VITAMIN A REQUIREMENTS OF INFANTS: THE HEALTH OF INFANTS FED ON ROLLER-PROCESS DRIED MILK, WITH AND WITHOUT A SUPPLEMENT OF VITAMIN A

BY

HELEN M. M. MACKAY, M.D., F.R.C.P.

Member of the Staff of the Medical Research Council, Physician to the
Queen's Hospital for Children, London

Some years ago the author (Mackay, 1934b) compared the progress made by two groups of infants fed on a roller-process dried milk, one group receiving extra vitamin A as an added supplement, the other wholly dependent for their vitamin A on that present in the dried milk, until such age as they received a mixed diet and derived part of their vitamin A from 'table food.' The comparison revealed no difference between the two groups except in one particular: the number of minor infective skin lesions in the control group was approximately double that in the group receiving extra vitamin A. The lesions classified as infective were for the most part due to some local irritation, where an infection (due to local organisms of low virulence) had presumably taken temporary root, e.g. sore buttocks, intertrigo.

A search of the literature on vitamin A deficiency in man revealed the fact that, although until recent years attention had usually been focussed on the lesions of the eyes, yet there was much to suggest that objective eye changes were often preceded by changes in epithelial cells in other parts of the body; moreover, in clinical accounts of xerophthalmia and keratomalacia there was frequent mention of skin infections of various types (Mackay, 1934a). In recent years 'phrynoderma' or 'papular dry skin' has been recognized as part of the symptomatology of vitamin A deficiency in school-children and adults, and many of these cases have no clinical lesions of the conjunctiva or macroscopic epithelial changes in the eyes (Loewenthal, 1933 and 1935a; Nicholls, 1934; Goodwin, 1934; Frazier and Hu, 1936; Reiss, 1936). In the light of these various observations the author (Mackay, 1934b) suggested that diminished resistance to skin infection was probably one of the earliest results of vitamin A deficiency in children. However, the number of infants with such infections in the two groups then studied was insufficient definitely to establish that the difference between the two groups could not have arisen by chance; although the uniformity of the differences obtained in each season and for the various types of skin lesion made this unlikely. The question is one of importance, both because it should be known whether in this country there is a risk of widespread, if slight, vitamin A deficiency in infants if they do not receive a supplementary ration of vitamin A, and also because it is highly

desirable that the earliest signs of this condition should be known. Potent vitamin D preparations nowadays often replace cod-liver oil as an antirachitic supplement, so that milk is often the only source of vitamin A in the diet of infants.

As against the author's findings, Hess, Lewis and Barenberg published in 1933 an account of an investigation, similar to the author's, but carried out on in-patients in the Home for Hebrew Babies, New York. They concluded that the babies who received the usual diet of this institution, without a supplement of cod-liver oil or any vitamin A concentrate, did not show any evidence of vitamin A deficiency or of increased susceptibility to skin infections. In 1938 Lewis and Barenberg published another paper from this home. Two groups of babies were given a diet consisting of a partly skimmed dried milk (which when reconstituted contained 1.5 per cent. fat) up to the age of four months, after which semi-solids and solids gradually replaced part of the milk. Certain rich sources of vitamin A, such as spinach, butter and egg, were excluded. One group received in addition to this basic diet a supplement of halibut oil, which greatly increased their vitamin A intake. No difference was found in the nutritional status or in the incidence of infections between the two groups—and no excess of skin infections in the group getting partially skimmed milk. The authors give no indication of how they assessed the skin infections. They conclude that the ordinary diet of the home, which provided each child daily with one to two ounces of full milk per pound of body weight, with the addition of vegetables, butter, and eggs, as the child grew older, allowed an ample margin of safety as regards vitamin A without the administration of cod-liver oil. However, it should be stated that the average time a baby was on the partly skimmed milk without other sources of vitamin A was under four weeks, since the average age of babies at the beginning of their observation was a little over five months, and by six months old they were having vegetables. The result, too, may have been influenced by whether or not the babies had built up vitamin A reserves before five months old (e.g. by cod-liver oil medication before they came under observation).

In recent years the author has tried to ascertain whether, in older children of the hospital class in London, an extra ration of vitamin A will diminish infective skin lesions or bring about their more rapid cure. Unfortunately this work has not produced positive results :

(1) Vitamin A was given to children attending hospital with skin infections (unpublished work), but so many factors entered into the results that no clear conclusion could be reached.

(2) Children admitted to hospital with measles were treated with vitamin A. They showed no superiority over the control group in resistance to skin infections or in any other respect, but their average stay in hospital, and consequently the average period of treatment, was too short for any final conclusions to be drawn as to the possible effect of extra vitamin A on their skins (Mackay, Linford, Mitman and Wild, 1936).

Workers studying clinical cases of overt vitamin A deficiency in East Africa (Loewenthal, 1935b) and in China (Sweet and K'Ang, 1935; Frazier and Hu, 1936 ; Reiss, 1936) did not find evidence of the existence of increased susceptibility to skin infections in their cases. The author decided, therefore, to repeat the investigation with babies given roller-process dried milk with and

without a supplement of vitamin A, and particulars of this work are given in the present paper.

Nature of present investigation

This investigation lasted nearly three years, and as before was concerned with artificially-fed babies and young children up to two years of age living in their own homes. A few babies received some breast milk. The babies were divided into two groups, the conditions for each group being kept as similar as possible except for the factor under investigation. The control group received only the vitamin A present in their dried milk or mixed food, and were given an emulsion of vitamin D ; the group with which they were compared received extra vitamin A as well as D in the form of an emulsion of cod-liver oil.

Clinical material.—The children were out-patients at the Queen's Hospital for Children, which is in a poor district in London, and as before children of the poorest social classes were included.

NUMBER OF BABIES.—The number of babies originally started in the investigation was 145, but only 102 were eligible for the final comparison : i.e. 49 infants given extra vitamin A, and called for brevity the 'A group,' and 53 controls.

No child was included who did not attend and receive the vitamin emulsion for at least four weeks. The majority of the 43 children excluded either did not attend long enough or did not receive sufficiently regular treatment. Some are omitted for other reasons, such as the giving of cod-liver oil to a control by a mother, or evidence of a condition which would influence normal development irrespective of the diet, e.g. one child proved to be a midget and another had tuberose sclerosis.

AGE OF INFANTS.—All infants were under five months old when first included in the series ; and over three-quarters of them were under three months old. The age distribution of the 102 cases was as follows : under one month old, 8 cases (7·8 per cent.) ; one to two months old, 34 cases (33·3 per cent.) ; two to three months old, 36 cases (35·3 per cent.) ; three to four months old, 21 cases (20·6 per cent.) ; four to five months old, 3 cases (2·9 per cent.). The oldest child at the end of the observation was twenty-seven months old.

PERIOD OF ATTENDANCE.—The period of attendance varied from thirty-five days to nearly twenty-six months, and averaged 8 months 23·7 days.

CLINICAL CONDITION OF THE INFANTS.—Nearly all the children were under normal weight when first included, and many were in poor condition. The commonest reason for attendance at hospital was underfeeding or feeding difficulties (with complaints of vomiting, fretfulness), but 20 of the total 102 suffered from some infection, such as bronchitis, otitis media or whooping cough when first seen. Very few had had any cod-liver oil or other vitamin A supplement. The average birth weight was 7 pounds 0·7 ounces.

The great majority made good general progress while under observation.

ECONOMIC STATUS OF THE FAMILIES.—The majority of the fathers, as in the previous investigation, were manual workers, a number were casual labourers or unemployed, whilst others were small shop-keepers and skilled workers in better circumstances. Many parents received public or charitable assistance in the form of milk grants or monetary help.

ATTENDANCE OF INFANTS.—The babies were usually examined naked at fortnightly intervals, and many attended very regularly. A child who did not attend for six weeks was considered to have ceased to attend.

The diet given.—The diet was similar to that given in the previous investigation, but mixed feeding was started rather earlier. Up to six months old, the infants received dried milk, with added sugar, iron and orange-juice. The babies in the control group were given an emulsion of vitamin D, those in the A group an emulsion of cod-liver oil to provide vitamin D and vitamin A. Mixed feeding was started between six and seven months old, and in the course of about four to five weeks the child's milk ration was reduced to about one to one and a quarter pounds in the week (say about one pint or half a litre daily) and the baby was given fish on two or more days weekly, three or more eggs in the week, and fruit daily, besides cereal foods, vegetables, and gravy. Between eight and ten months old most children were started on meat. In the previous investigation mixed feeding was started between seven and eight months old, so that in the present work babies received food containing vitamin A, other than milk, about one month earlier.

DRIED MILK AND SUGAR.—The same brand of dried milk* was used as in the previous work—i.e. a full-cream roller-process dried milk incorporating iron and ammonium citrate. This time no vitamin D or vitamin A was added to the milk before drying, as was done in the previous investigation. The dried milk was sold to the mothers at hospital at cost price, or, if the mother, on account of poverty, was eligible to a milk grant from the borough, she was asked to exchange the dried milk she received from the borough for the special dried milk at hospital. Many mothers, however, obtained their dried milk at welfare centres, in which case it was not possible to keep a check on the quantity consumed. Up to six months old, each baby received daily 60 to 90 calories in added sugar and the rest of its calorie needs in dried milk; by six months old he was usually having one and three quarters to two pounds of dried milk in the week, say nearly one and three quarter pints or about one litre of milk daily. After seven months old the milk allowance was decreased to about one pound of milk powder or a little more weekly.

IRON.—Each pound of dried milk contained $31\frac{1}{2}$ grains of iron and ammonium citrate, a quantity found sufficient to prevent nutritional anaemia (Mackay and Goodfellow, 1931). The haemoglobin levels of the babies in the A group were estimated monthly (as this group served also as controls in another investigation), and in a few cases where the mother was not buying iron-containing dried milk* at the hospital a slight grade of anaemia developed.

* Hemolac, Messrs. Cow and Gate, Ltd.

It is probable that in these cases the mothers did not give their infants the milk prescribed. Nevertheless the haemoglobin level from five to eighteen months old averaged 82 per cent. in the A group, and it can be concluded that the great majority of both groups received sufficient iron.

VITAMIN C.—One teaspoonful and upwards of orange juice daily was advised for each baby. After six months old, various fruits and vegetables were given.

VITAMIN D.—Every baby was ordered an extra supplement of vitamin D. The controls were ordered 1575 international units daily in the form of an emulsion containing irradiated ergosterol (obtained from the British Drug Houses), 60 minims being given three times daily. The A group were ordered 60 minims three times daily of a 50 per cent. emulsion of cod-liver oil, supplying a minimum of 580 units daily. No definite evidence of rickets, clinically or radiologically, was found in any child in the series. Forty skiagrams of thirty children of susceptible ages made in the late winter and spring months showed one child in each group with some cupping or irregular calcification at the distal end of the ulna, which was probably evidence of mild rickets already healed ; but the change was extremely slight.

Vitamin A in the diet.

VITAMIN A IN THE DIET OF CONTROLS.—The quantity of vitamin A in the dried milk was not estimated during the present investigation. In the earlier investigations the vitamin A value was estimated several times in terms of cod-liver-oil-equivalent by the biological and antimony-trichloride methods. There were obvious discrepancies in the results. Two examples are given : (a) One pound of dried summer milk was estimated by the biological method to contain the equivalent of 13 grammes of cod-liver oil of 12.0 blue value, and by the colorimetric test the equivalent of 2.1 c.c. of cod-liver oil of 7.5 blue value, both estimations being made on samples from one batch of milk. (b) When comparing the A value of two samples of milk, to one of which vitamin A had been added, there was approximately a tenfold discrepancy between the biological and colorimetric tests, and the differences were not consistent (Mackay, 1934b). A sub-committee of the British Pharmacopoeia Commission (1936) has published data demonstrating the wide limits of error of the biological test. From this it was obvious that no conclusion could be drawn from a comparatively small number of tests as to the relative vitamin A values of dried milk supplies over different years, and therefore such tests were not repeated during the present investigation.

However, as the source and method of preparation of the dried milk was the same, and individual variation in cows supplying the milk would probably be smoothed out by the pooling of milk from different herds, there was no reason to anticipate a difference in A value over the two periods.

VITAMIN A CONTENT OF DIET OF A CASES.—The earlier investigations showed that those babies whose supply of vitamin A was solely derived from their dried milk, though they were thought to have a slight deficiency of vitamin A,

certainly suffered from no gross deficiency. Hence even a small addition of vitamin A to the diet should have ensured a sufficiency of this vitamin. All the vitamin A group were ordered 90 minims daily of cod-liver oil obtained from Messrs. Allen and Hanbury. This was given as a 50 per cent. emulsion, 60 minims three times daily. One pound of the dried milk used in the previous investigation was estimated (average of six tests) to contain as much vitamin A as about 10 grammes of one of the standard cod-liver oils used. The dosage of cod-liver oil ordered in the present investigation was approximately 40 grammes weekly, supplying a minimum of 32,000 units weekly—say 4600 international units daily. Hence it was presumably ample to ensure a sufficiency of vitamin A. After six months old, when babies were given mixed feeding, their sources of vitamin A were multiple.

Results

The children in the control group and in the A group were fairly evenly matched at the outset of the investigation (see table 1). In round figures the average weight at first attendance differed by only $\frac{3}{4}$ ounce and was just over 9 pounds ; the average age differed by five days and was about $2\frac{1}{4}$ months ; and the balance of sexes was not dissimilar : in the control group 64 per cent., and in the A group 59 per cent. were males. The average duration of attendance was, however, longer in the A group. These infants attended for an average period of 9 months 14.2 days, against 8 months 4.7 days in the control group, a difference of about $1\frac{1}{8}$ months ; so that the A cases at the end of the observation period averaged nearly $1\frac{1}{2}$ months older than the controls. In the matter of infections the scales were weighted slightly against the controls, for 26 per cent. of them had at the outset some infection, e.g. bronchitis (7 cases), whooping cough (1 case), enteritis (3 cases) ; whereas in the A group only 12 per cent. had infections. The birth weight, as stated by the mothers, averaged 7 pounds 1.5 ounces for the controls and 6 pounds 15.7 ounces for the A cases.

Weight.—Judged by weight (see table 1) the great majority of babies in both groups made good progress. Taking both groups together, babies attending at five months old averaged 14 pounds 2 ounces in weight and at twelve months they averaged 21 pounds 7 ounces. They started well under Holt's standard weight curve, but from eight months old and onwards were above it. Taking the two groups separately the average weekly gain of each over the whole period was similar, vitamin A cases 4.35 ounces weekly, controls 4.24 ounces weekly, a difference of only about 0.1 ounce weekly, or under $\frac{1}{2}$ ounce monthly. Since the A cases averaged about $1\frac{1}{2}$ months older at the end of the observation period, and the normal rate of gain diminishes at about the sixth month, age should have given the controls a slight advantage. This was probably set off by the fact that a larger proportion of the controls had an infection when first seen. If the groups are subdivided by season, the vitamin A cases show slightly superior growth in one season, the controls in the other, in each case (as would be expected if other factors were equal) the younger age group show the larger

TABLE 1
THE AGES AND WEIGHTS OF THE VITAMIN A CASES AND CONTROLS COMPARED

WHOLE PERIOD	NO. OF CASES	SEX		AVERAGE AGE		AVERAGE ATTENDANCE	AVERAGE WEIGHT		AVERAGE TOTAL GAIN	AVERAGE WEEKLY GAIN
		M.	F.	FIRST ATTENDANCE	LAST ATTENDANCE		FIRST ATTENDANCE	LAST ATTENDANCE		
A Cases Controls	49	29	20	moth. 2	days 10-6	moth. 9	lb. 9	oz. 1-2	lb. 11	oz. 0-6
	53	34	19	2	5-7	8	9	1-9	9	4-2
SUB-DIVIDED BY SEASONS		NO. OF PERIODS *								
SUMMER (3 SEASONS)										
A Cases Controls	49			5	12-5	3	13	6-3	4	6-0
	43			6	15-5	3	14	13-6	4	0-5
WINTER (3 SEASONS)										
A Cases Controls	71			6	19-7	4	14	9-2	4	11-2
	72			5	18-1	3	13	4-6	4	6-0

* In the seasonal subdivisions, children attending during more than one summer or winter period cause the number of periods, of attendance to be in excess of the number of children attending.

weekly gain. Hence it may be said that added vitamin A did not increase the rate of growth.

Morbidity rates.—(a) GENERAL.—The general morbidity rate was assessed in the same way as described in other papers (Mackay and Goodfellow, 1931 ; Mackay, 1934b). There is undoubtedly a subjective element in such counts, but carefully carried out, with the case sheets of the two groups intermingled to prevent risk of a change in standard between the assessment of one group and the other, there is no doubt that they give a fair comparison. Table 2 shows that the morbidity rates were closely similar for all illnesses ; and this holds good for illnesses of the respiratory tract, diseases of the intestinal tract and specific fevers when estimated separately.

TABLE 2
GENERAL MORBIDITY RATES—VITAMIN A CASES AND CONTROLS
COMPARED

	VITAMIN A CASES		CONTROLS	
No. of infants	49		53	
Average attendance	9 months 14·2 days		8 months 4·7 days	
No. of child-months	464 $\frac{1}{6}$		432 $\frac{3}{10}$	
DISEASE	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS
Respiratory tract—				
Cold in head or sore				
throat	57	12·3	53	12·3
Bronchitis	30	6·5	33	7·6
Pneumonia	1	0·2	0	—
Otorrhoea	5	1·1	6	1·4
		20·0		21·2
Gastro-intestinal—				
Diarrhoea and vomiting,				
or either	19	4·1	24	5·6
Other diseases—				
Specific fever	8	1·7	5	1·2
Not otherwise classified	2	0·4	2	0·5
		2·2		1·6
Totals	122	26·3	123	28·4

Hence added vitamin A did not reduce the general morbidity rate.

(b) LESIONS AFFECTING SKIN, MOUTH AND EYES.—In the course of the author's previous investigations, attention was not concentrated on lesions of the skin, but analysis of the figures after the completion of the clinical observations showed that whereas non-infective skin lesions were approximately equally common in the two groups, the infective skin lesions were about twice as common in the control group as in the A group. Consequently when the investigation was repeated, careful notes were made of all skin lesions, and many minutiae

were counted. Moreover, if a skin lesion, e.g. chapping of the buttocks, lasted for over one month after it was first observed, it was reckoned twice and counted as two lesions, if it persisted into the third month as three lesions, and so forth. Hence the totals for skin lesions in this investigation are much larger than in the earlier one.

Under infective skin lesions are included pustules, boils, infected scratches, and all excoriations of the skin whether resulting from discharges (e.g. nasal discharge or ear discharge) or from dribbling or from irritation of the napkin area. Such excoriations are reckoned as infective on the assumption that they are due to local irritation together with infection by local organisms of low virulence.

TABLE 3

LESIONS OF SKIN, MOUTH AND EYES—VITAMIN A CASES AND CONTROLS COMPARED

	VITAMIN A CASES		CONTROLS	
No. of infants	49		53	
Average attendance ..	9 months 14.2 days		8 months 4.7 days	
No. of child-months ..	464 $\frac{1}{2}$		432 $\frac{3}{10}$	
LESION	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS
SKIN				
Infective—	79	17.0	70	16.2
Excoriation, pustules, boils, intertrigo, external otitis, etc.		58.2		59.9
Non-infective—	191	41.0	189	43.7
Erythema, peeling, chapping, papules, sudaminal rashes, urticaria				
MOUTH				
Thrush or other stomatitis, ulcer or cracked lip	7	1.5	8	1.9
Geographical tongue ..	3	0.6	0	0
EYES				
Conjunctivitis, blepharitis, styes	9	1.9	6	1.4
Totals	286	62.2	273	63.1

Table 3 sets forth the comparison. In each sub-division of the skin lesions the figures are similar for the two groups of children. The addition of vitamin A to the diet did not diminish the incidence of either infective or non-infective

skin lesions. As before, no difference was found in the texture of the skin in the two groups.

The incidence of infections of the mouth and of the eyes is small, and of a similar order in both groups—so that the addition of vitamin A did not diminish these lesions. Geographical tongue has been included under mouth infections, although admittedly its etiology is uncertain. Its omission, however, would make no difference to the conclusions, since the number of cases is small.

Discussion

The results of this investigation have been wholly negative—the controls and the group given extra vitamin A were similar in rate of growth and general progress, in general morbidity rates, and in the incidence of infections of the mouth and eyes, as well as in the incidence of skin lesions, whether infective or non-infective, and also in skin texture. It must be concluded, therefore, that in 1935–38 the roller process full-cream dried milk used supplied sufficient vitamin A for the child's needs up to six months old, and that thereafter the smaller ration of milk together with the addition of other food was still sufficient for all the child's needs of vitamin A. The milk used in this work was from the same source and put through the same processes as that used in the earlier investigation, and so, *a priori*, would be likely to contain a similar amount of vitamin A.

However, the vitamin A value of fluid cow's milk apparently shows wide variation—Willstaedt and With (1935), summarizing the findings of different authors, say that these vary between 15 and 700 international units per 100 c.c. On the other hand, Sherman (1937), who gives an average value of 292 ± 12 international units per 100 grammes (or 1708 units per pint), considers that as the probable error of this figure is only 4 per cent. of its value, the figures in the literature give 'a very exaggerated impression of the extent to which the vitamin A values of milk' varies. For the ordinary reader, however, the variations in the estimates of vitamin A value seem chaotic and one concludes that many estimates must be erroneous.

The estimates of vitamin A requirements will now be considered. Booker (1938) from an examination of the available data suggests that for an adult the minimum requirement of vitamin A to preserve normal vision (i.e. normal dark adaptation) is 20–30 international units per kilogramme of body weight. Guilbert, Miller and Hughes (1937) have reached the conclusion that this 'minimum requirement' per unit of body weight is probably the same for different species of animals, for young animals and old, and for the gestating female. They find, however, that the minimum necessary to produce normal vision and normal growth will not ensure normal reproduction or allow of storage of the vitamin. They suggest that five to ten times the so-called 'minimum requirement' as judged by the preservation of normal dark adaptation is actually 'a desirable minimum to set for practical purposes,' and even this will result in the lactating female producing a milk low in vitamin A values. On the basis that 10×25 international units is required per kilogramme of body weight, a baby of 9 pounds or 2 kilogrammes body weight would require 1000 international units daily.

Can it be stated if the control cases in the author's investigation are likely to have received less than this amount? Averaging six estimates (three biological and three by the antimony-trichloride method) of the vitamin A value of the dried milk used in the previous investigation, the result is obtained that one pound of this dried milk was equivalent in vitamin A value to 10.4 grammes of one of the standard cod-liver oils used. If it can be assumed from these data that one pound of the dried milk had a vitamin A value of at least 6000 international units, then the A value of one pint of reconstituted milk would be approximately 1000 units. A baby weighing 9 pounds and consuming about one pound weekly of dried milk would get about 1000 international units of vitamin A, i.e. its theoretical requirement on the basis taken in the calculation above. But as there was a six-fold difference between the lowest and the highest estimation of vitamin A value made by one method (the antimony-trichloride test) there still appears to be uncertainty in this estimation.

Meulemans and de Haas (de Haas and Meulemans, 1936; Meulemans and de Haas, 1938) approach the question of vitamin requirement from a different standpoint. They find that the vitamin A value of the milk of women of good income-level is considerably over double the vitamin A value of the milk of cows fed on pasture, and is, say, six times the value of that of stall-fed cows. They argue from this that dairy milk is unlikely to contain sufficient vitamin A to meet the infants' needs, and that all artificially-fed babies should be given a vitamin A supplement.

Thus it still remains unproven whether or not increased susceptibility to skin infections is an early symptom of vitamin A deficiency, and in the author's opinion it seems probable that the milk used in the earlier work did in fact contain less vitamin A, and that this quantity was insufficient for the babies' needs. In favour of this, to quote from the previous paper, is the fact that the difference in incidence of skin infections: '(a) is statistically significant between the total groups; (b) shows itself both in the total number of 'attacks' and in the number of children affected, so that it is not only a question of some few children having repeated attacks; (c) is apparent in each seasonal sub-division of the total groups; and (d) is apparent in each sub-division for the different types of lesions, though figures are admittedly small in these sub-divisions.'

The work of Lewis and Barenberg (1938), already described, does not support this view. They estimate that the half-cream dried milk they used had a vitamin A value of 325 international units per pint of reconstituted milk. The fact that they found no evidence of vitamin A deficiency when using this partly skimmed dried milk will certainly suggest to many that a full-cream dried milk, such as used in the present work, must provide a sufficiency of vitamin A. But the half-cream milk was not tested out as the sole source of vitamin A. Their babies averaged over five months old at the beginning of the observation. Semi-solids were started at four months old and by six months all were getting vegetables providing extra vitamin A. Hence the average time during which their babies depended solely on their milk as a source of vitamin A was under one month. Xerosis of the conjunctiva takes three to four months to develop

in very young babies fed on a grossly deficient diet, i.e. machine-skimmed dried milk (Forest and Wolff, 1932), though it is not suggested that xerosis is the earliest symptom of vitamin A deficiency. There is no information as to whether or not many of their babies might have built up their reserves of vitamin A by getting cod-liver oil or other vitamin supplements before starting the observation.

On the other hand, the babies in the present author's earlier London observations averaged less than three months old at the start; extremely few had any vitamin A supplement when first taken on, and they had an average period of four to four and a half months to run on bottle feeds, during which time they were entirely dependent on the dried milk for vitamin A. Hence if the milk were deficient in vitamin A, then the London babies had a very much better chance of showing it than the New York babies.

The criticism will probably be made that the vitamin A content of the milk used in the present investigation should have been determined. In answer to that it may be said that, in view of the discrepancies in the laboratory tests carried out in the earlier work, it is improbable that more tests would have established a small difference between the milks used in the two periods, if such did exist.

The practical conclusion to the author's two investigations would seem to be that, pending other evidence on the subject, it is advisable to supply infants with a daily supplement of cod-liver oil or other potent source of vitamin A, in spite of the fact that the roller process dried milk used in the second observation has been proved to supply all the vitamin A required by the infant.

Summary

The results of an investigation carried out some years ago on a series of London babies seemed to indicate that they suffered from a slight grade of vitamin A deficiency, manifested by an increased susceptibility to minor skin infections (Mackay, 1934b). These babies were given roller-process dried milk, which was their sole source of vitamin A up to seven or seven and a half months old. According to the (tentative) estimate put forward the vitamin A value of this milk when reconstituted was not less than 1000 international units per pint, so that a baby of about 9 pounds body weight would have received, say, 1000 international units daily, and a baby of 17 pounds nearly 2000 international units daily. This work has now been repeated.

Between August, 1935, and March, 1938, two groups of babies were kept under observation in the out-patient department of the Queen's Hospital for Children. The average age at first attendance was a little over two months, and the average duration of attendance 9 months 14 days and 8 months 5 days respectively. All babies were fed on full-cream dried milk prepared by the roller process and obtained from the same sources as in the previous investigation. A few babies received some breast milk. All were ordered supplements of iron and ammonium citrate, vitamin C in orange juice, and vitamin D.

Approximately half (49 babies) received cod-liver oil supplying vitamin A as well as vitamin D, the rest (53 babies) received vitamin D as an emulsion prepared from irradiated ergosterol and no extra source of vitamin A. After six months old the babies were started on solid food.

Results.—The progress of the two groups of babies was closely similar in all the points examined : i.e. in rate of gain in weight ; in general resistance to infection, and in resistance to infections of the mouth, eyes and skin ; in incidence of non-infective skin lesions, and in texture of the skin. The roller process dried milk used, therefore, supplied a sufficient amount of vitamin A to meet the infants' needs.

This work does not negative the author's previous findings, which suggested that roller-process dried milk did not fully meet the infants' requirements of vitamin A, as, for reasons stated in the paper, it cannot be affirmed that the vitamin A content of the milk was the same over the two different periods. It is suggested that, pending other investigations on the subject, it is desirable to give artificially-fed babies a supplement providing extra vitamin A.

As yet little evidence exists concerning the quantitative needs of the infant in vitamin A (Booker, 1938), and estimates of the vitamin A value of milk show excessively wide variations (Meulemans and de Haas, 1938).

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