XXXII. RELATIVE ANTI-SCORBUTIC VALUE OF FRESH, DRIED AND HEATED COW'S MILK.

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- (1) Experiments with guinea-pigs by R. E. Barnes.
- (2) Experiments with monkeys by E. M. Hume.

INTRODUCTION.

IN two previous communications [Chick, Hume and Skelton 1918, 1, 2] one of us (E. M. H.), in conjunction with other workers in this Department, has shown that raw cow's milk must be classed among the less valuable foodstuffs as regards anti-scorbutic properties. It was shown, for example, that whereas in case of many raw fruits and vegetables amounts varying from 1·5 to 10 g. daily will protect guinea-pigs from scurvy upon a diet otherwise devoid of all anti-scorbutic material, 100—150 cc. of raw cow's milk was needed to give similar protection. The opinion was also put forward that dried milk was even less valuable than raw milk in respect of anti-scorbutic properties; this decision was reached mainly on theoretical grounds—there being at that time few experimental results available. But it had been shown that sundry other foodstuffs, rich in the anti-scorbutic vitamine, lose the greater part of this principle when no longer associated with a living tissue, as, for example, when the foodstuff is dried or preserved by other means. As regards dried milk, this view is in opposition to that expressed by many medical authorities, who, on the basis of their clinical experience, consider that dried milk is in every respect a satisfactory substitute for fresh milk and may be adopted as a sole diet for children without any risk from scurvy [see Coutts 1918, Naish 1914].

The present paper deals with an attempt to gain by direct experiment a quantitative estimate of the anti-scorbutic value of dried milk compared with raw milk. The first series of experiments was made with guinea-pigs by one of us (R. E. B.) and the details of the work are set out in the next chapter.

The methods and technique were the same as those employed in the previous work already mentioned. Guinea-pigs are however not well suited for work upon the anti-scorbutic value of milk. In order to maintain health

and to prevent scurvy, these animals need a comparatively large amount of anti-scorbutic material in their diet; in case, therefore, of a foodstuff like milk with a low content of anti-scurvy vitamine, it is necessary for large quantities to be consumed. It is against the habit and nature of these animals to take much liquid and we have never come across an animal which would take voluntarily the large daily ration (100 cc. and upwards) of raw milk necessary to afford protection from scurvy. Hand feeding of these large quantities is indescribably tedious and in many cases they cannot be tolerated without digestive disturbance. The results obtained in a few successful cases out of a large number of trials are given below (Table I), together with those obtained by similar methods with dried milk. The inferiority of the latter as regards anti-scorbutic properties is clearly shown.

The importance of this result in relation to the artificial feeding of infants made it very desirable to repeat the experiments with a second experimental animal. Young, growing monkeys were selected, and the work was carried out by E. M. H. Many monkeys are extremely fond of milk in any form, and once the right species and individual have been selected, there is little difficulty in persuading the animal to take the daily ration ordained. Symptoms of scurvy in the monkey are more closely allied to those of the human disease than is the case with guinea-pig scurvy, and in these young monkeys appeared to be identical with those of infantile scurvy. The results obtained were in complete accord with those obtained from the work with guinea-pigs. The quantity of milk which, added to a diet containing no other anti-scorbutic material, successfully prevented the onset of scurvy when given in the raw condition, failed to avert it when prepared from dried milk; and, further, the scurvy symptoms developed in the latter case could be cured if the dried milk ration was substituted by an equal amount of raw milk.

In these experiments with monkeys, evidence was obtained that the anti-scorbutic value of cow's milk (and of the dried milk prepared from it) was dependent to some degree upon the season of the year, summer milk, from May onwards, being richer in anti-scorbutic properties than winter milk (see below, p. 316). This fact is doubtless to be attributed to the difference in the cow's diet at these different seasons, the winter diet of mangolds, hay, cotton cake and cereals being poor in anti-scorbutic vitamine when compared with the summer diet of fresh greenstuff.

The bearing of these results upon the problems connected with infant feeding will be discussed later on, when the experimental work has been described in detail.

EXPERIMENTS WITH GUINEA-PIGS, BY R. E. BARNES.

Raw Milk.

The fresh milk used for these experiments and for those with monkeys, described below, was obtained from a model dairy and was very pure, specially delivered country milk.

The successful trials with raw milk are comparatively few for the reasons given above. The results of six experiments set out in Table I *a* afford, however, useful confirmation of similar work described in the previous communication referred to above [Chick, Hume and Skelton 1918, 1]. The diet, as then, consisted of oats, wheaten bran and fresh cow's milk, and it was again found that scurvy could be prevented and health maintained in those cases in which 100—150 cc. were taken.

The symptoms of guinea-pig scurvy and the post-mortem appearances have been described in previous communications [Chick, Hume and Skelton 1918, 2; Delf and Tozer 1918] and it is unnecessary to recapitulate them here.

Of these six experiments made with raw milk, the cream was removed in three cases by simple centrifuging. Milk thus separated seemed to agree with the animals better than full cream milk, and fewer animals were rejected after trial. As regards the anti-scorbutic value, no evidence was obtained that this treatment had any marked influence.

Dried Milk.

The dried milk used was a well-known commercial brand prepared by the Hatmaker process. In this process milk is poured in a thin film over steam-heated rotating cylinders, the water of the milk is rapidly evaporated and the solids left in a thin skin on the surface of the drums. After the drum has made about two-thirds of a revolution this skin is scraped off with knife blades, broken up and passed through a sieve as a finely granular powder. The temperature of the revolving drums is considerably over 100°, but the time of contact is stated by the manufacturers to be a few seconds only.

Two varieties of this dried milk were obtained for these experiments with the kind cooperation of the manufacturers. In one set of experiments the dried milk was quite fresh, being delivered at the Institute less than one week after manufacture, and used for experiment about one week later (Table I *b*). The second variety was imported from a distant colony and was at least six months old when received, and probably not less than nine months. It must therefore have been nearly one year old before the conclusion of some of the experiments (Table I *c*).

The results obtained gave no indication that the age of the product had much effect upon its anti-scorbutic value, but the experiments were not calculated to show any fine shades of difference. Against the greater age of this second sample of Colonial origin, must however be set the fact that the

Table I. (a) *Anti-scorbutic value of raw cow's milk; experiments with guinea-pigs.*
The basal diet consisted of 10-20 g. oats and wheaten bran mixed.

No. of animal	Average amounts of milk consumed daily, in successive periods of 28 days,				Date experiment began	Length of experiment, days	Weight of animals in g.			Change %	Result
	cc						Initial	Highest reached	Final		
	1st	2nd	3rd	4th							
*675	91.8	76.7	—	—	Aug. 12th, 1918	46	360	446	330	- 8.3	Death from unknown cause; traces only of scurvy found post-mortem; no symptoms of scurvy during life
*676	90.1	109.9	128.2	—	Aug. 12th, 1918	91	356	583	580	+ 60.2	In good health all through experiment—no scurvy
*680	103.6	103.3	112.2	—	Oct. 28th, 1918	87	353	577	458	+ 29.7	Death from disease—no evidence of scurvy post-mortem
†670	129.8	88.3	—	—	July 10th, 1918	36	365	466	280	- 23.2	Death from scurvy
†674	79.4	133	161.5	—	July 24th, 1918	89	334	543	442	+ 32.3	Animal in good condition. Slight signs of scurvy post-mortem
†681	98.1	119.3	134.9	147.2	Aug. 12th, 1918	111	340	474	474	+ 39.4	Animal showed signs of scurvy from 22nd day, improved from 44th day, recovered and enjoyed good health until end of experiment. Post-mortem—signs of old scurvy

(b) *Anti-scorbutic value of dried cow's milk, 1-2 weeks after manufacture.*

660	118.1	97.3	—	—	June 3rd, 1918	43	282	373	222	- 21.2
661	82.1	86.8	—	—	May 31st, 1918	48	278	293	176	- 36.7
668	98.7	78	—	—	July 2nd, 1918	32	342	406	298	- 12.8
677	92.5	—	—	—	Aug. 18th, 1918	25	360	410	286	- 20.5
683	106.4	70	—	—	Nov. 4th, 1918	30	348	396	266	- 23

(c) *Anti-scorbutic value of dried cow's milk, 6-9 months after manufacture.*

648	88.5	102.4	112.5	—	—	67	341	414	282	- 17.3
649	97.5	120	93.1	—	—	71	306	400	238	- 22.2
650	90.1	104.4	112.1	—	—	70	322	399	300	- 6.8
651	92.7	100.1	115.1	—	—	72	318	380	239	- 24.8
653 A	82.	88	—	—	—	33	301	360	220	- 26.9

* Full cream.

† Separated.

Colonial cows, so the manufacturers stated, are grass fed all the year round. It is probable therefore that this Colonial dried milk had a much greater anti-scorbutic value to start with and even after six months may still have contained more than milk from stall fed cows even when freshly manufactured. Out of a total of five animals on each type of dried milk, not one escaped scurvy, although one animal in each series showed slight signs only (Nos. 648 and 683). On the whole, those receiving the older material lived longer, suggesting a greater reserve of anti-scorbutic vitamine, but the scurvy lesions, post-mortem, were correspondingly more severe.

When these results are compared with those obtained with raw milk, a great difference in the anti-scorbutic value is at once evident. In those cases where a large enough ration of raw milk was consumed, scurvy was prevented and in cases like 681 (Table I *a*) where the average amount consumed for the first 28 days of the experiment, 98 cc., was not enough to protect the animal, the larger rations consumed afterwards (119 cc. daily for a second period of 28 days and 135 and 147 cc. respectively for two succeeding similar periods) caused an improvement in the symptoms, and effected a successful cure. In case of the animals on dried milk no such effect was noticed. The amounts consumed (reckoned in terms of raw milk) were in many cases not less than those which successfully prevented scurvy in case of raw milk, and some experiments show a close parallel in the quantity actually taken. For example, No. 676 (Table I *a*) on raw milk enjoyed good health throughout while No. 650 (Table I *c*) on dried milk died from scurvy and these two animals consumed very similar amounts during the three periods of 28 days, into which the experiments were divided. In case of No. 676, these amounts were 90 cc., 110 cc. and 128 cc. and in the case of No. 650, 90 cc., 104 cc. and 112 cc. respectively for the three periods. It was usual for the appetite to fall off with onset of scurvy symptoms, and the usual increase in the amount of milk taken with increasing age of the animal, which is very noticeable in many of the raw milk experiments, is not apparent in case of dried milk.

GROWTH PROMOTING PROPERTIES OF RAW AND DRIED MILK.

The four curves in Fig. 1 show growth of four animals receiving respectively full cream raw milk (A); separated raw milk (B); freshly manufactured dried milk (C); dried milk 6—12 months old (D); normal diet of cabbage and grain for comparison (N). Those animals were selected for comparison whose consumption of milk was as nearly as possible the same. During the first 20—30 days of the experiment, the degree of growth is similar in all cases; with the onset of scurvy symptoms, there is decline and failure to grow in case of the animals receiving dried milk.

This failure is satisfactorily explained by the onset of scurvy and it is not necessary to assume that the growth promoting vitamins, water-soluble B, or fat-soluble A, have suffered serious damage in the process of drying. If

Fig. 1. Weight curves of guinea-pigs upon diet of oats, bran and milk of various types, the quantities taken being roughly equivalent.

— A. Full cream raw milk. No. 676. No scurvy. --- B. Separated raw milk. No. 681. Slight scurvy cured later.
 C. Dried milk (English) 1—2 weeks after manufacture. No. 668. Scurvy developed. - - - - - D. Dried milk (Colonial)
 6—9 months after manufacture. No. 651. Scurvy developed. — N. Average weight curve on diet of oats, bran and cabbage leaves.

there had been any defect in the diet from this cause, the failure to maintain growth in case of dried milk would have been evident from the beginning of the experiment, whereas it was only evident after sufficient time had elapsed for the lack of anti-scorbutic material to make itself felt. It must be admitted that in case of the experiments with raw milk, owing to the size of the ration, the fat-soluble factor was probably present in large excess of the guinea-pig's requirements, and that any loss occurring during the drying might not have been sufficient to bring it below this level.

This point seemed of sufficient importance to warrant further investigation, and special experiments are now in progress to determine the relative value, as regards growth, of raw milk, dried milk and strongly heated milk respectively. In this work, the results of which will be published shortly, the quantities fed to the animals were considerably reduced, in order to determine the amounts which, in the several cases, will limit growth in guinea-pigs upon diets arranged to be satisfactory in all other respects. The results at present obtained show no significant difference between the growth promoting properties of equivalent amounts of dried and fresh milk.

Note.

While the present paper was in course of preparation two articles appeared by Hess and Unger [1919] and by Hart, Steenbock and Smith [1919] upon which comment is necessary.

Hess and Unger [1919, pp. 295, 296] find that 80 cc. daily of fresh milk or the equivalent dried by the Just-Hatmaker process are sufficient to cure guinea-pig scurvy which has already developed. This result is apparently in conflict with our experiments in which 100—150 cc. raw milk were found necessary to prevent guinea-pig scurvy and protection with dried milk was not attained at all. The reason for this discrepancy is doubtless to be found in differences in the basal diets adopted by these workers and ourselves. We employed oats and bran only, while Hess and Unger included hay *ad libitum*. Delf and Skelton [1918] have shown that vegetable leaves (cabbage) lose a great proportion, but not all, of their anti-scorbutic value when dried, and that the loss varies according to the length of time which has elapsed since the drying took place. Hay must therefore be looked upon as not entirely devoid of anti-scorbutic properties which will vary according to its age, probably also according to its composition. If fed *ad libitum*, a third variable is introduced, in the difference between the appetite of individual guinea-pigs and consequently in the amount consumed.

In experiments destined to estimate the anti-scurvy value of any particular food stuff, *e.g.* milk in this instance, the foodstuff in question should constitute the only variable in the diet; if hay *ad libitum* is given with the basal diet, two and possibly three, variables are included in addition.

The inclusion of anti-scorbutic material in the basal diet makes it possible to protect guinea-pigs from scurvy with smaller rations of milk than could

otherwise be effected, and by such a procedure it might be possible to obtain a quantitative estimate of the comparative value of dried compared with raw milk, which could not be obtained by our method.

But the results of such experiments can only be regarded as trustworthy when the included material is standardised both as regards its own anti-scorbutic value and the quantity consumed by the guinea-pigs.

It is stated by Hess and Unger [1919, p. 295] that Chick and Hume and other workers at the Lister Institute have used dried milk as part of their basal dietary—"because it was found that this milk was devoid of anti-scorbutic power." We have never used dried milk as part of our basal diet in this Institute, nor do we regard it as devoid of anti-scorbutic power as the present paper shows clearly. The milk which has been used regularly in our basal diet has been autoclaved at 120° for one hour and given in constant quantity, 60 cc. daily to each guinea-pig. In milk so treated we have been unable to find any significant survival of anti-scorbutic value.

In the paper by Hart, Steenbock and Smith [1919] to which attention is also drawn, hay *ad libitum* was again included in the basal diet of the guinea-pigs and the same criticism applies. They too obtain protection from scurvy with rations of milk considerably smaller than those which we have found necessary: in the case of fresh milk a daily ration of 84 cc. gave complete protection from scurvy and partial protection was obtained with 30 cc. daily. The authors themselves [1919, p. 308] suggest the probability that "the hay still contains some of the anti-scorbutic vitamine, which in addition to that in the milk and grain is sufficient to prevent the development of the disease" on a ration of fresh milk smaller than would be needed to protect when no hay is given.

EXPERIMENTS WITH MONKEYS, BY E. MARGARET HUME.

Scurvy in monkeys has been described by Hart and Lessing [1913], Harden and Zilva [1918], and Chick, Hume and Skelton [1918, 3]. When these animals are fed upon a diet deficient in anti-scorbutic material but otherwise adequate, scurvy is developed in about ten weeks [Harden and Zilva 1918], with symptoms closely resembling those of human scurvy. Such are sponginess and bleeding of the gums with loosening of the teeth, and haemorrhages under the periosteum and in almost any part of the body. There is weakness and ultimately almost complete powerlessness of the hind limbs, a condition characteristic of infantile scurvy which has been called "pseudo-paralysis" [Barlow 1894], and which is apparently the result of haemorrhages into the hip and knee joints. The bones also become fragile and there is enlargement and disruption of the rib-junctions. When the disease is far advanced the whole body and limbs are tender.

Barlow ascribes the sub-periosteal haemorrhage in scurvy of infants to an increased vascularity of the periosteum from which blood is assumed to

escape and to collect between the periosteum and the bone. From post-mortem examinations of slight and incipient scurvy in monkeys it has seemed rather as if the bone became rarified at an early stage of the disease and that blood oozed outwards through the bone, presumably from haemorrhage in the bone marrow.

Alterations in the gums were observed to occur earlier and to be much more severe in monkeys which were changing their temporary for their permanent dentition; the onset of scurvy arrested the eruption of the teeth, the gums became swollen and blood blisters were frequently formed over the site of the budding tooth. Gum symptoms were usually the first sign of scurvy to be observed, but occasionally the weakening of the hind legs preceded them. This so-called "pseudo-paralysis" is very characteristic. At first only a slight decrease in activity is noticed, the animal does not jump as high or as carelessly as it was wont to do; this condition progresses until at last the hind legs become useless and the animal swings itself about in a sitting posture by the aid of its fore-limbs.

The effect of scorbutic symptoms upon the weight of the monkey is similar to that observed in case of guinea-pigs. About the time of the first appearance of scurvy symptoms, the animal ceases to gain in weight and soon afterwards a slow but gradually accelerated loss of weight begins (Fig. 3, curve A, p. 321). If a cure is then administered, this loss is soon checked and after a short period of maintenance weight is again put on at a remarkable rate (Fig. 3, curve A, p. 321). The original weight of the animal is regained and the normal rate of growth, if the animal is young and growing, is re-established.

The monkeys used in this set of experiments were not very numerous and were of various kinds and sizes. All were young, growing, healthy animals at about the age of the second dentition, probably, therefore, from one-and-a-half to three years old. They included the genera *Macacus* (two species), *Cercopithecus* (two species) and *Cercocebus* (one species). As the animals were so few and so various, special precautions had to be taken to avoid error due to idiosyncrasy. The method pursued was, in the first place, to determine the minimum dose of fresh and dried milk respectively, which would protect a monkey from scurvy when on a diet otherwise devoid of anti-scorbutic material. In the second place, when scurvy had developed upon a certain daily ration of dried milk, cures were attempted by substituting the same sized ration of raw milk. This procedure eliminated many sources of error, in that the comparison between the two foodstuffs was carried out upon the same individual animal.

The basal diet. The staple item was boiled polished rice, of which 100 g. (dry weight) was allowed daily to each animal; to this was added 30 g. daily of raw wheat germ to provide an abundant supply of the water-soluble B or anti-beriberi factor. A piece of wheaten biscuit, a few pea-nuts or dried peas or a little paddy rice were given as a relish. To the basal diet was added

the measured ration of milk, warmed very slightly and heavily sweetened; this served as the source of the anti-rachitic and fat-soluble A factor and was also the only source provided of the anti-scorbutic factor. When the ration was below 200 cc. a day it was made up to this amount by addition of milk autoclaved at 120° for one hour to deprive it of anti-scorbutic vitamin. This addition was made in order to increase the amount of anti-rachitic factor in the diet; the monkeys, however, would not always accept it.

The milk ration was usually divided into two parts and offered to the animals morning and evening, the monkeys being trained to drink out of a dish held in their cages. It was occasionally necessary to feed with a pipette, syringe or spoon if the animal grew tired of the milk and had to be coaxed to carry the experiment through.

The milk used for the experiments with raw milk was the same as that used in the work with guinea-pigs (p. 308). The dried milk was also of the same brand as in the foregoing experiments, but the work was confined to the English material of recent manufacture; in some trials it was one to two weeks old and in others two to three weeks old.

A summary of the results obtained is set out in Table II and full protocols of all the experiments are given later, p. 320. They include three trials with dried milk and six trials with raw milk. One of the latter, Exp. 1 A, was a curative experiment following a period on dried milk during which definite and severe scurvy was developed.

As regards the amount of raw milk which must be consumed daily to prevent scurvy in monkeys, rations of 50 cc. and 75 cc. proved too small in case of two monkeys, David (initial weight 2080 g.) and Diana (initial weight 2770 g.) respectively. 125 cc. was found adequate (see Exp. 6, Imp, weight 1940 g.), so also was 200 cc. (Exp. 8, Rags, weight 2230 g.), while 175 cc. cured Jane (Exp. 1 A, initial weight 2180 g.) of scurvy which she had acquired on a diet containing an equivalent amount of dried milk.

On the basis of these results we might place the minimum protective ration of raw cow's milk at about 100 cc. daily. The case of the monkey Chirgwin (Exp. 7) who developed slight symptoms of scurvy, but was otherwise in good health for six months upon a daily ration of 150 cc., is somewhat out of line with the above. This particular experiment was of less value than some of the others from the fact that the raw milk experiment followed a period of 43 days on dried milk, after which the nature of her ration had to be changed owing to her sudden, but persistent, refusal to take dried milk.

In the case of dried milk we have definite proof of the inadequacy of amounts equivalent to 175 cc. and 200 cc. milk daily in case of monkeys Jane (Exp. 1) and Toby (Exp. 2) respectively. Both these monkeys developed definite and severe scurvy in from three to four months; and in case of Toby, the ration was increased to 300 cc. without in any way relieving the scurvy symptoms which, on the contrary, became progressively more severe. The third monkey, Caesar (initial weight 2740 g.), received the

equivalent of 250 cc. daily. After about four months his condition suggested most distinctly the onset of scurvy, his ceaseless activity became less marked, his hind limbs became slightly weak and his weight stationary. As the time progressed, his condition improved, however, and it appeared as if his milk ration was increasing in anti-scorbutic value. The change for the better took place about the middle of June, about four weeks after incipient scurvy had been detected, and at a period of the year shortly after the time when cows change their winter stall feeding for the open pasture. Such an alteration in diet may be expected to influence the anti-scorbutic value of the milk given by the cow and also of the dried milk prepared therefrom, especially when, as was the case in these experiments, it is consumed very shortly after manufacture. A disturbing factor is thus introduced into the experimental work, when the series of experiments extends over one year as was the case in the present research. The milk was consequently derived from cows which during a portion of the time were stall-fed and during other portions were pasture fed. The milk, either dried or fresh, cannot therefore be regarded as a uniform article throughout the period. It is judged, however, that this fact did not materially alter the trend of the experiments, seeing that trials with raw and dried milk went forward simultaneously, and the latter was given so soon after manufacture. In the case of the monkeys Caesar and Chirgwin (see below, p. 323), however, the taking of the cows out to pasture about the middle of May was doubtless the means of raising a ration of dried milk of 250 cc. (Caesar) and a ration of fresh milk of 150 cc. (Chirgwin) from a non-protective to a protective amount.

The influence of differences in the cow's diet upon the anti-scorbutic value of the milk given makes it, however, impossible to obtain an absolute standard for the anti-scorbutic value of cow's milk and it is only possible to say that *the daily ration of raw milk which protects from scurvy a monkey of 2—3 kg. weight is from 125 to 175 cc., while the corresponding ration of dried milk, of fresh manufacture, is from 250 to 300 cc.*

It is interesting to note that the amount of raw milk needed to protect a guinea-pig from scurvy, 100 to 150 cc., is almost as great as that needed to protect a monkey. The corresponding amount of dried milk, freshly manufactured, necessary for a guinea-pig, would therefore be the equivalent of well over 200 cc., an amount far too large to be consumed by an animal of 300 to 400 g.s weight. It is not, therefore, surprising that all efforts to protect guinea-pigs from scurvy with dried cow's milk, even when given in a concentration greater than the normal, should have proved unsuccessful.

EXPERIMENT WITH HEATED MILK.

Only one experiment was made in which the anti-scorbutic value of raw cow's milk, scalded, was tested.

The experiment was designed to show whether milk, heated to a degree

which is commonly believed to destroy the bacillus of tuberculosis, suffers serious loss in anti-scorbutic vitamine.

The milk was heated quickly in an enamel pan over a Bunsen burner; it was removed at the moment when it frothed up, at the boil, and was allowed to cool in the air. The total period of heating was found to be about four minutes, during which time the milk was between 70° and 100° for about one-and-a-half minutes. After the pan was lifted from the flame, four minutes elapsed before the temperature of the milk fell again to 70°, and a further 17 minutes before it reached 40°. The whole operation consisted therefore in exposure to a temperature between 70° and 100° for about five-and-a-half minutes.

A ration of 200 cc. of such milk was given to a monkey (Toby) which had developed scurvy on a daily ration of 200 cc. of dried milk. The cure was rapid and complete.

The loss in anti-scorbutic vitamine is therefore not as great as is the loss suffered by milk in drying, but since the minimum amount of raw milk needed to protect a monkey is less than 200 cc., being about 150 cc., the milk might, in the scalding, have suffered loss to the extent of 25 per cent. of the anti-scorbutic vitamine it originally contained, without its being possible to detect such loss by the one experiment made. A loss of more than 25 per cent. would however have reduced the anti-scorbutic value of the ration to less than that of 150 cc. raw milk, but the rapidity of the cure suggested that the animal was receiving a considerable excess over and above the minimal ration needed to protect. Such scalding may therefore be looked upon as a means of sterilisation causing comparatively little damage to the anti-scorbutic vitamine.

GROWTH PROMOTING POWERS OF RAW, DRIED AND HEATED MILK.

None of the experiments described was specially designed to test the growth promoting powers of the milks used, but as in most cases the milk ration was, at the same time, the chief, if not the sole source of the fat-soluble A (anti-rachitic) growth promoting factor, it is possible to draw certain deductions. These are necessarily somewhat rough owing to the diversity in kinds and ages of the monkeys used.

It was found that a ration of 200 cc. daily of milk of any description, raw, dried, scalded or autoclaved, gave good growth but where smaller quantities were used growth was retarded.

In the post-mortem examination of the monkey, David (Exp. 4), which received 50 cc. or less of raw milk, distinct symptoms of rickets were observed. The rib junctions were enlarged and there were also secondary enlargements on the bony shaft of the rib, enclosing cartilaginous islands (see Fig. 2), such as are so frequently seen on the ribs of monkeys kept long in confinement on unsuitable diet in zoological gardens. This monkey although

Table II. *Anti-scorbutic value of raw, dried and heated cow's milk. Experiments with monkeys.*

No. of exp.	Period of year	Name of animal	*Average daily ration, cc.	Time of exp. days	Time after which onset of scurvy noted, days	Initial weight of animal g.	Change in weight during course of experiment, %	Remarks
1	July 1918 to December 1918	Jane (<i>Macacus cynomolgus</i>)	175	142	105	2090	+ 4	Cured with equivalent amount of raw milk before any great loss in weight had occurred (Exp. 1 A)
2	Dec. 1918 to March 1919	Toby (<i>Cercopithecus fuliginosus</i>)	1st period 200 2nd period 300	97 7	87 continuous	2470	+ 10.5	Cure attempted with 300 cc. dried milk, symptoms worse after 7 days (see also Exp. 2 A)
3	Feb. 1919 to July 1919	Caesar (<i>Cercopithecus callitrichus</i>)	250	161	117 but disappeared later	2740	+ 15.5	Scurvy symptoms observed on 117th day, remitted later about time when cows go to pasture
1 A	Dec. 1918 (1) to Feb. 1919, (2) to July 1919	Jane (<i>Macacus cynomolgus</i>)	1st period 175	54	—	2180	+ 12	Successful cure of scurvy developed on similar ration of dried milk
4	July 1918 to Dec. 1918	David (<i>Macacus rhesus</i>)	+2nd period 125 50 (maximum value)	162 150	— 66	2450 2080	+ 14 - 40	Excellent health and growth Scurvy developed on full ration of 50 cc. daily, later part of ration refused; died from dysentery, signs of mild scurvy and rickets at post-mortem examination
5	July 1918 to Dec. 1918	Diana (<i>Macacus rhesus</i>)	75	143	119	2770	+ 7	Gained in weight until onset of scurvy, refused part of ration with increase in severity of symptoms; successful cure with 10 g. daily germinated peas
6	Dec. 1918 to July 1919	Imp (<i>Cercopithecus sabaeus</i>)	+125	182	—	1940	+ 20	Excellent health and fair growth
7	Jan. 1919 to July 1919	Chirgwin (<i>Cercopithecus sabaeus</i>)	150	184	115 (diminished later)	2770	+ 10.5	Previous to experiment received ration of dried milk equivalent to 200 cc., imperfectly taken, for 43 days. Scurvy symptoms on 115th day but much mitigated when cows go to pasture
8	Dec. 1918 to July 1919	Rags (<i>Cercopithecus fuliginosus</i>)	200	225	—	2230	+ 50	Excellent health and growth
2 A	March 1919 to May 1919	Toby (<i>Cercopithecus fuliginosus</i>)	200	49	—	2730	+ 11	Successful cure of scurvy developed on dried milk, marked improvement after 7 days (see Exp. 2 above)

* In case of dried milk expressed as the equivalent volume of fresh milk.

† 75 cc. autoclaved milk added from the 60th day in Exp. 1 A 2nd period, and from 105th day in Exp. 6.

Fig. 2. Diagrammatic representation of a section of a rib junction and secondary nodule believed to be of rachitic origin (Monkey 4 David). Distance of nodule from junction 1.1 cm.

a young and growing one (initial weight 2080 g.) showed a daily increment of 1.5 g. only, up to the time when he developed scurvy. The histology was kindly examined by Miss F. M. Tozer, to whom I am indebted for the drawing reproduced in Fig. 2.

If a comparison is made between the weight curves (Fig. 3) of the monkeys Toby (curve A, 200 cc. dried milk) and Rags (curve B, 200 cc. raw milk), for the first 70 days of the experiment, *i.e.* up to the time when Toby developed scurvy, it is seen that Toby on dried milk shows a daily increment of 6.4 g. while Rags on raw milk shows one of 6.1 g. The rate of growth is therefore almost the same, being slightly in favour of the monkey on dried milk. These two animals are particularly well chosen for comparison as being more nearly alike than any of the other experimental monkeys. Both were male *Cercocebus fuliginosus*, purchased together, presumably of the same past history, and their initial weights, 2470 g. and 2230 g. were also nearly the same.

No two of the other animals are strictly comparable either in themselves or in the ration they received.

Jane (initial weight 2090 g.) over the various periods of her experiment gives the following daily increments:

Daily ration of milk	Days of exp.	Rate of growth, g. per day
Dried milk, 175 cc.	63	4.1
Raw milk, 175 cc. (period of cure) ...	24	2.5
„ 125 cc.	60	2.0
„ 125 cc.; autoclaved milk, 75 cc.	102	2.2

The only marked superiority here, seems to be in the case of the large ration of dried milk; the large ration of raw milk was not continued sufficiently long to give a conclusive result. In considering these figures it must, however, be remembered that monkeys' growth is not necessarily uniform and conclusions drawn from comparative growth, over consecutive periods, on the same animal may not give reliable results. As far as the experiments go, however, the results obtained with monkeys confirm those obtained with guinea-pigs and show that dried milk is not appreciably inferior to raw milk as regards the growth promoting properties, and the content of the fat-soluble A factor. Experiments with rats [see Coutts 1918; Lane Claypon 1916] are in harmony with this view.

PROTOCOLS.

David. (No. 4, *Macacus rhesus*. Male. Initial weight 2080 g.) Raw milk ration 50 cc. Scurvy developed.

For the first 42 days he refused to drink the milk, it was therefore poured over the cooked rice meal; the amount consumed was consequently less than 50 cc. per diem.

For the next 41 days the milk was taken regularly from the syringe. About the 66th day haemorrhagic spots were noticed on the gums and incipient scurvy was diagnosed. On the 85th day the animal met with an accident, biting its tongue so severely that it refused its milk and never again consumed the full 50 cc. The scurvy symptoms progressed, stiffness of the hind legs

Fig. 3. Weight curves of two monkeys, showing comparison between fresh milk scalded, dried milk, and raw milk. Toby (curve A) received 200 cc. dried milk daily for 104 days, scurvy developed on 87th day. Fresh milk scalded (200 cc.) daily administered from 104th day with complete cure. Rags (curve B) received 200 cc. raw milk daily throughout and remained in health.

was observed, the animal lost weight and finally severe dysentery set in; he was chloroformed on the 148th day.

The post-mortem examination showed incipient scurvy, haemorrhage into the synovial cavities of knees, elbows and hips, and petechial haemorrhage in the dura mater; there was sponginess at the ends of the long bones and incipient sub-periosteal haemorrhage in the same regions. There was enlargement of the costochondral junctions, probably of rachitic origin, and there were also secondary enlargements along some of the rib bones, nearer to the spine (see Fig. 2, p. 319). The bones of the ribs and skull were much rarified and could be cut through easily with scissors.

The large intestine showed the inner surface mucoid and slightly haemorrhaged, probably from dysentery, but no organism was recovered which corresponded to a typical dysentery.

Scurvy symptoms first appeared when the full ration of 50 cc. of raw milk was being consumed. A moribund state was induced by dysentery supervening, presumably on a condition where the immunity was lowered by incipient rickets and scurvy.

Diana. (No. 5, *Macacus rhesus*. Female. Initial weight 2770 g.) Raw milk, average consumption 75 cc. Scurvy developed.

This monkey consumed on an average 75 cc. raw milk daily from the syringe and on this diet she gained weight slowly till scurvy symptoms supervened. Slight sponginess and haemorrhage of the gums were observed on the 119th day. From this time onward the milk was consumed less well and the scurvy symptoms progressed more rapidly; the gums became markedly spongy and bleeding; the hind legs became uncertain and a haemorrhage about the eye produced the discoloration characteristic of a black eye.

On the 143rd day, anti-scorbutic material in the form of 10 g. daily of raw germinated peas (soaked 24 hours, germinated 48 hours) was administered together with a liberal ration of auto-claved milk. A gain in weight soon became apparent and the scorbutic symptoms disappeared.

An average consumption of 75 cc. raw milk a day was therefore insufficient to protect this animal from scurvy.

Jane. (No. 1, 1A, *Macacus cynomolgus (fasciatus)*. Common macaque. Female. Initial weight 2090 g.) Dried milk, average daily ration equivalent to 175 cc. Scurvy developed and was cured later by an equal ration of raw milk.

This monkey began to show haemorrhage of the gums about the 105th day and leg weakness appeared soon after. About this time the change from primary to secondary dentition took place. On the 96th day one of the upper median incisors was lost and at first the new budding tooth could be seen in the gap; soon however the gum became swollen and purplish and a haematoma developed over the new tooth.

The monkey continued to take her milk well and did not lose weight seriously. The symptoms progressed in the gums which became much swollen and of a dusky purple colour; the haematoma continued unchanged and the new tooth remained uncut. The legs became very weak and almost useless.

On the 142nd day the ration was changed to one of fresh milk and in order to make the comparison perfectly fair, the quantities given were exactly the same in inverse order as had been the quantities of dried milk consumed. Improvement was rapid. In ten days the animal was much more active and weight was put on speedily; in 20 days the haematoma was almost gone and the cutting of the tooth, delayed for over nine weeks by the attack of scurvy, proceeded normally.

After the cure had proceeded for 54 days and was deemed to be complete, the ration of fresh milk was cut down to 125 cc. daily. Good health and fair growth were maintained but on the 68th day of this treatment, it was decided to raise the ration to 200 cc. by adding 75 cc. of auto-claved milk. In this way it was intended to increase the ration of the fat-soluble A growth factor, while keeping the supply of the anti-scorbutic material the same. This change seemed to lend a slight impetus to growth but it seems probable that the monkey was in any case a slow growing one.

After 162 days the animal was still in good health and it was concluded that in this case 125 cc. daily of raw milk provided sufficient of the anti-scorbutic factor, while 175 cc. of dried milk had failed to do so.

Imp. (No. 6, *Cercopithecus sabaeus*. Male. Initial weight 1940 g.) Raw milk ration 125 cc. Protection from scurvy.

This monkey received 125 cc. raw milk as its sole source of the anti-scorbutic factor for 182 days and showed no sign of scurvy throughout.

On the 60th day 75 cc. autoclaved milk was added as the animal, although in excellent condition, was occasionally subject to convulsions. It was thought that these might be of rachitic origin and it was decided to give an additional supply of fat-soluble A in this manner. The convulsions ceased but the rate of growth was never rapid, 125 cc. raw milk daily however seemed to supply enough of the anti-scorbutic factor as no symptom of scurvy was ever observed.

Chirgwin. (No. 7, *Cercopithecus sabaeus*. Female. Initial weight 2770 g.) Dried milk ration 200 cc. for short period, followed by raw milk ration 150 cc. Result inconclusive.

This monkey started under somewhat unsatisfactory conditions and never cooperated well at any time. It was originally intended that she should receive a ration of 200 cc. of dried milk which she took more or less regularly for 40 days; from that period she refused to touch it and the experiment had to be altered to one with a daily ration of 150 cc. raw milk. This amount was regularly consumed, for any lapses were made up by proportional increase on succeeding days.

Growth was very slow but the animal refused to drink an additional 50 cc. of autoclaved milk which was offered in order to raise the total volume to 200 cc. and to afford an increased supply of fat-soluble growth factor. On the 104th day of the raw milk experiment a slight redness of the gums was noticed, which increased. On the 120th day a large fluctuating swelling on the crown of the head, which had been noticed for several weeks, had become so large that it was decided to operate. No pus was found, only liquid blood which was drained away and the incision sewn up. Such a haematoma was probably not formed traumatically, on account of its slow growth, and it is concluded that the haemorrhage was due to scurvy, a conclusion confirmed by the slightly scorbutic condition of the gums. Contrary to expectation the wound did not fill up again with blood, but healed satisfactorily and at the same time the gums also regained their normal healthy appearance.

The opening of the haematoma took place on May 17, 1919, and on enquiry it was ascertained that May 13th was the date upon which the herd, whence the fresh milk was derived, had been turned out to pasture. The conclusion drawn, therefore, is that the alteration in diet of the cows had raised the anti-scorbutic value of the milk from a ration below, to a ration just above, the protective minimum. The preliminary feeding on dried milk had ended 15 weeks before any scorbutic symptoms began to show, this may have had an influence upon the subsequent history, but it seems unlikely.

The ration of 150 cc. raw milk was continued till the 188th day when the experiment was terminated; the animal seemed in excellent health, there were a few minute bleeding points on the gums, however, which may have been of scorbutic origin.

The conclusion to be drawn from this experiment seems to be that 150 cc. raw milk was in this case just on the borderline of protection, the discrepancy between this result and that of the two preceding experiments, where Jane and Imp were protected with 125 cc. raw milk daily, is doubtless due to individual idiosyncrasy and also possibly to differences in the size of the animals, for the animal at present under consideration was considerably larger than either of the other two.

Caesar. (No. 3, *Cercopithecus callitrichus*. Male. Initial weight 2740 g.) Dried milk equivalent to 250 cc. Result inconclusive.

This animal was fed a ration of dried milk equivalent to 250 cc. daily: growth was fairly good until the 88th day, when it ceased. About the 113th day, the animal's activity became

diminished and very slight redness of the gums was apparent. These symptoms continued and the animal became progressively less active with slightly falling weight until the 130th day, when the weight began to rise again, activity was slowly restored and the slight gum symptoms disappeared.

Such a mild attack of scurvy and spontaneous cure without any intentional alteration in the diet or the amount of it taken, is probably to be explained in the same way as with Chirgwin, the preceding monkey. In that case it was attributed to alteration in the properties of the raw milk ration, consequent upon the taking of the cows out to pasture with corresponding alteration in the antiscorbutic properties of their diet and of the milk given by them. In Caesar's case the date of his sickening and recovery was early in June 1919, but as the dried milk used was two to three weeks old, it would probably have been milked in the beginning or middle of May, *i.e.* just about the time that the cows supplying our fresh milk were proved to have changed their habits and diet for the summer. The manufacturers of the dried milk were applied to for information concerning the herd from whose milk the dried milk was prepared, but they were unable to make any definite statement with regard to dates, since the dried milk was prepared from material furnished by a great number of farms. It is, however, a fair assumption that the majority of cows would go to pasture early in May.

It may be concluded from the results of this experiment, therefore, that 250 cc. dried milk, freshly prepared, is about the minimal protective ration for a monkey weighing from two to three kgs.

Rags. (No. 8, *Cercocebus fuliginosus*. Male. Sooty Mangabey. Initial weight 2230 g.) Fresh milk, daily ration 200 cc. Excellent health and growth.

This animal and the next, Toby, form an excellent contrast as they were similar in every particular, save only for the difference in the daily ration of milk fed to them. Their weight curves are set out for comparison in Fig. 3, p. 321.

Rags received 200 cc. raw milk daily for 225 days during the whole of which time he remained in perfect health and added 50 % to his weight. No trace of any symptom of scurvy was ever observed. At the close of the experiment he weighed 3000 g. but notwithstanding his size, 200 cc. daily was a ration ample to protect from scurvy and to promote good growth.

Toby. (No. 2, *Cercocebus fuliginosus*. Male. Sooty Mangabey. Initial weight 2470 g.) Dried milk, daily ration equivalent to 200 cc. Severe scurvy developed, and was cured upon an equivalent ration of fresh milk, scalded.

This animal was fed 200 cc. daily, and thrived and grew well for about 70 days (Fig. 3, Curve A). After the 70th day growth slackened and it was noticed that there was a slight diminution in the animal's agility. By the 77th day, the symptoms were definite, the gums were swollen and purple and the hind limbs showed distinct weakness. The symptoms still progressed and the monkey lost flesh rapidly. On the 97th day he could not walk at all but was only able to swing himself in a sitting posture and his gums bled freely. On this day it was decided to attempt a cure by increasing the daily ration to 300 cc. of dried milk. The amount was taken readily and continued for a week, but the weight still fell and the general condition became worse.

On the 104th day the ration was changed to 200 cc. of fresh milk which had been "scalded" (see p. 317). The day after this treatment was commenced a slight improvement was detected, in four days the animal could scramble out of his cage and in a week was markedly better. The fall in weight was, however, not arrested for six days and a definite rise in weight did not set in for over a fortnight, when the monkey began to gain in weight with astonishing rapidity. In 16 days after the cure began, he could run about; in 62 days after, he was deemed to be completely recovered and the experiment was ended. Dried milk equivalent to 200 cc. therefore was insufficient, and 200 cc. raw milk, scalded, was amply sufficient to protect this animal from scurvy.

APPLICATION OF THE FOREGOING RESULTS TO THE FEEDING OF INFANTS.

At the present time dried milk is being used for the feeding of infants to an ever increasing extent and it cannot be denied that it offers many advantages over ordinary raw milk both in general convenience and in absence of risk from tuberculosis and other infections. The question arises as to whether its nutritive properties are equal to those of raw fresh milk, or boiled fresh milk, and, seeing that its anti-scorbutic value has definitely been proved to be lower, whether this defect is of serious importance, when it is employed for the nourishment of infants.

Many infant specialists having large experience of feeding with dried milk declare that they have never encountered a case of scurvy among the children fed upon it [see Lane Claypon 1916]. It is not, however, stated always for how many months an exclusive diet of dried milk was continued nor whether all extra anti-scorbutics were excluded. It must also be remembered that slight scorbutic defects may exist without giving rise to the classic appearance of severe infantile scurvy and may even escape detection altogether. Such conditions have been observed by Hess and Fish [1914] and by Miller [1917]. But in absence even of such mild symptoms as were described by these workers, there might yet be conditions which were unsatisfactory as regards the health of the infant, due to an insufficient supply of the anti-scorbutic material in the diet. The experimental work upon scurvy has shown that there may be defects in the structure of bony tissues, only discoverable by microscopical examination, when there has been only a slight deficiency of anti-scorbutic material in the diet, and when no macroscopic signs of scurvy have been detected during life or post-mortem [see Delf and Tozer 1918; Zilva and Wells 1919]. For example, it is during the first months of an infant's life that processes are at work upon the construction of the permanent teeth, and any defect in the structure of these may not be apparent until many years later. It is probable, therefore, that an entirely trustworthy estimate of the anti-scorbutic value of dried milk as the sole food during infancy cannot be formed until this point has been investigated.

The results of the experimental work leave no doubt that dried cow's milk is inferior to raw milk in anti-scorbutic properties and that raw cow's milk itself is a food of comparatively poor value in this respect. It is reasonable to assume that in a diet of raw cow's milk there is not any great excess of anti-scurvy vitamine above the infant's requirements and that when dried milk is substituted, there is risk that the supply of this vitamine may fall below what is necessary for complete safety. Under these circumstances the only wise course is to provide a supplementary anti-scorbutic.

With regard to the growth promoting properties of milk, and in particular its content of the fat-soluble accessory factor, no evidence was obtained from the present work, either from the experiments with guinea-pigs or from those with monkeys, that any loss is suffered during the process of drying. The

results of a separate series of experiments upon this point by one of us (R.E.B.) are shortly to be published. The results of this work also go to show that the growth promoting value of fresh milk and dried milk are roughly about equal. If, as seems probable, from the work of E. Mellanby [1918, 1919], the fat-soluble growth factor and the anti-rachitic factor prove to be the same, then whole dried milk can be relied upon to possess the same value as fresh milk for maintenance of growth and for prevention of rickets. As regards the water-soluble B accessory growth factor, its presence in abundance in many dry foodstuffs indicates that dried milk may be assumed to possess it in about the same amount as fresh milk. As a matter of fact none of the foregoing experiments was designed to give information upon this point, as the water-soluble or anti-neuritic factor was provided also in the grain ration of the experimental animals. The question is of importance, however, when, as is the case with infants, the diet is composed exclusively of milk.

There is urgent need for experimental work in which comparison is made between human milk and cow's milk in respect of the content of the three accessory factors, (1) anti-scorbutic, (2) fat-soluble (or anti-rachitic), (3) water-soluble or anti-neuritic factor. There is at the present time no direct information upon this point and such results would be of great value in helping to settle many of the problems of infant feeding. The obstacle to such work is the great difficulty in obtaining a regular supply of human milk for the long period of time required for trustworthy experiments of this type.

On theoretical grounds we should expect the milk of pasture-fed cows to be richer in the first two of the above vitamins, seeing that a diet of green leaves is a rich source of both. Moreover cow's milk is constituted to be the sole nourishment of the calf, an animal of much quicker growth than the human infant, and therefore presumably needing a more abundant provision of all diet constituents, including the vitamins. On such a basis of argument summer milk from cows may be supposed to contain an amount of accessory factors in excess of the requirements of the human baby. On the other hand, it must be remembered that human milk has important advantages in that it is always taken in the raw condition and undiluted, and that the above arguments in favour of cow's milk refer only to the milk given on the natural diet of grass. In the winter stall-fed cows commonly receive an artificial diet of hay, roots and oil-cake prepared from seeds, which is a diet deficient in the fat-soluble growth factor and, especially if the roots consist of mangolds and not of swedes or turnips [see Chick and Rhodes 1918], deficient also in the anti-scorbutic factor. The milk given will show corresponding deficiencies.

Seeing therefore that cow's milk is a foodstuff of inconstant value as regards its anti-scorbutic properties and that the latter are much reduced in the process of drying, there is every reason to advocate the use of an extra anti-scorbutic in the dietary of infants nourished on dried milk. The results of experiments specially carried out to determine the most suitable substances

for this purpose have been published by Chick and Rhodes [1918], working in this Institute, and among the foodstuffs investigated, raw orange juice and raw swede juice were specially recommended both for potency and for general acceptability. Hess and Unger [1918] have recommended the use of the juice of raw or tinned tomatoes, and their results, as regards tinned tomatoes, have since been confirmed by Chick and Rhodes [unpublished experiments].

SUMMARY AND CONCLUSIONS.

1. A series of nutritional experiments with guinea-pigs is described in which the diet consisted of oats and bran, and a ration of cow's milk constituted the only anti-scorbutic material. It was found possible to prevent scurvy and to maintain good health in animals of 300 to 400 g. weight if 100 to 150 cc. of raw cow's milk were consumed daily. When dried milk was substituted for the fresh milk scurvy was not prevented even when amounts equivalent to these were taken. This was true whether the dried milk was of recent manufacture (one to two weeks old) or of much greater age (six to twelve months).

2. A similar result was obtained in a series of experiments with monkeys. In this case only dried milk of recent manufacture was used. Rations of fresh milk of 50 to 75 cc. daily were not sufficient to prevent scurvy in young animals of 2 to 3 kg. weight; a ration of 100 to 150 cc. daily was however adequate. In case of dried milk the equivalent of about 250 to 300 cc. (at least) was necessary. In one instance severe scurvy, developing on an average daily ration equivalent to 175 cc., was cured rapidly and completely by substituting an equal ration of raw milk. In another case, where scurvy developed on an average daily ration of dried milk equivalent to 200 cc., increase of the ration to the equivalent of 300 cc. caused no improvement, but a cure was successfully effected with a daily ration of 200 cc. "scalded" milk, *i.e.* raw milk quickly brought to the boil and immediately set to cool (exposure to a temperature between 70° and 100° for about five-and-a-half minutes).

3. No indication was obtained from either series of experiments that the growth promoting properties of fresh milk suffer any serious damage during the process of drying.

4. Evidence is brought forward indicating that summer cow's milk has a higher anti-scorbutic value than that given in the winter. This is to be explained by the difference in diet, from fresh herbage in the summer, to hay, oil-cake, cereals and roots in the winter. The use of turnips or swedes, rather than mangolds, should result in a milk of higher anti-scorbutic value.

5. The bearing of these results upon infant feeding is discussed and arguments are given in favour of employing an extra anti-scorbutic in the diet of infants nourished upon dried cow's milk. For this purpose the raw juices of oranges, swedes, and tomatoes are specially to be recommended and in case

of the last named, good results have been obtained even with the tinned material.

The above experiments were carried out under the guidance of Dr Harriette Chick in continuance of work already published in collaboration with her and others, and the authors wish to express their gratitude to her for her help and advice throughout. Thanks are also due to Mr Willis Ginger of the Glaxo Milk Co. and to Mr Wilfred Buckley for kindly furnishing information with regard to the materials used for the experiments, also to Mrs E. Price for timely help in the feeding experiments, to Miss Tozer and Miss Rhodes and lastly to Miss Mary Tazelaar, for her devoted ministrations to the monkeys.

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