement disproved with respect to the latter enzyme, by my investigations.

Fibroin contains more than 50 per cent. glycine and alanine and 10 per cent. tyrosine, leucine being present in only small amounts, while

[1] This investigation was undertaken at the suggestion of the late Professor W. F. Koelker, at the University of Wisconsin, and was pursued in its early stages under his direction. The author also wishes to acknowledge his indebtedness to Professor Richard Fischer and Louis Kahlenberg for their interest in the work.

[2] *Ann.*, 111, 12.

[3] *J. prakt. Chem.*, 96, 76 (1865).

[4] *Ber.*, 21, 1407 (1888).

[5] *Compt. rend.*, 115, 613 (1892).

[6] *Z. physiol. Chem.*, 26, 535 (1899).

[7] *Ibid.*, 33, 171 (1902).