GASTRIC DIGESTION IN INFANTS*

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The prevailing views on gastric digestion in infants may, I believe, be fairly stated by quoting from a recent text-book on pediatrics:¹

The opinion has been steadily gaining ground that the function of the stomach is largely that of a reservoir. . . . The only part of the food acted on in the stomach is the proteids, which are transformed successively into acid-albumins, albumoses, and peptones. This is accomplished by the agency of the pepsin and the acid of the gastric juice—generally hydrochloric acid, although lactic acid may take its place. . . . The reaction of the stomach contents in fasting is acid, and at this time usually HCl can be demonstrated; soon after a meal of human milk it is alkaline or neutral; after one of cow's milk it is acid or neutral. In fifteen minutes after feeding the reaction is always acid. Free HCl can usually not be demonstrated until about one hour after feeding; then only in very small quantities and in very many cases not at all. Some good observers go so far as to say that in health free HCl is never present during digestion. The reason for this is apparently that the acid combines with the casein of the milk, that of cow's milk in particular having a great power of combining with HCl. . . . The coagulation of the milk in the stomach is accomplished through the agency of the rennet ferment. This is independent of both the pepsin and the acid of the gastric juice. It acts in acid alkaline and neutral media. . . . The existence of a fat-splitting ferment in the stomach of infants is now generally admitted, though it plays but a small rôle in digestion.

Some of the above statements require modification in the light of recent studies; and the methods which have been employed by investigators of this subject are now open to criticism. Excellent historical reviews of the literature have been published by Henry Heiman² and T. Wood Clarke.³ The chief points of criticism of the usual methods of gastric analysis may be grouped under several headings:

1. Acidity: This has been studied almost exclusively by titration methods, which, it must be admitted, have given results of clinical value in the study of the adult stomach. I will show, however, that in infants at least more accurate and useful information may be gained by studying the gastric acidity from a different angle.

2. Ferments: These have usually been studied only qualitatively. It seems certain that all the gastric ferments are present at all ages and practically under all conditions. More information can be gained by

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* Submitted for publication Jan. 21, 1914.

1. Holt: *Diseases of Infancy and Childhood*, 1911.

2. Heiman, Henry: *Trans. Am. Ped. Soc.*, 1910, xxii, 17.

3. Clarke, T. Wood: *Am. Jour. Med. Sc.*, N. S., 1909, cxxxvii, 872.

quantitative determinations and we have simple methods for this purpose. The importance of pepsin has been generally emphasized, but it will be shown that this ferment must be relatively inactive under the conditions present in the infant's stomach, and so should be regarded as secondary in importance to both rennet and lipase.

3. Motility: Motility will not be considered in this paper, but studies which are being made in this field by the use of radiography appear to give more dependable results than can be obtained with the stomach tube.

H. Davidsohn, working in Finkelstein's clinic, has outlined a method for gastric analysis in infants which he has presented in a recent publication, and which makes use of newly acquired knowledge of ferments and of modern technic for the study of ferments.⁴ It is adapted for clinical purposes and seems to offer improvements over the usual methods of analysis along the lines indicated in the above criticism. Dr. Davidsohn concludes his article by announcing his intention of applying the routine described by him to the study of infants under various conditions. It was my task to examine a series of normal infants. Before giving my results, however, I wish to discuss briefly the main points in the method.

Acidity.—The functional significance of the acidity of the gastric juice is that it activates the contained ferments. Modern chemistry has shown that the degree of acidity of a solution depends on the concentration of the dissociated hydrogen ions. The inadequacy of titration for determining the true acidity of the gastric juice is well illustrated by Michaelis and Davidsohn in the following example:⁵

If one titrates 10 c.c. $n/10$ HCl against phenolphthalein, one must use 10 c.c. $n/10$ NaOH. If one titrates 10 c.c. $n/10$ acetic acid, one must use the same quantity of NaOH. And yet no one can doubt that the HCl is a very much stronger acid solution than the acetic acid. But if one titrates against methyl orange, one must again use for the HCl 10 c.c. NaOH; the acetic acid shows no acidity at all. Without giving more examples, one sees from this that the titration acidity and the real acidity are two quite different things. The titration acidity is a quite artificial conception, depending on the manipulation of the titration and the artificial condition produced thereby in the solution. . . . The real acidity, for example, of equivalent HCl and acetic acid solutions is, in spite of the same titration values against phenolphthalein, enormously different, because a $n/10$ HCl solution is 91 per cent. dissociated into ions, while a $n/10$ acetic acid solution is only 1.4 per cent. dissociated.

The same writers have further shown the fallacy in differentiating between combined and free acid. When molecular equivalent amounts of casein and HCl are combined, the resulting solution is weakly acid owing to the dissociated H-ions. These free H-ions alone are of importance in determining the efficient acidity of the solution.

4. Davidsohn, H.: *Ztschr. f. Kinderh.*, 1913, ix, 470.

5. Michaelis, L., and Davidsohn, H.: *Ztschr. f. exper. Path. u. Therap.*, 1910, viii, 398.

Gastric acidity has been measured in terms of H-ion concentration by F. A. Hoffman⁶ in 1889, and by B. Moore⁷ in 1905. These investigators used the method of measuring the velocity of the hydrolysis of methyl-acetate. Michaelis and Davidsohn used the electro-metric method, which is more convenient and more accurate. The details of this method are described in Abderhalden's handbook.⁸ It consists essentially in measuring the difference in electric potential between a normal hydrogen electrode and one immersed in a solution of unknown H-ion concentration. This method requires a rather complicated set of apparatus and considerable skill in physical-chemical technic and so is not practical for ordinary clinical work. A far more suitable method is the indicator method, which is very simple, and accurate enough for clinical purposes. It consists in noting the color changes produced by adding various indicators to the solution without titration and comparing them with a table constructed from solutions whose acidity has been determined electrometrically. As albumin and salts in solution are a source of error, the table must be modified for solutions of a given type. Such modifications have been made by Michaelis and Davidsohn for adult gastric contents, and by Davidsohn for the stomach contents of infants.

INDICATORS FOR GASTRIC CONTENTS OF INFANTS

(H)	Methyl-orange	Paranitrophenol	Lacmus
0.3×10^{-5}	yellow	dark green	blue-violet
$0.3-1.0 \times 10^{-5}$	yellow	light green	red-violet
$1.0-7.0 \times 10^{-5}$	yellow	colorless	pink
$7.0-20.0 \times 10^{-5}$	orange	colorless	pink
$20.0-60.0 \times 10^{-5}$	orange-red	colorless	pink

The hydrogen-ion concentration, indicated by the symbol (H) in the table is expressed in terms of gram-ions. (One gram-ion of hydrogen, atomic weight = 1, is equivalent to 1 gram per liter.) It is customary to abbreviate small decimal fractions by using negative coefficients of 10, as $10^{-1} = 0.1$, $10^{-2} = 0.01$, etc. The indicators used are methyl-orange 1.25 per cent. in aqueous solution; paranitrophenol 1.25 per cent. in 50 per cent. alcohol; and tincture of lacmus, formula of Kubel-Tieman von Kahlbaum. The gastric contents are filtered and diluted two and a half times. This is for the purpose of counteracting the small error caused by the albumins and salts in solution and by the slight color tint of the gastric juice, and this degree of dilution has been shown to produce no change in the H-ion concentration. The technic is quite simple; 2 drops of each indicator are added to $2\frac{1}{2}$ c.c. of the diluted gastric juice, in small test-tubes and the colors noted by reflected day-light. The acidities in my tables have all been determined electrometrically by Dr.

6. Hoffman, F. A.: *Centralbl. f. klin. Med.*, 1889, xi, 793.

7. Moore, B.: *Proc. Roy. Soc., Lond.*, 1905, lxxvi, 138.

8. Abderhalden, E.: *Handb. d. Biochem. Arbeitsmethod.*, 1913.

Davidsohn, who has kindly permitted me to publish his figures. They agree very well in all cases with simultaneous determinations made by the indicator method.

The acidities in this series are remarkably constant, approximating the value $(H) = 1.0 \times 10^{-5}$. This is in striking contrast to the great variation in acidity found by previous observers and indicates that the determination of the H-ion concentration is a distinct advance over the titration methods for this purpose. From the results of this series of analyses $(H) = 1.0 \times 10^{-5}$ may be regarded as the normal reaction at the height of digestion for infants fed on $\frac{1}{3}$ milk and $\frac{2}{3}$ milk. Salge⁹ has confirmed this value for infants on an exclusive milk diet, but finds higher acidities in children who are getting other foods. A study of the action of the gastric ferments will show that this degree of acidity is the most favorable for the gastric digestion of infants. Each ferment has an optimum reaction for its activity, which is as constant as, for example, the optimum temperature for the growth of bacteria. The optimum reaction for pepsin is $(H) = 1.6 \times 10^{-2}$; the limits of reaction⁵ at which this ferment is active are 3×10^{-2} , and 1.4×10^{-3} . At $(H) = 1.0 \times 10^{-5}$, the normal reaction of the infant's stomach, pepsin is inert, showing the relative unimportance of this ferment for infants. Experimental evidence in support of this statement is given by Davidsohn, who, working with casein and gastric juice of infants at low acidities, was not able to demonstrate an appreciable amount of digestion. The acidity found, is, however, the optimum reaction for the coagulation of milk by rennet, as determined by Van Dam, who also discovered that rennet may cause a slight gradual digestion of casein, which proceeds optimal at the same reaction.¹⁰ This is also the optimum reaction for gastric lipase, while that for pancreatic lipase is a much lower H-ion concentration, which fact indicates a simple means of differentiating these two ferments.¹¹ The acidity $(H) = 1.0 \times 10^{-5}$, which I have found constantly at the height of digestion in the stomachs of infants examined by me, is, then, the optimum reaction for all ferment activities that participate in the gastric digestion of infants, i. e., for the coagulation of milk and the digestion of casein by rennet and for the splitting of fats by gastric lipase.

Lipase.—Was determined quantitatively by the stalagmometric method described in Abderhalden's handbook. This method is quite simple in spite of its formidable name. It depends on the diminution in surface tension effected in a saturated tributyrin solution by the action of a lipolytic ferment. The lipase content is calculated in terms of a

9. Salge: 1912, iv, 171.

10. Van Dam: Ztschr. f. physiol. Chem., 1912, lxxix, 247.

11. Davidsohn, H.: Biochem. Ztschr., 1913, xlix, 249.

standard lipase solution whose strength is such that 1 c.c. acting on 60 c.c. of a saturated tributyrin solution for sixty minutes under the given conditions, will split 80 per cent. of the tributyrin. This standard solution has the empirical value—100. The only apparatus required is a simple dropping pipet; the technic is easily learned and the results are accurate. With each determination of gastric lipase there has also been made a parallel determination of pancreatic lipase to avoid the error which might arise from regurgitation of duodenal juice into the stomach. This, however, rarely occurs in infants.^{12, 4} Lipase is of growing importance in the study of gastric digestion of infants. A fat-splitting enzyme was demonstrated in the stomach by Volhard¹³ in 1901, and the activity of this enzyme was first studied in infants by Sedgwick¹⁴ in 1906. Sedgwick and other investigators¹⁵ have found that there is a considerable splitting of fat in the infant's stomach, as the fat of milk is present in a finely divided, emulsified condition, and so readily acted on by ferments. Sedgwick and Schlutz¹⁶ have further shown that the gastric lipase increases the activity of the pancreatic lipase. Finally the importance of this ferment for the gastric digestion of infants may be assumed from our clinical experience that a high fat content in the food causes gastric indigestion, i. e., vomiting. It has been shown experimentally that the length of time the food remains in the stomach increases with the fat content of the milk.¹⁷

Pepsin and Rennet.—Was determined quantitatively by the edestin method of Fuld and Lewison, the details of which may also be found in Abderhalden's handbook. This method consists in subjecting edestin in amounts of 2 c.c. each, in n/30 HCl at 37 C., to the action of a series of dilutions of the stomach contents, the dilutions increasing in a geometrical progression. The pepsin content is calculated in terms of a standard pepsin solution which is given the empirical value—1. The strength of the standard pepsin solution is such that 1 c.c. under the given conditions will just digest 2 c.c. of edestin in one hour. Although the identity of pepsin and rennet has not been proven, it has been shown that the two ferments are always present in corresponding amounts.¹⁸ The pepsin determination therefore suffices for both. Pepsin is apparently not an important agent in the gastric digestion of infants. The

12. Reiche, A.: Ztschr. f. Kinderh., 1913, vi, 235.

13. Volhard: Ztschr. f. klin. Med., 1901, xlii, 14, and xliii, 397.

14. Sedgwick, J. P.: Jahrb. f. Kinderh., 1906, lxiv, 194.

15. Heinsheimer: München. med. Wehnschr., 1906, xix, 949; Uffenheimer: Ergebn. d. inn. Med. u. Kinderh., 1908, ii, 271.

16. Sedgwick and Schlutz: AM. JOUR. DIS. CHILD., 1911, ii, 243.

17. Tobler and Bogen: Monatschr. f. Kinderh., 1908, vii, 12.

18. Oppenheimer, C.: Die Fermente, Leipsic, 1913.

reasons for this opinion have been stated. On the other hand, coagulation by rennet is evidently an essential part of the digestion of milk, although the purpose of this process is at present not clear.

RESULTS OF ANALYSES

In Table 3 are given the results of my analysis of ninety-four specimens of stomach contents from thirty-seven infants. For the acidities, determined electrometrically, I am indebted to Dr. H. Davidsohn, who also supervised the entire series of analyses. The original purpose of the examinations was to obtain a series of what might be regarded as standard analyses from normal breast- and bottle-fed babies. This plan, however, could not be carried out. For obvious reasons it is difficult to obtain a large number of breast babies for such a study; the infants in

TABLE 1.—ONE-THIRD CREAM-MILK FEEDINGS ($\frac{1}{3}$ C. M.)

250 c.c. milk; 100 c.c. 28 per cent. cream; 650 c.c. water; 5 per cent. milk-sugar or "Nährmaltos." Percentage composition: protein, 1.5 per cent.; fat, 3.8 per cent.; carbohydrate, 6.5 per cent.

Age Month	No. Analyses	Lipase	Rennet-Pepsin	Acidity (H)
1st...	4	4.8 (0—15)*	21.3 (10—25)	0.7×10^{-5} ($0.4-1.1 \times 10^{-5}$)
2d....	8	45.8 (8—134)	11.8 (0—40)	0.9×10^{-5} ($0.2-1.9 \times 10^{-5}$)
3d-4th	19	58.4 (11—94)	30.1 (10—100)	1.5×10^{-5} ($0.2-9.8 \times 10^{-5}$)

* In Tables 1 and 2 the mean values are given and in parentheses the lowest and highest values.

TABLE 2.—TWO-THIRDS MILK FEEDINGS ($\frac{2}{3}$ M.)

650 c.c. milk; 350 c.c. water; 5 per cent. "Nährmaltos." Percentage composition: protein, 2.5 per cent.; fat, 2.5 per cent.; carbohydrate, 7.5 per cent.

Age Month	No. Analyses	Lipase	Rennet-Pepsin	Acidity (H)
4th- 6th	17	123 (64—209)	74.4 (30—100)	1.5×10^{-5} ($0.2-2.6 \times 10^{-5}$)
7th- 9th	17	97.7 (47—220)	77.8 (10—300)	2.1×10^{-5} ($0.2-11.8 \times 10^{-5}$)†
10th-11th	11	105.5 (50—212)	77.2 (16—120)	2.9×10^{-5} ($0.2-15.9 \times 10^{-5}$)‡

† Eliminating the exceptional value 11.8×10 gives the mean value 1.5×10^{-5} .

‡ Eliminating the exceptional value 15.9×10 gives the mean value 1.5×10^{-5} .

the series are all artificially nourished. Moreover, they are not strictly normal, but are for the most part somewhat underdeveloped children such as are commonly found in foundling institutions. They were, during the period of study, free from manifest signs of infection, nutritional disturbance or constitutional disease.

The test meals consist chiefly of $\frac{1}{3}$ milk and $\frac{2}{3}$ milk according to the age of the children. According to experiments on Pawlow fistula dogs, the stomach attempts to pour out a secretion which is adapted to the usual food of the individual. It seems most practical to study the function of the stomach under physiological conditions; that is, to study the reaction of the stomach to the usual food of the infant. The com-

position of $\frac{1}{3}$ cream-milk ($\frac{1}{3}$ C. M.) and $\frac{2}{3}$ milk ($\frac{2}{3}$ M.) is given in Tables 1 and 2. There are a few cases on whole milk (W. M.) and albumin milk (A. M.); these are, however, too few to be of much significance. The amount of the feedings varies and is controlled by the appetite of the children. This did not influence the results; compare Nos. 7-8, 18-21, 22-26, in Table 3, which present uniform values with varying size of test meals. The stomach was emptied as completely as possible with a catheter, No. 20 F., no attempt being made to study motility. The contents were removed at different intervals of time after feeding, but always at what was considered the height of digestion, which remains constant for some time. That this variable factor was not a source of error is again seen in the table by comparing analyses which show uniform results with different periods of digestion, Nos. 35-37, 38-41, 69-71, 92-94. Specimens removed too late were discarded, as with small amounts of material the technical errors are magnified. Figures in the table showing duration of digestion are counted from the end of feeding to the time of emptying the stomach.

One may differentiate in this series two groups of children, (1) a group with corresponding values in stomach contents removed on different days, and (2) a group presenting marked variations. Examples of the first group are Nos. 35-37, 43-44, 68-71; of the second group Nos. 12-15, 51-53, 72-77. As the children in this series cannot be strictly regarded as normal, regularly developing infants, but belong to a type of children who present frequent variations in their clinical symptoms, so the variations of gastric function observed in them may be regarded in the same light, as, for example, irregularities in the appetite and the weight curve. These variations refer only to ferment content, the acidity or (H), remaining essentially constant. On account of the physiological instability of infants it is advisable in a study of this kind to take the average in each case of several analyses made on different days. The mean values obtained in this way have been taken for comparison and are given in Tables 1 and 2.

In the cases on $\frac{1}{3}$ cream-milk, 1 to 4-months-old infants, Table 1, there is found a lipase content increasing with the age of the infants; there is no great variation in the rennet-pepsin values in these cases.

In the older children, 4 to 12 months, on $\frac{2}{3}$ milk, Table 2, the mean values for all ferments appear remarkably constant. Absolutely the ferment content is higher than in the first group. There may be a fallacy in comparing young infants on $\frac{1}{3}$ milk with older infants on $\frac{2}{3}$ milk, but the figures apparently show that the functional power of the stomach increases with the age of the infant. In this respect the findings in the albumin-milk cases, though too few to be conclusive, are very suggestive. Of nine analyses in five infants from 9 days to 2 months old on albumin-

TABLE 3.—RESULTS OF ANALYSES OF STOMACH CONTENTS OF THIRTY-SEVEN INFANTS

Speci- men No.	Case No.	Date of Birth	Date of Analysis	Weight gm.	Feeding	Amount Taken, c.c.	Amount Recovered c.c.	Length of Digestion Hours	Rennet- Pepsin	Lipase	Acidity (H)
1	1	9/15	9/27	2,840	$\frac{1}{2}$ C. M.	100	20	1	10	0	0.4×10^{-5}
2	2	10/14	10/27	2,860	$\frac{1}{3}$ C. M.	90	30	1	25	0	0.7×10^{-5}
3	3	9/ 4	9/27	3,640	$\frac{1}{3}$ C. M.	120	22	$1\frac{1}{4}$	25	3.8	0.5×10^{-5}
4	4	9/ 1	9/27	3,950	$\frac{1}{3}$ C. M.	130	30	$1\frac{3}{4}$	25	15.4	1.1×10^{-5}
5	5	5/ 1	6/ 7	2,950	$\frac{1}{3}$ C. M.	70	21	$\frac{3}{4}$	5	8.2	0.2×10^{-5}
6	5	.....	6/10	.....	$\frac{1}{3}$ C. M.	70	20	$1\frac{1}{4}$	10	36.9	1.0×10^{-5}
7	5	.....	6/13	.....	$\frac{1}{2}$ C. M.	70	30	$1\frac{1}{4}$	25	50.6	0.6×10^{-5}
8	5	.....	7/25	3,450	$\frac{1}{3}$ C. M.	130	40	$1\frac{1}{2}$	10	25	$0.3-1.0 \times 10^{-5}$
9	6	4/30	6/20	2,800	$\frac{1}{2}$ C. M.	100	65	1	8	25	0.5×10^{-5}
10	6	.....	6/21	.....	$\frac{1}{3}$ C. M.	100	47	1	8	17.2	1.2×10^{-5}
11	6	.....	6/27	.....	$\frac{1}{3}$ C. M.	100	31	1	5	11.2	1.3×10^{-5}
12	7	.....	9/ 8	3,880	$\frac{1}{3}$ C. M.	140	40	$1\frac{1}{2}$	8	134.3	1.9×10^{-5}
13	7	7/12	9/12	.....	$\frac{1}{3}$ C. M.	150	65	$1\frac{1}{2}$	30	62.2	9.8×10^{-5}
14	7	.....	9/17	.....	$\frac{1}{3}$ C. M.	150	59	$1\frac{3}{4}$	20	80.6	0.4×10^{-5}
15	7	.....	9/24	4,260	$\frac{1}{3}$ C. M.	160	40	$1\frac{1}{2}$	30	37.2	1.0×10^{-5}
16	8	.....	9/15	3,820	$\frac{1}{3}$ C. M.	150	22	$1\frac{1}{2}$	63	62.3	1.6×10^{-5}
17	8	.....	9/18	.....	$\frac{1}{3}$ C. M.	150	32	$1\frac{1}{2}$	100	90	1.1×10^{-5}
18	9	7/ 7	9/ 3	4,510	$\frac{1}{3}$ C. M.	160	88	$1\frac{3}{4}$	30	70.4	0.6×10^{-5}
19	9	.....	9/11	.....	$\frac{1}{3}$ C. M.	150	55	$1\frac{1}{2}$	30	76.6	0.7×10^{-5}
20	9	.....	9/23	.....	$\frac{1}{3}$ C. M.	160	65	$1\frac{1}{2}$	25	94.2	0.7×10^{-5}
21	9	.....	9/27	4,900	$\frac{1}{3}$ C. M.	200	80	2	40	30.3	1.2×10^{-5}
22	10	6/19	8/20	3,820	$\frac{1}{3}$ C. M.	160	70	$1\frac{1}{2}$	25	35	0.3×10^{-5}
23	10	.....	9/ 9	.....	$\frac{1}{3}$ C. M.	200	30	2	16	41.5	3.6×10^{-5}
24	10	.....	9/11	.....	$\frac{1}{3}$ C. M.	200	40	2	16	29.3	0.5×10^{-5}
25	10	.....	9/16	.....	$\frac{1}{3}$ C. M.	200	39	2	40	44	0.3×10^{-5}
26	10	.....	9/22	4,530	$\frac{1}{3}$ C. M.	200	32	2	30	50	0.2×10^{-5}
27	11	3/ 4	5/21	3,940	$\frac{1}{3}$ C. M.	140	65	$1\frac{1}{2}$	12.5	11	0.2×10^{-5}
28	11	.....	5/22	.....	$\frac{1}{3}$ C. M.	140	38	$1\frac{3}{4}$	20	14	0.4×10^{-5}
29	11	.....	5/24	.....	$\frac{1}{3}$ C. M.	140	85	$1\frac{3}{4}$	12.5	30	0.4×10^{-5}
30	12	2/22	5/27	.....	$\frac{1}{3}$ C. M.	140	21	$1\frac{3}{4}$	12.5	39	1.4×10^{-5}
31	12	2/22	6/19	.....	$\frac{1}{3}$ C. M.	150	59	$1\frac{3}{4}$	40	67	4.2×10^{-5}
32	13	3/ 4	5/28	4,120	$\frac{2}{3}$ M.	140	14	$1\frac{3}{4}$	25	42	0.6×10^{-5}
33	13	.....	5/29	.....	$\frac{2}{3}$ M.	140	18	$1\frac{3}{4}$	20	38.5	0.2×10^{-5}
34	14	3/18	7/ 4	3,870	$\frac{2}{3}$ M.	200	40	2	63	111.2	1.0×10^{-5}
35	15	2/19	6/21	5,060	$\frac{2}{3}$ M.	180	30	$1\frac{3}{4}$	40	96.2	0.8×10^{-5}
36	15	.....	6/23	.....	$\frac{2}{3}$ M.	180	85	$1\frac{1}{2}$	40	111.0	1.1×10^{-5}
37	15	.....	6/26	.....	$\frac{2}{3}$ M.	180	120	1	40	111.9	0.6×10^{-5}
38	16	3/25	9/ 4	4,850	$\frac{2}{3}$ M.	200	80	2	75	208.8	0.5×10^{-5}
39	16	.....	9/ 8	.....	$\frac{2}{3}$ M.	200	50	$2\frac{1}{4}$	30	146.6	2.4×10^{-5}
40	16	.....	9/10	.....	$\frac{2}{3}$ M.	200	60	2	48	191	2.6×10^{-5}
41	16	.....	9/18	5,170	$\frac{2}{3}$ M.	200	72	2	48	120	1.7×10^{-5}
42	17	2/ 3	8/22	5,250	$\frac{2}{3}$ M.	180	50	2	100	85.8	0.4×10^{-5}
43	18	3/26	9/12	6,320	$\frac{2}{3}$ M.	200	70	..	66.9	63	0.3×10^{-5}

44	18	...	9/22	6,480	$\frac{2}{3}$ M.	200	65	2	48	64	0.2×10^{-5}
45	19	4/7	9/16	6,620	$\frac{2}{3}$ M.	200	20	2	120	129	1.8×10^{-5}
46	19	...	9/18	...	$\frac{2}{3}$ M.	200	59	2	120	74.2	0.1×10^{-5}
47	19	...	9/20	...	$\frac{2}{3}$ M.	200	76	2	186	208.2	0.3×10^{-5}
48	19	...	9/23	...	$\frac{2}{3}$ M.	200	76	2	186	208.8	0.3×10^{-5}
49	20	5/7	9/13	5,180	$\frac{2}{3}$ M.	200	76	2	120	192.8	0.3×10^{-5}
50	20	...	9/23	5,270	$\frac{2}{3}$ M.	200	85	2	48	114.3	0.4×10^{-5}
51	21	3/13	9/18	4,780	$\frac{2}{3}$ M.	200	71	2	300	126.8	0.2×10^{-5}
52	21	...	9/23	...	$\frac{2}{3}$ M.	200	45	2	120	108.9	0.6×10^{-5}
53	21	...	9/25	4,900	$\frac{2}{3}$ M.	200	68	2	120	46.9	0.6×10^{-5}
54	22	3/20	9/25	5,400	$\frac{2}{3}$ M.	200	50	2	75	60.6	0.4×10^{-5}
55	23	1/31	8/30	5,140	$\frac{2}{3}$ M.	200	75	2	100	110	1.5×10^{-5}
56	23	...	...	...	$\frac{2}{3}$ M.	200	78	1 $\frac{3}{4}$	159	220	0.8×10^{-5}
57	24	11/20*	6/27	7,590	$\frac{2}{3}$ M.	200	97	2	40	69.7	0.8×10^{-5}
58	24	...	7/5	7,850	$\frac{2}{3}$ M.	200	60	2 $\frac{1}{4}$	25	108.8	4.3×10^{-5}
59	25	1/7	6/27	5,630	$\frac{2}{3}$ M.	200	42	2	40	133	2.3×10^{-5}
60	25	1/7	9/6	...	$\frac{2}{3}$ M.	200	42	2	75	79.2	1.1×10^{-5}
61	25	...	9/26	6,060	$\frac{2}{3}$ M.	200	40	2	48	67.2	0.5×10^{-5}
62	26	10/6*	6/20	5,850	$\frac{2}{3}$ M.	180	95	2	100	106	1.3×10^{-5}
63	27	10/10*	6/26	5,270	$\frac{2}{3}$ M.	200	50	2	16	87	1.8×10^{-5}
64	27	...	6/28	...	$\frac{2}{3}$ M.	200	20	2 $\frac{1}{2}$	16	104	
65	27	...	6/30	...	$\frac{2}{3}$ M.	200	50	2	16	56	2.5×10^{-5}
66	27	...	7/3	...	$\frac{2}{3}$ M.	200	65	2	63	121	1.1×10^{-5}
67	27	...	7/5	...	$\frac{2}{3}$ M.	200	40	2	10	56	3.8×10^{-5}
68	27	...	7/21	6,060	$\frac{2}{3}$ M.	200	60	2	16	111	1.0×10^{-5}
69	28	9/11*	6/21	...	$\frac{2}{3}$ M.	200	92	1 $\frac{3}{4}$	100	60	0.2×10^{-5}
70	28	...	6/24	...	$\frac{2}{3}$ M.	200	70	1 $\frac{1}{2}$	100	50	0.2×10^{-5}
71	28	...	6/30	...	$\frac{2}{3}$ M.	200	53	2	100	56.1	0.2×10^{-5}
72	29	11/11*	8/30	6,010	$\frac{2}{3}$ M.	200	40	2	40	21.2	15.9×10^{-5}
73	29	...	9/5	...	$\frac{2}{3}$ M.	200	52	2	100	111.2	2.0×10^{-5}
74	29	...	9/8	...	$\frac{2}{3}$ M.	200	39	2	100	105	0.6×10^{-5}
75	29	...	9/12	...	$\frac{2}{3}$ M.	200	50	2	100	124.5	4.5×10^{-5}
76	29	...	9/17	...	$\frac{2}{3}$ M.	200	50	2	48	152.2	4.7×10^{-5}
77	29	...	9/20	6,720	$\frac{2}{3}$ M.	200	81	2	120	90.2	0.4×10^{-5}
78	30	9/5*	9/2	4,880	$\frac{2}{3}$ M.	200	50	2	25	88.8	1.6×10^{-5}
79	30	...	9/5	...	$\frac{2}{3}$ M.	200	75	2	100	79.2	0.5×10^{-5}
80	30	...	9/12	...	$\frac{2}{3}$ M.	200	40	2 $\frac{1}{4}$	40	40.6	0.3×10^{-5}
81	31	10/4*	9/19	5,150	$\frac{2}{3}$ M.	200	58	2	30	40.6	0.7×10^{-5}
82	32	6/19	6/28	6,700	W. M.	200	25	3 $\frac{3}{4}$	10	19	
83	32	...	7/1	...	A. M.	770	20	1	10	0	2.4×10^{-5}
84	32	...	7/5	...	A. M.	100	30	1	10	0	1.0×10^{-5}
85	33	5/20	7/2	3,900	A. M.	100	40	1	10	55.6	6.0×10^{-5}
86	33	...	7/4	...	A. M.	120	70	1	10	44.8	3.0×10^{-5}
87	34	7/27	8/29	3,140	A. M.	110	40	1 $\frac{1}{4}$	5	26.4	0.3×10^{-5}
88	35	5/31	7/8	4,100	A. M.	100	50	1	5	15.2	1.0×10^{-5}
89	36	3/4	5/7	3,740	A. M.	120	18	1 $\frac{1}{2}$	5	15	2.8×10^{-5}
90	36	...	5/8	...	A. M.	120	46	1 $\frac{3}{4}$	5	11.5	1.2×10^{-5}
91	36	...	5/9	...	A. M.	120	25	1 $\frac{1}{2}$	5	25	3.8×10^{-5}
92	37	2/28	6/11	3,900	A. M.	150	18	1 $\frac{1}{2}$	20	41	1.5×10^{-5}
93	37	...	6/13	...	A. M.	150	85	1 $\frac{3}{4}$	31	54	1.4×10^{-5}
94	37	...	6/28	4,120	A. M.	150	30	1 $\frac{3}{4}$	25	41	3.8×10^{-5}

* Dates marked (*) are 1912; all others in 1913.

milk, the values for rennet-pepsin were all less than 10; the mean value for lipase was only 23.6. This is in striking contrast to the figures for older children given in Table 2. These must not be regarded as pathological cases, as in Professor Finkelstein's clinic, where this work was done, it is customary to give albumin-milk to normal young infants who cannot be given breast milk. These cases also suggest that the gastric juice is influenced more by the age of the child than by the composition of the food; for the percentage composition of albumin milk (protein 2.8-3.2 per cent., fat 2.0-2.5 per cent.¹⁹) is practically identical with the percentage composition estimated for $\frac{2}{3}$ milk (Table 2), so far, at least, as their principal constituents are concerned. This and other points which will be readily suggested must be determined by the study of a large number of cases by many observers, using the routine which has been discussed in this paper and which seems to be the most satisfactory for the purpose that we have at the present time.

CONCLUSIONS

1. The determination of the hydrogen-ion concentration is the only rational method of measuring gastric acidity in infants.

2. The hydrogen-ion concentration, $(H) = 1 \times 10^{-5}$, is the normal reaction of the stomach contents at the height of digestion for infants fed on $\frac{1}{3}$ cream-milk and $\frac{2}{3}$ milk.

3. $(H) = 1.0 \times 10^{-5}$ is the optimum reaction for rennet and gastric lipase; pepsin is inert at this reaction.

4. The important processes in the gastric digestion of infants are the coagulation of milk by rennet and the splitting of fat by gastric lipase; the peptic digestion of casein is unimportant for the infant.

5. In infants from 1 to 4 months old fed on $\frac{1}{3}$ cream-milk the lipase content increases with the age of the infant.

6. In infants from 4 to 12 months old fed on $\frac{2}{3}$ milk the content of all gastric ferments is greater than in infants from 1 to 4 months old on $\frac{1}{3}$ cream-milk.

I wish to express my thanks to Dr. H. Davidsohn for his assistance and guidance in carrying out this work, and to Prof. Finkelstein for permission to use the material of his clinic.

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19. Pelka, H.: *Arbeiten zum zehnjährigen Bestehen d. Kinderasylo d. Stadt, Berlin, 1911.*