analogous to the hydrochlorides of amino acids, are physiologically much less active. Such mixtures hold scarcely enough acid to digest themselves perfectly. If further amounts of protein are added, with pepsin, digestion becomes very slow. When the protein and hydrochloric acid are so related as to bring the [H] concentration down to $P_H = 2.96$ the rate of digestion is slow. This is the case when the weight of the acid is about 3.5% of the weight of the egg albumin, and 150 cc. of $N/15$ acid is the liquid volume.

On the other hand, when the weight of the acid in 150 cc. of $N/15$ HCl is about 10% of the weight of the albumin, and the hydrogen concentration of the supernatant liquid is about $P_H = 1.69$, we have very rapid digestion. This appears to be near the maximum of activity. We find all degrees of digestive activity between these limits. Dry preparations of protein and hydrochloric acid about midway between these limits cease to be physiologically active.

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GASTRO-INTESTINAL STUDIES. VII. THE UTILIZATION OF INGESTED PROTEIN AS INFLUENCED BY UNDERMASTICATION (BOLTING) AND OVERMASTICATION (FLETCHERIZING).

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Received July 18, 1914.

1. Introduction.

Within the last few years attention has been frequently called to the importance of the proper mastication of food. Campbell[1] in 1903 made the following statements:

"The primary object of mastication is to break up the food so as (1) to facilitate the swallowing of it and (2) to insure its admixture with the digestive juices, both of the mouth and whole digestive canal. Mastication has other far-reaching effects. It promotes the flow of saliva, secures proper insalivation of food, increases the quantity of alkaline saliva passing into the stomach, stimulates the heart and circulation, and, finally, influences the nutrition of the jaws and their appendages by stimulating blood and lymph circulation. Proper mastication tends to diminish the amount of food consumed, by reducing the quantity needful to constitute a sufficiency, for the more perfectly a food is chewed the more perfectly is it digested and the more economically is it disposed of in the system. Insufficient mastication is the cause, direct or indirect, of many evils. It may cause local irritation resulting in acute gastritis; appendicitis is believed by Sir Frederick Treves to be due directly to food bolting, gastric intestinal catarrh may be induced through the action of certain toxins; gastric secretion may be checked through paralysis of stomach nerves, while the teeth and jaw structures are underdeveloped and disposed to disease."

[1] *Lancet*, July 11, 1903.

Chittenden[1] has stated that thorough mastication of food is a material aid to digestion which is to take place in the stomach and intestine. Metchnikoff,[2] on the other hand, argued that it is harmful to chew food too long and to swallow it only after it has been kept in the mouth a considerable time. A disease known in America as "Bradyphagia" has arisen from the habit of eating too slowly. Einhorn[3] found that the disease is rapidly cured when the patients make up their minds to eat more quickly. According to Brown[4] the importance of chewing with reference to protein foods at least, has been grossly overestimated. He has emphasized that all high-protein feeding animals bolt their food.

In recent years the advantages of eating slowly and chewing thoroughly have been suggested by Horace Fletcher[5] and his associates. As a result the term, fletcherism, has crept into our language. Experimental work undertaken by Chittenden, Fletcher and others has shown that by practicing thorough mastication man can, for a time at least, maintain his life processes normally on a supply of protein food less than one-half as large as that prescribed by the socalled standard dietaries.

2. Description.

Purpose and Plan.—The purpose of this investigation was to study the utilization of a typical protein as influenced by different degrees of mastication. The experiment was conducted upon two young men and consisted of four seven-day periods as follows: (1) Preliminary normal, during which the food was masticated normally; (2) bolting, in which the meat was swallowed with no attempt at mastication; (3) fletcherizing, when the food was chewed until carried down the oesophagus by the "swallowing impulse;" (4) final normal, in which ordinary mastication was practiced. The preliminary normal period of nine days was subdivided into a six-day and a three-day period. This is explained by the fact that the diet was increased at the beginning of the latter subperiod.

Subjects.—The subjects of this experiment were two laboratory assistants, F and J. F was a man of medium size, 22 years old and 58.3 kg. in weight. Previous to the experiment he had been on a comparatively simple protein diet. J was of larger build, 24 years of age, and weighed 63 kg. Previously, he had been ingesting a rather high protein diet at one of the local boarding clubs.

Diet.—A uniform diet of the following composition was fed throughout the experiment:

[1] Chittenden, "Nutrition of Man," New York, **1907**, p. 23.

[2] Metchnikoff, "Prolongation of Life," New York, **1908**, p. 159.

[3] Einhorn, *Z. diät. u. physik. Ther.*, **8**, 622 (1905).

[4] Brown, "Parcimony in Nutrition."

[5] H. Fletcher, "New Glutton or Epicure," New York, **1906**.

TABLE I.

Food.	Subject F. Amount. G. or cc.	Subject F. Nitrogen. G.	Subject J. Amount. G. or cc.	Subject J. Nitrogen. G.
Beef	185	11.207	215	13.025
Graham crackers	150	1.932	150	1.932
Milk	650	3.309	800	4.072
Butter	150	0.155	150	0.155
Water	1800	..	2100	..
Salt	16	..	2.0	..
Agar-agar	10	..	15	..
Total	..	16.603	..	19.184

It is to be noted that meat contributed the major portion of the protein of the diet. The meat, which consisted of the best round steak procurable, was freed from all visible fat and connective tissue and was cut into 15 mm. cubes. It was cooked by being allowed to simmer for two and one-half hours in boiling water. After thorough mixture it was sampled for analysis, placed in pint mason jars, and autoclaved at 115° by the discontinuous method. The jars were stored in a refrigerator. Distilled water was drunk throughout the experiment. Agar-agar was added to the diet to facilitate defecation.

Methods.—Carmine was used to separate the feces of the several periods, satisfactory differentiations resulting in every instance. The carmine was taken in a gelatine capsule with the initial meal of each period. Total nitrogen was determined in foods, feces, and urine. The Kjeldahl method was employed, copper sulfate being used in the digestion. Analysis of feces was made on each individual stool, except when two or three small stools were passed within a short time, in which cases they were combined. Determinations were made in duplicate upon the fresh stools without previous drying. After defecation each stool was weighed, thoroughly mixed until uniform throughout, and transferred to a weighing bottle. As soon after as possible, samples were weighed for analysis. During the bolting period the macroscopic meat residues present in the feces were carefully removed and their nitrogen content determined separately. Urine was collected in 24 hr. periods, two-liter acid bottles being used as containers and powdered thymol added as a preservative.

Daily Routine.—The daily periods began and ended at 7.15 A.M. The daily program was as follows: 7.15 A.M., urination and defecation; 7.20, body weights without clothing; 7.45, breakfast; 12.00, luncheon; 5.00, exercise; 6.00, dinner; 10.30, bed. Defecation did not always occur before breakfast.

The daily ration was divided approximately into three equal portions, one for each meal. Subject F took 300 cc. of water with each meal. Two or three hours after each meal 300 cc. were drunk, making a total of 1800 cc. for the 24 hours. Subject J also ingested 300 cc. with each meal but took 400 cc. after meals, making a total 24-hour intake of 2100 cc. Exercise was taken at 5.00 each afternoon. This consisted either of a brisk two and a half mile walk or a twenty-minute swim. Both subjects were working especially hard on research problems throughout the experiment

3. Experimental.

Discussion of Data.—The protein utilization was calculated by the ordinary method:

$$\frac{(\text{Nitrogen in Food} - \text{Nitrogen in Feces}) \times 100}{\text{Nitrogen in Food}} = \text{Percentage Utilization}$$

1. Subject F—Table II.—In the ordinary preli minary normal period the average daily output of fecal nitrogen was 0.759 g. This value was increased to 0.948 g. in the bolting period. The protein utilization fell from 95.43% to 94.29%. As a result of fletcherizing the food, the daily output of fecal nitrogen was lowered to 0.726 g. This was a slight decrease from the value obtained in the preliminary normal period. A correspondingly higher utilization, 95.63% was sustained during this period. In the final normal period the daily nitrogen output increased slightly to 0.765 g., a value differing but little from that of the preliminary normal period.

The results obtained are not surprising. The fine comminution of the food brought about by fletcherizing would induce its more complete utilization, thus reducing the nitrogen output in the feces. On the other hand the fact that every stool passed during the bolting period contained macroscopic meat residues seemingly indicates that the food was less efficiently utilized during this period. However, if the mean nitrogen excretion of the two normal periods is compared with that of the fletcherizing period, a slight difference of 0.036 g. of nitrogen per day is noted. Comparing in the same way the protein utilization we note that the increase is but 0.22% in favor of fletcherism. It may be concluded that even though meat residues of macroscopic size were found in the feces passed during undermastication, the total amount of meat residues was but slightly in excess of that in the normal feces.

Passing to the urinary data, the average daily nitrogen excretion of 16.369 g., during the preliminary period fell to 16.229 g., in the bolting period. This value rose to 16.697 g., in the fletcherizing period and fell to 16.639 g. in the final normal period.

The decreased urinary nitrogen excretion during food bolting might be explained by the fact that less of the ingested protein was hydrolytically split by the digestive juices. The increased output of fecal nitrogen coupled with the appearance of macroscopic meat residues in all stools from this period, lends support to this explanation. The fine division

TABLE II.

Subject F.

Day.	Urine. Vol. cc.	Body wt. Kg.	Weight stool.	Total nitrogen. (G.) Food. Feces..	Urine.	N balance. G.	N absorbed. G.	Utilization. %.
				Preliminary Normal 3 days.				
1	1200	58.36	95.5		16.712	—0.868	..	...
2	1568	58.38	127.0		16.351	—0.507	..	...
3	1635	58.37	153.5	16.603—0.759	16.044	—0.200	..	...
Average...........			94.0		16.369	—0.525	15.844	95.43
				Bolting 7 days.				
1	1820	58.12	94.0		15.511	+0.144	..	...
2	1580	57.94	121.5		16.273	—0.618	..	...
3	1730	57.92	78.2		16.312	—0.657	..	...
4	1490	58.10	104.9		16.250	—0.595	..	...
5	1335	57.90	224.0	16.603—0.948	16.869	—1.214	..	...
6	980	57.87	111.4		15.956	—0.301	..	...
7	1160	57.81	...		16.433	—0.678	..	...
Average........			90.6		16.229	—0.574	15.655	94.29
				Fletcherizing 7 days.				
1	1560	57.77	88.5		18.106	—0.229	..	...
2	1530	57.69	158.0		17.234	—1.357	..	...
3	1590	57.54	76.2		16.876	—0.999	..	...
4	1410	57.70	152.4		16.447	—0.570	..	...
5	1675	57.46	115.6	16.603—0.726	16.919	—1.042	..	...
6	1220	57.44	...		13.748	+2.139	..	...
7	1700	57.40	...		17.546	—1.669	..	...
Average........			84.4		16.697	—0.620	15.877	95.63
				Final Normal 7 days.				
1	1435	57.14	42.7		16.445	—0.607	..	...
2	1295	57.07	120.0		16.271	—0.433	..	...
3	1560	57.29	216.5		16.349	—0.511	..	...
4	1455	57.23	114.9		16.502	—0.664	..	...
5	1868	57.28	117.3	16.603—0.765	16.559	—0.721	..	...
6	1820	56.78	...		16.309	—0.471	..	...
7	1760	56.83	...		18.041	—0.203	..	...
Average........			87.3		16.639	—0.801	15.838	95.39

of the meat by fletcherism, on the other hand, probably induced the splitting of a larger quantity of protein by the digestive juices, and this in turn resulted in the appearance of an increased amount of exogenous nitrogen in the urine. As the daily nitrogen excretion was slightly higher during the final than in the preliminary normal period, it may be concluded that the effect of fletcherizing the food extended into the subsequent period.

2. **Subject J—Table** III.—During the preliminary normal period protein was not so well utilized as in the subsequent periods. The average

daily nitrogen output in feces was 1.306 g., the utilization being 93.19%. In the bolting period the daily nitrogen output was 1.266 g., with a utilization value of 93.41%. In the fletcherizing period the fecal nitrogen decreased, the average output being 0.906 g. per day. An accompanying increased utilization value of 95.32% was manifest. An average output of 0.919 g. was sustained during the final normal period of the experiment. The utilization was only slightly decreased, the value here being 95.21%.

TABLE III.

Subject J.

Day.	Urine. Vol. cc.	Body wt. Kg.	Wt. stool. G.	Total nitrogen. (G.) Food. Feces.	Urine.	N balance. G.	N absorbed. G.	Utilization. %.
				Preliminary Normal 3 days.				
1	1690	63.80	103.5		18.850	—0.942	..	...
2	1707	63.55	147.0		18.798	—0.920	..	...
3	1660	63.64	130.0	19.184–1.306	18.827	—0.949	..	...
Average........			126.8		18.827	—0.949	17.878	93.19
				Bolting 7 days.				
1	2110	63.09	125.5		18.519	—0.601	..	...
2	1760	63.80	133.5		16.073	+1.845	..	...
3	1595	63.30	70.2		19.150	—1.232	..	...
4	1690	63.10	146.8		18.131	—0.213	..	...
5	1960	63.18	69.4	19.184–1.266	17.872	+0.046	..	...
6	1834	62.80	61.5		17.841	+0.031	..	...
7	1815	62.70	...		18.345	—0.427	..	...
Average........			86.7		17.990	—0.072	17.918	93.41
				Fletcherizing 7 days.				
1	1850	62.65	27.4		21.189	—2.911	..	...
2	1640	62.52	90.0		19.946	—1.668	..	...
3	1195	62.62	76.7		19.708	—1.430	..	...
4	1440	62.75	141.0		20.130	—1.852	..	...
5	1880	62.72	169.2	19.184–0.906	20.464	—2.186	..	....
6	1707	62.57	80.5		19.845	—1.567	..	...
7	2170	62.58	...		19.557	—1.279	..	...
Average........			83.5		20.118	—1.840	18.278	95.32
				Final Normal 7 days.				
1	1490	62.23	40.2		19.960	—1.425	..	...
2	1735	61.88	247.0		20.243	—1.926	..	...
3	1790	62.05	123.6		20.062	—1.797	..	...
4	1910	62.07	144.5		19.745	—1.480	..	...
5	2320	61.91	87.7	19.184–0.919	19.396	—1.131	..	...
6	1812	62.05	...		19.353	—1.188	..	...
7	2422	61.76	...		19.431	—1.166	..	...
Average........			92.0		19.703	—1.438	18.265	95.21

The incomplete utilization of protein during the preliminary period was undoubtedly due to the extremely nervous condition of J. His diary for one of the last days of the period reports, "Much gas in my stomach, a constant taste of the meat eaten, and a general feeling of lassitude." J was constipated during the last days of the period, the final feces not appearing until the fourth day of the subsequent period. It seems reasonable to infer that under these conditions digestion was somewhat sluggish and a consequent inefficient utilization of protein resulted.

The discrepancy in protein utilization between the preliminary and final normal periods is perhaps susceptible of another interpretation. The effects of over mastication may have extended into the final period, in other words, a specific adaptation of the protein digestive juices may have been induced by the fine division of the protein through complete mastication. Neilson and Terry[1] have reported adaptations in the salivary glands of dogs. These investigators found that the saliva of dogs fed on bread exhibited stronger amylolytic power than that of meat-fed dogs. Neilson and Lewis[2] found evidence of adaptation in human saliva, while Simon[3] reported a greater amylolytic activity in human saliva on carbohydrate diet than on either a mixed or protein diet. Mendel, Chapman and Blood,[4] Carlson, and Chittenden,[5] Garry,[6] and Wohlgemuth,[7] have failed to detect any evidence of adaptation of human saliva to diet, even as a result of years of feeding a particular diet. Walther[8] holds that adaptation of the digestive juices may occur if a particular diet be maintained some time, while Labosov[9] has noted lasting alterations in the gastric glands as the result of altered dietetic conditions. London and Krym[10] failed to determine any specific adaptation in the intestinal secretion of dogs. London and Lukin[11] as well as London and Dobrowolskaja[12] failed to detect any adaptation of digestive juices as a result of feeding a particular food. A review of the literature on the subject of adaptation seems to justify the following conclusions of Mendel, Chapman and Blood:[13]

[1] *Am. J. Physiol.*, 15, 406.

[2] *J. Biol. Chem.*, 4, 501 (1908).

[3] Simon, cited by Neilson and Lewis, *Loc. cit.*

[4] Mendel, Chapman and Blood, Collected Papers from Physiological Chemistry Laboratory of the Sheffield Scientific School.

[5] *Am. J. Physiol.*, 26 (1910).

[6] *J. Biol. Chem.*, 3, 11 (1907).

[7] Wohlgemuth, cited by Mendel, Chapman and Blood, *Loc. cit.*

[8] Pawlow, "The Work of the Digestive Glands;" p. 43.

[9] Pawlow, *Loc. cit.*, p. 46.

[10] *Z. physiol. Chem.*, 74, 325 (1911).

[11] London and Lukin, *Z. physiol. Chem.*, 68, 366 (1910).

[12] London and Dobrowolskaja, cited by London and Krym, *Loc. cit.*

[13] Mendel, Chapman and Blood, Collected Papers from Physiological Chemistry Laboratory of the Sheffield Scientific School.

"It is difficult to conceive of a sudden adaptation resulting from several days' feeding of a certain diet as advocated by the Pawlow school. The assumption of an entirely new role by a secretion or gland as the result of a few days' feeding is scarcely a biological probability."

It seems probable that in the case of J the output of fecal nitrogen and consequent protein utilization during the final period of the experiment, should be considered more nearly normal values. The slightly abnormal condition of J during the preliminary period would seem to explain his lowered utilization.

More pronounced difference in the amounts of urinary nitrogen excreted in the several periods were noted in the case of J than was true with F. The daily average of 18.827 g. in the preliminary fell to 17.990 g. in the bolting period and rose to 20.118 g. in the fletcherizing period. As in the experiment on F, a higher value in the final normal than in the preliminary normal period was noted, this output in case of J being 19.703 g. The lowered nitrogen excretion during bolting, and its marked increase during fletcherizing, possibly indicates that the degree of comminution of protein food determines, to a certain extent at least, the amount of hydrolytic cleavage by the digestive juices.

Composition of the Feces. 1. Metabolic Products.—It was formerly believed that all, or nearly all, of the nitrogen of the feces was due to undigested food, Voit[1] first showed that this was not necessarily true but that digestive juices and epithelium might leave residues Voit reached this conclusion when he found that fasting dogs eliminated a dark colored feces. The mucous membrane of the intestine by its secretion and by the abundant quantity of detached epithelium contributes essentially to the formation of feces. This follows from the finding of L. Hermann[2] that a clean, isolated loop of intestine collects material similar to feces.

In studies on food utilization it is important to know what part of the fecal nitrogen is metabolic in origin and what portion is due to undigested food. At present no sharp method of separation is known. Tsuboi[3] has shown that on a flesh diet animals eliminate a feces consisting largely of metabolic products, the composition of which is widely different from that of the ingested meat. There was no proportionality between the amounts of nitrogen fed and the metabolic nitrogen excreted; neither did moderate amounts of nitrogen-free food appreciably alter the character of the feces. This investigator concluded that the greater part of the fecal dry matter is metabolic in origin. Rieder[4] found more nitrogen in feces on a nitrogen-free diet than in fasting feces. Later, this same investigator, using men and dogs as subjects found an increase in the fecal nitrogen

[1] Voit, cited by Mattill and Hawk, **This Journal**, **33**, 12 (1911).

[2] Hermann, *Pflügers Arch.*, **46**, 93 (1890).

[3] *Z. Biol.*, **35**, 68 (1897).

[4] Rieder, cited by Tsuboi, *Loc. cit.*

excretion with the amount of nitrogen-free food fed. Tsuboi reported a similar finding. Rubner[1] found as much nitrogen in feces from a fluor-sugar-starch diet as the average from a meat diet. Using diets varying widely in composition, he obtained feces that differed but slightly in nitrogen content. The percentage of nitrogen in the feces was greater than in the food, except in cases of slightly utilized vegetable foods. Prausnitz[2] held that the composition of human feces never resembles that of ingested food, but on account of residual intestinal juices nearly always has a higher nitrogen content. This investigator also believed that human feces consist largely of residues not of ingested food but of intestinal secretions. Prausnitz reported meat residues in quantities varying from 1–3% of the moist feces, or 0.2%–1% of the ingested meat. The amount of feces, he holds, is dependent upon the character of the food, as some varieties require larger amounts of intestinal juices for digestion than others. H. Fletcher[3] reports a feces of very small volume, pillular in form and almost odorless, as the result of proper mastication of food with its consequent reduction in the amount ingested.

Regarding utilization, Tsuboi[4] maintained that previous work gave values that were too low, and concluded that, as nitrogen is continually being lost in the feces, to preserve body equilibrium it is necessary to replace this as well as the nitrogen excreted in the urine. Mendel and Fine[5] believe that upon the ingestion of a meat diet, whose utilization as usually calculated is about 95%, the resulting feces are for the most part metabolic in origin. From the accumulated evidence it is reasonable to assume that a mixed diet gives fecal nitrogen the major quantity of which is metabolic in origin.

2. **Bacteria in Feces.**—It has been stated that one-third of the dry matter of human feces consists of bacteria, and at least one-half of the total nitrogen content is of bacterial origin.[6] It is a well-known fact that the bacteria of the large intestine depend to a large extent for their nutrition upon the residues, not only of unabsorbed intestinal juices, but also of undigested protein food. Consequently, a quantitative determination of the bacterial nitrogen in feces gives no absolute value, but one that necessarily includes a portion of the nitrogen due to undigested food residues. For this reason fecal bacteria cannot, with absolute accuracy, be included as metabolic products. However, as may readily be recognized, it is impossible experimentally to make a quantitative separation of the metabolic from the non-metabolic products of feces.

[1] Rubner, cited by Tsuboi, *Loc. cit.*

[2] *Z. Biol.*, **35**, 334 (1897).

[3] H. Fletcher, "New Glutton or Epicure," New York, **1906**, p. 150.

[4] *Z. Biol.*, **35**, 68 (1897).

[5] *J. Biol. Chem.*, **11**, 5 (1912).

[6] Strasburger, cited by Mattill and Hawk, *Loc. cit.;* MacNeal, Latzer and Kerr, cited by Mattill and Hawk, *Ibid.;* Mattill and Hawk, *J. Expt Med.*, **14**, 433 (1911).

3. **Estimation of Metabolic Nitrogen in Feces.**—It has been suggested that for every gram of total nitrogen in feces, 0.92 g. arise from residues of digestive juices, while the remaining 0.08 g. are due to unutilized protein food. Though this correction was not based upon any experimental data, it has been used to some extent in calculating utilization values.

To determine experimentally as nearly as possible the portion of total fecal nitrogen due to metabolic products, the method of Mendel and Fine[1] was employed. At the close of the final period of the experiment, the average daily output of feces by each subject during the four periods was calculated. A nitrogen-free diet of equal calorific value to that previously ingested was chosen. To supplement this diet an attempt was made to add agar-agar in amounts sufficient to bring the daily output of feces up to approximately the average daily output during the experiment.

Agar-agar is especially valuable in cases like the present. It gives bulk and softness to the feces and facilitates their elimination. Further,[2] being resistant to bacterial action it causes neither gas formation nor the production of harmful decomposition products. Though in certain of the herbivora common agar my be utilized up to 50%, Lohrisch[3] found that in man it is digestible to but a very small extent. The minute quantities digested are probably hydrolyzed to galactose. The indigestibility of agar is recognized and therefore it is given in cases of constipation. Schmidt[4] believes it to be the best form of cellulose for the correction of constipation, as it is high in hygroscopic properties, non-irritant and absolutely insoluble and unabsorbable.

The feces obtained from the nitrogen-free diet were analyzed for total nitrogen, and daily averages calculated as in the experiment proper. Corrections were applied for the nitrogen of the unutilized butter, carmine and gelatine capsule. This resultant value was subtracted from the average daily nitrogen output of each period. The difference was assumed to be the N due to unabsorbed residues of meat, and the protein utilization was calculated on this basis.

The following nitrogen-free diet was selected for determining the metabolic-nitrogen of the feces:

TABLE IV.

	F.		J.	
	Amount.	Grams N.	Amount.	Grams N.
Butter	300	0.31	320	0.33
Sugar	128	..	128	..
Agar-agar	20	..	25	..
Water	2900	..	3100	..
Salt	1.6	..	2	..

[1] *J. Biol. Chem.*, 11, 5 (1912).

[2] Swartz, *Transactions of ths Connecticut Academy of Arts and Sciences*, **16**, 247 (1911).

[3] Lohrisch, cited by Swartz, *Loc. cit.*

[4] Schmidt, *Münch. Med. Wochschr.*, **41** (1905).

Assuming that the butter was 90% utilized, 10% of the butter nitrogen should appear in the feces. Correction was made for this nitrogen. The actual water ingestion was greater than during the experiment, when the subjects had been receiving milk which contained approximately 87% water. The water represented in the daily milk intake was calculated and the amount added to the original intake. The diet was ingested throughout a four-day period, during which time the usual routine of the experiment was followed as previously described.

a. Subject F.—The daily output of feces was 166.5 g., a much greater average than during the experiment. The average nitrogen content of the output was 0.5 g. No doubt this value is too high, inasmuch as the volume of feces during this period was nearly twice that obtained during the ingestion of the experimental diet and we would be justified in expecting an increase in metabolic nitrogen with an increase in bulk of the material in the intestine. The actual relationship could only be determined by a separate experiment. In Table V are found corrections for fecal nitrogen. It should be noted that after applying this high value as a correction the excretion of nitrogen in form of food residues is still approximately a quarter of a gram per day during normal mastication. The utilization percentages calculated on the basis of the above correction are of course somewhat higher than those in Table II, but undoubtedly they are more nearly correct values.

By calculating the metabolic nitrogen from a bulk of feces equal to that excreted during the experiment, proper, a smaller correction was obtained. The metabolic nitrogen was calculated by a direct proportion as follows: Daily output of feces from experimental diet: Daily output of feces from nitrogen-free diet:: Daily output of metabolic nitrogen during experiment: Daily output of nitrogen from nitrogen-free diet, or

$$89.1 : 166.5 :: M : 0.500 \qquad M = 0.268 \text{ g. per day.}$$

The corrected fecal nitrogen output and the corresponding utilization values are found in Table VI. In using the correction obtained by calculation, tacit assumption is made that the content of metabolic nitrogen is proportional to the volume of feces excreted. Although there are no experimental data covering this point, it is hardly reasonable to expect that such would be the case. It is quite probable that 0.268 g. of metabolic nitrogen per day is a low value. The original value of 0.5 g. per day probably is more nearly normal, although the actual output undoubtedly lies between this and the 0.268 g. obtained by calculation.

b. Subject J.—The daily output of feces, from the nitrogen-free diet, was 124.3 g., in the case of J. As the average daily excretion during the experiment was 97.3 g., the discrepancy here was less than that manifested in the case of F. The metabolic nitrogen output and the corrected utilization percentages (Table VI) should be considered more nearly accurate than were the corresponding values in the case of F. The calculation for metabolic nitrogen was made as previously described:

$$97.3 : 124.3 :: M : 0.552 \quad M = 0.432 \text{ g. per day.}$$

In Table VI may be found the values obtained by using this correction.

TABLE V.

CORRECTION FOR NITROGEN IN UNABSORBED BUTTER

Day.	Weight stool. G.	Total N feces. G.	Fecal N from butter. G.	Metabolic N. G.
		Subject F.		
1	151.5	0.474	0.031	...
2	127.3	0.420	0.031	...
3	171.0	0.581	0.031	...
4	216.0	0.687	0.031	...
Average	166.5	0.531[1]	0.031	0.500
		Subject J.		
1	...	...	0.033	...
2	93.3	0.448	0.033	...
3	189.5	0.967	0.033	...
4	214.5	0.965	0.033	...
Average	124.3	0.585[1]	0.033	0.552

TABLE VI.—CORRECTION FOR METABOLIC NITROGEN.

Period.	Total N food. G.	Total N feces. G.	Metabolic N. G.	N in feces from unabsorbed food. G.	N absorbed. G.	Utilization. %.
Normal	16.603	0.759	0.500	0.259	16.344	98.44
Bolting	16.603	0.948	0.500	0.448	16.155	97.30
Fletcherizing	16.603	0.726	0.500	0.226	16.377	98.64
Normal	16.603	0.765	0.500	0.265	16.338	98.40
Normal	19.184	1.306	0.552	0.754	18.430	96.07
Bolting	19.184	1.266	0.552	0.714	18.470	96.27
Fletcherizing	19.184	0.906	0.552	0.354	18.830	98.15
Normal	19.184	0.919	0.552	0.367	18.817	98.09

TABLE VII.—CORRECTED FECAL NITROGEN OUTPUT.

Period.	Total N food. G.	Total N feces. G.	Metabolic N. G.	N in feces from unabsorbed food. G.	N absorbed. G.	Utilization %.
			Subject F.			
Normal	16.603	0.759	0.268	0.491	16.112	97.04
Bolting	16.603	0.948	0.268	0.680	15.923	95.39
Fletcherizing	16.603	0.726	0.268	0.458	16.145	97.24
Normal	16.603	0.765	0.286	0.497	16.106	97.01
			Subject J.			
Normal	19.184	1.306	0.432	0.874	18.310	95.45
Bolting	19.184	1.266	0.432	0.834	18.350	95.65
Fletcherizing	19.184	0.906	0.432	0.474	18.710	97.52
Normal	19.184	0.919	0.432	0.487	18.697	97.45

[1] Corrected for the nitrogen contained in capsule and in carmine.

4. General Discussion.

In establishing the digestibility of a food Best[1] has suggested that we must respect its influence on secretion; its absorption and sojourn in the stomach and intestine. It is a well-known fact that meat remains a relatively long time in the stomach. Tabler[2] has shown that the stomach acts as a reservoir for protein and that considerable absorption takes place there. Chittenden[3] has taken this same view, although he believes that absorption is slow. Fermi[4] found that finely hacked or well chewed meat was more easily digested by dogs than either coarsely cut or poorly chewed material. Cohnheim[5] fed two fistulated dogs with meat, the first receiving it in finely hashed condition, the second in the form of cubes of 1–3 centimeters diameter. In the case of the first dog the material left the stomach 1 hour and 35 minutes after ingestion, 59% being digested. The meat cubes remained in the stomach of the second dog 2 hours and 31 minutes, 92% being digested. It was evident that although the cubes remained longer in the stomach, peptonization was markedly higher. Cohnheim concluded that the ingestion of finely chopped meat places more work on the intestine than on the stomach, whereas the reverse is true in case of ingestion of cubes. In one case trypsin brought into solution 0.13 g. of nitrogen; in the other 0.8 g. London and Polovzova[6] found that with few exceptions, proteins are not absorbed in the stomach, but that most proteins are made soluble in the stomach to the extent of about 78%. 92% of this soluble material consists of proteoses and peptones, which is quickly attacked by the intestinal juices. It has been shown by Zunz[7] that enzymes of the stomach have the ability to hydrolyze protein to peptones, proteoses, and amino acids, yet the length of time required is far in excess of that during which protein remains in the stomach.

It seems reasonable to suppose in the case of man that bolted meat would remain longer in the stomach than material which had been reduced to a state of fine division through fletcherism. Abderhalden and Meyer[8] have demonstrated that the activity of pepsin is not necessarily confined to the stomach, but that it may be continued in the intestine. The proteins undigested in the stomach adsorb the enzyme and carry it into the intestine. Following the digestion of these proteins by the contained enzyme, this released pepsin is free to digest other proteins as well, since the reaction of the intestinal canal is often acid. It would seem from these

[1] *Deutsches Archiv. Klin. Med.*, **104**, 94 (1911).
[2] Tabler, cited by Best, *Loc. cit.*
[3] Chittenden, "Nutrition of Man," New York, **1907**, p. 31.
[4] Fermi, cited by Best, *Loc. cit.*
[5] *Münch. Med. Wochschr.*, **54**, 2582 (1907).
[6] *Z. physiol. Chem.*, **49**, 328 (1906), and **57**, 113 (1908).
[7] *Beitr. Chem. Physiol. und Path.*, **3**, 339 (1903).
[8] *Z. physiol. Chem.*, **74**, 67 (1911).

findings that in food bolting, peptic digestion in the intestinal canal may have an important bearing.

Despite the claim that fletcherism[1] and the use of smaller quantities of food decrease the number of intestinal bacteria, Metchnikoff[2] does not agree that putrefaction is prevented. It is logical to infer that for the optimum utilization of starchy foods, habits of thorough mastication, should be encouraged with the purpose of increasing the digestion of the material at the beginning of the alimentary tract.

Concerning the utilization of meat protein, it may be concluded that the results of this investigation fail to demonstrate the advantages of fletcherism or the harmfulness of food-bolting.

5. Summary.

1. The question of the influence of mastication on the utilization of protein food was made the subject of this investigation. So far as could be determined, no work has been done on this problem; the statements of Fletcher and his associates are mainly theoretical assumptions.

2. Normal men were fed a fairly high nitrogen diet, the principal protein constituent of which was cooked beef in the form of 15 millimeter cubes. The experiment was divided into four periods: (1) Preliminary normal; (2) bolting; (3) fletcherizing; (4) final normal. Feces and urine were analyzed for total nitrogen.

3. The output of fecal nitrogen was highest during the food bolting; that during fletcherism was lowest. Protein utilization was most complete as the result of fletcherism, and least complete when bolting was practiced. The discrepancies, however, averaged only 1.6%. Utilization during fletcherism averaged 0.17% higher than during normal mastication.

4. During food bolting macroscopic meat residues appeared in every stool. In a single stool the amount was 16.5 g.

5. The fineness of the protein may determine the amount of its hydrolytic cleavage. This fact was shown by the higher nitrogen content of the urine in the fletcherizing period and the lowered output during bolting.

6. A nitrogen-free diet was fed through a four-day period at the close of the experiment proper. Total nitrogen was determined in the feces. The purpose of this was to determine as nearly as possible the average daily output of fecal metabolic nitrogen. This value was applied as a correction, and more accurate utilization data were thus obtained.

7. The fact that pepsin may be adsorbed in the stomach by particles of undigested food and carried into the small intestine to aid further in protein hydrolysis may have an important bearing on the question of the digestion of bolted meat.

[1] H. Fletcher, "The A, B, Z of our Nutrition," New York, 1904, p. 41.

[2] Metchnikoff, "Prolongation of Life," New York, 1908, p. 159.

8. Fletcherism of starchy foods should be encouraged so as to insure the salivary digestion of a large quantity of material.

9. The results of the present experiment so far as protein utilization is concerned do not support the claims of Horace Fletcher and his followers for the efficiency of excessive mastication of food, nor do they demonstrate the harmfulness of food-bolting to the organism.

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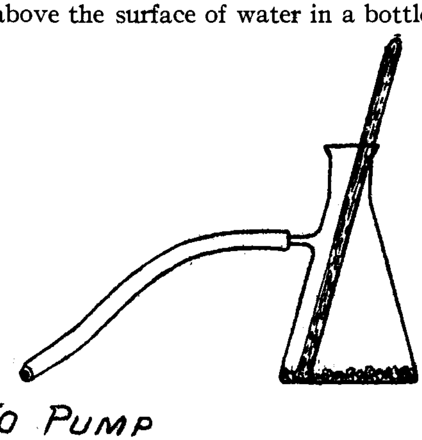
NOTES.

A Convenient Apparatus for Chlorination with Phosphorus Pentachloride.—The common methods employed in chlorinating solid organic compounds, such as the sulfonic acids or their metallic salts are: (1) Shake material and PCl_5 together in a flask with or without reflux condenser, some authors advocating the use of a one-hole stopper and tube for the delivery of the HCl gas just above the surface of water in a bottle or flask. (2) Grinding material and PCl_5 together in a mortar or evaporating dish.



In method (1) it is difficult to thoroughly mix the materials, and the reaction is often slow in starting. In (1) and especially in (2) the large amounts of HCl gas evolved make the use of a hood necessary and the operation unpleasant at best. In this laboratory it has been customary to perform (2) out of doors.

The authors while working on sulfonic acid derivatives devised the following simple apparatus:

The material is placed in a heavy-walled, side-neck filter flask attached to a Richards or similar filter pump. Suction is applied and the PCl_5 added. The materials are ground together with a pestle made from heavy glass rod or large tubing. No HCl fumes escape into the air, making the use of a hood unnecessary.

If but small amounts of material are available a thick-walled, side-neck test tube may be used.

The method is, of course, not applicable if the product of chlorination is volatile.

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March 1, 1915.