AN EXPERIMENT ON THE NUTRITIVE VALUE OF WINTER-PRODUCED "SUMMER" MILK

By J. C. DRUMMOND, ELEANOR SINGER,
From the Department of Biochemistry, University College, London

S. J. WATSON, W. S. FERGUSON AND M. S. BARTLETT
From I.C.I. Research Station, Jealott's Hill, Bracknell, Berks

Introduction

Nearly twenty-five years ago Palmer & Eckles (1914) demonstrated the influence of the carotenoids of food on the colour of cow's milk. Later attention was drawn to the apparent relation of this transference of pigments to the nutritive value of the butter (Steenbock, 1919; Rosenheim & Drummond, 1920; Drummond & Coward, 1920), but the full significance of the original discovery was not understood until Euler *et al.* (1928) had shown that carotene can replace vitamin A in the diet—as Steenbock had suspected nine years earlier—and Moore (1929) had obtained evidence that the pigment is a precursor of the vitamin in the animal body. To-day it is widely recognized in agricultural circles that the diet of the cow determines the "vitamin A value" of the milk and that the proportion represented respectively by carotene and by the vitamin itself may be different in the milks of different breeds although the cows are receiving the same ration.

Under ordinary conditions of feeding the "vitamin A value" is highest in the early summer when the cows are out on fresh pasture and lowest at the end of the period of winter feeding on roots, hay, and concentrates (Drummond *et al.* 1923). The vitamin A content can be artificially raised by administering cod-liver oil during the winter, but a more satisfactory method of improving the nutritive quality of the milk during the months in stall was discovered when artificially dried grass or lucerne became available as a winter feed. By replacing 70% of the concentrates of a typical winter ration by such material, it was found possible to maintain "summer levels" of carotene and vitamin A (Watson *et al.* 1933).

One important aspect of this new development in practical agriculture was its relation to problems of child nutrition, there having been, over a period of ten or more years, a steadily increasing weight of evidence indicating that the rise in the incidence of certain disorders, often noticeable in February or March, is related to the depletion of reserves of fat-soluble vitamins during the winter months.

In this country it was the investigation carried out by Dr Corry Mann on

https://doi.org/10.1017/S0022172400032629 Published online by Cambridge University Press

behalf of the Medical Research Council that first brought home to those interested in practical nutrition the beneficial effect of adding milk to the ordinary diet of young children of school age (M.R.C. Special Report, 1926). Confirmation from trials carried out on an even larger scale (Leighton & M'Kinlay, 1930) was soon forthcoming, and it was not long before the practical issue of providing milk for undernourished children in schools acquired great importance.

To one aspect of this matter attention had not been drawn when the investigation, now being described, was begun. It concerned the relative nutritive values of "winter" and "summer" milks. It was decided, therefore, to carry through an investigation, planned on the general lines of Corry Mann's, to compare the effect of supplementing the diet of a large number of schoolboys with ordinary "winter" milk, i.e. the supply they would normally be receiving, with the response to an artificially produced "summer" milk. For obvious reasons the test period of the trial was to cover the winter months when, under the usual circumstances, the boys might be expected to suffer some deprivation of fat-soluble vitamins as the amount in the milk gradually declined.

Details of trial

(1) *Centres*

Partly in order to obtain larger numbers of children and partly in order to duplicate the investigation under different local conditions the trial was made at two institutions. Both are situated on the fringe of London and are of the "cottage" type, that is, the children, in groups of from twenty to thirty, live in separate cottages or houses, each of which is under the supervision of a sister or a housekeeper. The cottages are detached and pleasantly situated in large grounds. In this particular branch of institution A, there are only boys. The cooking of the food is there done centrally, and the boys take meals in one large mess room.

In institution B there are children of both sexes, but to reduce variables it was decided to confine the investigation to houses containing boys. Here the food is cooked and consumed in each house.

An interesting extension of the trial was made at the suggestion of the Medical Officer of institution A, and with the approval of the headmaster and the County Education Committee concerned. The boys at A attend a local Council school, which also draws boys from homes in the locality. Arrangements were made to form two groups of the latter which should receive daily one-third of a pint of milk in the morning break; the "summer" and "winter" milks to be drawn from the same supplies as those being used at the neighbouring institution A. In this way provision was made for a very useful comparison, because the boys in question represented the outside population, some less well, some, possibly, better fed at home than those living in the institution. These groups will be referred to as at centre C.

(2) *Basal diet*

Table I shows the character of the ordinary daily diet at the two homes A and B. The figures for the vitamin contents must be regarded as approximations in view of the uncertainty regarding the value of certain of the foods consumed, but they are useful as general indications.

Table I

	Centre		Estimated requirements*
	A	B	Ages 5–14
Calories	2000–2600	2000–2500	2000–3000
Protein	75–92 g.	65–75 g.	55–75 g.
Animal protein	18–26 g.	18–28 g.	22–30 g.
Fat	73–83 g.	72–80 g.	70–90 g.
Vitamin A†	2000–3700 I.U.	2500–4000 I.U.	2000–5000 I.U.
Vitamin B	450–550 I.U.	300–400 I.U.	300–600 I.U.
Vitamin C	2000–3000 I.U.	2000–3000 I.U.	1400–2000 I.U.
Vitamin D	120–150 I.U.	50–100 I.U.	(?)

* There were some boys older than 14 in all the groups. Their calorific intake was, of course, higher. It seems better, however, to compare the figures for centres A and B with the estimated requirements of boys from 5 to 14, as most of the children were within that range.

† Where "vitaminized" margarine was used, it has been given the values of 60 I.U. of vitamin A and 4 I.U. of vitamin D per g.

There is as yet a good deal of uncertainty regarding the daily requirements of growing children for the various vitamins. The figures for these given in the last column are, therefore, provisional estimates.

(3) *General plan*

The investigation opened with a "fore-period" beginning early in July 1934 and lasting until nearly the end of September. During this period of 3 months the boys were receiving the customary diet of their respective institutions A and B. When the main period began a random choice was made to determine which cottages, houses or groups of boys should receive the "summer" and which the ordinary or "winter" milk. It must be remembered that the only change was in the character of the milk; institution basal diets were not changed in any respect.

The main experimental period covered the winter months from the end of September 1934 to the early part of March 1935. The boys were then observed for a further 3 months, an "after" period, during which they received the ordinary milk from the respective farms. By this time, of course, the cows were again at pasture and the colour of the milk was improving normally by grazing.

In institution A the greater part of the two milks was delivered to the central kitchen in the morning where it was served out to the respective groups of boys at breakfast, either to be drunk or to be eaten with porridge. A smaller portion was delivered to the cottages in the afternoon to be drunk as an extra allowance by the delicate children. At institution B the milks were delivered to the cottages and there drunk by the boys or used in the preparation of meals. No attempt was made to measure the quantity of milk consumed by individual children. The average consumption per head of the two milks over the experimental period was, however, almost identical.

(4) *Milk supply*

Institution A derived its milk from a local farmer and dairyman who willingly consented to participate in the experiment by putting aside the requisite number of cows for special feeding during the winter.

Institution B maintained a home farm where with the co-operation of the farm manager similar arrangements were made.

At both institutions the control milk was obtained from the main herd fed on a winter ration, usually consisting of hay, roots, and a cake made up of concentrated foods, cereals and oil seed residues, all these foodstuffs being almost devoid of carotene. The "summer" or vitamin A and carotene-rich milk, was obtained from four to five cows, which were taken from the herds at each centre, and fed on artificially dried grass in place of some of the hay and concentrates.

Early in October 1934 the cows chosen for the production of the "summer" milk were separated, and the feeding of the dried grass commenced about the second week of this month. These cows were, on the whole, freshly calved, and it was found that at the commencement of the experiment they were producing milk lower in carotene content than that produced by the main herd. This was more evident at centre A than at B. The probable reasons for this are that during the calving period they would have been housed indoors, and therefore would not have access to pasture which supplies the necessary carotene; there is also a considerable drain on the carotene reserves of the animals during the first few days following parturition, as it is known that colostrum is rich in carotene.

Unfortunately the only dried grass available in October was of rather poor quality, containing approximately 20 mg. % of carotene.

At centre B, the feeding of the dried grass was started on 16 October, 5 lb. per day per cow being given, replacing 5 lb. of hay in the ration. The "winter" and "summer" milks were delivered separately to their respective groups of boys on this date. On 28 November, the dried grass fed was increased to 10 lb. per day.

At centre A, the dried grass was fed at the rate of 10 lb. per cow per day, commencing on 10 October, but the separate delivery of the milks was not started until 25 November.

During November it was evident that the colour of the milk at both centres was falling, and that the dried grass was not maintaining the colour of the "summer" milk as satisfactorily as had been hoped. To prevent further reduction in the colour, dried lucerne of high carotene content was given to the cows at the rate of 5 lb. per cow per day, commencing 5 December. The

https://doi.org/10.1017/S0022172400032629 Published online by Cambridge University Press

average carotene content of a number of samples of this dried lucerne taken at various times through the experiment was approximately 37 mg. %

The daily rations of the cows producing the "summer" milk at both centres from 5 December, therefore, included 10 lb. of dried grass and 5 lb. of dried lucerne per day, the dried grass replacing a similar amount of hay and the dried lucerne replacing the concentrates which would have been fed for 1 gallon of milk. At centre B, the cows did not greatly relish the dried grass and lucerne, and occasionally small quantities were left uneaten, but the ration remained unchanged until early May when pasture was available for the cows, and as a consequence the yellow colour of the milks from the herd and the "summer" cows became more pronounced.

At centre A, the cows ate the dried grass and dried lucerne readily, and on 26 February the quantity of dried lucerne given was increased to 7 lb. per cow per day. No further changes were made, and the special rationing ceased on 16 April, when pasture was available.

Carotene content of the butterfat.

At fairly frequent intervals throughout the experiment, milk samples were collected from both groups of cows at each centre, the samples consisting of equal proportions of the morning and evening's milk. The butters prepared from these milks were examined for carotene content by a colorimetric method, (Ferguson & Bishop, 1936) and the results are shown in Table II.

Table II. *Carotene contents of butters (mg. per 100 g. butterfat)*

	A		B	
Date	"Winter"	"Summer"	"Winter"	"Summer"
9 October 1934	0·80	0·60	—	—
15 October 1934	—	—	0·80	0·64
23 October 1934	0·91	0·69	—	—
15 November 1934	0·67	0·64	—	—
27 November 1934	—	—	0·58	0·51
4 December 1934	0·37	0·49	—	—
20 December 1934	0·35	0·67	0·51	0·53
8 January 1935	0·30	0·64	—	—
5 February 1935	0·21	0·51	—	—
7 February 1935	—	—	0·37	0·51
5 March 1935	0·17	0·53	—	—
8 March 1935	—	—	0·25	0·49
2 April 1935	0·27	0·51	—	—
11 April 1935	—	—	0·44	0·56
7 May 1935	0·78	0·78	—	—
8 May 1935	—	—	0·75	0·78

Considering the centres separately, at A the "winter" butterfat showed a typical fall in carotene content from 0·80 mg. % in early October to the lowest value of 0·17 mg. % in early March. From March onwards, as pasture gradually became available, the carotene content increased. The "summer" butterfat was less rich in carotene than the ordinary butterfat at the commencement of the period, for reasons given previously. The carotene content fell in early December, but following the feeding of dried lucerne at this time, the value

https://doi.org/10.1017/S0022172400032629 Published online by Cambridge University Press

again rose and maintained a fairly high level, although this was below a normal summer level, until early February. A slight drop to 0·51 mg. % was evident in February, but this figure remained stationary until the influence of the fresh pasture was apparent.

The milks at centre B were not separated into their respective groups until 25 November, and the reason for this is clearly seen in Table II, but it was not until 20 December that the special milk showed any marked superiority over the ordinary milk as far as the carotene content was concerned.

At this centre the carotene content of the "winter" butterfat did not fall as rapidly as at centre A, whereas with the "summer" butter the reverse held. It is seen that on 20 December the butters were approximately equal in carotene content, and, therefore, although the milks were fed separately from 16 October, no benefit from the "summer" milk could be expected before the former date. In fact, if any benefit is to be derived from the carotene in the milk, the group of children receiving the "winter" milk would have had a slight advantage up to 20 December.

At both centres it is evident that only in the months of January, February, and March was there any striking difference between the carotene contents of the two types of milk.

(5) *Records of development and health*

All clothes except "shorts" were removed by the boys before weighing and measuring. Weight, height, and contracted and expanded chest (see Friend, 1935) were recorded.

In each centre the boys were periodically inspected by the medical officer. The record cards were available in case information regarding medical history was required.

The duration of the three periods and the intervals between the inspections are given below.

Table III

Dates		A	B	C
(1)	"Fore" period	4. vii. 34	9. vii. 34	27. vii. 34
(2)		24. ix. 34	27. ix. 34	28. ix. 34
(3)	"Trial" period	14. xii. 34	18. xii. 34	13. xii. 34
(4)		7. iii. 35	5. iii. 35	6. iv. 35
(5)	"After" period	3. vi. 35	4. vi. 35	25. vi. 35

Progress of the trial

There is little noteworthy to record. The investigation was undisturbed by illness more serious than the common minor winter ailments. The majority of the boys were in good health throughout the winter. There was no difference in the general appearance or vitality between the two groups noted either by those in daily contact with the boys or by those who at intervals of some weeks weighed and measured them.

EXAMINATION OF THE DATA

The period of the trial, from July 1934 to June 1935, consisted of a "fore" period of 2–3 months, till the end of September, the experimental period from September 1934 to March or April 1935, when the "winter" and "summer" milks were being fed, and an "after" period, when the children returned to their usual diets, lasting till the end of the trial. Five weight determinations were made, corresponding to the four change-over dates, together with one, date 3, in the middle of the experimental period: three height determinations corresponding to the beginning and end of the complete trial, together with one again in the middle of the experimental period; and chest measurements (normal and expanded) at the same time as the height determinations. The change-over dates did not exactly correspond at the different centres, and are referred to for convenience as dates 1–5. In the statistical analysis the circumstance was provisionally ignored that the "winter" and "summer" milks did not show any quality difference as early as had been hoped, but it will be seen that the conclusions reached did not need to be modified to allow for this.

An examination of the data is a little complicated by the inevitable absence of children on particular dates. In order to obtain figures which should be amenable to as rigorous an analysis as possible, the figures for all children absent on either of the dates at the beginning and end of the experimental period proper have been omitted entirely. For all the remaining children a measure of the gain in weight during this period is thus possible.

Age groups

The boys, whose ages ranged from 5 to 16 years, were divided into three-year groups, one of which, 13–16, normally covers the spurt in development associated with puberty.[1]

Any further averages given in the summary of results in connexion with any other date will refer to these children, less, of course, those absent on the date concerned.

Table IV summarizes the results so obtained.

Before a statistical analysis of the gains in weight between dates 2 and 4 was made, the individual gains for each group were plotted in spot diagrams for most of the groups against weight (date 2), height, and preliminary increase in weight (dates 1–2). The gains in height (dates 1–5) were also plotted against initial height.

There were occasionally slight indications of a relationship between gain in weight and height, or gain in weight and weight, but this was not sufficient to make any adjustment of the gains in weight worth while, especially as there was no apparent evidence for initial differences between the "winter" and

[1] We are obliged to Prof. R. A. Fisher for making suggestions regarding this grouping.

'summer" groups, except perhaps in one case, the weights on date 2 for the 1923–26 age group at centre C, being somewhat discordant for the two groups.

From these diagrams, by a comparison of corresponding groups, any apparent differences between groups could be noted. In one or two cases, differences in the gains in weight were discernible, this being borne out by the subsequent analysis. No apparent differences in the gains in height were detected, except possibly at B. There was little evidence of any relationship between gain in weight and gain in height.

The results of the analysis of the gains in weight are given in Table V.

Table IV. *Increases in weight and height**

	Group		No. of children†	Increase in weight (oz.) 1–2	Weight (st.) 2	Increase in weight (oz.) 2–3	Increase in weight (oz.) 2–4	Increase in weight (oz.) 2–5	Height (in.) 1	Increase in height (¼ in.) 1–3	Increase in height (¼ in.) 1–5
A	Age group 1	S	22 (4)	49·4	5·58	1·8	47·5	78·5	55·6	3·33	6·53
	(1919–22)	W	26 (5)	37·1	5·45	27·7	60·3	77·5	55·3	2·33	7·00
	Age group 2	S	22 (6)	38·5	4·38	5·2	30·7	55·3	50·4	3·23	6·40
	(1923–26)	W	18 (6)	34·2	4·55	23·5	49·3	61·1	50·6	2·73	7·08
	Age group 3	S	6 (1)	35·2	3·17	15·0	19·5	56·2	43·3	3·20	10·20
	(1927–35)	W	7 (2)	24·3	3·10	32·0	46·3	63·0	42·4	2·80	9·83
C	Age group 1	S	16 (2)	40·1	5·82	32·8	50·1	102·2	57·8	2·85	8·20
	(1919–22)	W	12 (7)	43·3	5·61	31·6	74·0	110·0	56·3	3·73	8·67
	Age group 2	S	35 (5)	3·6	4·34	27·5	43·6	55·5	51·9	2·39	6·68
	(1923–26)	W	36 (11)	10·0	4·69	34·3	58·8	75·6	52·8	3·09	7·28
B	Age group 0	S	23 (3)	96·5	8·62	34·6	88·1	90·6	64·4	3·53	5·19
	(1916–18)	W	17 (1)	60·5	8·69	27·4	101·3	95·5	65·9	2·08	3·42
	Age group 1	S	24 (2)	80·3	6·53	36·1	99·3	115·3	58·5	3·95	8·15
	(1919–22)	W	30 (0)	69·8	6·41	44·0	107·9	117·5	58·0	3·93	7·64
	Age group 2	S	15 (0)	37·6	4·57	43·7	66·1	66·4	51·7	3·64	7·73
	(1923–26)	W	13 (0)	34·0	4·96	31·1	67·7	66·2	53·1	3·25	6·17

* S and W stand for "summer" and "winter" milk groups. The numbers 1–5 at the head of columns indicate the dates 1–5 (p. 30).

† Number present on both dates 2 and 4.

The figures in brackets denote remaining children, absent on one or other of these two dates.

Table V. *Increases in weight (dates 2–4)*

		"Summer"			"Winter"			Significant difference ($P=0·05$) between mean gains in weight
		Number	Weight (st.) date 2	Gain in weight (oz.)	Number	Weight (st.) date 2	Gain in weight (oz.)	
A	Age group 1	22 (4)	5·58	47·5	26 (5)	5·45	60·3	23·7
	Age group 2	22 (6)	4·38	30·7	18 (6)	4·55	49·3	14·0 (sig.)
	Age group 3	6 (1)	3·17	19·5	7 (2)	3·10	46·3	33·2
C	Age group 1	16 (2)	5·82	50·1	12 (7)	5·53	74·0	34·8
	Age group 2	35 (5)	4·34	43·6	36 (11)	4·69	58·8	14·5 (sig.)
B	Age group 0	23 (3)	8·62	88·1	17 (1)	8·69	101·3	42·6
	Age group 1	24 (2)	6·53	99·3	30 (0)	6·41	107·9	29·0
	Age group 2	15 (0)	4·57	66·1	13 (0)	4·96	67·7	28·2

In view of the apparent differences in height increase for the B groups, the gains in height over the whole period were also analysed, and the results of this given in Table VI.

A provisional examination of the chest measurements was also made, but these appeared variable, and it was not considered that they provided any information not indicated by the weight and height figures.

Table VI. *Increases in height* (*dates* 1–5)

		"Summer"			"Winter"			Significant difference ($P=0·05$) between mean gains in height
		Number	Height (in.) date 1	Gain in height (¼ in.)	Number	Height (in.) date 1	Gain in height (¼ in.)	
A	Age group 1	15	55·6	6·53	21	55·3	7·00	2·02
	Age group 2	20	50·4	6·40	13	50·6	7·08	1·19
	Age group 3	5	43·3	10·20	6	42·4	9·83	3·48
C	Age group 1	11	57·8	8·20	9	56·3	8·67	3·53
	Age group 2	28	51·9	6·68	29	52·8	7·28	1·09
B	Age group 0	21	64·4	5·19	12	65·9	3·42	2·33
	Age group 1	20	58·5	8·15	25	58·0	7·64	1·38
	Age group 2	15	51·7	7·73	12	53·1	6·17	1·42 (sig.)

DISCUSSION OF STATISTICAL RESULTS

The gains in weight showed a significant difference ($P=0·05$) between the "winter" and "summer" groups for the second age group at both A and C centres. Though no other differences were significant, the differences for the other age groups at these two centres were consistent in showing similar apparent effects in favour of the "winter" groups. At B, the differences are in the same direction, but clearly are of no importance.

For the gains in height, on the other hand, both A and C centres show no significant differences; there is, however, a significant difference in favour of the "summer" group at B, with the remaining age groups consistent in showing a similar effect.

From Table IV it will be seen that the gains in weight, analysed for date 4, have tended to equalize up for the later date 5, the only exception being for the second age group at centre C. It could thus be concluded that the difference in the gains in weight found at A was due to a temporary set-back of the children in the "summer" group.

There seems from the data to be little doubt of the reality of this set-back. It can be indicated by a table of the children actually *losing* weight during the period 2–3 (24 September 1934 to 14 December 1934).

Table VII. *Gains and losses in weight at A* 24. ix. 34 *to* 14. xii. 34

	Age group 1		Age group 2		Age group 3		Total		
	Gain	Loss	Gain	Loss	Gain	Loss	Gain	Loss	
"Summer"	10	11	14	6	5	0	29	17	46
"Winter"	20	5	16	1	4	1	40	7	47
							69	24	93

The value of χ^2 for the totals of the three age groups is 4·81 (using Yates' correction for continuity), this being significant ($P<0·05$). (In Table VII the five losses in age group 1 for the ordinary group include one doubtful solitary loss in one of the houses, the weights on the original card being queried.)

The persistence of the difference for the second age group at C has been

https://doi.org/10.1017/S0022172400032629 Published online by Cambridge University Press

noted. It should perhaps be remembered, however, that the initial difference in weight (date 2) was 0·35, which, though not significant (sig. diff. = 0·38), was the most outstanding initial difference observed.

An explanation of the significant differences observed cannot, from the technique of the experiment, be decisive. Though the "summer" milk for both centres A and C was obtained from the same source, it would be difficult to believe that this milk had caused the significant losses in weight observed at A. It is true that little evidence for initial differences between experimental groups was found, but this does not preclude the possibility of differences arising subsequently from unknown causes.

If it be accepted that the differences in weight could arise in this way, it must also be recognized that the differences in height at B could arise from a similar cause.

Differences between "houses" at A

The possibility of observed differences being due to differences arising between the different houses can be examined to some extent when it is remembered that at A and B a comparison between houses receiving the *same* type of milk is possible.

In the previous summaries of results, the various age groups have been kept distinct, significant differences being calculated separately for each group. This was considered advisable as it does not appear that the variability in each age group is the same. Since it is convenient to exhibit the significance of the differences between houses by a comprehensive analysis of variance, the possible limitations due to the pooling of the variability in the different age groups should be borne in mind, though it is not considered that this vitiates the significant effects indicated by the analysis.

An additive form of the analysis of variance is given below (Table VIII) for the gains in weight at A. Here the numbers of children in the different classifications being practically the same for both milks, and the differences between age groups being in any case slight, the very slight confounding in this table of the comparisons between houses (including "summer" *v.* "winter") with age differences can be neglected. It might, on the other hand, be misleading to give a similar analysis for the gains in height at B, owing to marked age effects and greater inequality of numbers.

Table VIII. *Gains in weight at A (oz.). Analysis of variance*

	24. ix. 34 to 14. xii. 34			24. ix. 34 to 7. iii. 35		
Comparison	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.
"Summer" *v.* "winter"	1	9,500·3	9,500·3*	1	8,095·6	8,095·6*
Between houses of same group	2	4,196·9	2,098·5†	2	9,559·2	4,779·6*
Between age groups of same house	8	4,763·9	595·5	8	12,623·4	1,560·9
"Error"	84	51,407·2	612·0	89	86,475·0	971·6
Total	95	69,868·3		100	116,753·2	

* Highly significant ($P<0·01$). † Significant ($P<0·05$).

The mean increases in weight for the four houses are as follows:

Table IX. *Mean gain in weight at A (oz.)*

Period	Group	Gains for separate houses		Mean
24. ix. 34 to 14. xii. 34	"Summer"	5·8	3·8	4·8
	"Winter"	15·0	33·6	24·7
24. ix. 34 to 7 iii. 35	"Summer"	22·6	49·9	36·8
	"Winter"	52·2	56·9	54·7

Till December, the houses of the "summer" group have both experienced a set-back, but there appears a difference also between the two houses of the "winter" group. By March, these two houses have become comparable, and one house of the "summer" group has caught up with them, the other still lagging behind. It becomes evident from these tables that the difference observed between the "summer" and "winter" groups at centre A could easily be interpreted as merely due to differences between the houses.

Summary of results of statistical analysis

Significant differences in gains in weight (dates 2–4) between the "summer" milk and "winter" milk groups were observed at institution A and centre C, in favour of the "winter" milk. At A the difference was due to a temporary set-back in the "summer" milk groups, a considerable number of children actually losing weight between dates 2–4. A significant difference in gain in height (1–5) was observed at institution B, in favour of the "summer" milk group. These observed differences are not compatible with any consistent superiority of one or other of the groups. Though there was little evidence of initial differences between the groups, it has to be remembered that the technique of the experiment does not allow the possibility of subsequent differences between the groups from other unknown causes to be excluded. Thus at centre A it is shown that there are similar significant differences between houses of the *same* group.

GENERAL DISCUSSION

While it is true that the total number of children coming under the scheme of the experiment was not remarkably large, it will have been noted that the negative results of the experiment were due not to the absence of differences, but to the obscurity of their cause. It was hardly anticipated, for example, that at centres A or B any of the houses receiving the same milk would have shown differences, and the value of the results in indicating the need for very careful planning of future experiments of this kind seems worth stressing, if the results are to have full rigour.

As regards the main object of the investigation the results fail to reveal that the substitution of an artificial "summer" milk for ordinary "winter" milk was beneficial to growth and development. It was suspected when the experiment was planned that the basal diet of the boys at the two institutions

https://doi.org/10.1017/S0022172400032629 Published online by Cambridge University Press

A and B was probably adequate in so far as constituents likely to be supplied in larger amounts by the "summer" than by the "winter" milks were concerned. At that time we did not have the information we now possess regarding the amount of vitamins A, B_1, C, and D, in common foodstuffs. A quantitative estimate of the value of the basal diet with respect to these substances could, therefore, not be made.

The estimates given in Table I and which have been made quite recently show, however, that the basal diets at both institutions probably provide adequate amounts of these vitamins. The matter really primarily concerns vitamin A because, so far as we know, the most important effect of feeding the cows on dried grass through the winter months is to enrich the milk in this substance and its precursor carotene.

The figures for the vitamin A content of the basal diets (Table I) are probably under-estimated, because no allowance has been made for the fact that the boys in both institutions get liver at least once a week. The vitamin A content of ordinary butcher's liver (pork or sheep) varies a great deal and it is difficult to assess what this item might add to the weekly intake. It is not improbable that this one item might raise the average daily intake figure by 1000 I.U. It seems likely, therefore, that the boys in institutions A and B were receiving ample carotene and vitamin A in their basal diet and that in consequence there was no response to the increased intake resulting from the consumption of "summer" milk. It is reasonable to conclude that a daily intake of from 2500–5000 I.U. of vitamin A supplies the demands of growing boys from 5 to 16 years of age.

The two groups at centre C must be considered separately from those at A and B because they consisted of boys drawn from homes in the immediate locality. No details of individual diets were obtained, but there are good reasons for believing that a large number of the boys belonged to families which could be classified in the first four groups of Orr's survey (Orr, 1936).

Table X

	Income per head per week	Average expenditure on food	Orr's estimate of vitamin A intake of diet (I.U.)
Groups I	Up to 10*s*.	4*s*.	774
Groups II	10*s*. to 15*s*.	6*s*.	1250
Groups III	15*s*. to 20*s*.	8*s*.	1624
Groups IV	20*s*. to 30*s*.	10*s*.	2015

The examination of their case is rendered easier because we know each boy drank one-third of a pint either of "winter" or "summer" milk in the morning "break". It is possible, in the light of recent work, to assess approximately the "vitamin A value" of these milks. Unfortunately this information was not available at the time of the investigation.

Gillam *et al.* (1936) found that the ratio of vitamin A to carotene in the milk fat of Shorthorn and Ayrshire cows was respectively 2·5 : 1 and 2·4 : 1. Estimations of the fat content of the "summer" and "winter" milks made during the course of the experiment justify our taking 3·75% as a mean figure. This means that the boys received about 7·8 g. of milk fat in the supplement. Assuming a ratio of vitamin A to carotene of 2·5 : 1, we can derive figures representing the vitamin A provided by the milks at the outset of the experiment, at the time when the value of the "winter" milk was at its lowest, and at the end of the investigation when both lots of cows were out at pasture again.

Table XI

Date	Milk	mg. carotene per 100 g. fat	mg. carotene ⅓ pint	I.U. as carotene	mg. vitamin A ⅓ pint	I.U. as vitamin A	Total I.U.
9. x. 34	"Summer"	0·8	0·062	100	0·155	400	500
	"Winter"	0·6	0·047	80	0·117	300	380
5. iii. 35	"Summer"	0·53	0·041	70	0·102	260	330
	"Winter"	0·17	0·013	25	0·032	80	105
7. v. 35	"Summer"	0·78	0·061	100	0·155	400	500
	"Winter"	0·78	0·061	100	0·155	400	500

Almost certainly these figures are too low, for they represent the best milk as providing about 2·5 I.U. of vitamin A per g. and indicate only 0·5 I.U. per g. at the lowest point reached during the winter.

Biological assays of cows' milks seem to indicate higher figures; thus, Coward & Morgan (1935) regard 3 I.U. per g. as a good average figure. The range appears to be from 3 to 7 I.U. per g.[1] On the other hand, if we calculate from estimations of the carotene and vitamin A content of milk fats, lower values are obtained. The highest figures recorded by Gillam *et al.* (1936) in an extensive study were 1·97 mg. carotene and 1·42 mg. vitamin A per 100 g. of milk fat. This sample was from a Guernsey milk, and, assuming a fat content of 5·2%, we can calculate the vitamin A value of the milk to be only 3·6 I.U. per ml. The highest figures they give for the analysis of a Shorthorn butterfat correspond to a vitamin A value of the milk (3·65% fat) of 1·5 I.U. per ml.

If we accept the results of the calculations set out in Table XI, it means that the boys at centre C who drank one-third of a pint of "summer" milk daily augmented their intake of vitamin A by 330–500 I.U., whilst those getting "winter" milk added only from 100 to 380 I.U. to that present in their basal diets.

Remembering that a considerable proportion of these boys came from poorish homes and bearing in mind Orr's estimates (Table X) it might reasonably have been expected that the "summer" milk groups would have shown better weight and height increases than those getting the "winter" milk. Actually, as has been shown, no significant difference was detected. Biological assays might have revealed a considerably higher vitamin A value for both "winter" and "summer" milks than those derived from calculations based on spectroscopic estimations of the carotene and vitamin A content. If values twice as great were obtained, and we have already indicated that the difference

[1] Private communication from Dr K. H. Coward. The highest value was obtained on a sample of Guernsey milk.

between the results given by the two methods may be of that order, it appears less likely that the intake of the "winter" milk group was significantly inadequate. Without more precise knowledge of the vitamin intake of the daily diet of these boys and of the actual requirements at the different ages, it is useless to carry the discussion further.

Summary

1. Two herds of cows were divided into two groups for winter feeding. One group was given the usual ration of hay, roots and "concentrates", the other was fed on a similar diet in which part of the hay and concentrates was replaced by artificially dried grass.

2. The carotene content of the butterfat in the control group fell steadily from 0·8 mg. per 100 g. of fat to about 0·2 mg. between October and March. That of the group to which dried grass was given did not fall below 0·5 mg. per 100 g. of fat.

3. The milks from the two groups were employed in a nutritional investigation on the boys of two institutions. During a "fore-period" from July until the end of September, the boys received the ordinary milk of the herd as part of their diet. They were then divided into two groups which, during the experimental period from October until March received the "winter" or the dried grass "summer" milk respectively. Then followed an "after-period" during which all the boys received the mixed milk of the herds, then out at pasture. The composition of the basal diet of the boys at these institutions was known. Boys attending an elementary school in the vicinity of one institution were also investigated in a similar experiment but no details of their home diet were obtained.

4. Excluding children whose records were incomplete there were 159 in the group on "winter" milk, and 163 in that receiving "summer" milk.

5. Periodically records of height, weight, and chest measurement were made. All the boys were under medical supervision.

6. Statistical examination of the results fails to show that the artificially produced "summer" milk exerted a beneficial effect detectable by the improvement in growth or general condition of health.

7. The most probable explanation is that the basal diets of the two institutions were already adequate in respect to carotene and vitamin A.

8. The variations exhibited by the records of the groups provide another example of the very great difficulty of eliminating or adequately controlling sources of error in a big-scale nutrition experiment of this type.

Acknowledgements. We desire to acknowledge gratefully the permission given by the Governing Bodies of the two institutions and the Educational Authority controlling the elementary school, to carry out this investigation. Our indebtedness to the principals, medical officers, house sisters and staff of the institutions was very great, but we desire particularly to thank for their willing collaboration and help Capt. and Mrs F. H. L. Lewin, Mr G. F. Bush, Mr E. W. Masson, Mr J. C. Jones, Dr A. H. Macdonald and Dr T. N. Kelynack. The supervision of the two dairy herds was in the capable hands of Mr F. J. Ward and Mr G. C. Warder respectively, and we would like to express our appreciation of their interest and co-operation. We also thank Miss Anne Wilbraham for assistance in taking many of the measurements. The cost of the investigation was defrayed by a grant from the Research Council of Imperial Chemical Industries. This is gratefully acknowledged.

REFERENCES

Coward, K. H. & Morgan, B. G. E. (1935). *Brit. Med. J.* ii, 1041.

Drummond, J. C. & Coward, K. H. (1920). *Biochem. J.* **14**, 734.

Drummond, J. C., Coward, K. H., Golding, J., Mackintosh, J. & Zilva, S. S. (1923. *J. Agric. Sci.* **13**, 144

Euler, B., Euler, H. & Hellström, H. (1928). *Biochem. Z.* **203**, 370.

Ferguson, W. S. & Bishop, G. L. (1936). *Analyst,* **61**, 515.

Friend, G. E. (1935). *The Schoolboy. A study of his nutrition, etc.* Cambridge.

Gillam, A. E., Heilbron, I. M., Ferguson, W. S. & Watson, S. J. (1936). *Biochem. J.* **30**, 1729.

Leighton & M'Kinlay (1930). Dept. of Health for Scotland.

Med. Res. Council (1926). *Special Report,* No. 105 (1926).

Moore, T. (1929). *Lancet,* i, 499.

Orr, Sir John (1936). *Food, Health and Income.* London.

Palmer, L. S. & Eckles, C. H. (1914). *J. Biol. Chem.* **17**, 191.

Rosenheim, O. & Drummond, J. C. (1920). *Lancet,* i, 862.

Steenbock, H. (1919). *Science,* **50**, 352.

Watson, S. J., Drummond, J. C., Heilbron, I. & Morton, R. A. (1933). *Empire J. Agric.* i, 68.

(*MS. received for publication* 22. v. 1937.—Ed.)