had categorically and correctly announced the cause of scurvy and 162 years after Lind had described its cure, and it was made in the course of a research primarily undertaken for another purpose. It is difficult not to believe that an active clinical science, by its situation so favourably placed for a direct attack, could have saved some of these long and costly years.

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SOME ASPECTS OF INFANT FEEDING*

BY

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To ensure that a baby will make normal progress it is necessary that it shall retain sufficient suitable food. If we concentrate our attention on suitability and on adequacy and on some examples of under-feeding and of over-feeding we shall find material for profitable discussion.

Suitability

The percentage composition of the feeding mixture is used extensively as the guide to the suitability of an artificial feeding. It would be wise to abandon this basis in favour of the caloric basis, to which a great deal of attention has been directed since 1925, when Grover Powers¹ published his stimulating paper. The distribution of the total calories between the basal components may be calculated readily by splitting the caloric value per ounce into fractions derived from carbohydrate, protein, and fat respectively. Each of these fractions can be expressed as a percentage of the whole. The number of calories out of a hundred derived respectively from each component forms the caloric basis, by means of which different feeding formulae may be compared. On this basis terms such as "high-protein diet" acquire a new and a better meaning.

In the "majority group" of Powers, which included most of the successful feeding formulae, "the percentage of the total calories in protein varies between 10 and 20 per cent., and in fat between 15 and 30 per cent."² I am of opinion that the lower limit for protein and the upper limit for fat are both strained, and I am able to state that when the percentage of the total calories in protein lies between 13 and 18, and, in fat, between 15 and 40, the mixtures prove safe and suitable for the vast majority of babies in Melbourne (16 per cent. from protein and 32 per cent. from fat are safe average proportions). In other words, one aims at a protein ratio by calories between 1 : 4½ and 1 : 7.

Provided that the fat percentage of the milk used lies between 2.5 and 4.5, these conditions will be fulfilled if 70 per cent. of the total calories comes from cow's milk and 30 per cent. from added sugar (Table I). Enough water must be added to bring the fluid intake up to two and a half ounces per pound of body weight per day in cold weather, and to three ounces per day in hot weather.³

TABLE I.—Feeding with Milk 70 per cent. and Sugar 30 per cent. of Total Calories

Irrespective of the caloric intake or of added water, the distribution of each 100 calories will vary with the fat content as under. (Carbohydrate assumed to be constant at 5 per cent. and protein at 3.5 per cent.)

Percentage of Fat	Distribution of 100 Calories			Protein Ratio by Calories
	Carbohydrate	Protein	Fat	
2.5	54.70	17.20	28.10	4½
3.0	52.78	15.91	31.21	5½
3.5	51.31	14.82	33.87	5½
4.0	49.91	13.85	36.23	6½
4.5	48.70	13.02	38.28	6½
5.0	47.71	12.26	40.03	7½

The caloric value per ounce of the milk used will also vary with the fat content, and the number of ounces of milk to be used in a given case will be determined by dividing the number of calories to be supplied from milk by the caloric value per ounce of milk. In Table II will be found calculations of these variants.

TABLE II.—Feeding with Milk 70 per cent. and Sugar 30 per cent. of Total Calories

The effect of the varying fat percentage on the caloric value per ounce of milk, on the total carbohydrate percentage from milk and sugar, and on the caloric value per ounce of milk and sugar. Addition of water will make a proportional decrease in these figures.

Percentage of Fat	Caloric Value per ounce of Milk	Carbohydrate percentage of Milk and Sugar	Caloric Value per ounce of Milk and Sugar
2.5	16.57	11.12	23.71
3.0	17.91	11.62	25.63
3.5	19.24	12.11	27.54
4.0	20.57	12.60	29.45
4.5	21.91	13.09	31.35
5.0	23.24	13.60	33.28

Those who always like to know the percentage composition of the mixture used should note that there is a constant difference between the fat percentage (Col. 1) and the sugar percentage (Col. 3) of 8.6. Those who like to use a mixture of constant energy value per ounce can calculate the amount of added water required from Col. 4, the caloric value per ounce of milk and sugar. Those who prefer low-protein mixtures can dilute proportionally with water. If each of you will give this matter of the caloric basis of comparison your earnest thought in the light of its applicability to the system of feeding you practise, it is probable that we shall find in it a common ground for justifying the good results we each obtain, and also recognize that some of our pet principles are mere shibboleths.

We know that the biggest variable in cow's milk is the fat percentage, and for accurate feeding we should have a good idea of the fat content of the milk that is used. In every institution for babies it should be the custom to estimate the fat percentage daily. It may be of interest to refer to the method adopted at the Presbyterian Babies' Home, Melbourne. The milk arrives in five-gallon cans, and a sample is taken of the mixed milk for fat estimation; it is usually about 4 per cent., but may be 4.8 per cent. The bulk milk stands in a refrigerator, and after being undisturbed for three hours, if the estimation was 4 per cent., one pint is dipped off the top to reduce the fat percentage of the remainder to 3.5. A little more or a little less is removed according

* Read in opening a discussion in the Section of Diseases of Children at the Annual Meeting of the British Medical Association, Melbourne, 1935.

to the sample estimation. The remainder is then tipped into a container with a tap, and pint bottles are filled with a 3.5 per cent. milk and are placed in the refrigerator. In a further three hours the pint bottles are skimmed according to requirements of individual babies. Table III shows the approximate fat composition of the remaining milk according to the amount of top milk dipped off. Special testing is carried out for premature babies or other special cases, and shows very slight variations from these results.

TABLE III.—Results of Skimming Milk (Presbyterian Babies' Home)

Milk standardized to contain 3.5 per cent. fat stands in pint bottles in a refrigerator, and the fat in the remaining milk varies with the amount of milk skimmed off as under.

Amount Skimmed	Fat Percentage of Remainder
1 oz.	3.1
2 oz.	2.9
3 oz.	2.8
4 oz.	2.7
5 oz.	2.6

When we are not able to get such estimations we must guess at the fat percentage of the milk. As 3.5 per cent. is the legal minimum it is too low a figure to use in average cases. I suggest that we should adopt the figure 4 per cent. for general use in our calculations instead of 3.5 per cent., and the figure 5 per cent. when the milk comes from a Jersey herd. It would be an advantage if milk intended for consumption by infants were standardized at approximately 4 per cent. Fat disturbances are prevalent, and one feels that on many occasions they are due to the difference between the actual and the calculated fat content of the feeding.

With modern methods of modifying protein by dilution and simmering, by desiccation or evaporation, by boiling and acidification, by boiling and the use of a whey diluent or a starch or gelatin (colloid) diluent, the older methods of citration, of pre-digestion, of extreme dilution, and of pasteurization in the home are being superseded, and protein damage is very rarely encountered. Though it is recognized that by the use of low-protein mixtures babies can be nurtured satisfactorily, the practice introduces an avoidable anxiety in the direction of excessive carbohydrate or of excessive fat feeding if the amount for the day is to prove adequate and still be within reasonable limits.

It is more difficult to achieve success with the extremes either of dilution or of concentration, and by steering a middle course and using mixtures of a caloric value a little less than that of human milk (say 18 calories per ounce) to ensure an adequate fluid intake, with a suitable distribution of the total calories and with well-modified protein, our main concern will then be adequacy and our problems will be under-feeding and over-feeding.

Adequacy of Diet

There are a number of systems in use for the estimation of adequacy,⁴ but perhaps the calculation of the theoretical caloric requirement by the Truby King method,⁵ combined with the theoretical fluid requirement, is of the greatest practical value. Whatever method we use we must realize that there are individual babies who need a little more and others who will flourish on a little less either all the time or at certain times. These theoretical calculations must be used as guides and not as absolute measurements.

In addition to accuracy in the measurement of the components of the feeding mixture and of the amount taken and retained by the baby, accurate weighing of the baby increases one's control over this important factor of adequacy. There should be, at every health centre, spare scales for loan in the homes for test feeding

purposes. In passing one may note that although it is usual to assume that one ounce of breast milk has an energy value of twenty calories, it would be better for the baby if we used the figure nineteen in our calculations. (Average formula: protein 1.5 per cent., carbohydrate 7 per cent., fat 3.5 per cent.; calculated caloric value per ounce is 19.25.)

When a baby is being fed naturally and the question of adequacy arises, test feeding is necessary and should be made the basis of an opinion. The only way to know how much breast milk a baby has taken at a feeding is to weigh the baby accurately before and after. It is a common practice to carry out several isolated test feedings and compute from the figures the daily intake. This practice is fallacious because of the extraordinary variation we find in the amount a baby will take at different feedings. Further, as the daytime feedings are often much smaller than the early or late ones, we may be positively misled, and initiate artificial feeding unnecessarily. It is much more satisfactory to insist on twenty-four-hour test feeding either consecutively or periodically.

On the breast milk analogy and on repeated observations of the behaviour of babies in this respect, there is no need to apologize for advocating appetite-feeding—that is, that babies should be allowed to vary the amount taken at each feeding. It is often safer to advise regular administration of a fixed amount, but this advice is short of the ideal. When appetite-feeding is permitted, it is important to keep a record of the amount taken. One finds that the results substantiate the soundness of the theoretical caloric requirement and of the theoretical fluid requirement as guides to adequacy.

Some Problems of Under-feeding

PREVENTION OF EARLY LOSS OF WEIGHT

If a baby is under weight at birth an effort should be made to prevent or minimize initial loss of weight after birth. This is especially desirable after induction of labour for toxæmia, and for premature babies and small babies who are to be fed artificially because of maternal tuberculosis or diabetes. Early complementary feeding and initiation of the re-establishment procedure in the early days of lactation has been regarded as the method of choice for those babies who can be fed at the breast. The complementary feeding selected should be suitably balanced on the caloric basis, and the protein should be relatively high and extremely well modified. By gradation, satisfactory artificial feeding can be established if lactation fails in spite of our efforts. When breast-feeding is contraindicated, a suitable feeding mixture may be used from the outset. The use of a hydrating solution such as that suggested by Kugelmass⁶ of New York in 1932 has interesting possibilities.

RE-ESTABLISHMENT OF FAILING LACTATION

During the early weeks of life it is highly desirable that close supervision of the baby's progress should be maintained, for, apart from congenital anomalies incompatible with life, such conditions as pyloric stenosis and pylorospasm may make their appearance, and, even when there is no physical basis for failure to thrive, unsuitability or inadequacy of the feeding may cause serious damage if unrecognized and uncorrected.

Early recognition of insufficiency of breast milk usually leads to rapid improvement when the re-establishment procedure is adopted promptly. When a number of weeks are allowed to pass without any action being taken there is a corresponding delay in re-establishment. When it is convenient for the mother, the mother and baby should be admitted to a special mothercraft institution for

re-establishment of failing lactation. These institutions are modelled on the famous Karitane Hospitals of New Zealand, and the procedure adopted is practically identical. Admission to an institution can be avoided if the mother is willing to carry out the procedure in a modified form in her own home with or without the assistance of a skilled nurse. Consecutive or periodic twenty-four-hour test feedings are used to measure the intake, and the complementary feeding should be given after the breast-feeding in unlimited but measured amount, preferably by spoon-feeding. The importance of complete emptying of at least one breast at each feeding must be stressed, and any milk that can be expressed should be given to the baby. As time goes on, as the amount of breast milk increases, the artificial feeding need be offered at fewer feedings each day, and, ultimately, in a successful case it will be discontinued.

The amount of expressed breast milk obtainable is an important index to the probability of successful re-establishment,⁷ and in an ideal case no artificial feeding need be used. As much as 20 per cent. of the total breast milk may sometimes be expressed and used for complementary feeding.

MIXED FEEDING

When both human milk and an artificial feeding have to be used together over a long period it is extremely difficult to gauge the adequacy of the combined feeding. If too much artificial food is given the natural supply diminishes; if the complementary feeding is too small the baby will be underfed. If regular twenty-four-hour test feedings cannot be obtained the progress of the breast supply can be estimated approximately by measuring the amount of complementary food retained and the weight of the baby. If the baby is making normal progress the theoretical caloric requirement for that baby at that time may be assumed to be the total caloric intake. By subtracting from this figure the caloric value of the complementary feeding the caloric value of the breast-feeding is obtained. Division by nineteen yields the estimated number of ounces of breast milk per day. By this method comparisons may be made from week to week which influence the decisions to increase or decrease the amount of complementary feeding with the object of improving the yield of breast milk.

Every effort should be made to prevent a sudden cessation of breast-feeding because of the inevitable under-feeding which follows before adequate amounts of the artificial feeding can be administered safely.

NORMAL WEANING

On account of weaning, a baby should not lose weight. It is of great importance that all changes in the dietary of an infant should be made gradually; the transition should be smooth and progressive. Educational diet should be included at the appropriate time for breast-fed babies, just as it is for those fed artificially. Cow's milk should be included in the educational diet. It follows that complementary feeding should precede supplementary feeding in the process of normal weaning. The breast-fed baby should not be handicapped dietetically. The energy value of the substitute feeding (supplementary feeding) should be somewhat greater than that of the natural feeding it replaces, to compensate for the failure of lactation that supplementary feeding entails.

POWER OF RECOVERY AFTER UNDER-FEEDING

If something from below pulls a cork which is floating in the water, the cork will go under the surface temporarily. When it is released it will come to the surface and will float along again. The baby's weight is the cork and the age-weight line of growth is the surface.

The unknown "something" may be any of the causes of loss of weight. When the cause of loss of weight is removed a baby should be expected to make rapid gains until the weight reaches the point indicated by a continuation of the original curve. If the weight does not return to the expected level, the cause of the depression is still acting, or serious damage has been done which has altered the metabolic rate.

The Victorian age-weight line of Scantlebury⁸ has proved extremely useful as a standard for comparison in my studies. In the main, it can be stated that most of the babies tend to parallel it. Those under weight at birth, with the exception of premature babies, are likely to remain correspondingly below the average weight. Those over weight at birth should not be regarded as over-fat unless the weight line rises out of proportion. There are two qualifications to these generalizations. First, most babies grow rather more rapidly in the last quarter of the first year, and secondly, there is a fairly common type of curve in which the rise is steeper throughout the first year. This steeper curve may be recognized by the time the baby is 4 months old. The essential facts are that there is a definite line of growth for each baby, and that this rate of growth is independent of the feeding, provided that the latter is suitably balanced and the baby is not underfed.

A baby that is regarded as frail in the first month or two should be given a "trial by food." Offer him an unlimited amount of well-modified, well-balanced food, such as a mixture of equal parts by weight of sweetened and unsweetened condensed milk with added water. If he gains weight rapidly his frailness will soon disappear. The really frail baby will make much slower progress.

Over-feeding

The principle concerning over-feeding that emerges on close observation of the feeding of babies is that, without forcing the feedings, a baby will not take too much of one constituent except to get enough of another. On this theory over-feeding will not occur if we study the requirements of each baby carefully and yet allow his appetite to be the guide to the amount. Standardization of infant feeding is not ideal, but when it cannot be avoided it should be based on sound principles.

When the over-feeding occurs on a suitably balanced diet it is very likely to be due to insufficient intake of fluid. The baby will take too much solid food to get enough fluid. In such a case, fat seems to be the first ingredient to cause trouble. It is important that the early signs of fat disturbance should be recognized. Increasing difficulty in administration of the feeding on account of loss of appetite and consequent small weekly gain in weight should be taken as a warning to skim the milk more and to give more fluid. If this action is not taken, further loss of appetite and occasional vomiting will occur. If this is disregarded more vomiting and diarrhoea with loss of weight and definite illness will follow, and a considerable alteration in diet will be necessary. Over-feeding with fat is frequently due to the actual fat in the milk being so much higher than is allowed for in the calculations.

Instances of carbohydrate over-feeding are encountered frequently. The babies are often being fed with a weak milk dilution with a lot of added carbohydrate, or are on a patent feeding consisting largely of carbohydrate. They take far too much carbohydrate in order to get enough protein. The percentage composition of the mixture is a poor guide. It is useless to fix on an arbitrary figure such as 7 per cent. carbohydrate as the upper limit of safety; 8.5 per cent. can be given safely in an undiluted cow's milk mixture, and yet 6 per cent. may cause

anxiety in a mixture with two parts of milk to three parts of water. In the first example, only 43 per cent. of the total calories are derived from carbohydrate, but in the second the proportion is 57 per cent. Unquestionably, it is safer to use a higher percentage of carbohydrate in a less dilute milk mixture, and yet one frequently sees the contrary advocated. No doubt the reason for this is the desirability of increasing the caloric value per ounce of the weaker mixtures, but this reason is not valid when it can be shown that an important principle of balance and of safety is being violated.

When mechanically separated milk is used in infant feeding the fat may be reduced to 1 per cent., and the non-protein side of the feeding has to be augmented with added carbohydrate. If such a feeding is to be given in adequate amount there is a danger of a carbohydrate disturbance. In a case of this kind the use of whey as a diluent will increase the caloric value and lower the protein percentage without raising the carbohydrate, and less sugar will be required to preserve the balance between protein and non-protein in the mixture. Even then it would be safer to add lactic acid to secure greater modification of the protein and to raise the acidity of the stomach contents, which is usually too low in the cases of infantile dyspepsia in which the low fat milk would be indicated.

OVER-FEEDING WITH BREAST MILK

The same theory is applicable as a basis for the management of the examples of over-feeding with breast milk we sometimes encounter. The babies will be taking too much of one constituent to get enough of another. When the cause is excessive concentration of the breast milk, free administration of fluid to the mother and to the baby is all that is required if the milk is suitably balanced. It is not possible, however, to reduce the protein in human milk by cutting down the protein in the mother's diet, and the same applies to the other ingredients. The high milk fat yield of a Jersey cow and the low fat of a Frisian cannot be explained by a difference of diet. One usually advises a reduction in the sugar or in the fat intake in an attempt to correct breast milk abnormalities, but when the free administration of fluids is not successful, analysis of the breast milk should be insisted upon. A reduction in the time of feeding is one way of countering excess of fat, because the end-milk is richest in fat. The end-milk should be removed and discarded, or progressive failure of lactation will follow through incomplete emptying. If the carbohydrate is low a suitable spoon-feeding of lactose solution or some such high carbohydrate may be given as a complementary feeding. The same type of spoon-feeding will help to restore the balance if the protein is too high. Very occasionally, it will be better for the baby to be weaned early.

Conclusion and Summary

1. An approach to some of the problems of infant feeding has been made by discussing (1) suitability, and (2) adequacy.

2. The percentage distribution of the calories—the caloric basis—has many advantages over the percentage composition—the percentage basis—as a guide to balance, grading, and suitability.

3. When the percentage of the total calories in protein lies between 13 and 18 the mixtures prove safe and suitable for most Melbourne babies.

4. These conditions will be fulfilled if 70 per cent. of the total calories come from cow's milk and 30 per cent. from added sugar. Enough water must be added to cover the fluid requirement.

5. Concentration of artificial feedings to a caloric value per ounce of approximately eighteen calories is desirable to eliminate anxiety concerning the fluid requirement.

6. The caloric basis of comparison reveals an explanation of the reason for the success of apparently dissimilar feeding methods.

7. Difficulties arising from the variable nature of the fat percentage of cow's milk complicate infant feeding and require solution.

8. Appetite-feeding with reservations and under control is to be preferred to the administration of a fixed amount at each feeding.

9. In estimating the intake of breast milk, consecutive or periodical twenty-four-hour test feedings are much more reliable than are scattered test feedings.

10. An attempt should be made, in selected cases, to prevent the usual initial loss of weight after birth.

11. Early recognition of failing lactation and prompt attempt at re-establishment will prevent avoidable under-feeding.

12. On account of weaning, a baby should not lose weight. Cow's milk should be included in educational diet. Complementary feeding should precede supplementary feeding.

13. Frail babies should be given a "trial by food." There is a definite line of growth for each baby, which will be followed if the baby receives sufficient suitable food.

14. The principle concerning over-feeding is that a baby will not take too much of one constituent except to get enough of another.

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M. Gundel (*Deut. med. Woch.*, July 19th, 1935, p. 1145) draws attention to the great rise in the incidence of diphtheria in Germany during the last few years. The figures rose from 57,000 in 1931 to 74,000 in 1933, and to well over 100,000 in 1934. To judge by the notifications for the earlier months of 1935, the disease is still on the increase. Though the absolute number of deaths also shows a rise the mortality remains low in relation to the morbidity. Up to the beginning of 1934 little use was made of active immunization, because the public was indiscriminately hostile to inoculations on account of the Lübeck disaster, and because the medical authorities did not consider the evidence in favour of active immunization strong enough to warrant its wholesale employment. Recently, however, Professor Gundel, who is attached to the Robert Koch Institute for Infectious Diseases in Berlin, has undertaken wholesale immunization against diphtheria among some 400,000 children with one or other of the three preparations available in Germany—toxin-antitoxin-gemisch (T.A.), toxin-antitoxin-flocken (T.A.F.), and formol-toxoid (a serum-free, completely detoxicated preparation). All these preparations were given by subcutaneous injection. In a considerable proportion of cases, and on account of shortage of material for inoculation, each child had only one or two instead of three successive injections. The statistics the author produces show that the immunity conferred by only one or two injections was considerably inferior to that developed by the child receiving three injections. While the incidence of diphtheria among all the children immunized by one, two, or three injections was as 1 to 6.5 among the controls not immunized, this ratio was as 1 to 13 when only those children were considered who had each received three injections.