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DOMESTIC INFECTION IN RELATION TO EPIDEMIC DIARRHOEA.

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For some years past a careful record has been kept of the method of feeding, not only of all children dying of epidemic diarrhoea, but also of all babies under one year of age in the houses of the working classes, which are visited year by year in the course of routine house-to-house inspections by the sanitary inspectors in my department. It is impossible to ask the necessary questions at every house, but in most houses information has been given without difficulty, and it may be

Table I. *Methods of feeding Infants under one year of age in Brighton.*

	A.—Census of 10,308 houses in house-to-house inspection in the 3 years 1903—05				B.—Infants who died from Epidemic Diarrhoea in the 3 years 1903—05			
	Age of infants in months				Age of infants dying in months			
	0—3	3—6	6—9	9—12	0—3	3—6	6—9	9—12
I.—Suckled only ...	271	237	186	92	5	3	—	—
Ditto and farinaceous food	14	29	41	69	1	1	—	1
Ditto and cow's milk	5	6	7	4	1	—	—	—
Ditto and condensed milk	3	6	7	1	1	—	—	—
II.—Cow's milk only ...	12	32	28	18	11	22	7	4
Ditto and farinaceous food	4	26	33	33	1	—	4	6
III.—Condensed milk only	6	12	10	11	2	16	12	7
Ditto and farinaceous food	2	6	10	7	—	3	—	1
IV.—Farinaceous food, including patent food only mentioned, or "same food as parents"	4	1	2	18	1	1	—	—
V.—Unknown	—	—	1	5	2	4	2	2

taken as certain that the 1259 babies living in 10,308 houses who are classified in the first four columns of Table I belong approximately to the same social stratum as the 121 babies dying from diarrhoea who are classified in the four last columns of the same table.

The significance of the facts in Table I is plainer when the different groups are stated as percentages of the total as in Table II. The three main groups are shown in roman type, and it is with these that we are mainly concerned.

TABLE II. *Percentage of Infants under one year of age fed in different ways.*

	A.—In 10,308 houses visited house-to-house (1259 infants)	B.—Among Infants dying from Epidemic Diarrhoea (121 infants)
I.—Suckled only	62·3	6·5
Ditto and farinaceous food ...	*12·1*	*2·5*
Ditto and cow's milk	*1·8*	*1·7*
Ditto and condensed milk ...	*1·4*	*0·8*
II.—Cow's milk only	7·2	36·0
Ditto and farinaceous food ...	*7·6*	*9·1*
III.—Condensed milk only	3·1	30·3
Ditto and farinaceous food ...	*2·0*	*3·2*
IV.—*Farinaceous foods only mentioned*	*2·0*	*1·7*
V.—*Unknown*	*0·5*	*8·2*
	100·0	100·0

Breast-feeding and diarrhoea. On the supposition that the infantile population classified in the first four columns of Table I is a fair sample of the population in which the deaths from diarrhoea occur, and taking the whole of the first year of life together, the number of deaths from epidemic diarrhoea among breast-fed babies was not much more than one-tenth of the number which would have occurred had the deaths from diarrhoea been evenly distributed among all the babies. This statement does not express fully the superiority of breast-fed over hand-fed babies in regard to diarrhoea. Of the total eight deaths from epidemic diarrhoea among breast-fed babies none occurred after the sixth month of life. If we then consider separately babies aged 6–9 months, bearing in mind the fact that breast-fed babies at this age must have been breast-fed from birth, the figures show that although 57 per cent. of the babies aged 6–9 months in the sample population were entirely, and an additional 17 per cent. were partially breast-fed, not one of the 25 deaths from diarrhoea at these ages occurred among breast-fed or partially breast-fed babies.

The protection given by breast-feeding could not be more clearly shown than by these facts.

If breast-feeding is a complete protection against epidemic diarrhoea at ages 6–9 months, why not also at the earlier months of the first year of life? Two conclusions are justified and one is suggested by the facts relating to breast-fed babies. It is certain in the first place that mother's milk being sterile and breast-fed babies being occasionally attacked by diarrhoea *milk is not the only vehicle for its infection.* Secondly, it is certain that in *a considerable proportion of the total cases of diarrhoea* (at least 8 out of 121 deaths or 6·6 per cent. in the above series) *the source of the infection must have been solely domestic.* Thirdly, if milk was not the vehicle of diarrhoeal infection in the breast-fed babies possibly it was not so also in a considerable number of hand-fed babies. The effect of artificial feeding is complex, and the same sources of domestic infection apart from food are operating in hand-fed as in breast-fed babies. Both alike may suck infective matter from dirty fingers, from dirty dummy-teats, and in other ways.

The amount of artificial feeding. Before considering the relation of artificial feeding to diarrhoea, the facts as to the relative amounts of artificial and natural feeding of babies given in Table I may be discussed. These facts may be set forth as follows:—

TABLE III.

Percentage of total babies in each trimester who were	Babies aged in months			
	0–3	3–6	6–9	9–12
Suckled only ...	84·4	66·8	57·2	35·7
Suckled and having other food	6·9	11·6	17·0	28·7
Had cow's milk only ...	3·8	9·0	8·6	7·0
Cow's milk and other food ...	1·3	7·3	10·2	12·8
Had condensed milk only ...	1·9	3·4	3·1	4·3
Condensed milk and other food	·6	1·7	3·1	2·7
Other artificial foods and method of feeding unknown ...	1·1	·2	·8	8·8
	100·0	100·0	100·0	100·0
Number of babies on which the percentage is based ...	321	355	325	258

Of the total 1259 infants under one year of age among the poor visited house-to-house 978 or 77·6 per cent. were breast-fed or breast-fed along with other food, and 62·4 per cent. of the total number were breast-fed only. This refers to the whole of the first year of life. During the four successive trimesters the percentage of the total who were solely breast-fed was 84, 67, 57, and 36 respectively, the percentages

breast-fed with or without other food being 91, 78, 74, and 64 respectively. These figures are more satisfactory than had been anticipated. It is evident that a large majority of mothers perform the first duty of motherhood during the first six months of their babies' lives, and that even during the next three months about three out of every four babies are entirely or partially breast-fed. No comparative data for earlier years are available, but the above facts do not make it very probable that among the poor there has been much if any reduction in the proportion of natural feeding, and they thus confirm the contention on this point advanced by Dr Chalmers at the meeting of the Society of Medical Officers of Health in February, 1906.

Artificial feeding and diarrhoea. Taking all forms of artificial feeding together, Table II shows that of the sample infantile population 22·4 per cent. were artificially fed, while 88·5 per cent. of the total deaths from diarrhoea were among artificially fed babies. The chance of death from diarrhoea during the first year of life is quadrupled by artificial feeding, or by conditions associated with it. Of the sample population 15·3 per cent. were partly suckled and partly fed artificially, while 5·0 per cent. of the deaths from diarrhoea occurred among the same group. Even partial breast-feeding therefore forms an important protection against death by epidemic diarrhoea.

Subdividing results of artificial feeding according to age it is found that in the first trimester the liability to fatal diarrhoea is 8 times, in the second 4½ times, in the third 4 times, and in the fourth trimester 2½ times as great among artificially fed as among breast-fed babies.

The two most important because the largest groups of artificially fed babies are those fed on cow's milk and on condensed milk. The group fed on cow's milk in the sample population formed 7·2 per cent. of the total, while the deaths from diarrhoea in the corresponding group were 36·0 per cent. of the total. The group fed on condensed milk formed 3·1 per cent. of the total, the deaths in the corresponding group 30·3 per cent. of the total. Thus the probability of death from diarrhoea was twice as great among infants fed on condensed milk as among infants fed on fresh cow's milk. Comparing these figures with those for breast-fed babies, the probability of death from diarrhoea was 48 times as great among babies fed on cow's milk and 94 times as great among babies fed on condensed milk as among those breast-fed.

The details can be further studied in Table I, but the preceding statements embody the main teaching of this table.

Is epidemic diarrhoea milk-borne? That epidemic diarrhoea is not exclusively milk-borne is shown as already stated by its occurrence to a considerable extent among breast-fed babies. This fact makes it probable that in at least a considerable proportion of the cases of diarrhoea among artificially fed babies infection was received otherwise than by milk. The direct evidence does not enable us to go beyond this. The same evidence enables us to state, as already seen, that in a considerable proportion of the total cases of diarrhoea infection is domestic in origin. To what extent we may extend these two inductions to the babies dying from diarrhoea while fed on fresh or condensed cow's milk is a matter of dispute. My opinion already quoted in this *Journal*[1] is that diarrhoea is mainly of domestic origin, due to contamination of milk or feeding appliances by infective material which in all probability has chiefly a human origin. This statement of opinion is derived from critical examination of all the facts of the case in regard to fresh and condensed milk.

If the infection of summer diarrhoea were chiefly derived from the farm or from contamination during transit diarrhoea should be more fatal among babies fed on fresh cow's milk than among babies fed on condensed milk, because as will be seen below the original bacterial contents are much reduced in condensed milk and the dangers of transit are avoided. But in actual fact cow's milk is only associated with about half the proportional number of deaths with which condensed milk is associated. Condensed milk must therefore exercise some special maleficent influence beyond what is exercised by fresh cow's milk. Why is this?

Bacterial contents of condensed and fresh cow's milk. The few experiments made in our municipal laboratory (page 146) do not throw any light on the above question, and incidentally they show that neither a simple bacterial count, nor a statement of the presence or absence of the kinds of bacteria enumerated hereafter, throws light on the specific pathogenicity of condensed milks.

Experiment 1 showed in two samples of fresh milk 65 and 200 million bacteria per c.c. respectively. Table V shows that the number of bacteria in condensed milk is much less than the number in fresh milk, whether (*a*) incubation at 20° C. or 37° C. is begun directly the tin is opened, or (*b*) after the milk has been left exposed and undiluted for several days before incubation, as in Dr Sandilands' Experiments 3 and 4[2].

A further experiment was devised to ascertain whether condensed milk exposed for several days undiluted in warm air would show a great increase of bacteria, but no such increase occurred (Experiment 3).

As to the quality of the bacteria, *B. coli* were shown to be absent from 50 c.c. of Nestlé's condensed milk, as well as from ·5 c.c. of the twelve condensed milks in Table V (Experiments 4 and 5). That this inability to find *B. coli* in the above condensed milks was not owing to the fact that this bacterium cannot multiply and spread in condensed milks is shown by Experiment 6. The only conclusion justified is that the processes of condensation and preservation of milk usually kill off *B. coli*, which may be assumed to be always present in fresh cow's milk. Experiment 6 also shows that the supposed failure of *B. coli* to multiply in condensed milk is not due to the inhibitory influence of sugar. Bacilli morphologically resembling *B. enteritidis sporogenes* were found in ·5 c.c. of six of the eleven condensed milks examined for it.

As the bacterial contents of condensed milk do not appear to explain its excessive association with epidemic diarrhoea some other explanation must be sought.

(1) It is conceivable that the excess of diarrhoea among babies fed on condensed milk might be at least partially due to the fact that condensed milk is cheaper when diluted, as directed on the tins, than fresh cow's milk. This might conceivably have led to its being used to a greater extent by extremely poor mothers, in whose houses the sources of domestic contamination would be likely to be more abundant than among those who are better off. A detailed investigation of 96 babies dying from diarrhoea during 1902–05, who were fed wholly or partially on condensed or fresh cow's milk does not show any excess of poverty among those fed on condensed milk. Table II shows that about three times as many babies were fed (in houses visited apart from sickness) on fresh milk as on condensed milk. This must be borne in mind in the following examples of social position among babies dying of diarrhoea:

TABLE IV.

Deaths from Diarrhoea in the babies of	Condensed Milk	Cow's Milk
Labourers	6	10
Domestic Servants ...	5	7
Artizans	8	15
Persons above artizan class	5	8
All others	17	15
	41	55

(2) It is possible that condensed milks may have formed an important prae-condition of diarrhoea by causing defective nutrition, by producing a semi-scorbutic condition, or by setting up preliminary catarrhs of the digestive tract. As bearing on this point it must be noted that the bad results of condensed milks do not arise from the cheaper brands of condensed milk being chiefly used, and therefore not from the use of machine-skimmed milks, which would doubtless be still more injurious. During the three years 1903–05, 37 babies fed solely on condensed milk died from diarrhoea. Of these 33 were fed on Nestlé's, one on Gallia's condensed milk, one on condensed milk of the Milkmaid brand, and two on condensed milk of an unknown brand.

All these condensed milks are preserved with sugar, a fact which probably is important, as bearing on the above possibilities. I know of no experience with unsweetened condensed milks, or of such milks modified and enriched to approximate more nearly to the composition of human milk, which can be compared with the above calamitous results of feeding with sweetened condensed milks.

(3) There can be no doubt that a tin of condensed milk when opened is, during the three or four days which elapse before it is emptied, very attractive to flies and receives apart from the visits of flies a considerable amount of domestic infection in the form of dust. It is probable that both the second and third suggested causes of excess of diarrhoea among infants fed by condensed milk play a part in producing this excess. Further experiments are required as to the toxic effects of condensed milks. The special proneness of condensed milk to domestic infection is probably more important than the conditions enumerated under the second heading above.

Conclusions.

1. Breast-fed infants have only one-tenth of the average proclivity of infants to fatal diarrhoea.

2. Continuous breast-feeding forms so important a protection against diarrhoea that in the experience here recorded no deaths from this disease occurred in the 7th, 8th, or 9th month of life.

3. The fact that 6·6 per cent. of the total deaths from infantile diarrhoea occur in breast-fed infants shows that milk is not the only vehicle for the infection of this disease.

4. In the above percentage of cases infection must have been domestic in origin.

5. A presumption is raised by the facts under 3 that in at least

a certain proportion of the remaining 93·4 per cent. of the total deaths from diarrhoea infection was not milk-borne.

6. Artificial feeding of infants is exceptional among the classes among whom diarrhoea chiefly occurs. There is no satisfactory evidence that it has increased among these classes.

7. Among these classes the liability to death from diarrhoea is nearly 50 times as great among infants fed on cow's milk, and nearly 100 times as great among infants fed on condensed milk as among those breast-fed.

8. Domestic infection has been shown to be the cause of diarrhoea in a considerable proportion of cases (4). That the infection of diarrhoea is not chiefly received in transit is indicated by the excess of diarrhoea among infants fed on condensed milk, in which the dangers of transit are avoided.

9. That the infection is not derived from the farm appears to be indicated by the bacterial examination of condensed milks, which reveals much more favourable conditions than those of fresh cow's milk.

10. There is, however, the possibility that both in the case of fresh and condensed milk infection may have been derived from the farm, and that the toxic products of bacterial action are the cause of diarrhoea. Further investigation is needed on this point.

11. Against the possibility expressed under 10, is the fact that nearly 7 per cent. of the deaths from diarrhoea are among breast-fed infants, thus eliminating the factor of toxic products from the farm.

12. In balancing up the above facts and considerations, I have no hesitation in adhering to the opinion stated in many of my past annual reports that diarrhoea is mainly due to domestic infection.

EXPERIMENTS MADE AT THE BRIGHTON MUNICIPAL LABORATORY.

BY T. B. HEGGS, M.D., D.P.H.

Experiment I. Two samples of cow's milk were obtained under sterile conditions about 24 hours after milking in July, and the ordinary methods of diluting with sterile water and plating on gelatine were used. No. of colonies present at the end of 48 hours were 65,300,000 and 200,000,000 per c.c. respectively.

Series of Experiments II.

The results obtained are shown in Table V.

Experiment III. A tin of condensed milk was opened, and the bacterial contents of a sample taken immediately from it were ascertained. As soon as the above sample had been withdrawn, the open tin of milk was placed in the incubator at 37° C. and the milk examined for number of bacteria, after having been subjected

TABLE V. *Examination of Condensed Milks.*

Number of Bacteria.

Name of Milk	Date of Examination	(1) Examination begun as soon as tin opened		(2) Examination begun some days after tin had been left opened and exposed to air of laboratory			Sweetened (S) or Unsweetened (U) milk	Extracts from Remarks and Directions on the tin for use of the Milk
		No. of bacteria found in 1 c.c. of the original milk at end of four days after incubation on		No. of days' exposure	No. of bacteria found in 1 c.c. of the original milk at end of four days after incubation on			
		Gelatine at 20° C. (1)	Agar at 37° C. (2)		Gelatine at 20° C. (3)	Agar at 37° C. (4)		
Nestlé's ...	11/10/1905	230	120	7 days	360	720	S	Directions—1 to 9 of water for infants 4 months old.
Hit Brand...	30/9/1905	280	484	3 days	183	1130	S	Machine skimmed. Directions—1 part to 5 of water.
Uncle Tom	1/1/1906	490	150	5 days	740	4000	—	Machine skimmed.
Milkmaid ..	3/11/1905	1300	600	7 days	1000	1200	—	Directions—Not less than 1 to 7 of water.
Posy Brand	9/12/1905	1360	21250	6 days	2700	not estimated	—	——
Gallia Brand	1/11/1905	2560	2000	8 days	3250	1600	—	Label states "absolutely free from bacteria." Directions—1 part to 4 or 5 of water.
Horse-Shoe Brand ...	14/11/1905	2570	3000	6 days	5630	6560	S	Machine skimmed. Directions—1 part to 5 of water for cooking.
Ideal Brand	4/10/1905	5450	4010	4 days	12800	5850	U	Label states it is *sterilised*. Directions—1 part to 2 of water.
Cup Brand	8/12/1905	5980	3300	6 days	15200	not estimated	—	Machine skimmed.
Crown Brand ...	16/12/1905	8800	11800	6 days	40000	not estimated	—	——
*Head Brand ...	1/12/1905	21800	44200	4 days	in 3 days 114740	in 3 days 128000	—	——
Tip Top Brand ...	16/10/1905	70940	7600	11 days	16500	not estimated	—	Directions—1 to 7 to 14 of water.

* This milk was much less viscid than the others on the list.

to this temperature for one, two, three, and four days. The results were as follows:

Bacterial contents of milk per c.c.

On opening the tin	1150
After 1 day's incubation	1370
„ 2 days' „	1160
„ 3 „ „	1960
„ 4 „ „	8960

Experiment IV. 5 c.c. of a 1 in 10 dilution of each of 11 of the condensed milks enumerated in Table IV was added to McConkey broth at 42° C. None produced gas and acid; 10 produced acid alone.

Experiment V. (1) 19 c.c. of a newly opened tin of Nestlé's condensed milk were taken under sterile conditions, and at once incubated in McConkey's broth after dilution to 1 in 10. No *B. coli* found.

60 c.c. of the above dilution equal to 6 c.c. of the same condensed milk were incubated for 48 hours at 37° C. before being added to McConkey's broth. No *B. coli* found.

It follows from these two experiments that no *B. coli* were present in 25 c.c. of the above milk, although in the last 6 c.c. multiplication was facilitated by a preliminary incubation at 37° C. of the milk diluted by sterile water.

(2) 50 c.c. of another tin of Nestlé's milk was shewn by the same method to be free from *B. coli*.

Experiment VI. (1) The lowest spot at the bottom of a sterile test-tube was inoculated with three loopsful of a broth culture of *B. coli* and then 25 c.c. of the condensed milk from the same tin as was used in Experiment V (and which was shown to have no *B. coli* in 25 c.c.) were drawn into this test-tube by means of a water exhaustion pump. The experiment was so done that the *B. coli* in the test-tube were necessarily imprisoned 2¾″ below the surface of the added condensed milk. Subsequent aerial contamination of the tube was prevented, and its contents were incubated for 48 hours at 20° C. At the end of this time 1 c.c. was carefully drawn from the surface of the milk in the tube, diluted with 10 c.c. and inoculated on McConkey broth. There was marked gas production and *B. coli* were demonstrated. It follows that *B. coli* can readily multiply and spread in condensed milk at ordinary temperatures.

(2) At the same time as the 50 c.c. in Experiment V (2) were withdrawn, more of the same milk was transferred to sterile test-tubes *A*, *B*, *C*, *D* (the largest quantity being 25 c.c.), so that the depth of condensed milk in these tubes was respectively 4¼, 3¾, 3¼, and 2½ inches. The upper surface of each of these milks was inoculated as in Experiment VI (1) with *B. coli*, and the tubes were then incubated at 37° C. for 10 days. Each of them was then broken at the bottom and ·5 c.c. of milk withdrawn from the point most remote from the point of inoculation of *B. coli*. From tube *A* 5 c.c. were also withdrawn. The four small quantities were inoculated on 10 c.c. of McConkey broth, the larger quantity on 25 c.c. of the same medium, and incubated at 42° C. After 24 hours copious gas production occurred in the subculture tubes from *A* (inoculated with 5 c.c. of milk) and from *D* (inoculated with ·5 c.c. of milk).

REFERENCES.

(1) Sandilands, J. E. Epidemic Diarrhoea and the Bacterial Content of Food, *Journ. of Hygiene*, this vol., p. 89.

(2) *Loc. cit.*, p. 87.