

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

THE VALUE OF DRIED BUTTERMILK AS COMPARED
WITH SKIM MILK FOR CALF REARING, AND THE
EFFECT OF FEEDING AT TWO DIFFERENT LEVELS
ON GROWTH TO WEANING UNDER NEW ZEALAND
CONDITIONS.

Thesis presented by
J.L. Corbett in partial
fulfilment of the require-
ments for the Degree of
M. Agr. Sc., November 1949.

CONTENTS.

	Page
Introduction	1
Objects of the experiment.	6
Review of literature.	6
Design of the experiment.	11
Management of the experimental animals and method of feeding.	14
Allocation to treatment and collection of data.	16
Health of the calves.	19
Results.	23
Discussion.	31
The general growth of the experimental animals.	31
The total quantities of liquid consumed in the experiment.	33
The effect of breed on growth.	34
The relative values of skim-milk and buttermilk.	34
The effect of level of feeding.	37
Suggested plans for calf rearing.	44
Grass in the diet of the dairy calf.	48
The nutritive value of the feeds.	48
Feeding standards for young cattle.	49
The contribution of grass to the diet.	52
Observations on grazing behaviour.	57
Summary and Conclusions.	62
Acknowledgements.	64
References.	65
Appendix <u>I</u> Photographs of the experimental animals.	
Appendix <u>II</u> Weekly growth data, experimental animals.	
Appendix <u>III</u> Growth data from Dairy Research Institute records.	

INTRODUCTION.

It is a startling fact that each year in New Zealand, the digestible protein lost for human consumption through the inefficient conversion of dairy by-products into pigment, is approximately twice the total annual output of protein in lamb and cheese; and the food energy lost nearly equals the energy in these two commodities (Filmer 1944). Though a proportion of the loss is through the associated feeding of coarse grain and meat meal, and also some from whey, the great majority arises from the feeding of skim milk and buttermilk which are of immediate human nutritional significance.

The case for making these high quality foods directly available for human consumption is strong, despite any repercussions on the pig industry and notwithstanding such economic considerations as secure markets. In order to do so it is obvious that the raw materials must be processed to reduce bulk and improve keeping quality for transportation. The utilisation in this way of skim milk is set back by the considerable problem of its collection from the cream supplying farms, though it may be easier where the density of these in an area is high. Since the buttermilk is produced at the dairy factory, this difficulty does not apply.

For many years the United States has dried buttermilk until now about 30% of the total creamery output is used in this way (Hunziker 1946), production of dried buttermilk having remained fairly steady during the past fifteen years or so at about sixty-six million pounds per annum (Cronshaw 1947). Much of this is made from sour cream, being thus used almost exclusively for animal feeding, notably hens and pigs. In New Zealand, however, the buttermilk is mostly derived from sweet cream.

Within the last few months (1949) the British

Ministry of Food has entered into a six year contract (with arrangements for its renewal) with the New Zealand Dairy Products Marketing Commission for the supply of dried buttermilk powder, the first year's price being £60 per ton. It is to be hoped that this is only a start in the more enlightened use of dairy by-products, for 75% of all milk produced is used in butter manufacture, and only about one-tenth of this by volume, containing comparatively little of the non-fatty solids, comes to the factories as cream.

Until this contract, New Zealand has annually been producing about thirty thousand tons of preserved milks (N.Z. Dairy Board 1948) of which 80% has been condensed or evaporated. The amount available for animal feeding has been small being mostly lactose mother liquor (not included in the above), and a few factories have been supplying dried buttermilk at the cost of threepence a pound. Now, because of the overseas demand, this price has risen to sevenpence (approximately £60 per ton). However, not all the export production will be suitable for human consumption. McDowall (1946) states that in the case of a butter factory with an output of two hundred tons of the dried material, about one hundred and fifty tons might be suitable. Whether or not this is unduly pessimistic from the factory's point of view, it does indicate that there will be fair supplies for stock feeding, and these should not be sold for the full price.

The particular interest to New Zealand farmers lies much in the use of the dried buttermilk for calf feeding on farms supplying cheese factories, condenseries or town milk. The problem in striking a balance between growing good calves, yet feeding the minimum quantity of whole milk is considerable, although it is met in some cases by letting calves out for rearing, or in lesser degree by feeding meals. But the possibility of a good, reasonably priced, supply of dried buttermilk, found to be of value in calf rearing,

would much simplify the position. For this, the probable maximum demand has been estimated by McDowall (1946) as eight hundred tons, with four hundred and fifty tons as a more likely figure.

The local market is not the only outlet for second quality powder. In England the concentration on the liquid milk trade and the almost complete absence of any fresh milk by-product has caused the widespread use of various gruels as a whole milk substitute for calf rearing. These are purchased dry by the hundredweight and made up at the rate of one pound to nine pounds of water. Many of these contain dried milk products, often those intended for human consumption (mostly from the United States) which have deteriorated during carriage. Since the United Kingdom -- New Zealand contract calls for the supply of the buttermilk in sacks only, and not drums or barrels, it seems likely that some proportion of this will also be used in this way. As far as can be foreseen there will not for many years be any unsaleable surplus of whole milk in England, and the wholesale price ranging from one shilling and eightpence in summer to well over three shillings a gallon in winter makes the use of a whole milk substitute very attractive. The price of these has recently been raised from about thirty to forty shillings per hundredweight and the new price for roller buttermilk powder for stock feeding is forty-four shillings and ninepence. Thus on diluting, the cost of these feeds is fourpence or fivepence a gallon. Early in 1950 the subsidy on animal feeding-stuffs bought by the British farmer is to be removed altogether, and the cost of whole milk substitutes will probably rise by a further ten shillings per hundredweight. Cost per gallon (diluted substitute) will then be approximately sixpence. Even if it were found necessary, in England, to introduce a manufacturing price for surplus milk of say a shilling a gallon, or wholesale prices were to be reduced,

calf gruels would still be a good proposition especially in the winter months.

It is necessary to supplement them with some concentrated energy food, for the non-fatty solids represent only half the energy content of whole milk, and rolled oats, flaked maize, bran, linseed cake meal and fish meal are often fed. However such a mixture will also be given in conjunction with whole milk.

It may be questioned whether the price of dried buttermilk - £60 per ton - is not rather high. However, these are the first years of large scale production and initial outlay in plant and building has been fairly heavy, so that the price is justified even if as an insurance against non-renewal of the overseas contract. Future contracts may be settled at a lower price, especially if some dried buttermilk is exported specifically as stock feed. Mention must be made of the English poultry industry which is now, and will probably continue to be, a willing market for quantities of dried milk products.

Table I gives figures for the total milk powder imports of the United Kingdom (Monthly Digest of Statistics 1949).

TABLE I.

Year U.K. Milk powder imports ('000 tons) Monthly average.

1935	0.9
1936	1.0
1937	1.2
1938	1.5
1944	6.9
1945	2.5
1946	3.1
1947	4.3
1948	1.7
1949 (first six months)	4.8

Home production is now averaging about seven

hundred tons weekly through the year, but the bulk is produced in the summer months. Though this may increase, the market for overseas producers will remain. Kay(1949) states that he believes Britain can use considerably increased quantities of some of the dairy by-products now being developed in New Zealand, referring particularly to skim milk powder and buttermilk powder, which he considers have great possibilities ahead of them for use in bread and other products.

The demand is at present largely met by imports from the United States, but because of Britain's efforts to purchase where possible from non-dollar sources, New Zealand has great opportunities for developing the export of dried milks so that they become an important contribution to her national income.

It was with these broad considerations in mind, that this study on a particular aspect of dried buttermilk utilisation was undertaken.

OBJECTS OF THE EXPERIMENT.

The principal object of the experiment was to determine whether dried buttermilk reconstituted with a calculated amount of water so as to be similar in gross composition to skim milk, was equivalent in feeding value to the latter as judged by the growth of calves to weaning. Both feeds were given in conjunction with pasture ad libitum.

It was also felt that information should be obtained from feeding the buttermilk at more than one level.

Pedigree female Jersey and Friesian calves from the College herd were available for the experiment.

REVIEW OF LITERATURE.

McCandlish (1939) after reviewing the literature on various dried dairy products concluded that they could be used successfully in calf rearing, their constitution giving a fair guide to their relative feeding values.

Buttermilk itself has long been fed to calves. Thus Otis (1904) showed "beyond a doubt" that calves could be successfully raised on it, and in this experiment had less trouble from scours in the buttermilk fed calves than those skim fed. Archibald (1916) found it slightly superior to skim milk. Shepherd and Converse (1939) were rather more cautious, noting that buttermilk has practically the same composition as skim milk, but also contains a small amount of fat and has a certain acidity. They state that it should not be diluted by washing water or condensed steam and should be pasteurised, and since it may be somewhat more laxative than fresh skim milk, it is best not to change from whole milk until three to four weeks of age, and then gradually so as to avoid digestive disturbances. This advice most calf-rearers would in any case practice.

Woodward (1922) fed eight calves whole milk

until two weeks of age, and then changed them to condensed buttermilk during the following two weeks; after this condensed buttermilk only was fed along with alfalfa hay and a grain mixture. The animals made daily gains of 1.3 - 1.6 lb. until they were four to six months old, being fed $1\frac{1}{4}$ lb. per day of the condensed buttermilk initially, increasing to 4 lb. per day at three months. He noted that the calves were not subject to scouring as often as occurred with skim milk feeding.

Rogers Johnson and Albery (1926) have developed a method of preparing a condensed buttermilk with good keeping qualities, in which a culture of streptococcus and a mycoderm is used to develop an acidity sufficient to prevent growth of micro-organisms, the acid buttermilk then being condensed in a vacuum pan to approximately one third its volume. The feeding value of the buttermilk is reduced since much of the lactose is reduced to lactic acid, as shown by the following figures on composition (Hunziker 1935).

Total solids	25.00	-	32.70%
Fat	1.00	-	2.60
Protein	9.00	-	11.85
Lactose	3.96	-	12.00
Ash	1.70	-	7.51
Lactic acid	4.30	-	6.19
Water	67.30	-	75.00

The packaging and transport costs of this bulky and acid liquid - requiring wooden barrels - are high, but despite these and other disadvantages, large quantities are produced in the United States, being known as "semi-solid" buttermilk.

Rupel (1929) found this product fairly satisfactory for calf rearing, but less economical than skim milk. An experiment at the Idaho station (1929) agreed on this point; it was found difficult to change a group of four calves from sweet milk to semi-solid buttermilk, the animals being less thrifty than those skim-fed. They also scoured until they began to eat quantities of hay and grain.

Morrison and Rupel (1926) fed semi-solid buttermilk

to calves given a minimum of whole milk (less than 400 lb.) which was discontinued at seven to nine weeks old. Given together with dried skim milk it increased the rate of gain over calves getting whole milk, both groups receiving hay and a grain mixture. However, the cost of feeding was increased.

Eckles and Gullickson (1924) conducted an experiment using a very small number of calves (five), of different breeds and sexes. This heterogeneity and paucity of material is the great weakness of most of the experiments here reviewed. They reared the calves on condensed or powdered buttermilk, each being diluted so as to give a similar total solids percentage to fresh buttermilk, and each group was given good hay and a grain mixture. Whole milk was fed for the first two weeks of life, the changeover being made gradually. All the calves made excellent growth, the daily gain to six months being 1.3 lb. on average. Scours or indigestion were never present, and no trouble was experienced in getting the calves to take the buttermilk as prepared; rather they seemed to prefer it to whole milk. The calves were as a whole sleek coated and thrifty.

Ellington and Knott (1926) raised eight calves on semi-solid buttermilk (three lb. in nine lb. water) or dried buttermilk (one lb. in nine lb. water) together with alfalfa hay and grain. Comparing their growth with Eckles standards, the two buttermilk products were concluded to be satisfactory substitutes for skim milk when this is not available.

In an experiment at the Idaho station (1928), calves were fed diluted powdered buttermilk as a substitute for skim milk, together with hay and grain. The animals suffered little from digestive disorders, were quite thrifty, and their growth in weight and height was very satisfactory.

Buttermilk powder has also been fed dry; Lindsey and Archibald (1929) found that in young calves it produced

almost the same rate of gain as skim milk powder. It was more economical, but not as palatable when first fed as the skim milk powder, and in some cases had a decided laxative effect.

In another experiment (Idaho, 1931) a group of Holstein calves was fed whole milk for two weeks, changed over to dried buttermilk solution during the third week and received twelve pounds of the solution daily during the fourth and fifth weeks. During the sixth week they were changed to a dry grain ration containing one third dried buttermilk powder and were also given alfalfa hay. From four to six months of age they were fed the alfalfa hay and grain mixture but without the buttermilk powder. A second group of calves was fed in the same manner except that up to four months of age they were given no buttermilk, but received a minimum of twelve lb. skim daily. Both at four and six months this latter group was considerably heavier and taller, (113% of "normal" weight as compared to 90% for the former at six months) and was also sleeker and thriftier in appearance.

Though buttermilk powder fed dry may not give quite as good results as when reconstituted, bearing in mind the drawbacks of this and the other experiments - the small number of animals used - it can be said that reconstituted buttermilk powder under the various experimental conditions has not given very different results in calf rearing from the fresh material, or indeed from skim milk. Semi-solid or condensed buttermilk appears to be slightly less valuable, largely owing to its acidity.

There are no experiments reported that are strictly comparable with that on level of feeding here conducted. Where trials of similar intent are described, the calves on the larger ration, as would be expected, showed the greater growth. Thus Woodward (1923) fed calves

- four in each group - on skim milk at one-fifth, one-sixth or one-seventh of body weight, and a further group was allowed as much as they would drink in two feeds daily. By drinking 80% more skim milk than calves on the lowest level of feeding, the latter group made 50% larger gains; it was noted that even though at times the calves were drinking more than 40 lb. per day there were no bad results, and was considered as indicating that overfeeding in itself is not a common cause of scours. This is surprising (taking "scours" to mean "nutritional scours") especially on considering the ages of the calves which were on the experiment for seventy days following their initial two weeks of life. Much would probably depend on the dry food given in addition, but no mention was made of this at all. Further, only four animals were used.

McCandlish (1939) reviews other trials variously conducted, which show that the more liberal allowance gives better results.

Campbell (1948) reported an experiment conducted under New Zealand conditions in which calves were fed skim milk, together with good pasture ad libitum. Two groups were fed equal quantities of skim milk per unit body weight, whilst one of them was given in addition $\frac{1}{2}$ lb. of meal per day (calculated to be the equivalent of 4 lb. skim milk). This latter group, however, only gained an additional 6 lb. in body weight on average during the age period six to twenty-two weeks so that the additional feeding had little effect, probably owing to the levelling influence of grass intake. In another trial, Campbell (1946) found very little difference between calves fed at either 10% or 15% of body weight of skim milk, with daily maxima of two and three gallons respectively, but in this year the season was exceptionally favourable for calf-rearing with good weather and grass growth, and low disease incidence (Campbell, personal communication).

Apparently, then, there is some question as to whether a higher level of ^{milk}feeding raises bigger calves under good New Zealand conditions. It must be emphasized that "good" conditions implies a supply of high quality grass.

The advantages or disadvantages which accrue from rearing calves at different rates will be discussed later.

DESIGN OF THE EXPERIMENT.

Data from previous calf experiments conducted by the Dairy Research Institute were examined in order to determine the variability in growth of similar animals at the age of twenty weeks, figures from ninety-one calves in five seasons with three or more top crosses of Jersey blood being used.

$$\text{Now } t = \frac{D}{\frac{s}{\sqrt{N}} \cdot \sqrt{2}}$$

Where D is the difference between the means of two groups, and the denominator is the standard error of this difference. N is the number of variates in each mean, and s in this case is the standard deviation of calf weights at twenty weeks of age.

$$\text{Thence } N = \frac{2t^2 s^2}{D^2} \quad \text{or } D^2 = \frac{2t^2 s^2}{N}$$

By substituting a suitable value of t, and the calculated variance, it is easily calculated how many calves are required in each group to make a certain weight difference at twenty weeks significant at the particular level of significance.

With so large a sample as ninety-one calves, 2.0 was taken as a safe approximation of t at the 5% level, and 2.7 at the 1% level.

In calculating the standard deviation of twenty weeks weights, differences between treatments within years

were all non-significant and were ignored, but seasonal effects over the five years were marked. The variance s_i^2 for each year was calculated with the corresponding number of degrees of freedom N_i , and the variance between calves within seasons - s^2 - found

$$s^2 = \frac{\sum N_i s_i^2}{\sum N_i}$$

This gave a figure of 537.2 lb. and thence a standard deviation of 23.2 lb.

In Table 11 are given the required numbers of calves and weight differences. These figures are plotted in Graph I. (See page 13).

The value for the standard deviation and thence weight differences required may be enhanced somewhat by slight intraseason treatment differences, and possibly by breed effects, but the magnitude of this error is uncertain and is unlikely greatly to affect the figures and general conclusion that numbers in each group are required to be large. Accordingly it was decided to include such pedigree female Friesian calves as became available, in addition to pedigree female Jerseys.

Further, rather than reduce group size by including a third treatment, that is by feeding buttermilk at two levels, a simple factorial design was employed, both skim and buttermilk being fed at 10% or 15% of body weight levels, choice of levels being guided by the experience of previous Dairy Research Institute calf experiments.

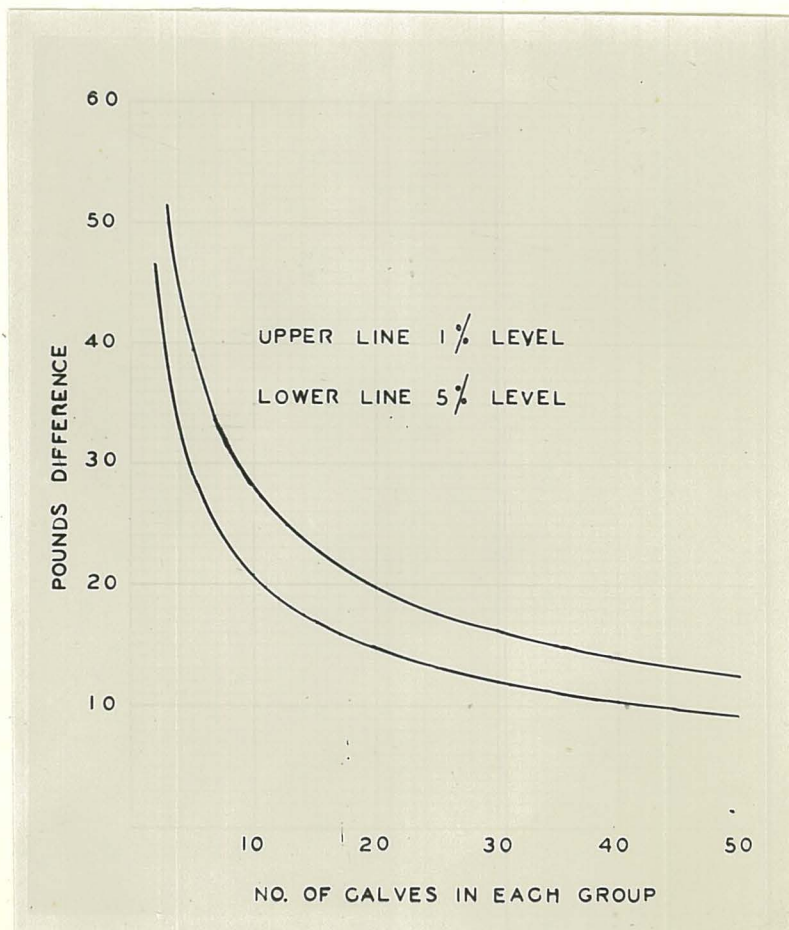
It was decided to feed the reconstituted buttermilk on an equal energy basis with skim milk. From an analysis of each, given later, it was found that this was very nearly achieved by mixing each pound of the buttermilk powder with 9 lb. water, which incidentally was also feeding on an equal "total solids" basis.

TABLE II

Pounds difference in bodyweight between groups of calves at twenty weeks of age, required for significance.

Number of calves in each group.	5% level	1% level
2	46.4	62.6
3	37.9	51.1
4	32.8	44.3
5	29.3	39.5
6	26.8	36.2
7	24.8	33.5
8	23.2	31.3
9	21.9	29.5
10	20.8	28.0
11	19.8	26.7
12	18.9	25.6
13	18.2	24.6
14	17.5	23.7
15	16.9	22.9
16	16.4	22.1
17	15.9	21.5
18	15.5	20.9
19	15.1	20.3
20	14.7	19.8
25	13.1	17.7
30	12.0	16.2
35	11.1	15.0
40	10.4	14.0
45	9.8	13.2
50	9.3	12.5

GRAPH I



MANAGEMENT OF THE EXPERIMENTAL ANIMALS AND METHODS OF FEEDING.

Calves born from July 17th onwards were obtained from Massey College Farm No.1 shed at around 24-48 hours of age, having been with their dams until that time, and taken over to the D.R.I. farm where they were weighed immediately and then turned into a paddock. Healthy calves were housed at night only during their first few days of life, and usually only if the weather was too severe, cold rain for example, or if their weekly weight gain was small. Otherwise the animals were at grass all the while.

Feeding was carried out in the new D.R.I. calf bail, times of feeding being kept as regular as possible at about 6.45 a.m. and 4.30.p.m. A few of the youngest and weakest calves were fed three times daily for a short period. All buckets and other utensils used in the feeding were rinsed and given a hot chlorine wash after every feed.

Colostrum was given to the newborn calf for two to three more days, after which herd milk (Jersey) diluted with water so as to bring the butterfat test to about 4% was fed at the rate of 10% of body weight rising to around 12% in the third and fourth weeks of life.

Water was added to the milk not so much in order to reduce the fat content - much has been said on the "richness" of Jersey milk and its possible unsuitability for calves, but virtually no definite experimental evidence is available - but rather to facilitate curd digestion. Milk fed only twice or even three times daily to calves tends to form a dense curd, some of which may remain undigested at the next feed and form a nucleus for increasing hard lumps. Thus Sheehy (1934) observed that calves receiving from eight to ten pints of milk a day at two weeks old (slightly more than 10% of body weight) were showing symptoms of digestive disturbances. A post-mortem examination showed that a large, hard and cheesy lump of milk curd, resistant to the digestive

juices, had formed in the abomasum and was causing inflammation of the walls. In in vitro experiments, rennin added to milk caused a similar curd, but when 25% of water was added the curd was much less dense and was softer; it was noted that colostrum proteins formed a soft digestible curd with rennet.

At four weeks, treatment to this age being the same for all calves, milk or substitute was individually rationed strictly to 10% or 15% of (the previous Friday's) body weight depending on treatment, the liquid being weighed to the nearest $\frac{1}{4}$ lb. on milk scales. One quarter of the total was given as either skim or reconstituted buttermilk, the remainder being diluted herd milk. At four weeks four days, the proportion of substitute was increased to 50%, to 75% at five weeks one day old, and the changeover was completed at five weeks five days. For Jerseys, a maximum of two gallons (20 lb.) per day was allowed, and for Friesians a maximum of three gallons (30 lb.) per day.

As previously noted the buttermilk powder was mixed with water at the rate 1 lb.: 9 lb. respectively, weighing of the materials being done on milk scales. All food was given as nearly as possible at blood heat and so warm water could be used in the mixing. Analysis showed that the solubility of the powder at 20°C was 59.9% and at 50°C was 70.2%. After a few trials the best method of mixing was found to be placing all the powder on half the required amount of water, the latter being up to 15°C above blood heat, mixing with a milk plunger and then adding the remainder of the water. The mixing was done in a twelve gallon milk can owing to the quantities required, a special can and plunger being used since the acidity of the buttermilk caused deterioration of this equipment. In this way a good dispersion of the buttermilk was obtained; settling did occur on standing, but this was overcome by plunging a

few times before weighing out to the calves.

During the first six weeks of the experiment, the calves were grazed on Dairy Research Institute property, but thereafter on College farm paddocks on a rotational system - one paddock for a morning and evening grazing - paddocks 2, 4, 5, 10, 11, 12, 14 and 15 being included. The quality of the grass was at all times good.

On reaching twenty weeks of age the experimental feeding period terminated, and the calves were then either weaned or returned to the College No.1 shed for some further feeding.

ALLOCATION TO TREATMENT AND COLLECTION OF DATA.

Further examination of the Dairy Research Institute data on calf weights revealed the correlations given in Table III, calculated on calves within years to reduce seasonal effects.

TABLE III

Correlations derived from D.R.I. calf growth data.

	No. of calves	Correlation coefficient r	Value for significance at 1% level
Weight at 4 weeks : weight at 20 weeks	91	+0.745	+0.283
Weight at birth : weight at 20 weeks	60	+0.620	+0.354
Gain in wt. birth to 4 weeks : weight at 20 weeks	60	+0.582	+0.354
Weight at 4 weeks : gain in wt. 4 to 20 wks.	91	+0.406	+0.283
Weight at birth : gain in wt. 4 to 20 wks.	60	+0.342	+0.354
Gain in wt. birth to 4 weeks : gain in wt. 4 to 20 wks.	60	+0.356	+0.354

With two exceptions, the correlation coefficients were easily significant at the 1% level, and were used as criteria in the initial pairing of the experimental calves

within breeds in order to increase the uniformity of blocks, and in the following order of attention.

(1) Weight at twenty weeks, the figure on which the relative value of the experimental treatments was to be judged, was found to be most closely correlated to weight at four weeks. Calves having similar four week's weights (estimated from previous weight gains and the three week's weights) were paired together.

(2) In order that any fluctuations in the weather or the grass supply should affect the calves within a block at approximately the same age and stage of growth, pairing by the first criterion was subject to the limitation that the calves should be born as near together as possible.

(3) The age of dam was taken into account in that when possible calves out of heifers were paired together. Eckles (1919) has found that calves produced by immature cows, two to four years of age, are smaller than those from mature cows as did Knapp, Lambert and Black (1940). Hammond (1944) has suggested that this effect is explicable on the theory of partition of nutrients between the different maternal tissues, this being determined by their metabolic rates. In the young mother the metabolic rate, and thus competition of the maternal tissue for nutrients would be greater. Pairing on age of dam was considered only a minor point, it was already taken care of to some extent by pairing at four-week's weight.

(4) Also as a minor point, pairing by sire was considered. Tyler, Chapman and Dickerson (1947) studying Holstein-Friesian cattle found variation between sires in the birth weight of their offspring.

A coin was then tossed between two similar pairs of calves, one pair being thus allocated to skim milk feeding, and the other to buttermilk. To decide which calf in a pair was to receive the 10% level of feeding, and which the 15%

level, a coin was again tossed.

Calves were weighed as soon as they were obtained, and thereafter every Friday morning as near as possible at the same time so that the alimentary tract might on each occasion be at an equivalent state of "fill". Despite this, unexplainable anomalies in the weights did occur. The weighbridge was found to be accurate to within a pound. Height at withers was measured fortnightly by means of a measuring stick with upright and crosspiece carrying a spirit level. These figures were taken as an index of skeletal growth.

If a calf was born on Tuesday, Wednesday or Thursday, the first Friday weighing was taken as the birth weight, otherwise it was regarded as weight at one week of age, no adjustments being made to the weights actually recorded. The same, in principle, applied to the fortnightly measurements. It was found that within experimental groups, the average of actual ages (weeks and days) fell very close to the appropriate number of the whole weeks (\pm half a day), and that no bias was thereby introduced.

On reaching the age of twenty weeks all calves were photographed behind a wire grid of six inch squares, photographs being taken from the same position each time and enlarged to the same extent in printing.

The skim milk was sampled for analysis by taking 50 ml. from the well mixed bulk at each of four successive milkings, two morning and two evening, and the single container was stored in a refrigerator during this time.

The buttermilk powder was contained in 80 lb. unlined sacks, and by means of a clean stainless steel pipe, two feet long and one inch diameter, a core was withdrawn from about thirty of the forty-five sacks. These samples were well mixed, and a subsample taken for analysis.

TABLE IV.

Analyses of buttermilk powder and skim milk used in the experiment.

Constituent	Skim milk	Buttermilk
Total solids	10.10%	91.43%
Fat	0.10	8.73
Total protein	3.94	31.13
Lactose	5.30	40.20
Ash	0.77	6.76
Water	89.90	8.57
Solubility of buttermilk powder at 20°C 59.9%		
50°C 70.2%		

HEALTH OF THE CALVES.

A diary was kept and full details recorded of any sickness occurring.

Much trouble was experienced from scours. Even before one week of age, calves, receiving not more than 10% of body weight of diluted herd milk, passed faeces in which blood was evident. Scours had in previous years been troublesome and from this and certain other evidence, the Veterinarians concluded that a virulent strain of coliform organism was present. As a measure against this a mixture of bismuth salicylate and brilliant green was administered, one fluid ounce in water at morning and evening feeds on October 20th and again a month later.

Treatment of scours was immediate isolation in calf pens and starvation for twelve hours. Castor oil, three to four ounces depending on the age of calf, was given. The first feed following this was a small quantity of milk diluted with an equal amount of warm water, the proportion of water gradually decreasing as the milk fed increased to the normal amount.

In addition, sulphaguanidine was given twice daily at the rate of 1 g. (two tablets) per 10 lb. body weight per day for two days, then 1 g. per 15 lb. body weight per day

for two ^g days, and finally 1 g. per 20 lb. body weight per day for two days. Wise and Coarsey (1945) found this drug efficacious in lowering calf mortality from infectious calf scours; in this experiment the effect was not clear cut owing to other, concurrent, treatments. In two cases sulphaguanidine did not have beneficial effects and the calves died, one at the age of twenty-two days having scoured with some blood for eight days, and the other at fifteen days having blood scoured for six days.

Sulphathalidine, also very sparingly absorbed from the alimentary tract (Scheidy 1940), and found more useful than sulphaguanidine for the treatment of bacterial intestinal infections (Udall 1946, Edmonds 1949), was twice used. Dosage rate was 1 g. per 15 lb. live weight initially, followed by six doses at eight-hourly intervals of 1 g. per 30 lb. body weight, and finally six doses of 1 g. per 50 lb. body weight. In both cases the treatment was effective.

In Table V are scours data on calves that later partook in the experiment (see page 21).

In addition during the experimental feeding, some calves at ages ranging from eight to fourteen weeks were "loose" in their faeces for varying periods and their feed was reduced for a few meals. This especially applied to Friesian No. 57 and Jersey No. 20 - both on 15% skim milk treatment, and also to Friesian No. 6 and Jersey No. 10 on the same treatment. On the 15% buttermilk treatment, Friesian No. 63 and Jersey No. 37 were most affected but less so than Jersey No. 20 or Friesian No. 57. Also affected were Jerseys 34 and 69. The only "10%" fed calves that were "loose" were the Friesians 26 and 51 - both on skim milk - and then only for a short time.

One calf - Jersey 86 - showed a continual tendency to bloat but the tympany was reduced by the

administration of a tablespoonful of sodium bicarbonate in warm water and by exercise. However, at the age of ten weeks this animal died from bloat despite this treatment and rumen puncture. The rumen contents were a frothy mass of grass. Several other calves occasionally showed tendencies to bloat, but without serious consequences

TABLE V.
Scours record of the experimental calves.

Calf ear mark	Age at scouring (days)	No. of days scouring	Treatment	Remarks
<u>Friesian</u>				
57	4	-	Sulphathalidine	Fraternal twins.
63	4	-	Sulphathalidine	Faeces firm, but containing blood for 2-3 days.
	and 19	3	Sulphaguanidine	
65	6	3	Starvation	Nutritional scours
<u>Jersey</u>				
12	20	4	Sulphaguanidine	
20	8	6	Sulphaguanidine	Blood in faeces.
35	14	3	Starvation	
36	19	2	Starvation	
44	11	3	Starvation	
50	14	5	Sulphaguanidine	Blood in faeces.
82	7	4	Sulphaguanidine	Blood in faeces.
	and 13	2	Sulphathalidine	
	and 42	4	Starvation	
48	51	2	Starvation	Nutritional scours
89	42	4	Starvation	Nutritional scours
93	29	4	Starvation	Nutritional scours
103	21	2	Starvation	Nutritional scours

Jerseys 35 and 69, both at around eight weeks old, showed signs of severe stomach ache. The animals were given 1 oz of Epsom salts in water, and starved for the one feed. Recovery was rapid and complete.

Jersey 55 became lame and at four weeks of age was found to have footrot. Rather than inject (the sodium salt), sulphathiazole was given in massive dose by mouth - fourteen $\frac{1}{2}$ g. tablets, followed by four doses of seven tablets. A sulphanilamide ointment was applied directly.

Recovery was rapid.

At ten weeks of age, Friesians 26 and 51 were observed to be passing urine tinged red. A drench of linseed oil and turpentine was given; the urine was normal at the next feed. Later, Friesian 64 at nine weeks of age, had a much more serious attack. Urine of a definite and fairly deep red colour was continually being passed. Unfortunately during drenching some of the mixture entered the lungs and caused distress; the calf was kept in a pen overnight during which time it died. Post mortem examination showed some lung congestion and also nephritis.

Two calves died from unknown causes. Jersey 67 developed a peculiar dry necrosis of the whole skin. No satisfactory diagnosis was obtained; veterinary examination revealed no skin parasites. Iodine deficiency was considered a possibility and Lugol's solution was given in the milk (and to all the other calves; 1 oz per day for a week, then $\frac{1}{2}$ oz per day for three weeks) without any improvement in condition. This animal was withdrawn from the experiment and later killed.

Jersey 20 at four months old lost interest in food and had to be coaxed into drinking. Death occurred five days later after considerable loss of condition. Post mortem examination revealed very large kidneys showing nephritis as the chief abnormality.

As noted, the calves were grazed rotationally on eight paddocks of the Dairy Farm. For part of the time some of these were shut for silage making which shortened the period of the rotation, and also grazing was fitted in with other groups of stock from the College No.1 shed. A little trouble was experienced with lungworms (*Dictyocaulus* sp.), and the calves were each given $\frac{1}{2}$ oz of phenothiazine in water on November 12th and again on December 3rd so as to prevent further migration from the stomach. In order

to lengthen the rotation it might have been advisable to graze each paddock for two whole days running instead of one day and night only as was usually the case.

Calves were dusted with Derris powder against lice on two or three occasions, two dustings at ten-day intervals being given.

Calves were dehorned with caustic potash at an early age. The operation was uneventful.

Without a doubt, the Jersey calves were much more prone to all types of sickness than the Friesians who proved much easier to rear.

RESULTS.

The weights and heights of each animal week by week are appended in tables. The figures are plotted in graphs II to VII inclusive.

Initially, animals were so arranged that there were equal numbers of each breed in each treatment group, and with the two "spare" Friesians fed as a skim-buttermilk comparison at the 15% level. Unfortunately as the trial proceeded some calves, for reasons detailed in the previous section, had to be excluded, making the subclass numbers unequal. An analysis of variance has been made of the weights and heights of animals forming complete blocks at different ages.

e.g. Analysis of variance, six weeks weights.

<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>	<u>Significant</u>
Blocks	7	19700			
Feed Level	1	50	50	4.23	Non-significant
Interaction	1	2	2		Non-significant
Error	21	1241	59		
Total	31	21243			

(Value of F for significance at 5% level = 4.32)
s = 7.7 lb. Coefficient of variation = 8.3%

TABLE VI

Summarised results of analyses of calf weights.

Age (weeks)	Number of calves in each mean	Number of Friesians included in each mean	Treatment means (lb.)				S E _m (lb.)	Significance	
			15%	10%	Skim milk	Butter- milk		Level	Feed
4	16	4	78.5	77.8	79.6	76.8	1.53	N.S.	N.S.
6	16	4	95.9	89.8	94.1	91.6	1.93	N.S.	N.S.
8	16	4	111.9	102.9	107.7	107.1	2.20	15% > 10% ^{XX}	N.S.
12	12	2	151.8	136.0	142.6	145.2	3.67	15% > 10% ^{XX}	N.S.
16	10	2	197.3	179.1	187.3	189.1	5.31	15% > 10% ^X	N.S.
20	10	2	242.9	221.0	230.6	233.3	6.51	15% > 10% ^X	N.S.

^{XX}Significant at 1% level^XSignificant at 5% level

At no time was the feed-level interaction significant.
In the above analyses, all coefficients of variation approximated to 8%.

TABLE VII

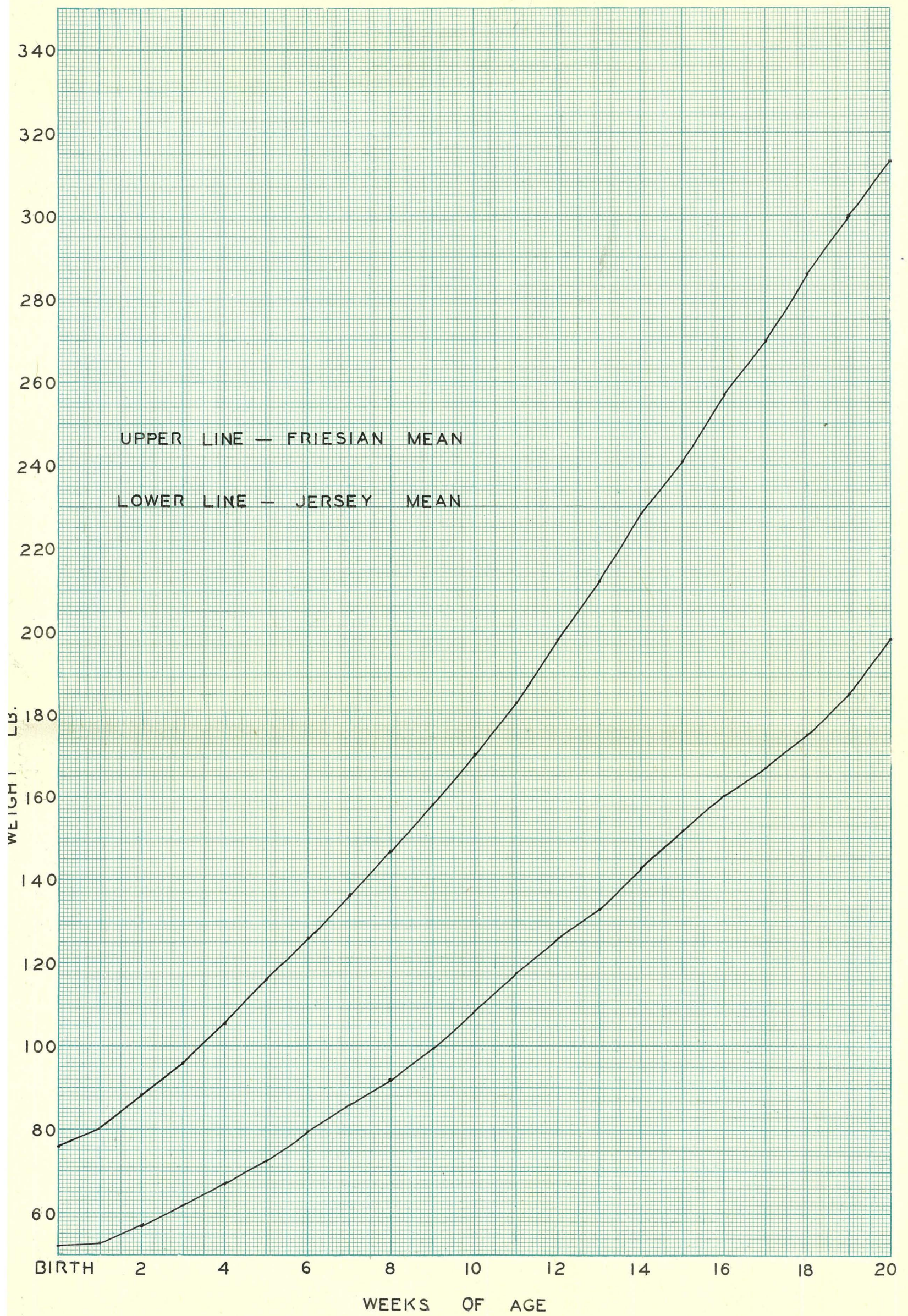
Summarised results of analyses of calf heights.

Age (weeks)	Number of calves in each mean	No. of Friesians included in each mean	Treatment means (inches)				S E _m (inches)	Significance	
			15%	10%	Skim milk	Butter- milk		Level	Feed
4	16	4	27.4	27.3	27.3	27.4	0.19	N.S.	N.S.
8	16	4	29.6	29.2	29.6	29.2	0.23	N.S.	N.S.
12	12	2	32.1	31.0	31.6	31.5	0.26	15% > 10% ^x	N.S.
16	10	2	34.1	33.4	33.8	34.0	0.37	N.S.	N.S.
20	10	2	36.2	35.1	35.7	35.6	0.31	15% > 10% ^x	N.S.

^x Significant at 5% level.

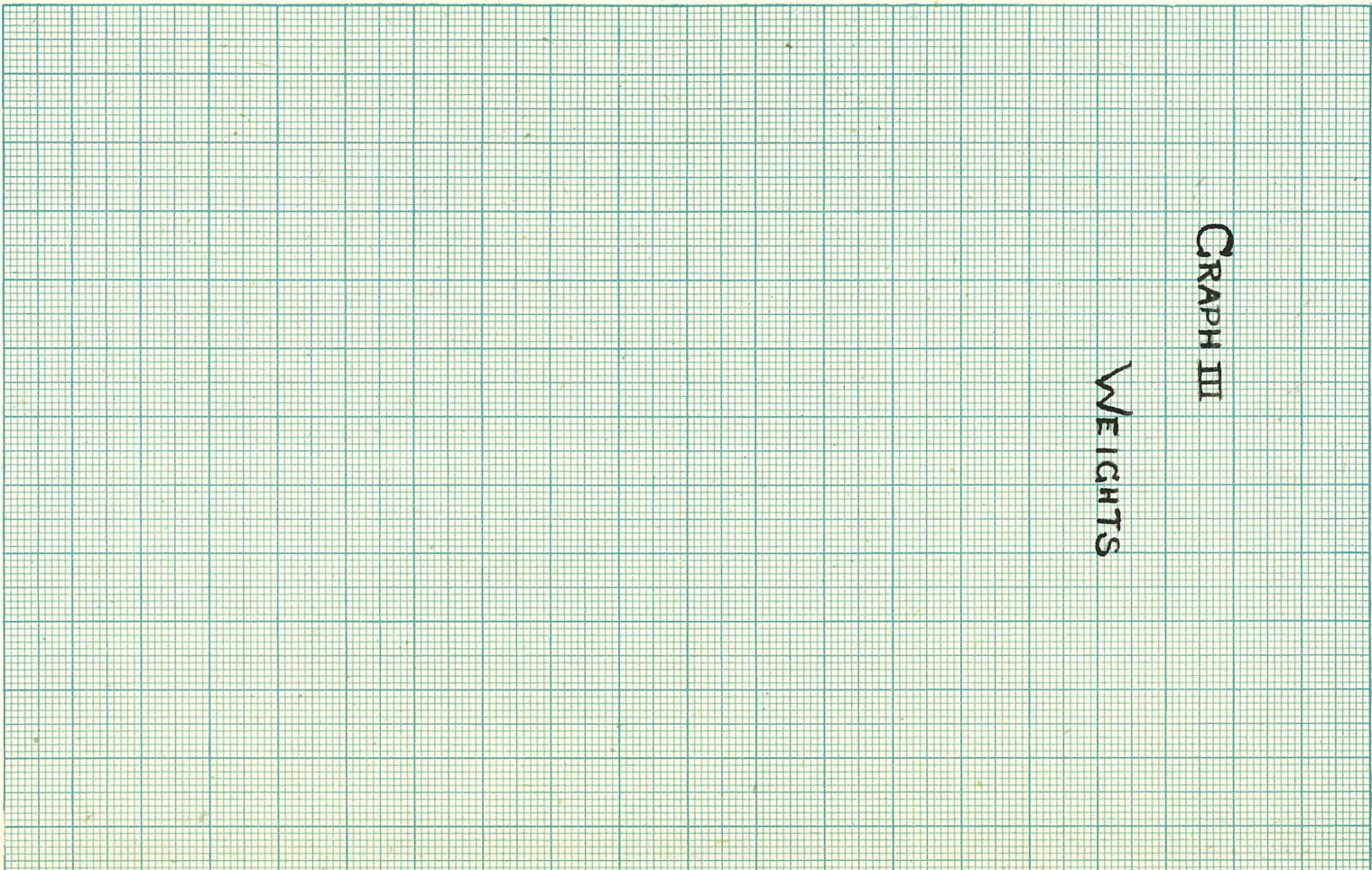
GRAPH II

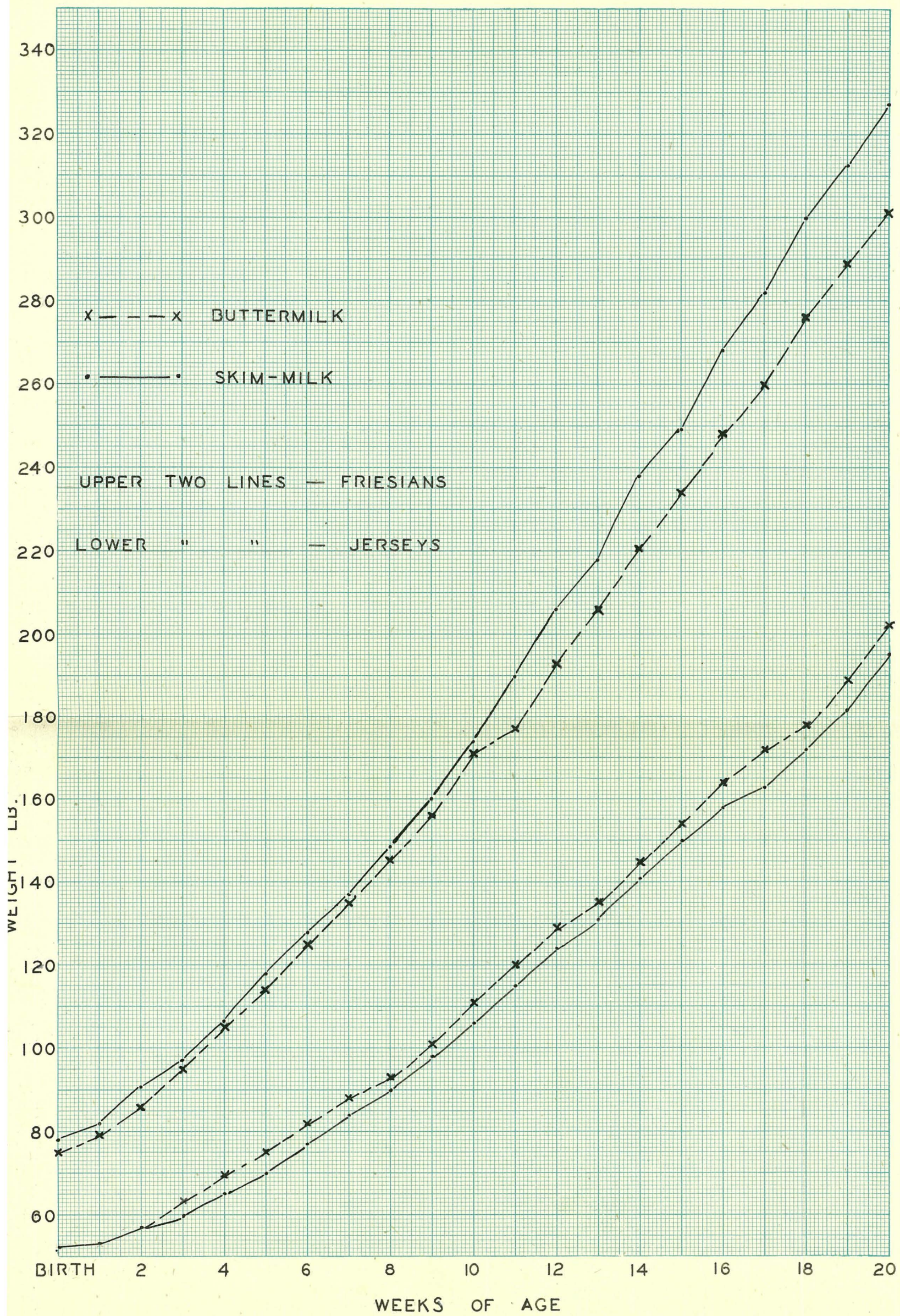
WEIGHTS



GRAPH III

WEIGHTS

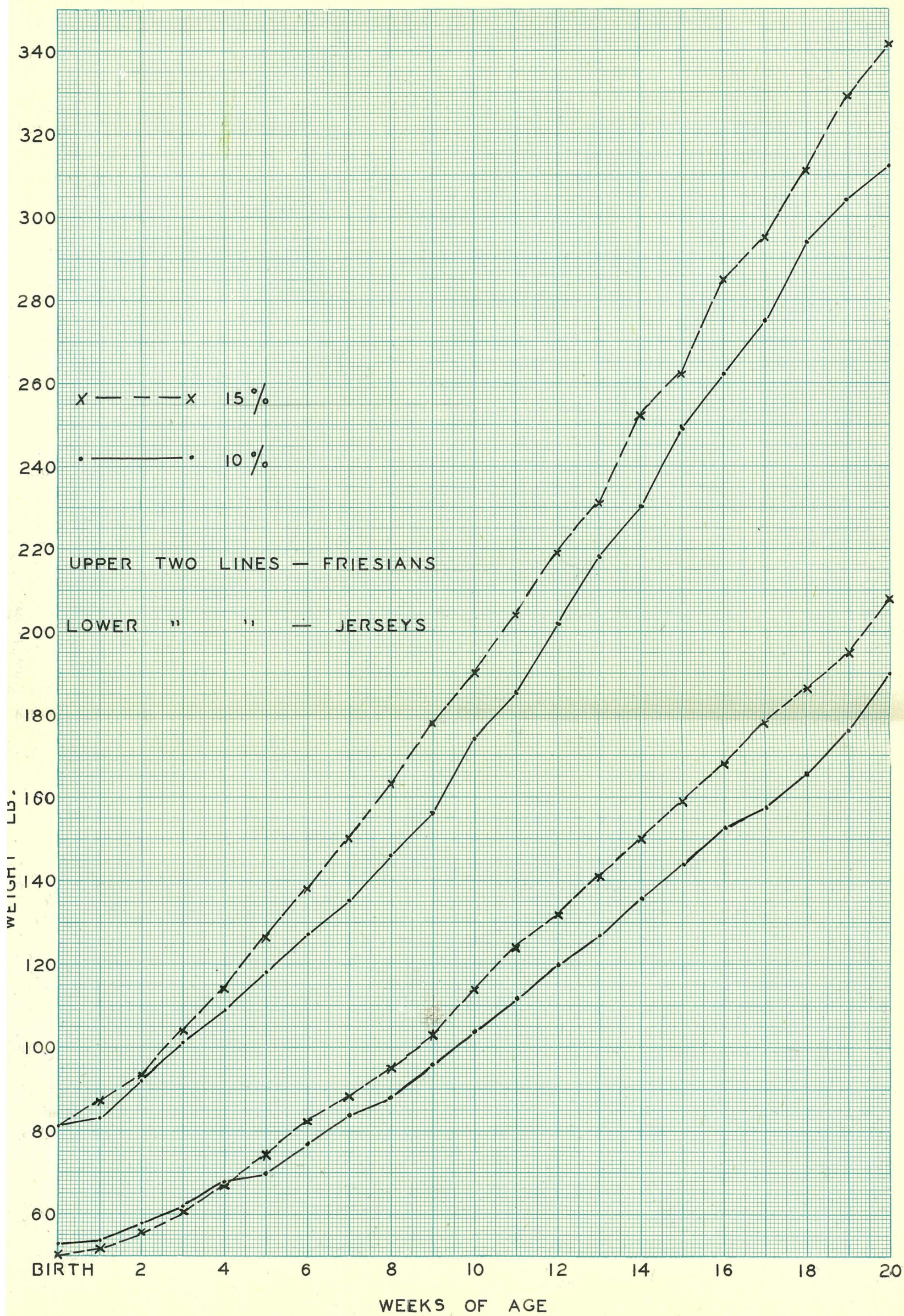




GRAPH IV

WEIGHTS

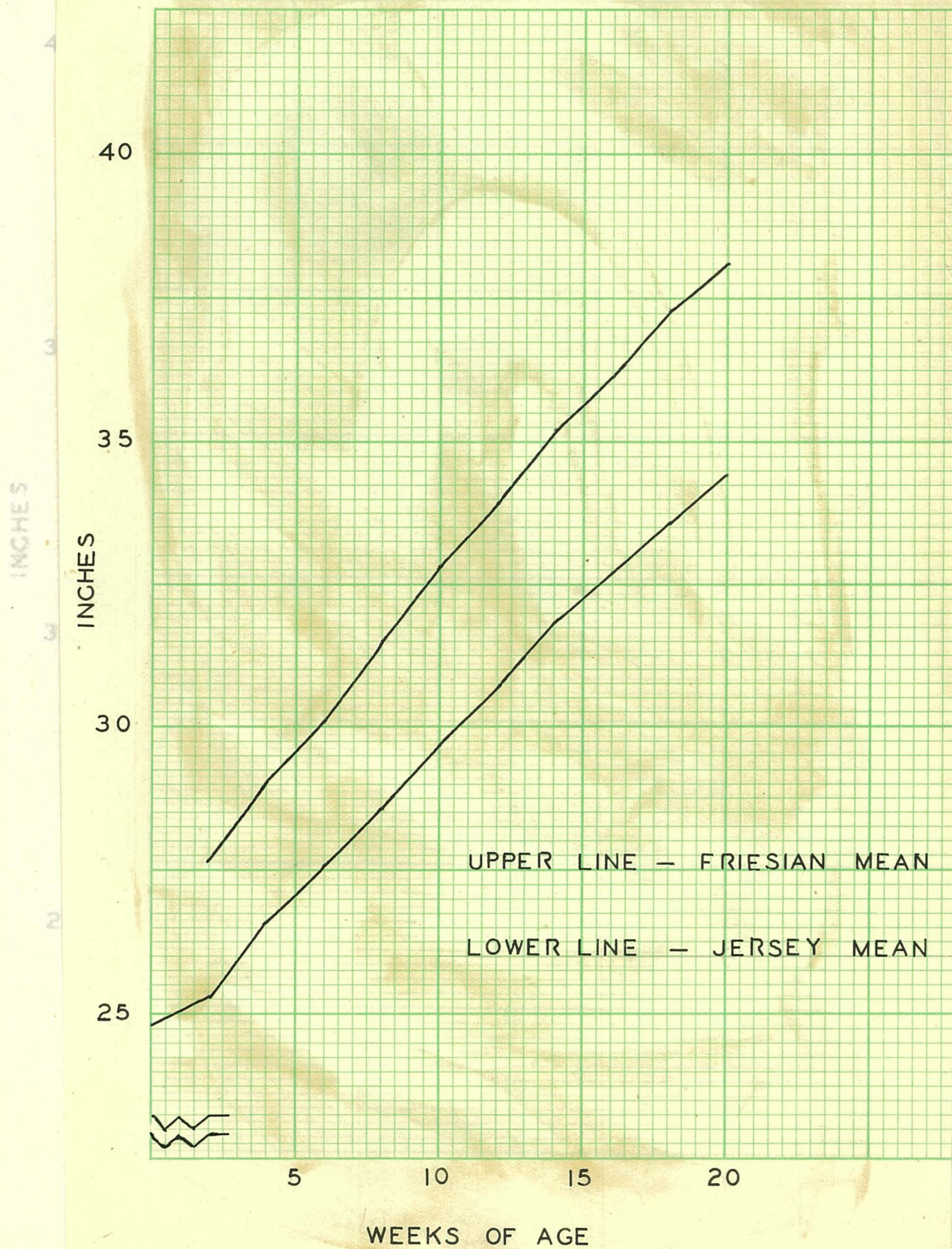
(FRIESIANS 57 & 63 EXCLUDED FROM
15% LINE)





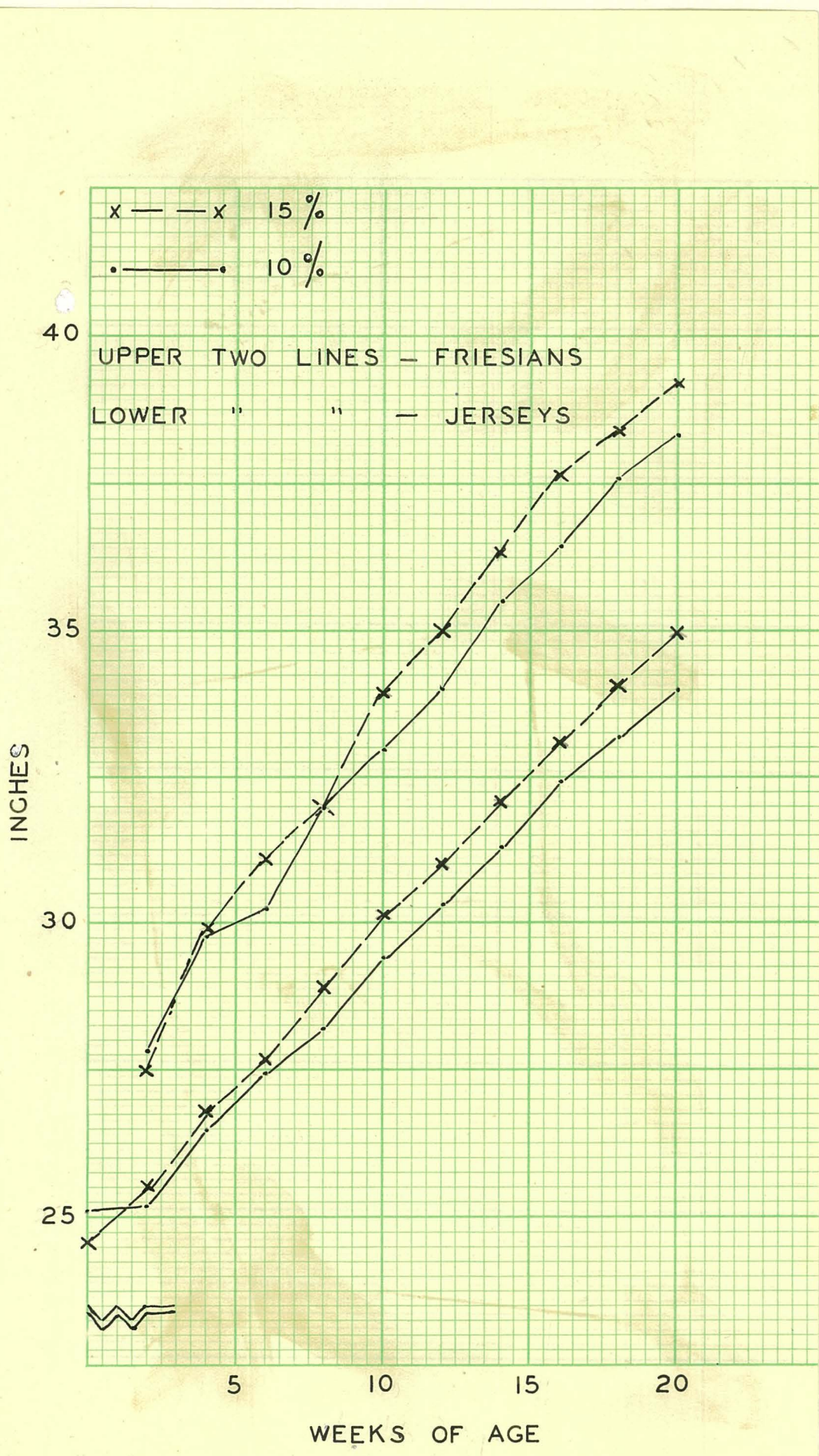
GRAPH V.

Height at withers.



GRAPH VII.

Height at withers.



the mean maximum and mean minimum temperatures over the same periods as rainfall.

Housing calves for the first few days of life is advisable during poor weather conditions, especially when there is little shelter in the paddocks.

Table XIII

Weekly weight gains of the experimental calves.

Week ending	Weekly weight gains lb.				
	Jerseys		Friesians		
	No. calves	Lb.	No. calves	Lb.	
Aug.	6	3	7.3	7	7.3
	13	9	5.1	7	11.6
	20	13	0.4	7	6.0
Sept.	27	18	4.6	8	9.8
	3	19	7.2	10	9.5
	10	22	3.0	10	7.2
Oct.	17	23	7.7	10	11.9
	24	24	6.2	10	9.8
	1	26	3.7	10	7.6
	8	26	7.2	10	14.6
	15	26	4.7	10	11.2
Nov.	22	25	10.3	10	15.9
	29	25	6.0	9	12.6
	5	25	9.0	9	15.0
	12	23	7.6	9	14.5
	19	23	8.7	9	12.8
Dec.	26	23	9.0	9	14.3
	3	23	10.0	9	18.3
	10	22	3.6	9	6.0
	17	20	12.1	5	20.2
	24	20	10.5	5	17.6
Jan.	31	20	12.3	4	19.5
	7	11	6.2	2	17.0
	14	8	9.6	2	9.5
	21	8	4.6	-	-
	28	3	26.6	-	-

In connection with height at withers, there are certain points that should be noted. Already at birth half of this linearly measured complex is completed so that the opportunity for modifying it by nutritional conditions is limited compared with, for example, weight. However height at withers is a suitable measurement of body growth for although correlated with various others it is one least

correlated with body weight; others, chest girth in particular, are influenced by the degree of fleshing. Though a fairly easy measurement to take, it is still subject to a considerable degree of error, and much care is needed. Consecutive readings on young calves can differ by an inch or more, even if the legs and head are set properly, for the animals can "flinch" considerably; in older animals, allowing them to remain quiet for a short time whilst the muscles relax alters the reading. Thus the measurements throughout, as in this experiment, should be taken by one operator, so that they are at any rate comparable; as a refinement, measurements taken by two people could be averaged.

The total quantities of liquid consumed in the experiment:

In the tables XIV A and B are given the mean weights, week by week, of each treatment group (no distinction has been drawn between feeds because of the non-significant differences between them, they being referred to collectively as whole milk substitute). Also are given the corresponding average liquid consumption (pounds per day) of the animals within each group, a weekly average total per head and the grand total per head. It is to be noted that in practice the weight at four weeks was used in calculating the food allowance for the fifth week of life (the start of the experimental feeding) the fifth week's weights for the sixth week of life (these two weeks being the "changeover" period) and the nineteen week's weights for the twentieth week of life, at the end of which the experimental feeding terminated.

On average during the experimental period four to twenty weeks, a

Jersey, 10%,	received	41 lb.	total whole milk &	1276 lb.	substitut
" 15%,	"	61 $\frac{1}{2}$ "	" " " "	1838	" "
Friesian 10%	"	67 $\frac{1}{2}$ "	" " " "	2125	" "
" 15%,	"	107	" " " "	2903	" "

TABLE XIV
Part A.

Whole milk and substitute consumption during "changeover" period, pounds per head per day, group means.

Treatment Group and Feed.	Fifth week of life.		Sixth week of life.			Total feed per calf "Change-over" period.
	4 days at 25% substitute.	3 days at 50%.	1 day at 50%.	4 days at 75%.	2 days at 100%.	
<u>Jersey 15%</u> Group average weight lb. 67			74			
Whole milk	7½ (lb.p.h.p.d.)	5 (lb.p.h.p.d.)	5½ (lb.p.h.p.d.)	2¾ (lb.p.h.p.d.)	-(lb.p.h.p.d.)	61½ lb. whole milk
Substitute	2½	5	5½ p.d.)	8½ d.)	11	85½ lb. subs.
<u>Jersey 10%</u> Group average weight lb. 67			70			
Whole milk	5	3½	3½	1¾	-	41 lb. whole
Substitute	1¾	3¼	3½	5¼	7	55¼ lb. subs.
<u>Friesian 15%</u> Group average weight lb. 114			126			
Whole milk	13	8¾	9½	4¾	-	106¾ lb. whole
Substitute	4½	8¾	9½	14¾	19	147 lb. subs.
<u>Friesian 10%</u> Group average weight lb. 109			118			
Whole milk	8¼	5½	6	3	-	67½ lb. whole
Substitute	2¾	5½	5¾	8¾	11¾	91¾ lb. subs.

TABLE XIV
Part B

Treatment Group	Week of Age														Total feed per calf 7th - 20th week.
	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	
Jersey 15%.															1752 lb. substitute.
Group aver. weight lb.	81	88	95	103	114	123	132	141	150	160	168	179	186	195	
Lb. subs. per head/day.	12	13	14½	15½	17½	18½	19¾	20	20	20	20	20	20	20	
Weekly tot. lb./head.	84	91	100	108	121	130	138	140	140	140	140	140	140	140	
Jersey 10%.															1221 lb. substitute.
Group aver. weight lb.	77	83	88	96	104	112	120	127	136	144	153	158	166	176	
Lb. subs. per head/day.	7¾	8½	8¾	9½	10½	11½	12	12¾	13½	14½	15½	15¾	16½	17½	
Weekly tot. lb./head.	54	60	61	67	74	79	84	89	95	102	107	110	116	123	
Friesian 15%.															2756 lb. substitute.
Group aver. weight lb.	139	150	163	179	190	204	219	231	252	262	285	295	311	329	
Lb. subs. per head/day.	21	22½	24½	27	28½	30	30	30	30	30	30	30	30	30	
Weekly tot. lb./head.	147	158	172	189	200	210	210	210	210	210	210	210	210	210	
Friesian 10%.															2034 lb. substitute.
Group aver. weight lb.	127	136	147	156	169	181	196	212	226	243	257	269	287	299	
Lb. subs. per head/day.	12¾	13½	14¾	15½	17	18	19½	21½	22½	24½	25¾	27	28¾	30	
Weekly tot. lb./head.	89	95	103	108	119	126	137	149	158	170	180	189	201	210	

Whole milk substitute consumption, pounds per head per day, group means.

In each case the total of substitute for the 15% calves is not 50% greater than the total for the 10% calves. The reason is that the animals on the higher plane of feeding fairly quickly reached their maximum daily food allowance (20 or 30 lb.) and remained at that level whilst the daily allowance for the 10% calves increased weekly throughout the experiment, closing the gap.

The effect of breed on growth:

In the analysis, when allowance was made for differences in initial weights, no significant difference in growth rate was found between breeds. There is little reason to expect that selection for "dairy" characters would have caused any. There was remarkable similarity between the two k values (Table XII).

Had a difference been found, no interpretation would have been possible since the Friesians were allowed a higher maximum (30 lb. liquid food per day) than the Jerseys (20 lb.), this being confounded with breed effect.

The relative values of skim-milk and buttermilk:

An answer to the original question is immediately forthcoming, that under the conditions of feeding and management in the experiment, and as judged by measurements of weight and height, skim-milk and reconstituted dried buttermilk are of equal value as feeds for calf rearing. The differences in the measurements at no time approached significance.

The only differences, as noted, were those of rather less looseness of the faeces, and a better coat appearance in the buttermilk fed calves. These observations are in accord with the reports by Otis (1904), Woodward (1922) and Eckles and Gullickson (1924) previously reviewed.

The feed of these calves contained, notably, a

larger proportion of fat - 0.87% in diluted buttermilk, 0.10% in the skim-milk - and this can possibly provide an explanation. It does not appear that butterfat or any particular fraction of it, for example an unsaturated acid, has superior growth promoting properties (Nath, Barki, Elvejhem and Hart, 1948; also Henry, Kon, Hilditch and Mears, 1945); Augur, Rollman and Deuel (1947) have shown that phospholipid can assist in fat emulsification and hence digestion and absorption. Buttermilk does contain several times the amount of phospholipid in skim-milk, Heinemann (1939) giving the figures

0.114 - 0.126% in buttermilk

0.015 - 0.010% in skim-milk

and Bird (1939) states that, on average, 21% of the fat in buttermilk is phospholipid. This would be of no importance here since milk fat is in any case very well digested; further because of the small amounts present, the possibilities that fat being a concentrated energy food may be more suited to the size of the young calf's stomachs, and the effects that fat has in satisfying hunger tending to reduce voluntary intake of other food, can be ruled out.

Admittedly bloom in the coat is a nebulous character, and its value other than aesthetic is obscure, but it is certainly taken as a good sign. It is worthwhile to investigate its possible physiological cause or causes.

Of the three major nutrients - protein, carbohydrate and fat - the latter has the lowest specific dynamic action, and can confer economy of utilization upon the combinations in which it is present (Nutrition Reviews 1947). Thus several workers have observed that "isocaloric" replacement of carbohydrate or protein in a ration by fat results in better growth; in this case caloric intake of liquid food, level for level, was very nearly equal, but the

buttermilk contained more fat (and less protein and lactose). This fairly small difference could have been manifested merely as a coat difference.

A property peculiar to butterfat is that it assists in the metabolism of dietary lactose, this advantage disappearing when other carbohydrates, e.g. glucose, dextrans, are fed in its place. Schantz, Elvehjem and Hart (1938) found that rats, a pig and a calf made very efficient utilization of all the milk sugar in a mineralized whole milk diet, but on a mineralized skim-milk diet, sugar, identified as galactose, was readily detected in the urine after a few days of this feeding in the case of rats, and after about two weeks in the cases of the pig and calf. The latter animal lost about 8% of the total lactose ingested, or approximately 16% of all galactose ingested. How butterfat acts in this way is not clear. Certainly galactose has a different course in its metabolism to glucose - fed in excess of 40% of the ration weanling rats die, but not as a result of acidosis or dehydration (Handler 1947). Perhaps butterfat merely acts in slowing up galactose absorption so that its metabolism may keep pace, but this seems unlikely since when only 2 ml. of skim-milk was fed to rats each half hour, they still showed the characteristic abnormal rise in blood sugar (Schantz et alia 1938); or the fat may intervene in the conversion of galactose to a metabolizable form.

Though some workers with rats (Zialcita and Mitchell 1945) have failed to confirm this effect, and others (Niefert and Deuel 1947) have found that cottonseed oil when compared with butterfat, both fed at the level of 10% of the diet, gave significantly lower urinary excretion of galactose, many others have confirmed it (Geyer, Boutwell, Elvehjem and Hart, 1945; Nath et alia 1948). Rojas, Schweigert and Rupel (1947) confirmed Schantz' finding with rats, but in attempting to repeat the work with calves obtained nowhere near the loss

Schantz reported (16% of galactose ingested), regardless of whether they fed whole or skim-milk (mineralized and vitaminized) their figures actually ranging from 1.1 - 3.4% total lactose ingested. It was only when the lactose content of the skim-milk was doubled by adding quantities that an 8% loss of lactose, equivalent to a 16% galactose loss, was obtained. This was accompanied by diarrhoea and unthriftiness though no reducing sugars were found in the faeces.

This effect is in part similar to the looser condition of the faeces of some of the skim fed calves in the experiment, and it appears that both this difference and the coat difference are at present best explained by the beneficial effect of the greater amount of fat in the buttermilk diet. However, Rojas does state that young calves (up to 1½-2 months old) being adapted to the milk diet utilize lactose efficiently, and absence of fat in the diet does not interfere with this; but further studies are needed in order to determine the difference, if any, between the very young and the older bovine in lactose utilization.

The effect of level of feeding:

Of far greater importance was the difference due to level of feeding. A previous trial by the Dairy Research Institute had indicated that 10% or 15% feeding had little effect on the growth of calves during the milk feeding period providing good grass was available. In this experiment there was again a good supply of grass throughout, and yet this was apparently unable to make good a deficit in the poorer ration. The reason for this can be deduced from two pieces of evidence,

From Table IX it is seen that the regression coefficient relating four and twenty weeks weights is + 2.81. Thus growth early in life can have marked effects, every extra pound in weight at four weeks resulted in an extra 2.81 lb. at the later age on average. In the second place, even at six weeks of age after two weeks on the 50% greater ration, these

animals were showing superior weight growth over the 10% calves and by eight weeks the difference was significant.

Though the differences between the two groups in height at withers failed to reach significance at the conventional 5% level in the analysis of all calves at twenty weeks, and of complete blocks at sixteen weeks, this can be ascribed to the limited opportunities for modifying height growth as compared to weight growth, and in the latter case to errors in measurement as shown by the larger standard error of the mean, 0.37 inches, in Table VII. Height difference was significant from the analysis of complete blocks at twenty weeks, and the same trend as for weight, the fairly early appearance of the difference, is observable from the figures.

The result at twenty weeks can thus be traced to an early age; the calves, owing in large part to the incidence of scours, did not grow very quickly during the first few weeks of life, and as a consequence those animals which received the larger ration from four weeks were in a far better position to offset this disadvantage and to make good growth. Since the intake of grass during this early period is comparatively small the 10% calves would in fact be having much less food.

In the saleyard, well grown animals are favoured, but it is pertinent to enquire whether greater size produced by a high level of feeding during growth does in fact confer any considerable advantage either on the calf or dairy cow herself, or upon her productivity.

There is no guarantee that a measurement of growth such as gross body weight implies a definite relationship of the diverse parts of the body. Such figures are superficial, expressing the overall increase in size during a period, but failing to differentiate the complex relative changes of, for example, the internal organs which may be variously modified by different diets. Thus the rumen which at birth is small and occupies an unimportant position in the abdominal cavity,

by three months has increased in size so that it approaches the relative proportions, with the other stomachs, of the adult (Lagerlof, 1929; Grossman, 1949). But Lagerlof emphasized that the development he described assumed the calf had hay at an early age and was not kept on milk and concentrate only for too long. As an extreme example Herman (1936) and Wise, Petersen and Gullickson (1939) reared calves on a diet of whole milk and minerals alone, their bedding of wood shavings, wooden pen divisions and hair being their sole source of "roughage". Good growth was obtained for the first six months of life but the animals died within a few months afterwards when their rumens were found to be much underdeveloped. One can surmise that one of the fundamental causes of the death of these animals was the absence of a normal micro-organism population in the rumen, with consequent deficiency of the manifold and beneficial bacterial and protozoan products.

A long period on a low plane of nutrition greatly retarding development, later giving way to a diet which permits growth to adult size, has been shown by McCay (1942), using rats, very much to prolong the length of life over initially similar animals allowed to grow steadily right from birth. Apparently growth in itself staves off senescent changes in the organism as originally suggested by Minot in 1879 (Brody 1945).

On the other hand, gross overfeeding reduces the length of life (Brody 1945 p.689) because of various factors such as increased energy metabolism, increased burden on the digestive, excretory and associated organs, the possibility of causing endocrine imbalances such as the pancreatic islets failing to maintain their hyperactivity, and excessive fat becoming a mechanical obstacle to free muscular movement, increasing their energy requirement, and impeding proper functioning of the organs as in the over-conditioned and thence

often infertile cow (Asdell 1949).

But an adequate or good diet is neither extreme, for it is not to be judged on one effect alone but rather as one that permits the optimum in life activities as a whole - the exception is, of course, animals grown rapidly for slaughter. Not only must longevity be considered, but also freedom from disease and efficiency in the various reproductive functions. With all of these the dairy husbandman is concerned. If it were possible to repeat with dairy cattle, McCay's (1942) experiments with rats - this has not as yet been attempted - and thereby increase longevity by some years, in practice the cost of maintaining them in a long initial non-productive state would prove uneconomical, even assuming their fertility was unimpaired. Even with normal management it is not until during or after her second lactation that a dairy cow has paid for herself with returns as milk and calves.

Eckles and Swett (1918) have shown that animals on a restricted diet, though they never become quite as large as others better fed, have their length of growth period prolonged. Periods of retardation in growth rate, if not too great are compensated for to some degree by an increased growth rate when limiting factors are restored; Steensburg (1947) illustrated this from an experiment on dairy heifers "lightly", "normally" and "heavily" fed from birth, and showed that when at twelve to eighteen months old they were allowed as much grass as they would eat, there was only slight variation in the quantities consumed. But on this the "lightly" fed animals ~~gained~~ gained $\frac{1}{4}$ lb. more per day than those "normally" fed, and nearly $\frac{1}{2}$ lb. more than those "heavily" fed. The reason lay not only in that the smaller animals had a smaller maintenance requirement, leaving more of the food for growth, but there was also evidence that the cost of a unit of gain was rather less.

The plan of feeding to be followed in calf rearing depends much on local conditions and management such as age of

calving, extent of reliance on bought in concentrate foods, and the importance of natural fluctuations in food supply throughout growth.

The dairy cow management in New Zealand is peculiar in that the majority of animals calve at two years of age. Whilst gestation has no great effect on the rate of growth of heifers, Eckles and Swett (1918) have shewn that lactation checks materially both skeletal and weight growth. Heifers which calved when twenty to twenty-four months old did not average so large at maturity as heifers that calved first when twenty eight to thirty four months old. Although growth rate would tend to compensate in the dry period following the first, and perhaps later, lactations, and Eckle's heifers were reared under American conditions, the general principle would apply in New Zealand that rate of growth to first calving would affect mature weight. This is important because of a possible relation of weight to milk yield - that is efficiency. It is generally accepted that between different cows of different liveweights, gross efficiency of milk production and liveweight are independant (Gaines 1939; Brody and Cunningham 1936). Larger cows produce more milk but not relative to body weight. It is not known whether the same relationship holds within cows or not - if, for example, the milk production genotype can reach the same level of phenotypic expression whether the cow is grown to a smaller mature size (but without vital nutritional deficiencies) or a larger mature size. If that is the case then there is advantage in rearing smaller cattle, for thereby their gross energy efficiency, or what Gaines, Rhodes and Cash (1940) call their "index of merit" - $\frac{\text{lb. fat corrected milk}}{\text{"physiological" weight}}$ - would be increased.

Davis and Willett (1938) did find no relation between the rate of growth of dairy animals up to two years of age (gain in weight by two years expressed as a percentage

of birth weight), and their milk and fat production either in the first or total of all lactations. But this is no more than would be expected for the animals were a large sample of Holsteins all being reared normally for inclusion as replacements in a dairy herd, and there would naturally be considerable variation of efficiency (body size:milk yield) about a mean, and distributed in fairly normal fashion.

Preliminary results of a long-term experiment at Ruakura Animal Research Station on the rearing of well and poorly grown calves, by rotationally grazing on good quality dairy farm pastures or set-stocking on poor pastures respectively, have been published by McMeekan (1948). Too great weight must not yet be placed on these results, but the indication is that the well reared animals which have averaged 140 lb. heavier at eighteen months of age than their (identical twin) set-stocked mates, give about 50 lb. butterfat more in their first lactations. The body-weight differences tend to persist at least as far as four years of age.

In addition to this question of efficiency, the effects of level of feeding of the dairy calf on her later disease susceptibility and breeding ability, both age at first calving and lifetime fertility, are in great need of investigation.

The other points mentioned above as influencing the plan of calf feeding - the extent to which deficiencies in home grown food supply are made good by purchased foods - can dictate that whilst food is abundant growth should be as rapid as possible, with storage of fat, in order to assist in tiding over a lean period. This does apply to New Zealand conditions for often coinciding with weaning of the calves, grass supply in most years may be much reduced in both quantity and quality through the impact of a summer drought. Thus the calves are liable to a double check and this is reflected in their growth curves at this time. Well grown

calves are then more likely to be able to withstand such conditions.

Following a severe summer drought, heavy losses of yearlings have been experienced in the North Island through placing them on the subsequent lush pasture growth. The animals fast lose condition and then scour to death. It is uncertain whether well-grown heifers per se are more resistant to this, or whether the better management usually associated with better feeding will reduce the losses. McMeekan (1948) emphasizes the necessity for feeding hay during the drought so as to accustom the animals to eating it, as they must be made to do when the rains come, and until the growth is more mature. This suggests that a cause of the upset is a rumen micro-organism population inappropriate to succulent grass. This population varies considerably in its characteristic types according to the nature of the diet (Pounden and Hibbs 1948; Gall, Burroughs, Gerlaugh and Edgington 1949). A possible prophylactic measure is the inoculation of the rumen of the young animals by feeding cuds taken from cows on the grass, with the intention of establishing more quickly a suitable microflora. Pounden and Hibbs (1949) have found this technique very effective under other mal-conditions in calf rearing, and it is a treatment that deserves trials in these conditions.

From this whole discussion on level of feeding, though long term policy is not clear-cut, certain recommendations on the feeding before weaning can be made. For reasons stated the calves at weaning should be of good size; in order to obtain this it is vitally important that they should have a good start right from birth. If they then grow well, and if, when the change-over to skim-milk or buttermilk from whole-milk occurs, the grass available is of good quality and quantity, subsequent feeding need not be at the higher level of 15% of body weight, but preferably

should not be below a 12% body weight level. This economy is more for farms such as those supplying cheese factories or town milk where skim-milk is not available in quantity, where calves are to be weaned at twenty weeks and where costs in buying a substitute such as buttermilk powder are to be kept down. If skim-milk is plentiful, as on farms supplying cream to the butter factories, there is little reason for stinting the calves. In this experiment, Jersey calves on the 15% level received about sixty gallons of whole-milk substitute more than those on the 10% level (see page 33). A figure of this order is probably a fair estimate of the difference between two such feeding plans. The alternative of feeding this quantity of skim-milk to pigs instead of calves would result in a cash return in practice of about five shillings (i. e. allowing one penny a gallon). On a sixty cow dairy farm rearing replacements the better feeding of the calves would cost only an additional five pounds per year in all.

If for any reason initial growth of the calves is poor, every effort should be made by subsequent feeding to overcome this. A 15% level should certainly be fed, perhaps even supplemented with meal. The same applies where the grass given is poor in quality.

SUGGESTED PLANS FOR CALF REARING.

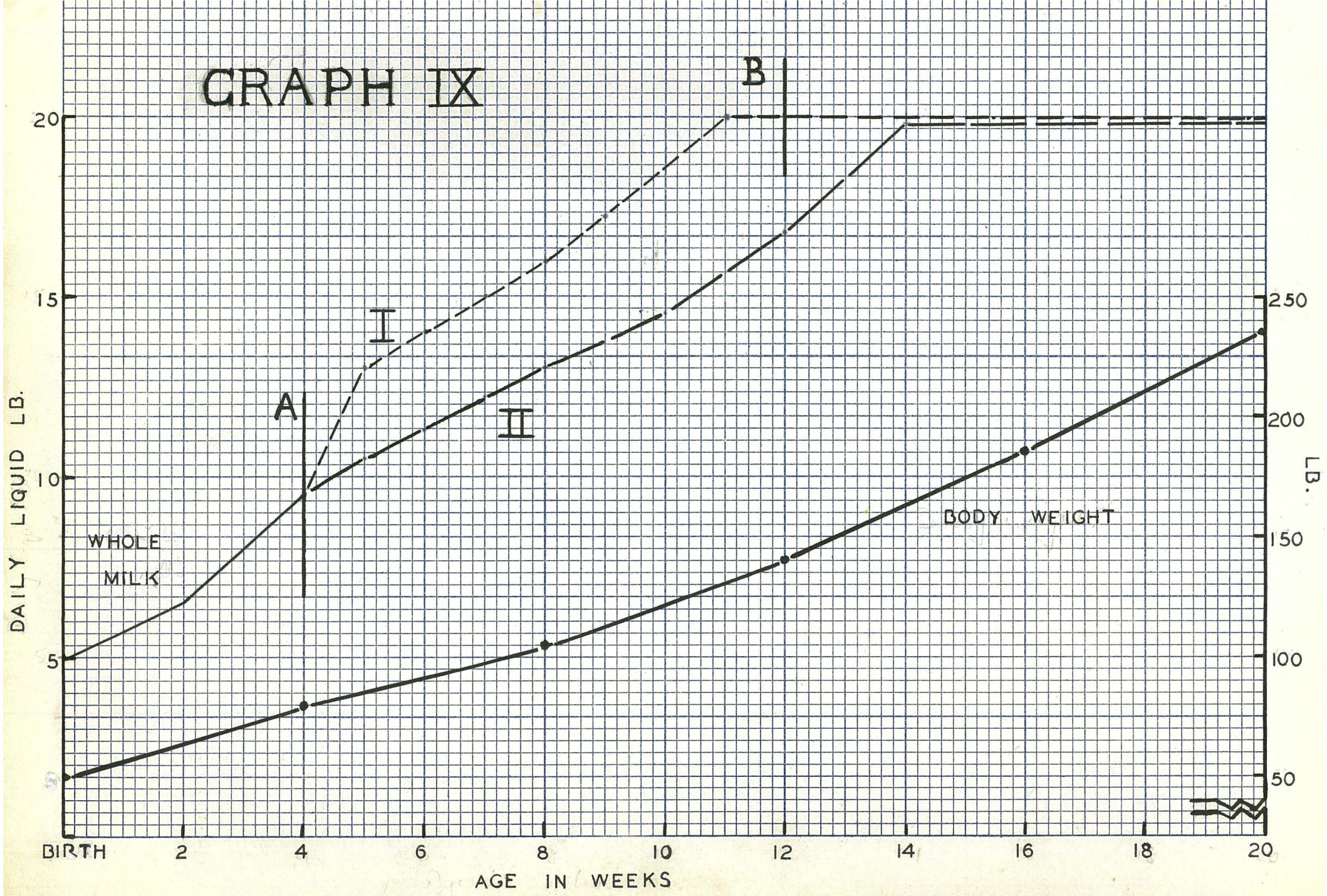
From the conclusions in the previous section, recommendations can be made on suitable plans for calf rearing under New Zealand conditions. However, one further point requires clarification - the age at which to wean the calves. Commonly this is not done until they are around four to five months old, but a few farmers are weaning them two months or more earlier. Providing that their food is of good quality pasture, if necessary supplemented with hay and

perhaps silage, and is not a poor set-stocked paddock, there is no powerful argument against such a procedure. Mention may be made of the fact that in England twelve weeks is the usual age for weaning heifer calves, and half of the liquid fed to them will often have been a gruel. Comparisons between the two countries are of limited significance because of the very different farming conditions, and it must be admitted that New Zealand animals, are calved at a younger age. This could be put forward as a point in favour of longer milk-feeding, but Edwards (1949) has found that the average age at first calving of Jerseys in England is two years five months, that is a few months older than with Jerseys in New Zealand. Good quality pasturage with supplements before and after weaning compares very favourably with the English system of rearing: 3-5 lb. of concentrates per day (protein equivalent about 20) and a similar quantity of good hay for the period three to six months of age, followed by eighteen months of "store" feeding on hay, silage, oat straw, marrow-stem kale or other roots, and about 2 lb. of concentrates per day.

There are two strong arguments for weaning at twelve weeks, one general and one particular. The former is that the earlier weaning lightens the task of calf rearing very considerably, releasing labour for other jobs, and the latter that on cheese factory and town-milk supplying farms less of a saleable product, or of a bought-in substitute, is fed. There is also the consideration that calves weaned at twelve weeks would have good grass to cushion this check, whereas at twenty weeks - near Christmas - pasture would be poorer because of the onset of the summer drought.

In Graph IX, feeding according to weight has been translated into practical terms of feeding Jersey calves according to age. This is possible from knowledge of the

GRAPH IX



average weight of well-grown Jersey calves at various ages. The figures used are the averages of many years data collected by the Dairy Research Institute.

Because of its laxative, immunological and highly nutritious properties all calves must receive colostrum for the first few days of life. Whole milk is fed first at 10% and then (at two weeks of age) at 12% of body weight, or in practice 5 lb. per day of whole milk to 9 lb. per day at four weeks old. At this age - "A" on graph - a change-over is made to whole milk substitute, being completed by six weeks of age. This substitute may be either skim-milk or dried buttermilk reconstituted at the rate of 1 lb. to 9 lb. of water.

The change-over may be made at this stage even if the calves are to be weaned at twelve weeks, for the substitute as compared with whole milk is short only in energy - half of the milk energy having been removed in the butterfat - the other valuable milk constituents remaining, with the exception of the fat soluble vitamins. These will be obtained in sufficient quantity whilst on grass as should the energy.

At four weeks, three feeding plans are possible.

(1) On farms selling whole milk, the substitute (here dried buttermilk could be used) should be fed at 15% of body weight, curve 1 in the graph, and in conjunction with rotational grazing on good quality dairy farm pastures. For all systems a maximum of two gallons (20 lb.) per day is suggested. This level is reached at eleven weeks. Calves are then weaned at twelve weeks of age, "B" on the graph. (Weaning is pictured graphically as a sudden cessation of feeding; in practice feed will be progressively reduced over a period of a few days). If the growth is not satisfactory, the plan will have to be modified probably by weaning a little later.

Following curve I until weaning at "B" would result in the feeding of 85 gallons of substitute. With dried buttermilk at 6d per lb. of powder, total cost would be £2.2.6.

(2) On farms such as those supplying cream to a factory, where skim-milk is in good supply, if it is preferred to wean calves at twenty weeks rather than the labour-saving age of twelve weeks, curve II could be followed. This is plotted on the basis of feeding the substitute at 12% of body weight. Two conditions apply, firstly that preliminary growth to four weeks has been good, and secondly that the calves are rotationally grazed.

Whole milk selling farms that prefer to wean at twenty weeks could also follow this curve, providing the two conditions above are met. This plan would entail feeding 180 gallons of substitute, costing £4.10.0. for dried buttermilk. This brings out the economy of weaning at twelve weeks.

Because of the present price of dried buttermilk powder it cannot be recommended that this should be fed in quantity. A suitable meal, costing about 2½d per lb. should replace some of the buttermilk from eight weeks or earlier, onwards, at the rate of 1¼lb. for a gallon. This would reduce the total cost figure given above considerably, and would also reduce the cost when weaning at twelve weeks, maintaining the greater economy of this plan.

(3) As has been pointed out previously, the extra cost of feeding calves skim milk to twenty weeks on a 15% level instead of a 10% level would be about five shillings. Feeding according to curve I through to twenty weeks (15%) instead of curve II (12%) would result in an even smaller cost increase, 210 gallons as against 180 gallons, the thirty gallons difference of skim milk being worth about 2/6d.

Wherever calves are growing slowly, the grass is poor, or the calves are set-stocked in a "calf-paddock"

feeding should definitely be according to curve I, carrying on to weaning at twenty weeks. In addition meal may be fed with advantage, beginning at four weeks and increasing in amount up to 2 lb. per head per day.

Finally it must be pointed out that the skill of the calf feeder is the basic condition for the success of any system of calf rearing.

GRASS IN THE DIET OF THE DAIRY CALF.

Throughout the previous sections, emphasis has been laid on the necessity for including good grass, rotationally grazed, in the feeding programme. Because the growth of the calves in terms of weight and their consumption of liquid feed are known with a fair degree of accuracy, some estimate can be obtained of the extent and importance of the contribution of grass to the diet.

The nutritive value of the feeds:

In Table XV are figures from the analyses of the feeds; the digestibility figures are from Schneider (1947) in the case of the buttermilk powder, and from Barnicoat (1945) in the case of the skim milk.

TABLE XV

Composition and digestibility of the feeds.

Constituent	Buttermilk powder		Skim milk	
	%	Digestibility %	%	Digestibility %
Total protein	31.13	90	3.94	91
Fat	8.73	98	0.10	95
Lactose	40.20	94	5.30	94

From these figures has been calculated (Table XVI) the value of both feeds in total digestible nutrients (T.D.N.)

Their starch equivalents (S. E.) have been calculated by taking the starch equivalents of protein, fat and lactose as 0.95, 2.41 and 1.0 respectively; and their caloric value assuming protein has a value of 2585 Calories per lb., fat 4264 Calories per lb., and lactose 1814 Calories per lb. (Brody 1945).

TABLE XVI.

The nutritive value of the feeds.

Feed	T. D. N.	S. E.	Calories per lb.
Skim milk	8.78%	8.62	187.2
Buttermilk powder	85.07%	85.04	1774.8
Buttermilk powder as fed (diluted)	8.51%	8.50	177.5

Feeding standards for young cattle:

In the following sections discussion is confined to a consideration of energy relationships which embraces the question of protein consumption. Because of the high protein diet - grass nutritive ratio 1:3, and milk by-product nutritive ratio 1:2 - protein as such would not be a limiting factor in the nutrition of calves reared as in this experiment. Grain mixtures recommended for feeding to calves to supplement their milk ration usually have a nutritive ratio at the narrowest 1:4, more often 1:5.

This is considered a valid assumption even though Swett, Eckles and Ragsdale (1924) showed that Jerseys especially responded to higher protein levels in the diet by increased growth rate. However their highest protein level when 18.4% of the total net energy for maintenance plus growth was furnished by the protein in the ration, is within the protein limits of the diet here.

Many total digestible nutrient standards have been proposed for growth and maintenance. Table XVII lists several and also the pounds T.D.N. actually received daily at corresponding weights by the various treatment groups

TABLE XVII

T.D.N. standards for maintenance plus growth lb. per day, various authorities, and quantities fed in the liquid diets at corresponding body weights.

Body Weight lb.	Wolff Lehman	Kellner	Armsby	Eckles and Gull-ickson									T.D.N. lb.fed to			
					Morrison		Ragsdale		Brody		Shepherd and Converse		Jerseys		Fries-ians.	
					Minimum	Maximum	Jersseys	Holsteins	Jerseys	Holsteins	Jerseys	Holsteins	10%	15%	10%	15%
100			2.70	2.32	1.20	2.0	1.72	1.20	1.53	1.12	2.36	1.64	0.86	1.30		
150	1.43	3.18	2.98	3.36	2.30	3.0	2.62	2.27	1.81	2.33	3.60	3.08	1.30	1.73	1.30	1.95
200	2.76		3.25	4.23	3.30	4.0	3.71	3.28	3.04	2.74	4.54	4.12	1.73	1.73	1.73	2.60
250	4.09		3.48	4.96	4.10	4.80	4.48	4.34	3.85	3.60	5.37	5.02	1.73	1.73	2.16	2.60
300	5.42	5.51	3.70	5.55	4.90	5.50	4.93	5.28	4.63	4.58	5.74	5.84			2.60	2.60
350	6.01		4.75	6.03	5.50	6.10	5.32	5.93	4.86	5.55	6.17	6.51			2.60	2.60

ignoring type of feed, for which an average value 8.65% T.D.N. is used.

The Wolff Lehmann standards (1903) are probably the earliest. Kellner (1926) gave figures in terms of starch equivalent and also as digestible crude protein, fat, nitrogen free extract and crude fibre from which it is possible (d. c. p. + (d. f. x 2.25) + dig. N.F.E. and C.F.) to recalculate his figures as T.D.N.

Armsby (1917) gave the net energy requirements at various weights. These figures are not immediately convertible to T.D.N. but Eckles and Gullickson (1931), from whom these figures are taken, calculated typical rations according to Armsby's net energy system, and then evaluated them in terms of T.D.N.

Ragsdale (1934) obtained figures from an experiment on the feed consumption of dairy cattle during growth. Those given in the table have been derived by interpolation, as have those from Brody (1945).

Morrison (1936) gives minimum and maximum figures, the former apparently for use as feed price rises. He states "the standards provide enough nutrients for normal growth. Young cattle consuming suitable rations that contain the amounts of nutrients shown in the standards should reach good size for their breed". Similar standards are given by Fitch and Lush (1931).

Eckles and Gullickson (1931) calculated their table after feeding growing Holstein and Jersey dairy heifers at 85%, 100% and 115% of an older Morrison standard, and comparing the growth of the groups with their "normal" growth figures; also in a second trial by feeding so that animals grew as nearly as possible at their normal rate.

Shepherd and Converse (1939) derived their figures from the original data of Eckles and Gullickson (loc. cit.)

TABLE XVIII

S.E. standards for growth plus maintenance lb. per day, various authorities, and quantities fed in the liquid diets at corresponding body weights.

Body weight lb.	Kellner	Armsby	McCandlish	Morrison		Steensburg		S.E. lb. fed to			
								Jerseys		Friesians	
								Minimum	Maximum	Jerseys	Friesians
100		2.89	1.92	1.12	1.87	2.77	3.47	0.86	1.28		
150	2.78	3.27	2.80	2.15	2.71	3.33	3.93	1.28	1.71	1.28	1.92
200	3.38	3.51	3.68	2.99	3.55	3.63	4.32	1.71	1.71	1.71	2.57
250	3.98	3.73	4.26	3.64	4.20	3.96	4.66	1.71	1.71	2.14	2.57
300	4.56	3.98	4.83	4.11	4.76	4.26	4.97			2.57	2.57
350	4.89	4.24		4.62	5.14	4.53	5.22			2.57	2.57

whose figures for maintenance requirements they retained, but recalculated the requirements per pound of live weight gain by regression formulae for Holsteins and Jerseys separately, total requirements for maintenance and growth being based on later "normal growth" figures by Ragsdale and by Fohrman and Swett. The T.D.N. requirements per pound gain are greater for Jerseys than for Holsteins, but because the latter make larger average daily gains the total requirements for maintenance and growth are approximately the same for both breeds at the same live weight.

Table XVIII is similar to the one preceding; requirements are given in terms of lb. starch equivalent (S.E.), whilst that actually fed to the various breeds and levels is calculated from a mean S.E. value of the feed of 8.56. Kellner's (1926) figures are taken from his book, two intermediate values being derived by interpolation; similarly figures given by McCandlish (1939). The Net Energy values given by Armsby (1917) have been multiplied by $\frac{1}{1.071}$ to convert them to S.E. as have values given by Morrison (1936).

Steensburg (1947) presents a new method for calculating the feed requirements of young cattle. In addition to a maintenance ration varying with weight, is given a production ration calculated in relation to the expected mature weight of the animal. Thus any animal which is small for its age is not penalized if feed according to weight, for otherwise it will be given too little and remain small. In the experiments reported, with animals fed "normally" so as to keep them in average condition and growing well, by subtracting maintenance food requirements (calculated from the liveweight by a formula of the type kW^n) from the total S.E. consumed per day, the remainder bore a general relationship to the mature weights of the animals of the order of 0.15 - 0.20%.

TABLE XIX

Calorie requirements for resting and fasting metabolism (Brody 1945) and Calories fed in the liquid diets at corresponding body weights.

Body weight lb.	<u>Holstein-Friesians.</u> Calories per 24 hours.				<u>Jerseys.</u> Calories per 24 hours.			
	Resting metabolism	Fasting metabolism	Supplied to 10% level calves	Supplied to 15% level calves	Resting metabolism	Fasting metabolism	Supplied to 10% level calves	Supplied to 15% level calves
110	2190	1671	2006	3010	2420	1798	2006	3010
165	3050	2327	3010	4514	3260	2422	3010	3648
221	3800	2899	4012	5472	3900	2898	3648	3648
275	4435	3384	5016	5472	4460	3314	3648	3648
331	4995	3811	5472	5472	4905	3644		
386	5495	4193	5472	5472	5285	3927		

In this experiment the Jerseys reared are expected to have a mature weight of about 900 lb., so the "production" ration for calves of this breed is $900 \times \frac{0.175}{100} = 1.58$ lb. S.E. per day, which, remaining constant, is added to the appropriate maintenance requirement (given by Steensburg) for the calf's weight.

e. g. maintenance for 100 lb. calf	=	1.19 lb. S.E.
plus Jersey production requirement	=	1.58 lb. S.E.
Total	=	2.77 lb. S.E. per day.

Mature weight of the Friesians was taken as 1300 lb. Production requirement = $1300 \times \frac{0.175}{100} = 2.28$ lb. S.E. per day. At 100 lb. liveweight, total requirement is 3.47 lb. S.E. per day.

In Table XIX the caloric requirements for resting and fasting metabolism (Brody, 1945 p. 467) are compared with the caloric values of rations fed, taking an average gross digestible energy value of the feeds as 182.4 Calories per lb. (as fed). Resting metabolism refers to the condition when the metabolism is not post-absorptive, that is in effect the resting energy maintenance cost per twenty-four hours; the term fasting metabolism is used rather than basal metabolism owing to the changing nature of the factors making up the heat production complex in rapidly growing animals (Brody 1945).

The contribution of grass to the diet:

If applied, all the feeding standards given would probably be found sufficient to raise satisfactory calves. The problem is to decide which most properly represent conditions in this experiment.

The agreement between the various T.D.N. standards is not marked. The earlier ones (Wolff Lehman, Kellner, Armsby) may be discarded as being based on insufficient data. Eckles and Gullickson (1931) showed that by comparison with

their figures derived from experiments, those of Morrison, induced from a variety of figures, were rather too low for young animals, and overfed them when their weight was over 500 lb. Also by comparison, then, Brody's and Ragsdale's standards will be too little. Their figures are based on virtually the same data of weight-age, which on examination do appear rather low when compared with the growth rates of Jersey and Friesian calves reared under good management in this country. Allowing for this, and for the criticisms of Eckles and Gullickson, the standards given by Shepherd and Converse although appearing rather high are probably the fairest to apply here.

Steensberg's S. E. standards are similar to those of Kellner and McCandlish (derived from Kellner), but do allow more for the younger calf; this is due to the "production" ration which is more than 50% of the total initially, the proportion decreasing as the animal grows when growth increments become progressively less with smaller demands on nutrient intake. At later ages the use of his figures, as he suggested, to insure that animals small for their age were not underfed is hardly necessary, since feeding according to weight (where food is rationed) of young stock is not rigid even if it is practised. In this experiment where feeding by weight was adhered to, the bad effects did appear even though grass intake allowed a chance of compensation for this.

As standards to be followed those of Steensberg and Shepherd and Converse both have the advantage of allowing for a good start that previously in the discussion has been shown to be of such importance. Their use would be more as a guide since at the earlier ages only milk intake is usually controlled, other foods being given ad libitum. They show the need for these other foods to be of good quality whether grain mixtures, or particularly that grass must be the best available and plentiful.

The weight ranges 100 - 220 lb. in Jerseys and 150 - 320 lb. in Friesians, as in the tables, both represent an age range of approximately eight to twenty weeks.

Comparing the intake of the 10% calves with either of these two standards above, it is seen that the liquid supplied little more than one third of requirements in the case of Jerseys, and from one third to one half to the Friesians. On the 15% ration the proportions were one half or somewhat less, and mostly greater than one half respectively. Even allowing that the standards are on the generous side, the role of grass in the nutrition of the calves was considerable. Calves apparently are very selective grazers, nibbling at the leafier parts of the plants; also considering the quality of the grass that was available, a fair estimate of the grass eaten would be 14. Then the deficiency of $1\frac{1}{2}$ - $2\frac{1}{2}$ lb. S.E. in the rations fed (Table XVIII) at various times to the different breeds and levels, is the equivalent of 11 - 18 lb. grass containing 2.2 - 3.6 lb. dry matter. 14 SE

Table XIX with its figures of caloric requirement and consumption in the ration gives a clearer picture than the feeding standards; uncertainty however lies in how different the net energy of the food given to the young vigorously growing animal is from the gross digestible energy figures given in the table, but no satisfactory answer can be given.

In the case of the Friesians, the lesser diet for several weeks followed very closely the resting metabolism requirements, but from the fourteenth to sixteenth weeks (230 - 260 lb.) came to exceed these by some 500 Calories. Until this time, then, grass would be supplying energy equivalent to all that required for standing above lying, for any movement, and for their actual stored weight gains. Brody (1945) p.910) has shown that in cattle the energy cost of standing above lying is about a 9% increase which here

would mean about 300 Calories per day whilst the net energy cost of walking (including the energy cost of standing) is circa 33 Calories per 100 lb. live weight per mile. These figures are again difficult to apply to calves, but with the fairly long periods of rest taken by calves (see later section on grazing behaviour) and the low energy cost of walking these two factors would not constitute a large demand, perhaps not more than 250 Calories per day in the earlier stages.

Yates, Boyd and Petit (1942) have estimated 1 lb. of liveweight gain to be equivalent to 10 lb. of 4% fat corrected milk = 3400 Calories, which agrees closely with Bonnier (1946) who gave a figure of 3630 Calories but these average figures derived from animals of all ages cannot justifiably be used here. In rapid growth, as in young animals, much of the gain will be protein, and because 1 g. protein is associated with 3 g. water in tissue, whereas its calorific equivalent $\frac{1}{2}$ g. fat, which would constitute more of the gain of older animals, is not, it follows that the energy cost of the calves' gain is much less and a lower figure must be used. Brody (1945) gives the much lower but still arbitrary figure of 909 calories per lb., and Armsby (1917) that of 1170 calories per lb. during the first month of life, later gradually increasing. To take these figures, which are a third of those given above, is compatible with the practical observation that in rearing veal calves three to four pounds of whole milk should produce one pound weight gain.

These figures are net energy requirement; the associated heat increment of feeding, and the energy costs of organizing the weight gain, are included in the resting metabolism figures. So again taking 14 as the S.E. of the grass eaten, the net energy value would be 750 Calories per lb. dry matter or five pounds actual grass (1 lb. S.E. = 1071 Calories); 7 lb. grass would then be required for 1 lb.

stored weight gain (i. e. circa 1000 Calories). The 10% Friesians under discussion actually gained $1\frac{1}{2}$ - 2 lb. in live weight per day, and including walking and standing requirements as above, they would have to be ingesting about 12 lb. grass from eight weeks of age.

In similar fashion it is calculated that the 15% Friesians, whose food in the main supplied energy above resting metabolism for 1 lb. weight gain, would be ingesting 9 lb. grass; the 10% Jerseys whose food to twenty weeks (190 lb.) barely supplied resting metabolism needs, and whose daily weight gain was about $1\frac{1}{4}$ lb., would be ingesting 10 lb. grass; the 15% Jerseys whose food up to eighteen weeks (185 lb.) was adequate for resting metabolism plus standing and walking energy costs, and earlier for a small portion of the growth - slightly under $1\frac{1}{2}$ lb. weight gain per day - would also be eating about 10 lb. grass.

These estimates of grass intake from the more theoretical approach of calorific relationships are on the whole consistent with those previously derived from calculations based on feeding standards. The figure of ten pounds of grass would mean that together with the liquid fed, calves of eight weeks or older would be ingesting three pounds of dry matter.

From evidence on hay and grain intake of calves in other experiments, it seems that these dry matter figures are not unreasonably large. Ragsdale (1934) presented data showing that in addition to milk, Holstein calves two to three months old were eating two pounds of hay or grain mixture, and Jerseys one and a half pounds. As already mentioned Ragsdale's weight figures, and thence perhaps food intake figures, are low in comparison with New Zealand standards; further, grass being more succulent and palatable than grain mixtures or hay would conceivably lead to a greater dry matter consumption, though as Huffman (1939) pointed out, palatability

is but one factor responsible for the extent of this. Stomach size is a contributory factor (Proctor and Wright, 1927), especially since in the young calf the rumen is developing. For this, grass would provide the necessary fibre and also be a direct source of rumen micro-organisms, partly from faecal contamination and also through slobbers from the cud-chewing of older animals (Pounden and Hibbs 1948).

Observations on grazing behaviour:

No figures for the actual intake of grass by calves on pasture have been reported, nor have any grazing behaviour studies been made on them as has been done with older cattle (Hancock 1948; Johnston-Wallace and Kennedy 1944).

Because such observations throw light on a number of animal husbandry problems, as well as on pasture management, a single twenty-four hour watch (morning feeding to morning feeding) was kept on seven pairs of identical twin calves belonging to the Dairy Research Institute, the ages ranging from nine to sixteen weeks.

Although it cannot be expected that the details of behaviour on one day (here in October) are widely applicable, being influenced by many complex factors such as weather and type of pasture, yet the general pattern revealed has been borne out by casual observations on these and other groups of calves.

The method employed was to keep the animals continually under observation and to record every five minutes the principal activity during that time of each individual, whether grazing (with some note of the intensity), loafing, lying down or chewing the cud. Details of urination or defaecation, or distance walked were not noted. Figure I shows the method of recording the data. A night with a full moon was chosen, but since it was at times obscured by cloud, a torch was also used. For some of the night it was found that there was little activity and the calves were observed

FIGURE 1. Method recording observations on calf grazing behaviour.

Time	Calf number			Explanation (Principal activity during preceding five minutes).
	1	2	--- up to 14	
1355				Calf no.1 Grazing
1400	→			Calf no.1 Grazing. Lies down
1405				Calf no.1 No activity
1410	X	→		Calf no.1 Cudding
1415	X			Calf no.1 Cudding. Gets up
1420		X		Calf no.2 Grazing
1425		X		Calf no.2 Grazing
1430	→	←		Calf no.1 Grazing. Lies down
1435	X			Calf no.1 Cudding
1440	X			Calf no.1 Cudding
				Calf no.2 Grazing

Across the observations are written comments on grazing intensity, drinking, weather etc.

at intervals ranging to half an hour. The calves did not appear to be disturbed by the presence of the observer.

During the period of observation there were $3\frac{1}{2}$ hours of bright sunshine; maximum and minimum temperatures were 61°F and 45°F respectively, temperature at 9.30 a.m. being 60.5°F . Rainfall was half an inch, but this was disposed in a few heavy showers of up to $\frac{1}{4}$ hour duration. (Meteorological data from observations at the D.S. and I.R. Station, Palmerston North).

The calves were grazed on good quality rye-grass pasture. The behaviour pattern to be described follows very closely that of older cattle in its main features. As noted by Southcombe (1947) with cows, it is cyclic and the animals tend to act as a unit. Calves are more selective grazers than cows; grazing is fairly intense after being turned out from feeding, sixty bites per minute more or less, but the calves attain this rate by taking a few bites in quick succession, searching around, and then taking a few more followed by a further pause and so on. Because of this selectivity it was at times difficult to determine whether the calves were actually eating or merely muzzling the grass. Field-glasses were of assistance in this connection. It was noted that a considerable amount of grazing was done along the fenceline. This was presumably because of a greater palatability of the grass there which was shorter and rather more varied in species composition. Probably it receives little animal manure, and the factors causing the relative unpalatability of strong growing manured grass ("clumps" in pasture) would not apply. Simple cleanliness of the herbage because of little treading might also be a reason.

The sequence of behaviour was broadly as follows.

<u>Time</u>	<u>Activity</u>
0800 hours	Turned into paddock after morning Feeding. Intensive grazing for 50 minutes, slackening off during the following $\frac{1}{2}$ hour (from 60 + bites per minute down to 25+). Loafing. Drinking.
0955 - 0945	Animals lying down and then no activity for 70 minutes except three twin-pairs cudding (ages 10 and 16 weeks for 10 minutes, and 13 weeks cudding for 20 minutes.
1050	Short heavy shower. All animals go up and "drifted" before the rain.
1100	Rain stopped. $\frac{1}{4}$ hour grazing, moderate intensity, then $\frac{1}{2}$ hour grazing and loafing.
1145	Loafing.
1245 - 1345	Mainly loafing with intermittent grazing of low intensity.
1400 - 1420	Animals standing. Several cudding.
1420 - 1600	All lying down and cudding for total of about 50 minutes each, but in two or three spaced periods.
1605	Afternoon feeding.
1700	Turned into paddock. Intensive grazing for $\frac{1}{2}$ hour then slackening off over a further 40 minutes. Loafing. Drinking.
1830	Dusk. All loafing for $1\frac{1}{2}$ hours; few cudding and short period of grazing included.
2000 - 0030	With few exceptions, lying down throughout this time. Older animals cudding for short periods. Sleeping.

<u>Time</u>	<u>Activity</u>
0030 hours	Grazing with fair intensity for 20 - 40 minutes, except two twin-pairs, ages 9 and 10 weeks.
0120	All lying down and cudding for periods totalling 30 - 40 minutes each. No other activity. Sleeping.
0500 - 0520	Dawn. All animals lying down.
0530 - 0540	All animals up and grazing intensively. Rate slackening off after $\frac{1}{2}$ hour until ---
0630	Morning feeding.
Total grazing time (i)	Intense and moderately intense - $4\frac{1}{2}$ hours approximately.
	(ii) Light grazing with loafing - $2\frac{1}{2}$ hours approximately.
Total cudding time:	2 - $2\frac{1}{2}$ hours.

These figures apply to all the calves, of which one pair was nine weeks old, four pairs ten weeks old, one pair thirteen and one pair sixteen weeks old. It is shown that grass really is an important part of a calf's diet and that an intake of 10 lb. per day at eight weeks is quite possible as previously suggested. Like cows, the calves eat steadily for some time after being put into a paddock; the second grazing period in the daytime - at about midday - is a regular one, though it was probably disturbed a little in this watch by the rain. The grazing at midnight corresponds to the behaviour of cows; Hancock (1948) shows that this time with the period after milking are the two regular periods of grazing during the night. The calves also grazed before their morning feed. This is undoubtedly because it was daylight, calves are always lying down when called for feeding before daybreak.

The extent to which these young animals were cuddling is of considerable interest. At what age they first do so when on grass is not exactly known; it will be shortly after calves are eating grass in fair quantities, and three week-old animals will do this. Calves will nibble grass even in their first week of life.

In addition to the factors of weather and type of pasture which can influence behaviour, the genotype of the animal is also involved. There was great similarity within twin-pairs in the various activities, and the record of one twin was quite closely matched by the other in details as well as in the broad pattern.

In conclusion, a study such as this is preliminary in nature, for it cannot provide quantitative data in a critical form. Measurements of the actual intake of grass are required and the effect upon this of various management factors such as amount of liquid fed per day, or whether earlier weaning results in much larger intake than with milk-fed calves of a similar age requires investigation.

SUMMARY AND CONCLUSIONS.

(1) The production of dried buttermilk in New Zealand is undergoing considerable expansion. The object of this experiment was to compare the value for calf rearing of this substance with skim milk, each being fed at two levels and in conjunction with good quality pasture ad libitum.

(2) After being fed on whole milk for the first four weeks of life, pedigree female Jersey and Friesian calves were allocated at random to four different treatments - skim milk (from a Jersey herd) at either 10% or 15% of body weight, or dried buttermilk powder, reconstituted at the rate of 1 lb. to 9 lb. of water, also at these two different levels. The changeover to these rations from whole milk was completed by six weeks of age. Jersey calves were allowed a maximum of 20 lb. per day, and Friesian calves a maximum of 30 lb. per day. The experimental period ended at twenty weeks of age.

(3) Calves were fed twice daily at regular times. Grazing was on a rotational basis on the dairy farm pastures.

(4) Data recorded were weights of calves at weekly intervals, height at withers at fortnightly intervals, and also details of any disease.

(5) It was observed that young calves tended to make poor weight gains during cold and wet weeks, and concluded that housing them during the first week of life in such conditions is advisable.

(6) The instantaneous percentage growth rates per week over the period four to twenty weeks for these samples of Jersey and Friesian calves were virtually identical.

(7) There was no significant difference in weight or height between the calves reared on either skim milk or buttermilk over both levels. This is in accord with trials reported in the literature. The buttermilk fed calves as a group had a superior coat gloss and also showed less tendency to be "loose" in their faeces. This also agrees with observations in other trials. It is suggested that these

effects are a result of the higher proportion of fat in the buttermilk.

(8) From a review of the literature it appeared that grass intake might compensate for a lower level of milk feeding. In this experiment, calves fed at the level of 15% of body weight made significantly greater growth in weight and height to twenty weeks than those fed at the 10% level. This difference was found to be partly a consequence of differential growth during the first two months of life, and it was concluded that in order to rear calves well grown at weaning, feeding should be such as to promote good growth in the early stages.

(9) Though there is no conclusive evidence from the literature that rearing calves on an ample rather than a sufficient plane of nutrition (but without tending to either extreme) results in long term advantages, it was concluded that of the two levels of feeding in the experiment, the greater was to be preferred in order that the calves might be better able to withstand the check from the poorer feed supply in the summer period following weaning.

(10) Recommendations are made for calf rearing plans to be followed under various conditions. Calves should be given colostrum and then whole milk (10-12% of body weight) during the first four weeks of life, and then changed over to a substitute by six weeks of age. In order to save labour and, particularly in the case of whole milk selling farms, expense in the rearing of calves, weaning at twelve weeks of age is advocated. This presumes good grass is rotationally grazed by the calves. Feeding should be at the level of 15% of body weight. Where it is preferred that calves should be weaned at twenty weeks, a lower feeding level may be used but should not be below 12% of body weight; if quantities of skim milk are available, the 15% level should be fed, and in all cases when the early growth of the calves is poor or the grass available is of poor quality. In the latter case, meal

should be fed in addition.

(11) Because of the present cost of buttermilk powder, where it is used as a substitute on whole milk-selling farms, a suitable meal should partially replace it in the calves' diet.

(12) From a comparison of feeding standards with the nutrients actually fed in the liquid diet, it is estimated that the calves in the experiment must have been eating approximately 10 lb. of grass daily from eight weeks of age in order to meet their requirements.

(13) A study of the grazing behaviour of calves confirms the importance of the grass supplement in their nutrition.

(14) The behaviour pattern is cyclic in nature and is similar to that exhibited by cows. Calves, however, are more selective grazers. Total grazing time was seven hours (varying intensity) and total cudding time two to two and a half hours. Studies on the actual intake of grass by calves are needed.

ACKNOWLEDGEMENTS.

My thanks are due to Mr. J. MacGregor, manager of the Dairy Research Institute farm for continued helpful co-operation, also to members of the College Dairy Farm staff. Also to Mr. P. Armstrong, Biometrics Section, D.S. and I.R. for advice on certain of the statistical work; to the D.R.I. Chemistry laboratory for analyses of the skim-milk and buttermilk, and to Miss S. McPike for the lettering of the graphs.

This work was carried out during the tenure of a post-graduate scholarship from the Ministry of Agriculture and Fisheries, England.

REFERENCES.

- ARCHIBALD, E. S. 1916. Quoted by McCandlish (1939)
- ASDELL, S. A. 1949. Nutrition and the treatment of sterility in dairy cattle. J. Dairy Sci. 32:60.
- AUGUR, V., ROLLMAN, H. S. and DEUEL, H. 1947. Effect of crude lecithin on the digestibility coefficient and rate of absorption of fat. J. Nutr. 33:177.
- ARMSBY, H. P. 1917. The Nutrition of Farm Animals. Publ. MacMillan, New York.
- BARNICOAT, C. R. 1945. Estimation of apparent digestibility coefficients by means of an inert "reference - substance". N. Z. J. Sci. and Tech. 27A:202.
- BIRD, E. W. 1939. Chem. Abstr. (1939) no. 5530.
- BONNIER, G., HANSSON, A. and DURING, T. 1946. The efficiency of the twin method (title transl.) J. Swedish Royal Academy Agric.
- BRODY, S. 1945. Bioenergetics and Growth. Reinhold Publ. Corp., New York.
- BRODY, S. and CUNNINGHAM, R. 1936. Further studies on the energetic efficiency of milk production and the influence of liveweight thereon. Mo. Agr. Expt. Station Res. Bull. 238.
- CAMPBELL, I. L. 1946. Report on the Dairy Research Institute (N. Z.) in 20th Annual Report Dept. Sci. and Ind. Res., N. Z.
- " 1948. Do calves fed on skim milk need meal? Massey Agric. College Dairy-farming Annual 1948 p. 85.
- CRONSHAW, H. B. 1947. Dairy Information. Publ. by Dairy Industries, London.
- DAVIS, H. P. and WILLETT, E. L. 1938. The relation between rate of growth and milk and fat production. J. Dairy Sci. 21:637.
- ECKLES, C. H. 1919. A study of the birth weight of dairy calves. J. Dairy Sci. 2:159.
- ECKLES, C. H. and GULLICKSON, T. W. 1924. Condensed and powdered buttermilk for dairy calves. J. Dairy Sci. 7:213.
- ECKLES, C. H. and GULLICKSON, T. W. 1931. The nutrients used for maintenance by growing dairy cattle; and, Nutrient requirements for normal growth of dairy cattle. J. Agr. Res. 42: 593 and 603.
- ECKLES, C. H. and ~~GULLICKSON, T. W.~~ and SWETT, W. W. 1928. Some factors influencing the rate of growth and the size of dairy heifers at maturity. Mo. Res. Bull. 31.
- EDMONDS, E. V. 1949. The treatment of enteritis (scours) and pneumonia in calves with sulphathalidine phthalylsulphathiazole and sulphamerazine. A clinical report. N. Amer. Vet. 30:301.

- EDWARDS, J. 1949. Report to the Milk Marketing Board on the Bureau of Records. Summary in Vet. Record 61:265.
- ELLINGTON, E. V. and KNOTT, J. C. 1926. A study of calf rations - Powdered buttermilk and semi-solid buttermilk. Wash. Agr. Expt. Sta. 36th Annual Report p. 18.
- FILMER, J. F. 1944. The animal in relation to food production Proc. 4th Annual Conf., N. Z. Soc. Animal Production.
- FITCH, J. B. and LUSH, R. H. 1931. An interpretation of the feeding standards for growing dairy cattle. J. Dairy Sci. 14:116.
- GAINES, W. L. 1939. Liveweight and milk energy yield in the Wisconsin dairy cow competition J. Dairy Sci. 22:49.
- GAINES, W. L., RHODES, C. S. and CASH, J. G. 1940. Age, liveweight and milk energy yields in Illinois cows. J. Dairy Sci. 23:1031.
- GALL, L. S., BURROUGHS, W., GERLAUGH, P. and EDGINGTON, B. H. 1949. Rumen bacteria in cattle and sheep on practical farm rations. J. Animal Sci. 8:441.
- GEYER, R. P., BOUTWELL, R. K., ELVEHJEM, C. A. and HART, E. B. 1945. The effect of fat on the utilization of galactose by the albino rat. J. Biol. Chem. 162:251.
- GROSSMAN, J. D. 1949. Form, development and topography of the stomach of the ox. J. Amer. Vet. Med. Assocn. 114:416.
- HAMMOND, J. 1944. Physiological factors affecting birth weight. Proc. Nut. Soc. 2:18.
- HANCOCK, J. 1948. Grazing habits of dairy cows. Massey Agric. Collegè Dairy-farming Annual p. 93.
- HANDLER, P. 1947. The biochemical defect underlying the nutritional failure of young rats on diets containing excessive quantities of lactose or galactose. J. Nutr. 33:221.
- HAZEL, L. N. 1946. The covariance analysis of multiple classification tables with unequal subclass numbers. Biometrics Bull. 2:21.
- HEINEMANN, B. 1939. The relation of phospholipids to fat in dairy products. J. Dairy Sci. 22:707.
- HENRY, K. M., KON, S. K., HILDITCH, T. P. and MEARA, M. L. 1945. Comparison of the growth promoting value for rats of butterfat, margarine fat and of vegetable oils. J. Dairy Research 14:45.
- HERMAN, H. A. 1936. Growth and development of dairy calves on a milk diet. Mo. Agr. Expt. Sta. Res. Bull. 245.
- HUFFMAN, C. F. 1939. Roughage quality and quantity in the dairy ration, a review J. Dairy Sci. 22:889.
- HUNZIKER, O. F. 1935. The butter Industry. Publ. by the

- author, LaGrange Illinois.
- HUNZIKER, O. F. 1946. Condensed Milk and Milk Powder. Publ. by the author.
- IDAHO AGRICULTURAL EXPERIMENT STATION 1928, 1929, 1931. Annual reports.
- JOHNSTON-WALLACE, D. B. and KENNEDY, K. 1944. Grazing Management practices and their relationship to the behaviour and grazing habits of cattle. J. Agr. Sci. 34:190.
- KAY, H. D. 1949. N. Z. Dairy Exporter, April p. 45.
- KELLNER, O. 1926. The Scientific Feeding of Animals.
- KNAPP, B., LAMBERT, W. V. and BLACK, W. L. 1940. Factors influencing the birth weight and length of gestation in cattle. J. Agr. Res. 61:277.
- LAGERLOF, N. 1929. Quoted by Savage, E. S. and McCay, C. M. (1942).
- LINDSAY, J. B. and ARCHIBALD, J. G. 1929. Milk substitutes in the growing of young calves. Mass. Agr. Expt. Sta. Bull. 247.
- MCCANDLISH, A. C. 1939. Skim milk powder for calves and a comparison of various supplemental feeds. W. Scotland Agric. College Research Bull. no. 7.
- MCDOWALL, F. H. 1946. The utilization of buttermilk in New Zealand. N. Z. J. Sci. and Tech. 28A:97.
- MCCAY, C. M. 1942. Chemical aspects and the effect of diet upon aging, in-Problems of Aging. Williams and Wilkins Publ. Co., Baltimore.
- McMEEKAN, C. P. 1948. Ruakura research shows how to rear well grown dairy heifers. N. Z. J. Agr. 77:138.
- MORRISON, F. B. 1936. Feeds and Feeding 20th Edn. Morrison Publ. Co., Wisconsin.
- MORRISON and RUPEL 1926. Rations for dairy calves. Wisconsin Agr. Expt. Sta. Bull 388 (Annual report).
- MONTHLY DIGEST OF STATISTICS. 1949. (July). His Majesty's Stationery Office, London.
- NATH, H., BARKI, H. V., ELVEHJEM, C. A. and HART, E. B. 1948. Further studies of the nutritive value of butterfat fractions. J. Dairy Sci. 31:793.
- NEW ZEALAND DAIRY BOARD 1948. 24th Annual Report.
- NIEFT, M. L. and DEUEL, H. J. 1947. The effect of fat on the absorption and utilization of galactose by the rat. J. Biol. Chem. 167:521.
- NUTRITION REVIEWS 1947. Dietary fat and food utilization 5: no. 5 p. 100.
- OTIS, D. H. 1904. Experiments with hand fed calves. Kansas Agr. Expt. Sta. Bull. 126 p. 163.

- POUNDEN, W. D. and HIBBS, J. W. 1948. The influence of the ration and rumen inoculation on the establishment of certain micro-organisms in the rumens of young calves. J. Dairy Sci. 31:1041.
- " " 1949. Rumen inoculations in young calves. J. Amer. Vet. Med. Assocn. 114:33.
- PROCTOR, F. and WRIGHT, N. C. 1927. Bulk in animals feeding. J. Agric. Sci. 17:392.
- RAGSDALE, A. C. 1934. Feed consumption of dairy cattle during growth. Mo. Agr. Expt. Sta. Bull. 338.
- RAGSDALE, A. C., ELTING, E. C. and BRODY, S. 1926. Growth and development with special reference to domestic animals. I Quantitative data. Mo. Agr. Expt. Sta. Res. Bull. 96 p. 8.
- ROGERS, L. A., JOHNSON, W. T. and ALBERY, H. G. 1926. U. S. Dept. Agric. Circ. 404.
- ROJAS, J., SCHWEIGERT, B. S. and RUPEL, I. W. 1948. The utilization of lactose by the dairy calf fed normal or modified milk diets. J. Dairy Sc. 31:81.
- RUPEL, I. W. 1929. Raising the dairy calf. Wisconsin Agr. Expt. Sta. Bull. 404.
- SAVAGE, E. S. and McCAY, C. M. 1942. The nutrition of calves; a review J. Dairy Sci. 25:595.
- SCHANTZ, E. J., ELVEHJEM C. A. and HART, E. B. 1938. The relation of fat to the utilisation of lactose in milk. J. Biol. Chem. 122:381.
- SCHEIDY, S. F. 1948. Recent developments in sulphonamide therapy. Cornell Vet. 38:40.
- SCHNEIDER, B. H. 1947. Feeds of the world; their digestibility and composition. Publ. by W. Virginia Agr. Expt. Sta.
- SHEEHY, E. J. 1934. Derangement of the digestive processes in the milk fed calf due to abnormal curd formation. Proc. Roy. Dublin Soc.
- SHEPHERD, J. B. and CONVERSE, H. T. 1939. Practical feeding and nutritional requirements of young dairy stock. Food and Life. U. S. DEPT. Agric. Year-book p. 597.
- SNEDECOR, G. W. 1946. Statistical Methods. Iowa State College Press.
- SOUTHCOMBE, F. J. 1947. Some observations on the grazing behaviour and water consumption of lactating Friesian and Jersey cows. M. Agr. Sc. Thesis, University of N. Z.
- STEENSBERG, V. 1947. Feeding requirement of young cattle Brit. J. Nutr. 1:139.
- SWEET, W. W., ECKLES, C. H. and RAGSDALE, A. C. 1924. The minimum protein requirement for growing dairy heifers. Mo. Agr. Expt. Sta. Res. Bull. 66.

- TYLER, W. J., CHAPMAN,
A. B. and DICKERSON,
G. E. 1947. Sources of variation in the birth
weight of Holstein-Friesian calves.
J. Dairy Sci. 30:483.
- UDALL, D. H. 1946. Diseases of calves. Cornell VET. 36:170.
- WISE, G. H. and COARSEY,
R. W. 1945. Measures used in the control of an
infectious type of calf scours. Cornell
Vet. 35:320.
- WISE, G. H., PETERSEN,
W. E. and GULLICKSON,
T. W. 1939. A whole milk ration for dairy calves.
J. Dairy Sci. 22:559.
- WOLFF-LEHMAN. 1903. Quoted by Eckles and Gullickson 1931.
- WOODWARD, E. G. 1922. A study of calf rations. Wash. Agr.
Expt. Sta. Bull. 167.
- WOODWARD, T. E. 1923. The optimum quantity of skim milk for
calf feeding. J. Dairy Sci. 6:243.
- YATES, F., BOYD, D. A.
and PETIT, G. H. N.
1942. The influence of changes in level of
feeding on milk production. J. Agric.
sci. 32:428.
- ZIALCITA, L. P. and
MITCHELL, H. H.
1945. The effect of fat upon the utilization
of galactose by the rat. J. Nutr. 30:147.

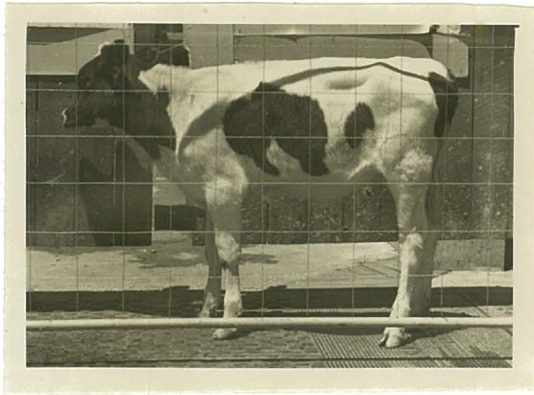
APPENDIX I

Photographs of the experimental animals.

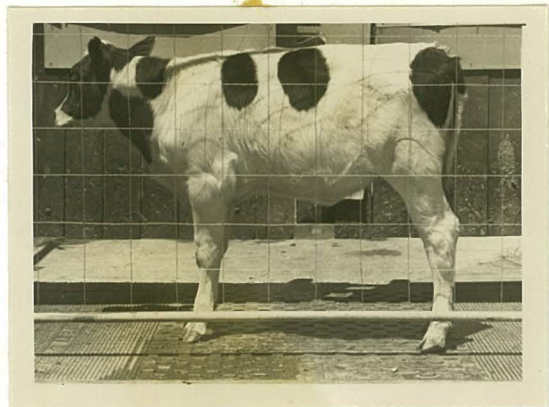
All taken at the age of twenty weeks from the same position and enlarged to the same extent in printing. The wires form a six inch square mesh, and the top of the horizontal pipe is six inches above the ground.

Friesian calves, 10% level.

Skim milk.

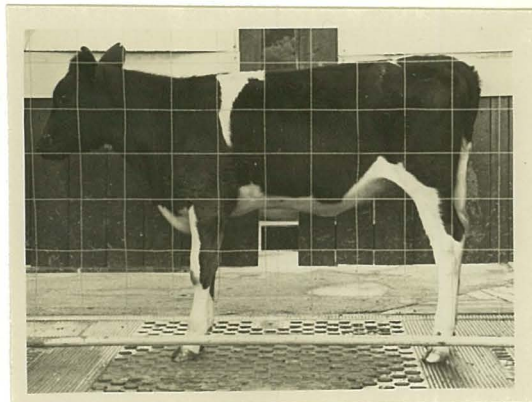


26



51

Buttermilk.

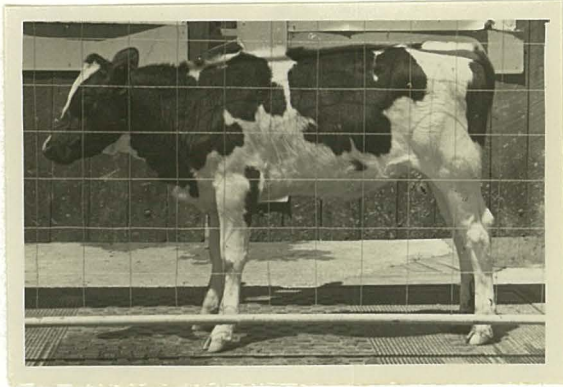


54

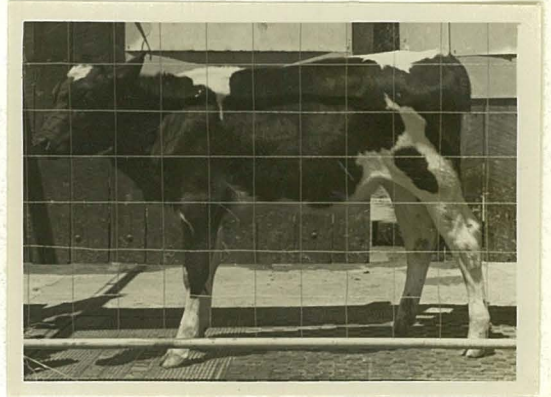
Friesian calves, 15% level.

Skim milk.

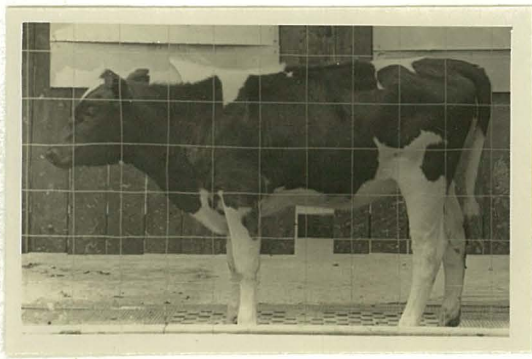
Buttermilk.



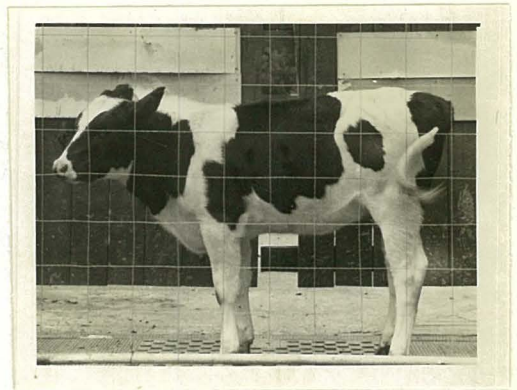
6



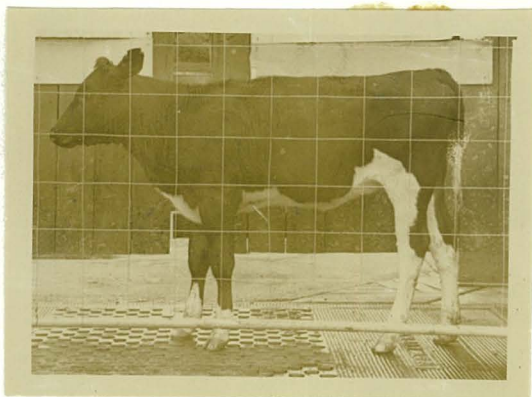
25



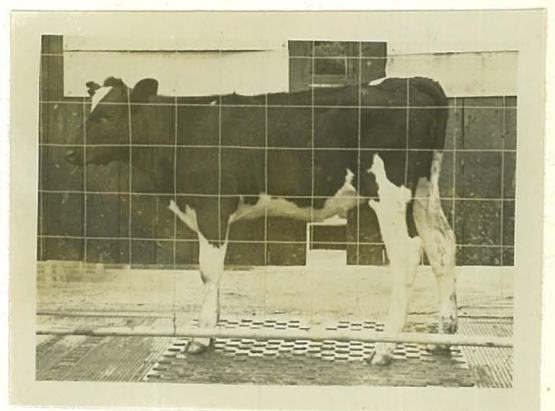
67



65

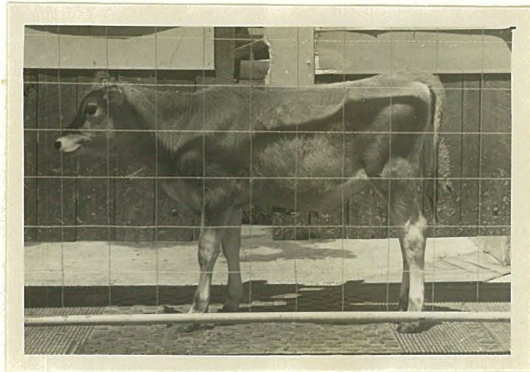


57

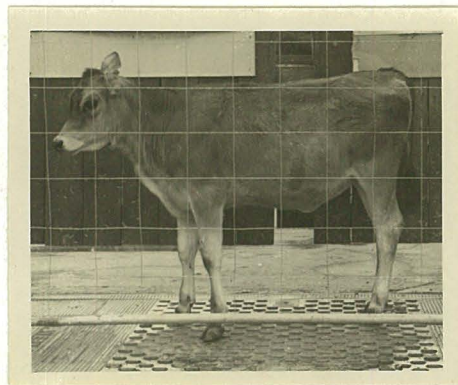


63

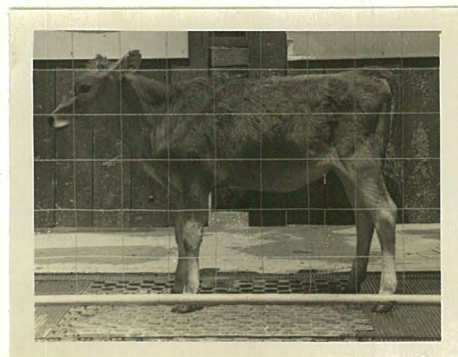
Jersey calves, skim milk, 10% level.



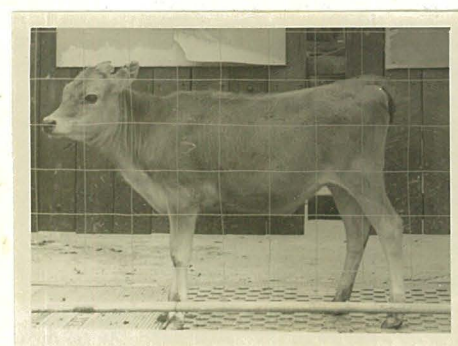
12



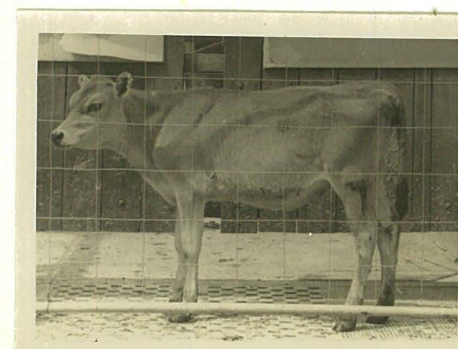
44



36



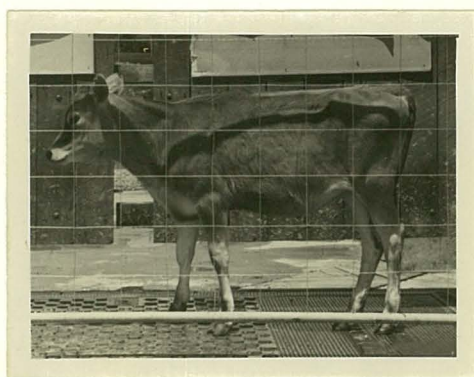
82



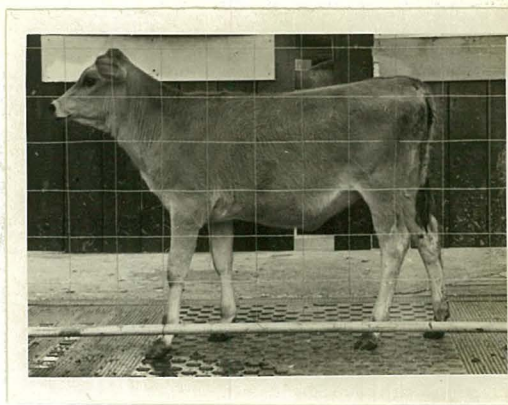
48

5

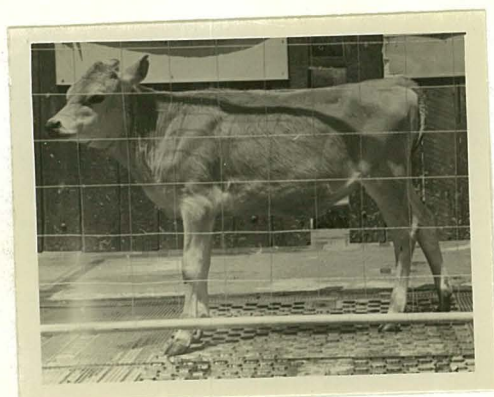
Jersey calves, buttermilk, 10% level.



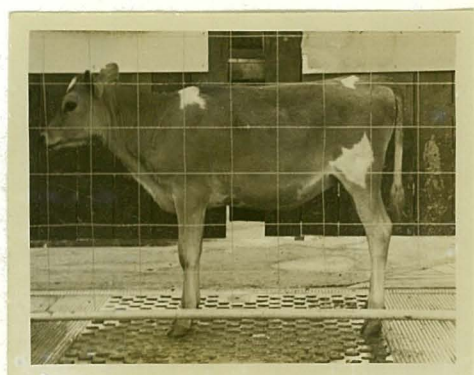
62



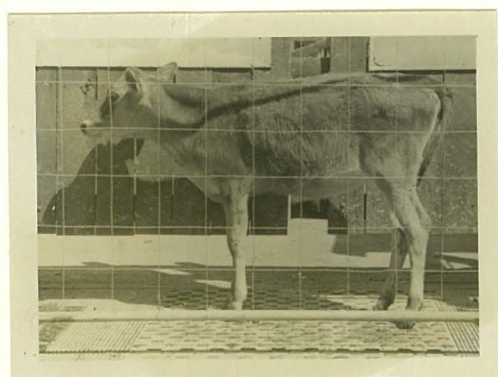
50



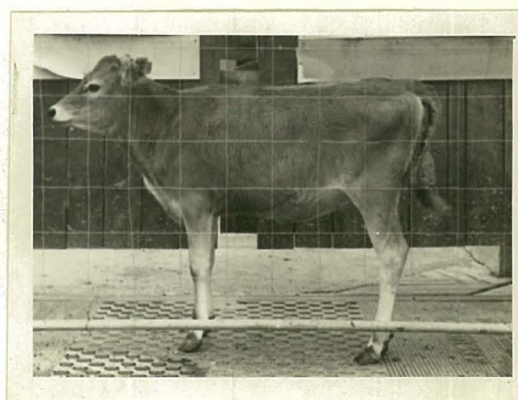
35



45

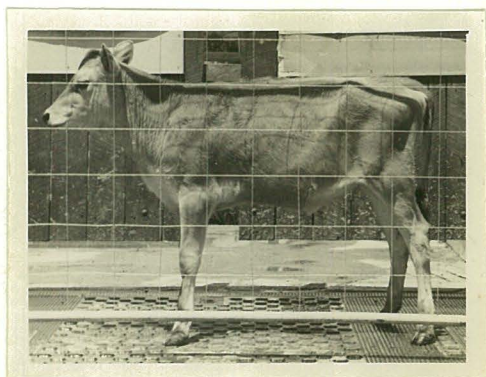


103

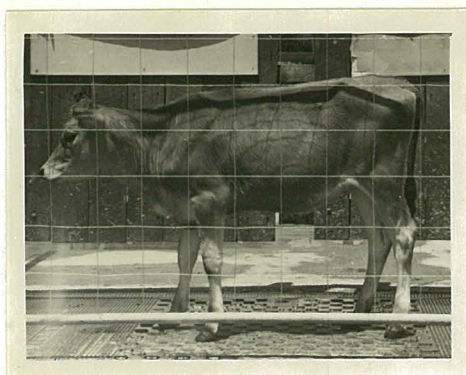


93

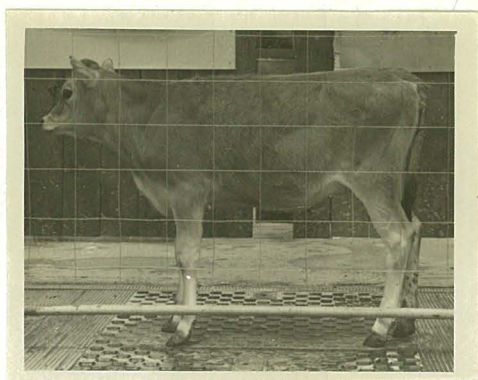
Jersey calves, skim milk, 15% level.



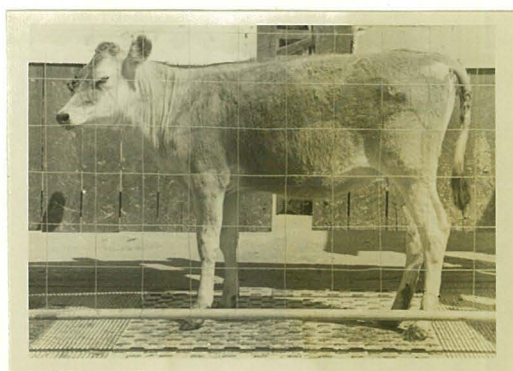
10



25

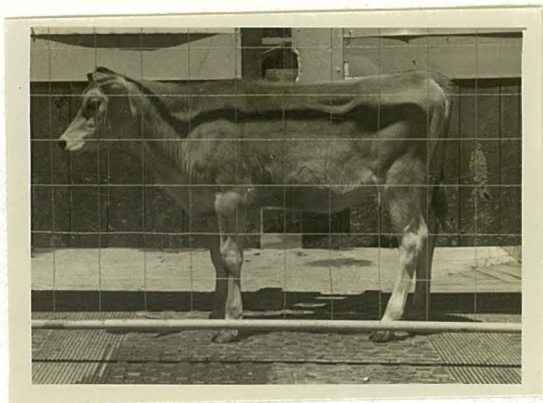


37

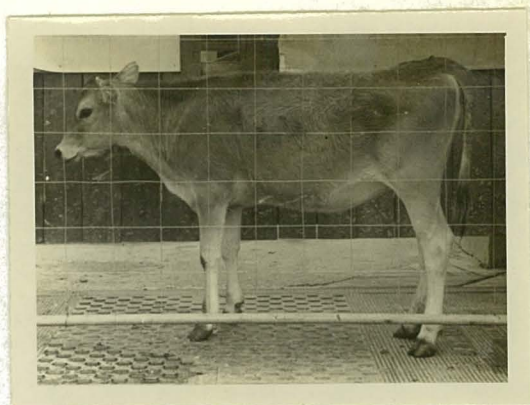


197

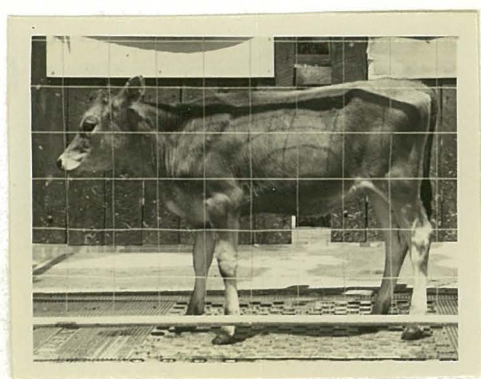
Jersey calves, buttermilk, 15% level.



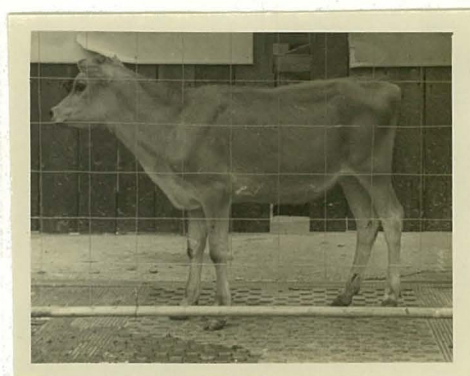
1



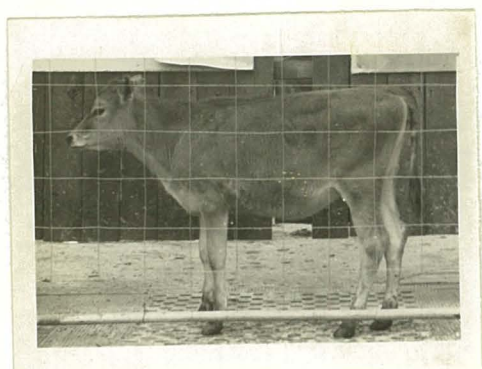
55



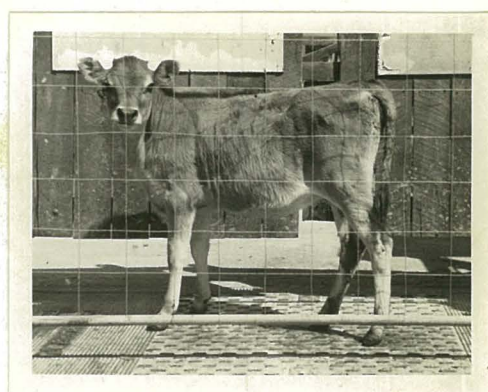
34



63



89



69

APPENDIX 11

Complete data on the growth in weight and height of the experimental animals up to twenty weeks of age.

TABLE XX INDIVIDUAL WEEKLY WEIGHTS (lb.) JERSEY CALVES

CALF E. M.	BIRTH WEIGHT	Weeks of Age																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<u>15% Skim-Milk</u>																					
10	52	57	64	65	73	82	85	92	99	104	112	118	128	135	147	157	164	175	187	192	204
20	51	47	51	61	66	77	88	91	97	101	118	134	143	145	151	158	166				
25	45	50	53	59	64	71	82	87	92	103	111	124	131	146	155	164	174	189	190	208	217
37	49	53	54	58	67	71	82	89	95	104	114	123	131	143	151	162	176	186	190	205	222
86	51	51	55	59	63	69	73	84	90	94											
197			68	76	82	89	97	105	114	124	135	145	153	160	168	178	191	198	206	205	228
<u>10% Skim-Milk</u>																					
12	50	48	56	62	63	70	77	81	90	102	107	118	127	141	148	161	171	179	187	198	201
44	65	64	65	69	80	82	92	99	105	115	122	133	138	149	158	165	174	188	192	205	221
67	52	58	60	64	71	72	79	84	85	94	99	106	108								
36	52	56	57	62	71	73	82	89	93	97	105	113	117	122	129	136	147	150	144	159	177
82	43	45	50	58	62	66	72	68	77	84	95	99	107	112	120	125	140	137	154	166	172
48	58	58	65	69	72	74	78	88	82	91	102	105	112	121	126	133	140	146	154	165	175
<u>15% Buttermilk</u>																					
1	56	57	66	72	75	82	93	99	108	118	126	136	146	158	167	179	186	196	203	220	225
55	52	47	51	58	62	76	81	85	94	97	112	126	134	145	156	166	178	184	200	214	230
34	47	50	52	57	67	71	80	87	91	103	108	118	127	138	148	158	167	175	182	190	206
63	48	51	47	55	58	68	74	83	86	92	102	105	113	120	129	136	144	147	156	158	167
89	55	55	53	55	53	58	63	69	74	83	89	98	106	114	117	126	135	144	145	154	160
69	46	51	56	58	69	76	82	91	99	112	119	129	134	148	157	167	166	180	185	200	208
<u>10% Buttermilk</u>																					
62	46	53	53	59	66	69	78	85	90	100	108	121	125	130	138	147	157	161	164	173	181
50	59	55	59	63	70	76	84	89	96	100	111	117	127	132	144	154	164	170	183	196	211
45	57	52	58	64	66	72	78	85	95	99	114	120	131	140	150	158	165	172	186	200	214
35	50	52	51	56	66	69	75	87	91	100	106	118	123	128	141	148	159	173	176	196	208
103	50	56	56	55	56	62	66	72	78	85	92	101	109	110	119	128	128	131	136	136	151
93			68	66	67	60	65	72	78	82	88	96	108	110	121	130	134	137	152	152	174
General Mean	51.5	52.9	57.0	61.7	67.1	72.3	79.5	85.9	91.7	99.3	108.5	117.5	126.2	132.9	142.7	151.6	160.3	167.0	174.9	184.9	

TABLE XXI INDIVIDUAL WEEKLY WEIGHTS (lb.) FRIESIAN CALVES

CALF E. M.	BIRTH WEIGHT	Weeks of Age																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<u>15% Skim-Milk</u>																					
6	85	95	106	114	128	138	150	165	176	195	202	206	226	238	258	268	281	298	308	324	343
67	74	78	82	94	102	112	122	134	146	158	174	185	201	212	226	236	252	269	286	300	312
57	57	62	71	73	84	94	104	117	124	126	143	151	167	179	193	206	218	225	244	244	262
<u>10% Skim-milk</u>																					
51	86	85	93	104	112	121	132	139	152	163	172	183	197	214	228	250	263	275	292	310	318
26	70	73	80	92	97	106	114	121	130	137	146	160	173	189	199	212	225	235	249	268	270
<u>15% Buttermilk</u>																					
25	91	98	109	121	132	147	166	172	191	210	219	243	255	271	287	296	321	334	352	376	385
65	75	76	76	87	95	108	116	128	138	153	165	181	191	203	236	244	264	277	296	316	323
63	56	63	69	70	78	89	93	103	109	113	124	136	152	164	178	190	205	219	234	238	257
<u>10% Buttermilk</u>																					
54	87	92	109	114	124	135	143	150	163	172	188	200	219	234	251	267	282	297	318	320	344
64	79	83	89	93	102	109	121	132	141	153											
General Mean	76.0	80.5	88.4	96.2	105.4	115.9	126.1	136.1	146.9	158.0	170.3	182.8	198.0	211.7	228.5	241.0	256.7	269.8	286.3	299.6	312.7

TABLE XXII INDIVIDUAL WEEKLY HEIGHTS (inches) JERSEY CALVES

CALF E. M.	DATE BORN	DAM	SIRE	BIRTH	Weeks of Age										
					2	4	6	8	10	12	14	16	18	20	
<u>15% Skim-Milk</u>															
Yreda 10 ⁽¹⁾	July 27	Yreda	V Jack *		24.6	25.2	26.6	28.0	29.1	29.9	31.1	31.5	32.9	33.4	
Kewpie 20 ⁽²⁾	Aug. 12	Kewpie	Victor '		25.6	26.8	26.8	28.9	29.9	30.8	31.9	33.1	33.1		
Betsy 25 ⁽³⁾	Aug. 5	Betsy	S. Sam "	24.9	25.0	26.4	28.0	28.8	29.9	31.3	32.6	33.7	34.5	35.9	
Belinda 37 ⁽⁴⁾	Aug. 9	Belinda	S. Sam		25.0	26.4	27.5	29.3	30.1	31.2	32.3	33.6	34.5	35.9	
Amy 86 ⁽⁵⁾	Aug. 31	Amy	G. Slam +	24.5	24.6	25.5	27.1	28.2							
Sally 197 ⁽⁶⁾	Sept 10	Sally	V. Jack		27.9	28.6	30.1	30.8	31.8	32.9	33.6	35.2	36.2	36.5	
* Pukeatea Union Jack															
' Maori Wonderful Victor															
<u>10% Skim-Milk</u>															
Alison 12 ⁽¹⁾	July 25	Alison	Victor		24.0	25.6	26.7	28.1	29.4	30.3	32.0	32.7	33.1	33.9	
Virtue 44 ⁽²⁾	Aug. 9	Virtue	L.D.Sam **		26.4	27.7	29.1	29.8	31.2	32.1	32.9	34.4	35.2	35.7	
Yerle 67 ⁽³⁾	Aug. 3	Yerle	V. Jack	25.0	24.8	26.8	28.5	29.1	29.7	30.4	30.4				
Beth 36 ⁽⁴⁾	Aug. 6	Beth	S. Sam		25.6	26.5	27.6	28.3	29.3	30.3	30.9	31.9	32.6	33.8	
Yuschia 82 ⁽⁵⁾	Aug. 24	Yuschia	G. Slam		24.5	25.9	26.6	27.0	27.7	29.0	29.1	30.5	31.9	32.6	
Jewel 48 ⁽⁶⁾	Sept 3	Jewel	G. Slam		26.3	27.4	28.1	28.8	29.5	30.0	30.9	31.7	32.6	33.4	
** Landsdowne Double Sam															
<u>15% Buttermilk</u>															
Amp 1 ⁽¹⁾	July 22	Amp	D. Sam		25.8	27.5	28.7	29.7	31.4	32.2	33.4	34.8	35.5	35.3	
Alma 55 ⁽²⁾	Aug. 15	Alma	Victor	24.0	26.1	26.6	27.8	29.0	30.9	32.1	33.2	33.9	35.7	36.3	
Blanche 34 ⁽³⁾	Aug. 5	Blanche	S. Sam	24.3	24.5	25.9	26.8	28.0	29.4	30.0	30.7	31.6	33.3	34.0	
Brenda 63 ⁽⁴⁾	Aug. 16	Brenda	G. Slam	24.8	25.7	26.9	28.0	28.7	29.5	30.2	31.4	32.0	32.7	33.7	
Yula 89 ⁽⁵⁾	Aug. 31	Yula	G. Slam	25.4	25.8	26.7	26.8	27.3	28.4	29.2	30.3	31.3	31.8	32.6	
Sonia 69 ⁽⁶⁾	Aug. 17	Sonia	Victor	24.5	24.8	26.3	28.0	29.4	30.4	31.6	32.6	33.2	34.1	35.0	
+ Dunlavin Grand Slam															
<u>10% Buttermilk</u>															
Juno 62 ⁽¹⁾	Aug. 4	Juno	Victor	24.1	24.1	25.5	26.4	27.3	29.0	30.1	30.9	32.4	32.4	33.5	
Meg 50 ⁽²⁾	Aug. 14	Meg	L.D.Sam	26.4	26.2	27.8	28.4	29.4	30.3	31.3	32.1	33.2	34.1	35.3	
Annette 45 ⁽³⁾	Aug. 12	Annette	L.D.Sam		23.9	25.9	26.5	28.2	28.9	30.0	31.6	32.7	33.6	34.3	
Bella 35 ⁽⁴⁾	Aug. 6	Bella	S. Sam		24.1	26.2	27.3	27.5	29.6	30.3	31.6	32.8	33.6	35.1	
Wilma 103 ⁽⁵⁾	Sept. 9	Wilma	V. Jack		25.4	26.4	26.9	27.9	29.0	29.6	31.1	31.6	32.6	32.6	
Yuten 93 ⁽⁶⁾	Sept 13	Yuten	Victor		26.3	26.9	27.3	27.2	28.6	29.8	30.4	31.6	32.2	33.1	
General Mean					24.8	25.3	26.6	27.6	28.6	29.7	30.7	31.6	32.7	33.6	34.4

TABLE XXIII INDIVIDUAL WEEKLY HEIGHTS (inches) FRIESION CALVES

CALF E. M.	DATE BORN	DAM	SIRE	BIRTH	Weeks of Age									
					2	4	6	8	10	12	14	16	18	20
<u>15% Skim-milk</u>														
Yola 6	July 17	Yola	Laddie *		29.4	30.5	31.5	33.8 ⁵	34.9	36.1	37.0	37.9	38.8	39.1
Yvette 67	Aug. 26	Yvette	Laddie		27.7	28.0	29.6	30.6	31.8	33.1	34.5	35.3	36.2	37.6
Starling 57	July 28	Starling	Laddie		26.3	25.7	28.2	30.1	30.4	31.9	33.0	33.7	34.4	35.6
<u>10% Skim-milk</u>														
Wimble 51	July 26	Wimble	Asjes "		28.4	29.3	31.0	32.3	33.1	33.8	35.7	36.2	38.1	39.0
Yelda 26	July 25	Yelda	Laddie		27.8	30.0	29.4	32.4	32.7	34.2	35.0	36.1	37.4	37.7
* Lauderdale Laddie Poscn														
" Tokaora Domino Asjes														
<u>15% Buttermilk</u>														
Yzora 25	July 25	Yzora	Laddie		29.0	31.3	32.4	33.5	35.6	36.5	38.1	39.2	40.3	40.8
Trix 65	Aug. 22	Trix	Laddie		27.6	29.6	30.9	30.4	33.3	34.2	35.7	36.6	38.0	39.1
Starling 63	July 28	Starling	Laddie		25.8	26.7	27.4	29.3	30.2	31.1	32.5	33.5	35.0	35.3
<u>10% Buttermilk</u>														
Sadie 54	July 27	Sadie	Laddie		27.9	30.4	30.4	32.0	33.0	33.9	35.7	36.6	37.3	38.2
Yatta 64	Aug. 19	Yatta	Laddie	27.9	27.3	29.2	30.2	31.2						
General Mean				27.9	27.7	29.1	30.1	31.5	32.8	33.9	35.2	36.1	37.3	38.1

APPENDIX III.

Data from previous calf experiments conducted by the Dairy Research Institute. Used for the calculation of the standard deviation of weights at twenty weeks (Table II), and in the correlation coefficients of Table III.

TABLE XXIV.

Growth data from D. R. I. records.

Calf Ear-Mark	Birth wt.	4 weeks wt.	20 weeks wt.
<u>1940</u>			
	4 lb.	63 lb.	206 lb.
	42	55	196
	51	73	193
	9	82	235
	3	80	234
	17	75	236
	4	67	221
	22	70	213
	2	72	217
	5	84	251
	1	82	203
	25	58	187
	7		
<u>1943</u>			
	51	72	242
	19	55	224
DZ	10	96	295
DZ	14	79	249
DZ	11	56	214
DZ	9	75	249
DZ	13	93	236
	8	85	245
	11	68	210
DZ	16	87	252
	26	96	272
DZ	3	89	261
	85	90	275
	84	86	265
	4	75	242
DZ	5		
<u>1945</u>			
	55	94	296
	32	93	295
	25	84	254
	58	97	272
	71	83	266
	94	76	248
	112	72	225
	116	77	243
	117	72	243
	119	81	255
	120	79	265
	123	73	264
	181	51	212
	45	85	278
	36	86	254
	54	80	252
	62	94	272
	85	87	250
	111	81	257
	114	72	249
	113	76	261
	115	72	260
	121	86	256
	125	82	260
	122	76	258
	153	57	204

TABLE XXIV (contd.)

Calf ear-mark	Birth wt.	4 weeks wt.	20 weeks wt.
<u>1946</u>			
146	57	90	256
35		87	204
138		95	256
150		76	218
168		87	264
196	60	82	220
160		78	237
163		77	241
151	57	90	233
166		74	215
170		78	220
172		70	206
174		70	213
156	59	94	263
137	48	81	235
136	55	92	256
132	45	71	207
145	62	100	295
158		89	254
161		77	229
162		80	258
165		72	209
169		68	210
173		75	218
176		73	227
175		64	215
<u>1947</u>			
28		54	202
30		62	186
130	49	58	244
60		54	193
100		49	156
149	50	66	241
27		57	191
52		62	239
43		54	204
57		56	210
113		67	148
162	43	53	199
Mean	52.5	75.9	235.6