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Studies in the growth and nutrition of dairy calves

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

by

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Studies in the Growth and Nutrition of Dairy Calves

Outline

STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

I. THE GESTATION PERIOD

Studies in the Growth and Nutrition of Dairy Calves

I. The Gestation Period.

The gestation period of the cow is generally recognized as of fairly definite length, though few reports have been made on this subject. These reports include a considerable number of animals but little study has been given to the variations which occur in the length of gestations.

Resume of Previous Work

On summarizing 764 gestation periods Spencer (4) found that 314 of them ended 284 days or less after the date of breeding, and 310 of them 285 days or more after that time. He stated that gestations of less than 260 days' duration had ended decidely prematurely, while that of over 300 days were very irregular though they did not affect the offspring. After studying 182 normal gestations on 20 cows Wing (3) found the average length to be 280 days regardless of the sex of the offspring. The majority were from 274 to 287 days in length and were fairly evenly distributed throughout that period. He also noted that some cows had uniformly long and other uniformly short periods of gestation. From 1062 observations Fleming (1) found the average length of the gestation period to be 283 days.

Experimental Work

The data presented here was collected from the herd on Iowa

State College Dairy Farm from December 1907 to November 1921 inclusive. A summary of 369 gestation periods are presented. Gestation periods during which twins were carried have not been included. In addition to the general results obtained an effort has been made to find what influence, if any, the age of the cow at the time of freshening and the season of freshening have on the length of the gestation period.

Table I

Average Length of Gestation Period

Breed	No. of Cows	Number of Calves			Average Gestation Period		
		Male	Female	Total	Male	Female	Total
					Days	Days	Days
Purebreds							
Ayrshire	14	15	20	35	277	279	278
Guernsey	25	42	35	77	282	281	281
Holstein	28	41	33	74	276	279	278
Jersey	31	38	35	73	280	280	280
Grades							
Ayrshire	2	2	—	2	282	—	282
Guernsey	21	22	26	48	282	282	282
Holstein	14	20	17	37	279	280	279
Jersey	10	7	12	19	279	277	278
Scrubs	4	2	2	4	287	285	286
Grades	47	51	55	106	280	280	280
Purebreds	98	136	123	259	279	280	279
All Calves	149	189	180	369	279	280	280

The gestation periods have been tabulated by breeds, and the scrubs separated from the grades and purebreds. The scrubs and grades were all used for experimental breeding work. A sex distinction was also made in the tabulation.

Table II

Distribution of Gestation Periods According to Their Duration

Length of Gestation	Number of Calves			Distribution of Gestations		
	Male	Female	Total	Male	Female	Total
Days				%	%	%
251	15	2	17	8.4	1.1	4.7
261	23	9	32	12.7	5.2	9.1
271	69	80	149	38.3	45.7	42.0
281	69	75	144	38.3	42.8	40.6
291	4	9	13	2.3	5.2	3.6

In order that a clearer conception of the connection between the sex of the calf and the length of gestation period may be obtained, the percentage of the calves of each sex carried through gestation periods of various lengths have been determined. Only 355 gestations could be used for this purpose and they are tabulated in groups varying in duration by ten days. The first group includes gestations of 251 to 260 days, the second group is made up of gestations of 261 to 270 days, and so on. Gestations of less than 260 days and those approaching 300 days in length must be looked on as somewhat abnormal although the calves were dropped in good healthy condition.

Table III

Influence of Age of Cow at Freshening on Length of Gestation Period

Age of Cow	Number of Calves			Average Length of Gestation		
	Male	Female	Total	Male	Female	Total
Years				Days	Days	Days
1	1	2	3	285	280	281
2	44	39	83	282	279	281
3	41	32	73	280	279	280
4	26	31	57	282	279	280
5	20	20	40	285	279	282
6	11	14	25	283	280	281
7	13	12	25	282	281	282
8	12	10	22	280	282	281
9	4	6	10	282	285	284
10	3	4	7	281	285	283
11	4	3	7	284	284	284
12	4	—	4	281	—	281
13	1	2	3	291	278	282
14	1	2	3	285	282	283

In determining the influence of the age of the cow on the length of the gestation period, some of the periods had to be discarded as records were not available in all cases of both the age of the cow and the length of the gestation period. As a consequence only 362 of the 369 periods are used for this purpose.

Table IV

Influence of Season of Freshening on Length of Gestation Period

Month of Freshening	Number of Calves			Average Length of Gestation		
	Male	Female	Total	Male	Female	Total
				Days	Days	Days
January	13	19	32	281	281	281
February	20	23	43	278	280	279
March	26	22	48	280	280	280
April	15	11	26	279	284	281
May	11	14	25	279	278	278
June	14	10	24	278	282	280
July	15	11	26	277	285	280
August	11	14	25	285	280	282
September	14	16	30	278	279	279
October	18	19	37	281	284	284
November	17	9	26	277	283	279
December	14	8	22	284	281	283

In determining the influence of the season of freshening on the length of the gestation period, the records were tabulated by months. It was again necessary to delete a few records so that only 364 are available.

Discussion of Results

When all the records available for this study are taken into consideration it is found that the average length of the gestation period for dairy cows is 280 days. There were no significant variations so far as the breed of the cows was concerned.

It has frequently been stated and is a very common belief that the periods of gestation during which bull calves are carried are longer than those for heifer calves. The average of all the records studied here however, shows an average gestation period of 280 days for both bull and heifer calves. On studying the distribution of the gestation periods of various lengths, it is found that 38.3% of the male calves were dropped after a period of 271 to 280 days in utero while an equal percentage of them were dropped after 281 to 290 days in utero. The corresponding figures for the heifers are 45.7% and 42.8%. This shows that the gestation periods are more closely grouped, so far as duration is concerned, in the case of heifer calves than in the case of bull calves. When the extremes are considered, it is found that 21.1% of the bull and 6.3% of the heifer calves are carried in utero for 270 days or less while 2.3% of the bull and 5.2% of the heifer calves are carried for

291 days or more. This does not indicate any greater length of the gestation period in the case of bull calves.

The age of the cow at the time of freshening and the season of freshening are factors which also appeared to have no influence on the length of the period of gestation.

Summary

From the data studied here it was found that:

1. The average length of the gestation period in dairy cows was 280 days.

2. This was not affected by the breed of the cows.

3. The sex of the calf had no a parent influence on the length of the gestation period.

4. Male and female calves were dropped in practically equal numbers.

5. On the average 82.6% of the calves were carried in ut ro for a period of 271 to 290 days.

6. The age of the cow at the time of freshening was without influence on the duration of the gestation period.

7. The length of the gestation period was not influenced by the season of freshening.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

II. THE BIRTH WEIGHTS OF CALVES.

Studies in the Growth and Nutrition of Dairy Calves

II. The Birth Weights of Calves

In spite of the fact that many feeding trials have been conducted with dairy calves, few reports are to be found regarding the birth wei ht of calves and the factors that influence them. The few reports available however contain data on several hundred animals and so are of considerable value, except in the case of some breeds.

Resume of Previous Work

The work so far reported on this subject can be very easily summarized as Henry & Morrison (2) reported the work available from all experiment stations while later Eckles (1) published data in similar form.

Table I.

Reported Average Birth Weights of Dairy Calves

Breed	Number of Calves	Average Weight			Relation of Weight of Calf to Weight of Dam
		Males	Females	Total	
		lbs.	lbs.	lbs.	%
		Henry & Morrison (2)			
Ayrshire	34	77	74	76	7.8
Guernsey	57	75	68	71	7.1
Holstein	104	94	85	89	7.7
Jersey	119	58	49	55	6.1
		Eckles (1)			
Ayrshire	53	73	65	69	6.9
Holstein	154	93	88	90	8.0
Jersey	196	58	53	55	6.5

Eckles (1) noted that the first and second calves of heifers were somewhat heavier than those borne at later ages but that old cows tended to have small calves. He also found that small calves were often delivered after short gestation periods and large calves after long periods, but between these extremes there was no evidence of correlation between the weight of the calf and the length of the gestation period.

Experimental Work

A digest has been made of the Herd records kept at the Dairy Farm of Iowa State College from December 1907 to November 1921 inclusive and the work reported here includes data on 369 calves and is closely connected with the material presented in Paper I of this series. Only records on single calves are included, as it was thought best to treat them alone and the number of twins was too small to really justify treatment here. An attempt has been made to study some of the factors which might be presumed to have some influence on the birth weights of calves.

Table II

Average Birth Weights of Calves

Breed	No. of Cows	Number of Calves			Average Birth Weight		
		Male	Female	Total	Male	Female	Total
Purebreds					lbs.	lbs.	lbs.
Ayrshire	14	15	20	35	68	65	66
Guernsey	25	42	35	77	66	61	64
Holstein	28	41	33	74	97	89	94
Jersey	31	38	35	73	55	52	54
Grades							
Ayrshire	2	2	—	2	60	—	60
Guernsey	21	22	26	48	68	63	65
Holstein	14	20	17	37	83	77	81
Jersey	10	7	12	19	55	53	54
Scrubs	4	2	2	4	67	51	59
Grades	47	51	55	106	72	65	68
Purebreds	98	136	123	259	73	66	70
All Calves	149	189	180	369	72	65	69

In the general summary the breeds have been kept separate, and the scrubs separated from the grades and purebreds. A sex distinction was also been made. The scrubs and grades were animals used in investigational work. A considerable number of grades, of the various breeds except the Ayrshire, are included. These grades vary considerably, as some of them are the result of but one cross of purebred bulls an scrub cows, while others are the result of two and three and in one case four crosses of purebred bulls.

Table III

Influence of Age of Cow at Freshening on Birth Weight of Calf

Age of Cow	Number of Calves			Average Birth Weight of Calves		
	Male	Female	Total	Male	Female	Total
Years				lbs.	lbs.	lbs.
1	1	2	3	97	64	75
2	46	39	85	65	64	64
3	41	33	74	75	67	71
4	26	31	57	78	68	73
5	20	20	40	77	69	73
6	11	14	25	70	65	67
7	13	12	25	79	62	71
8	12	10	22	72	73	72
9	4	6	10	67	76	72
10	3	4	7	79	57	66
11	4	3	7	70	55	64
12	4	—	4	62	—	62
13	1	2	3	65	54	58
14	1	2	3	60	59	59
15	—	—	—	—	—	—
16	1	—	1	60	—	60

On studying the influence of the age of the cow at the time of freshening on the birth weight of the calf, a few records had to be deleted as the age of the cow and the birth weight of the calf were not always available. Consequently, only 366 records are available for this part of the work. The age divisions are each of one year, for example, the two-year old group includes all cows two year old but under three. Cows from one to sixteen years of age are included.

Table IV

Influence of Weight of Cow at Freshening on Birth Weight of Calf

Weight of Cow	Number of Calves			Average Birth Weight of Calves			Relation of Weight of Calf to Weight of Dam
	Male	Female	Total	Male	Female	Total	
lbs.				lbs.	lbs.	lbs.	%
700	5	5	10	57	52	55	7.3
800	7	11	18	58	58	58	6.8
900	25	26	51	64	59	61	6.4
1000	32	26	58	72	60	66	6.3
1100	20	25	45	73	71	72	6.3
1200	14	19	33	82	72	76	6.1
1300	7	10	17	83	86	84	6.2
1400	10	8	18	103	92	98	6.8
1500	5	3	8	101	97	100	6.5

The number of cases in which the relationship of the weight of the cow at freshening to the weight of the calf at birth are more limited than in some of the other studies as in the earlier part of the period from which the records are taken the cows were not weighed regularly. Through the greater portion of the time, however, the cows were weighed weekly and the last weight before freshening was considered to be the weight of the cow at freshening. This renders 258 records available. The cows were then classified according to weight. Those weighing 700 pounds to 799 pounds were put in the 700-pound group, and so on. The true average live weight for each group was not determined but it was presumed to be 750 pounds for the cows in the 700-pound group, and so on. The weights arrived at in this way were those used in determining the percentage of the live weight of the dam that the weight of the calf represented.

Table V

Influence of Season of Freshening on Birth Weight of Calves

Month of Freshening	Number of Calves			Average Birth Weight of Calves		
	Male	Female	Total	Male	Female	Total
				lbs.	lbs.	lbs.
January	12	18	30	75	66	70
February	20	23	43	74	76	75
March	28	23	51	75	67	72
April	15	11	26	66	63	64
May	12	13	25	71	60	65
June	13	10	23	72	58	66
July	14	11	25	59	66	62
August	11	16	27	72	68	69
September	14	17	31	73	61	67
October	19	20	39	76	62	69
November	17	10	27	74	73	74
December	14	8	22	77	69	74

All of the records were available for determining the influence of the season of freshening on the birth weight of the calf. These records were arranged by months.

Influence of Length of Gestation on Birth Weight of Calves

Length of Gestation	Number of Calves			Average Birth Weight of Calves		
	Male	Female	Total	Male	Female	Total
Days				lbs.	lbs.	lbs.
251	15	2	17	75	43	71
261	23	9	32	70	68	70
271	69	80	149	73	65	69
281	69	75	144	73	65	69
291	4	9	13	69	77	74

In considering the influence of the length of the gestation period on the birth weight of the calf, the gestation periods have been taken by ten-day groups, for example, gestations of 251 to 260 days have been grouped together. Only 355 records were available for this purpose.

Discussion of Results

When the purebred calves are separated out according to breeds, it is found that the Holstein calves lead in weight and are followed by the Ayrshire, Guernsey and Jersey calves. The bull calves are heavier than the heifers in each breed. The grades, with the exception of the Ayrshires which are too small in number to be of significance, approximate the purebreds in birth weight. On the average the scrub calves have the lowest birth weight and the purebreds, the highest. When all classes are grouped together, it is found that the average birth weight is 72 pounds for the bull calves, 65 pounds for the heifer calves and 69 pounds for all.

The age of the cow at the time of freshening may have some influence on the birth weight of the calf. The weights for the calves of yearlings are high, due to the fact the one bull coming in this group is well above the average in birth weight. Leaving this class out of consideration however, it would appear that there is some slight rise in the birth weights of the calves as the cows go from two to five years of age; from then on there is a tendency for the calves to be of lower birth weight.

As the cows increase in weight from an average of 750 pounds in the first group to an average of 1550 pounds in the last group the average birth weights of the calves from these cows increase. This is true for both the males and females and the average of all. In the case of the average the increase was from 55 pounds to 100 pounds. The relation of the birth weight of the calf to the weight of the dam, when expressed as a percentage of the live weight of the dam does not follow this however. It decreases from 7.3% in the 700-pound cow group to 6.1% in the 1200-pound group and then shows irregular increases among the groups of greater weight.

It cannot be said that there is any very definite variation in the weight of the calves dropped at different seasons. However, it does appear that the average birth weights of the calves dropped in the months of April to October inclusive are lower than the weights of those dropped at other times. Within those two main periods however, there are irregular variations from month to month.

The length of the gestation period has little influence on the birth weights of the calves. However, when the gestation is about the average in length, the calves are near the average in birth weight and as the gestation period varies from normal the birth weight of the calves appears to increase slightly.

Summary

After considering the data presented here the following statements may perhaps be made.

1. The average birth weights found for the calves studied were 72 pounds for males, 65 pounds for females, and 69 pounds for all calves.

2. Of the purebred calves the Holsteins were the heaviest and they were followed by the Ayrshires, Guernseys and Jerseys.

3. The scrub calves had the lowest average birth weight and the purebreds, the highest, though the grades approximated the purebreds in weight.

4. As the cows increase in age up to five years, the average birth weight of the calves apparently increases. From then on there is an irregular decrease in the weights of the calves.

5. With an increase in the weight of the cows there is an increase in the birth weight of the calves, though this is not in direct proportion to the increase in the weight of the cows. It is not possible to determine from the data available just how closely the increase in weight of the cows follows advancing age. The two factors are correlated to a certain extent and it is difficult to determine which one is of more importance.

6. It may be true that calves dropped from April to October inclusive are lighter than those dropped during the rest of the year. There are fairly wide variations in the birth weights of the calves dropped in each of those periods however.

7. The length of the gestation period has little influence on the birth weight of calves, but the more closely the gestation approaches normal in length the nearer are the birth weights to normal. As the gestations recede from normal the greater become the birth weights of the calves.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

III. THE RATE OF GROWTH OF DAIRY HEIFERS

Studies in the Growth and Nutrition of Dairy Calves

III. The Rate of Growth of Dairy Heifers

In investigational work it is frequently found that a new unit of measurement, with which the results obtained can be compared, is necessary. In view of this fact it was deemed essential that curves for various forms of growth in calves be obtained. Such curves obtained from measurements of animals fed and grown out under normal conditions are extremely useful as bases with which to compare the growth of animals under experimental conditions. Little work of this character is at present available.

Resume of Previous Work

Practically the only work reported on the rates of growth of heifers is that by Eckles (2) who worked with Ayrshires, Holsteins and Jerseys and there the rate of growth to two years of age, when expressed as a percentage of the birth weights and measurements appears to be most rapid in the Jerseys with the Ayrshires second. This confirms general observations regarding the more rapid development of the smaller breeds of dairy cattle.

No effort will be made here to discuss the many factors which control growth but it may be noted that Waters (5) on feeding calves from the time of birth on rations of various types, from scanty to full-fed, found that in the early stages

of development growth in height was more rapid than growth in width. Later however, the growth in width tended to become more rapid. Eckles (1) confirms this observation that the growth impulse is decidedly stronger in the skeleton than in the fleshy parts of the body.

The results obtained by McCandlish (3) on feeding an unsuitable ration to young calves tend to give evidence in the same direction when the increases in live weight and body measurements are considered. The normal animals with which the abnormally fed individuals were compared showed the greatest percentage increase in live weight than in body measurements, but it was found that the decrease in percentage gain in live weight from the normal increase was greater than the average decrease in percentage gain in live weight was only 30% of normal, while the majority of the body dimensions increased at 50% to 60% of the normal rate. This would indicate that while under normal conditions gains in body weight are more rapid than body measurements, yet under adverse conditions the stimuli which cause increase in skeletal dimensions are not retarded so easily as are the stimuli which induce increases in live weight.

A factor of note in post-natal growth is the decrease in weight which is sometimes said to occur normally for some time after birth. Abnormal decreases are of course to be found in the case of many animals which are not properly

nourished or are stunted in some way at that time. No reports of this character have been noted with calves. Robertson (4) however, has reported on the average loss of weight of South Australian infants during the first week after birth. He states that the post-natal loss of weight is due to the mechanical shock at birth, and to the nutritional changes taking place at that time. He finds that the average loss due to these factors is 9.2% of the birth weight.

Post-natal loss is sometimes attributed to the fact that the young do not receive a sufficient supply of nutrients during the first few days after birth. This can hardly be looked on as the sole cause of the loss however, as there is post-natal loss in weight in guinea pigs, which have reached such a stage of development at birth that they can readily forage for themselves soon after that time.

Experimental Work

The data reported here has been collected from a group of 40 heifers that have been raised from birth to producing age on the Iowa State College Dairy Farm. These heifers are part of those discussed in Paper II of this series. The chief reason for obtaining the data was to have a growth curve to use as a basis with which the rates of growth of animals used in experimental work might be compared. The data was collected in the years 1916 to 1920 inclusive.

Purebreds and grades of the Guernsey, Jersey and Holstein breeds, and purebred Ayrshires were used in this work but so

far no attempt has been made to arrive at breed characteristics, as the numbers of animals in the various groups at present would be too small for such purposes. The animals have been grouped however, according to the season of the year at which they were dropped. Winter calves include those dropped from October 1 to March 31 and summer calves are those dropped from April 1 to September 30 inclusive. There are 24 heifers in the winter and 16 in the summer group. All of the heifers were reared under general herd conditions.

In addition to the general piece of work, consideration may be given here to results that were obtained on weighing a few calves daily for ten days after birth. In this limited test one heifer and four bull calves were used and the results obtained with them are tabulated.

Table I

Change in Weight of Calves for Ten Days After Birth

Calf No.	Sex	Age Days: Birth	1	2	3	4	5	6	7	8	9	10
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
381	M	83	87	91	94	91	85	87	89	88	88	91
382	M	52	54	55	55	58	55	54	55	57	55	53
384	F	64	62	65	63	61	59	59	59	60	60	61
386	M	108	106	104	100	97	97	102	102	101	99	99
387	M	70	73	71	67	65	65	60	59	60	62	63
Average		77	80	80	79	78	76	76	76	77	76	77
Percentage of Birth Weight		100	104	104	103	103	99	99	99	100	99	100

The general scheme for obtaining body measurements and weights of the heifers used in the major portion of this work can be outlined shortly. Each heifer was weighed at birth. Then on the three consecutive days at the middle of each calendar month all the heifers were weighed and on one of these days the body measurements were taken. This method was pursued to avoid continuous weighing of the animals. The three consecutive weighings obtained were averaged and then the average of the first series and the average of the second series of weighings were averaged to obtain the weights of the animals at one month of age. This method was then followed through to the time of freshening. It is believed that it gives a reasonably true average as at the first weighing the animals would range up to 30 days of age and at the second from 50 to 60 days of age and the average of all would be 30 days of age.

The body measurements taken were the height at withers, depth of chest and width of hooks. These measurements were averaged in the same way as were the live weights. No measurements were taken at birth however.

Table II

Average Live Weights and Body Measurements of Winter Calves.

Age Months	Live Weight	Height	Depth	Width	Percentage Increase			
					Live Weight	Height	Depth	Width
	lbs.	in.	in.	in.	%	%	%	%
Birth	68							
1	91	28.7	11.6	6.9	34			
2	120	30.7	12.6	7.5	76	7	8	9
3	163	32.9	14.2	8.5	140	11	22	23
4	210	34.8	15.4	9.4	209	21	33	36
5	262	36.4	16.7	10.2	285	27	44	48
6	317	38.4	17.9	11.0	366	34	54	59
7	373	39.8	18.7	11.8	449	39	61	71
8	424	41.0	19.7	12.8	524	43	70	86
9	467	42.2	20.3	13.4	587	47	75	94
10	500	42.9	20.9	13.8	635	49	80	100
11	533	43.7	21.5	14.2	684	51	85	106
12	569	44.5	22.0	14.8	737	55	90	114
13	604	45.1	22.6	15.3	788	57	95	122
14	644	45.7	22.8	15.6	847	59	97	126
15	680	46.1	23.4	15.9	900	60	102	130
16	708	46.5	23.8	16.3	941	62	105	136
17	729	46.9	24.0	16.5	972	63	107	139
18	750	47.3	24.2	16.7	1003	65	109	142
19	777	47.7	24.4	17.1	1043	66	110	148
20	806	47.9	24.8	17.5	1085	67	114	154
21	834	48.3	25.2	17.7	1126	68	117	157
22	861	48.5	25.4	17.9	1166	69	119	159
23	894	48.9	25.6	18.1	1215	70	121	162
24	928	48.9	25.8	18.5	1256	70	122	168
29	1010	49.4	26.4	19.5	1385	72	128	183

Table III

Average Live Weights and Body Measurements of Summer Calves

Age Months	Live Weight	Height	Depth	Width	Percentage Increase			
					Live Weight	Height	Depth	Width
	lbs.	in.	in.	in.	%	%	%	%
Birth	64							
1	89	28.7	11.4	6.3	39			
2	119	30.7	12.8	7.3	86	7	12	16
3.	163	32.7	14.4	8.3	155	14	26	32
4	212	34.6	15.7	9.4	231	21	38	49
5	262	36.4	16.9	10.2	309	27	48	62
6	309	38.2	17.9	11.4	383	33	57	81
7	355	39.8	18.7	11.8	455	39	64	87
8	396	40.8	19.5	12.4	519	42	71	97
9	429	41.8	20.1	13.0	570	46	76	106
10	464	42.5	20.7	13.4	625	48	82	113
11	504	43.3	21.3	14.0	688	51	87	122
12	540	43.9	21.7	14.4	744	53	90	129
13	576	44.5	22.2	14.8	800	55	95	135
14	607	44.9	22.6	15.3	848	56	98	143
15	629	45.3	23.0	15.4	883	58	102	144
16	651	45.9	23.2	15.7	917	60	104	149
17	676	46.5	23.6	15.9	956	62	107	152
18	698	46.9	24.0	16.3	991	63	111	159
19	720	47.3	24.2	16.5	1025	65	112	162
20	749	47.5	24.6	16.7	1070	66	116	165
21	782	47.7	24.6	17.1	1122	66	116	171
22	815	47.9	25.0	17.5	1173	67	119	178
23	844	48.3	25.4	17.5	1219	68	123	181
24	874	48.5	25.4	17.9	1266	69	123	184
29	941	49.2	26.2	18.9	1370	71	129	200

Table IV

Average Live Weights and Body Measurements of All Calves

Age Months	Live Weight	Height	Depth	Width	Percentage Increase			
					Live Weight	Height	Depth	Width
	lbs.	in.	in.	in.	%	%	%	%
Birth	67							
1	90	28.7	11.4	6.7	34			
2	120	30.7	12.8	7.5	79	7	11	12
3	163	32.9	14.2	8.5	143	15	25	27
4	211	34.8	15.4	9.4	216	21	35	40
5	262	36.4	16.7	10.2	291	27	47	52
6	314	38.4	17.9	11.2	369	34	57	67
7	366	39.8	18.7	11.8	446	39	64	76
8	413	41.0	19.5	12.6	516	43	71	88
9	452	42.0	20.3	13.2	575	46	78	97
10	486	42.7	20.9	13.6	625	49	83	103
11	521	43.5	21.5	14.2	677	52	89	112
12	557	44.3	21.9	14.6	731	54	92	118
13	592	44.9	22.4	15.1	784	56	96	125
14	628	45.5	22.8	15.4	837	59	100	130
15	659	45.9	23.2	15.7	884	60	104	134
16	685	46.3	23.6	16.1	922	61	107	140
17	708	46.7	23.8	16.3	957	63	109	143
18	729	47.1	24.2	16.5	988	64	112	146
19	754	47.5	24.4	16.9	1025	65	114	152
20	784	47.7	24.6	17.1	1070	66	116	155
21	813	48.1	25.0	17.3	1113	68	119	158
22	852	48.3	25.2	17.7	1171	68	121	164
23	874	48.5	25.4	18.1	1204	69	123	170
24	903	48.9	25.6	18.7	1248	70	125	179
29	982	49.4	26.4	19.3	1366	72	132	188

Discussion of Results

It will be noted in the tabulation that the live weights, starting at one month of age, are tabulated by months until the age of two years is reached. After that age the heifers were dropped from the work as they freshened and the live weights and body measurements are consequently omitted after that with the exception of the averages for the animals at the time of freshening. The average age of freshening was 29 months for each group.

In surveying the results obtained on weighing calves daily for 10 days after birth it may be said that immediately after birth the calves appear to gain 4% in live weight, probably due to intestinal fill and then gradually decrease until they have reached only 1% below their birth weights and then come back to normal. These results do not indicate any marked changes in live weight immediately following birth, though there are somewhat greater changes in individual cases.

The winter calves averaged 68 pounds in live weight at birth, the summer calves 64 pounds, and the total 67 pounds. This does not introduce any variation of importance.

There are variations from time to time in the rates of development of the two groups of heifers but at the age of two years the winter heifers exceed the summer heifers in all body measurements and in live weights, but have excelled the summer heifers in only one increase - the percentage increase

in height. By the time the age of freshening is reached however, the winter heifers are excelled only in the percentage increase in depth of chest and width of hocks. The significance of this is probably not great, especially as the winter heifers were larger and heavier than the summer heifers at the time of freshening.

Formulae have at various times been presented for the calculation of the live weight of various classes of live stock from body dimensions. Without discussing the accuracy or practicability of such methods a table is presented here which shows that from the data obtained in this work, it was observed that there was a fairly constant relationship between the live weight in pounds and the product of the height, depth and width in inches. This ratio is approximately 1:25. It holds fairly well for the averages of the group but would vary considerably with individuals. There also appears to be a variation connected with the ages of the animals as with the younger animals the ratio tended to become narrower while it widened with the older individuals.

Ratio of Average Live Weight of Calves in Pounds to Product of Average Height, Depth and Width in Inches

Age Months	Ratio 1:
1	24.5
2	24.6
3	24.4
4	23.9
5	23.7
6	24.5
7	23.9
8	24.4
9	24.9
10	24.9
11	25.9
12	25.4
13	25.7
14	25.4
15	25.4
16	25.7
17	25.6
18	25.9
19	26.0
20	25.6
21	25.6
22	25.3
23	25.5
24	25.9
29	25.6

Summary

From the data presented here a few facts appear to be in evidence.

1. There is apparently little indication of a post-natal loss in the weight of calves.

2. The live weight of the animals shows the most rapid increase.

3. When the body measurements taken are considered it is found that in rapidity of increase their rank from the highest to the lowest is width, depth and height.

4. Between winter and summer heifers there appears to be little difference except that the winter heifers reach a greater weight and greater body measurements by the time of freshening than do the summer heifers.

5. There appears to be a f irly definite ratio between the live weight of the animals in pounds and the product of the height, depth and width in inches.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

IV. THE FEED COST OF GROWING DAIRY HEIFERS

Studies in the Growth and Nutrition of Dairy Calves.

IV. The Cost of Growing Dairy Heifers.

Every year five to six million heifers are needed to replace the old and unproductive cows that are weeded out of the dairy herds of the United States and to increase the number of cows required to augment the supply of dairy products needed by the country.

Unfortunately in too many cases little attention is given to the proper raising of the young heifers that are ultimately to take their place in the producing herds of the country. Many calves are improperly fed from birth, while in an even larger number of cases the calves are reared well until weaning time when they are turned loose to rustle for themselves. In either case, when the heifers reach producing age they tend to be stunted and are generally undernourished, unthrifty and in poor condition. Such heifers can not be expected to do their best work when they come into the producing herd. The improper raising of heifers is a factor of great influence in causing the low average production of milk and butterfat in many of the dairy herds of today.

Many men make a practice of raising heifers and then selling them without having an idea as to the cost of production. The feed cost of raising heifers exceeds in amount all the other cost items combined and it was this fact which prompted this study.

Resume of Previous Work

Few trials are reported on the feed cost of raising heifers and only one of those reported carries the heifers through to producing age. In reviewing the literature therefore, only the studies which carry the heifers to two years of age or over are considered.

Table I

Feed Required by Dairy Heifers

Authority	Bennett & Cooper (1)	Hayden (3)	Trueman (5)
No. of Heifers	17	37	5
Months Fed	24	Fresh at 26½	24
Feeds	lbs.	lbs.	lbs.
Whole Milk	342	459	445
Skim Milk	3165	3330	2953
Grain	547	1710	737
Dry Roughage	2649	2634	3145
Silage & Soiling	3603	4042	2938
Pasture, Days	294	322	300

Of the three studies reported only the one carrying the heifers to producing age and one of these carrying them to two years of age include large enough numbers of animals to be of the greatest significance.

Experimental Work

The data reported here is obtained from a record of the growth and feed consumption of a group of forty heifers grown to producing age on the Iowa State College Dairy Farm, in the years 1916 to 1921 inclusive. They all ultimately entered the producing herd.

Purebred and grade heifers of the Holstein, Guernsey and Jersey breeds and purebred Ayrshires are included. No attempt is made to determine breed distinctions as the lots would be much too small for that purpose. An effort was made, however, to determine the difference in feed cost of production of heifers that were dropped in fall and winter on the one hand, and those that were dropped in spring and summer on the other hand. Winter calves were taken to be those dropped between October 1 and March 31, while summer calves were considered to be those dropped between April 1 and September 30.

Table II

Animals Used

Breed	Winter Calves		Summer Calves		All Calves	
	No. of Animals	Per Cent of Total	No. of Animals	Per Cent of Total	No. of Animals	Per Cent of Total
Ayrshires	4	10.0	2	5.0	6	15.0
Guernseys	8	20.0	7	17.5	15	37.5
Holsteins	9	22.5	3	7.5	12	30.0
Jerseys	3	7.5	4	10.0	7	17.5
Total	24	60.0	16	40.0	40	100.0

The calves used in this work were being raised to come into the producing herd and were kept under normal conditions. All were allowed to run with their dams for a few days after birth and were then put on whole milk which was fed for periods longer than is generally considered most economical. Gradually all calves were changed over to skim milk instead of whole milk. The skim milk was also fed for a considerable period. As a consequence it will be found that a large number of the calves were receiving whole milk up to near six months of age and skim milk for another period of about six months. In one case whole milk was fed after six months of age and skim milk after one year of age. This shows up in small amounts in the averages.

It will be seen therefore, that the policy was one of liberal milk feeding and concentrates were also allowed in greater proportions than are generally provided. The feeding of grain was started at about a few weeks of age and was allowed liberally when needed. The same holds true for alfalfa hay. Only relatively small amounts of non-leguminous roughages were allowed and they were fed to the heifers only when no other means of disposal was available.

Pasture was allowed at all possible times as was silage though generally not in large amounts as it was usually not available in large amounts after the producing herd had been allowed for. Soiling was provided in small amounts only on

special occasions. Salt and water were provided at free will at all times, with the exception of the calves receiving milk during winter and they had access to water but twice daily.

In distinguishing between the feeding of the winter and summer calves it may be said that the winter calves were not allowed to pasture until spring, while the summer calves were generally a little younger when allowed to pasture. During their first summer the winter calves were allowed grain liberally and in the fall - when they were a year of age - a more liberal allowance of feed could be allowed them than was given to the summer heifers which were of younger age. In the following summer little grain was allowed in any case, but when the animals of both groups were getting ready to freshen, liberal allowances of grain were given - the winter heifers getting more than the others, as they freshened later in the year.

The practice was to have all heifers, as nearly as possible, freshen in the fall or winter but this was not always possible, due to difference in age. Consequently, it was found on studying both lots, winter and summer dropped heifers, that they had come to production at the same average age of twenty-nine months. Throughout this study, calendar months are not used, as it has been found more convenient to consider each monthly period as thirty days; the first period beginning with the day on which the heifer was born.

Table III

Average Live Weight Gains per Heifer

Age Months	Winter Calves			Summer Calves			All Calves		
	Weight	Gain for six Months	Total Gain	Weight	Gain for six months	Total Gain	Weight	Gain for six months	Total Gain
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Birth	68			64			67		
6	317	249	249	309	245	245	314	247	247
12	569	252	501	540	231	475	557	243	490
18	750	181	682	698	158	634	729	172	662
24	922	172	854	874	176	810	903	174	836
29	1010	88	942	941	67	877	982	79	915

On consulting the data it is found that the winter calves were four pounds heavier than the summer calves at birth but at the age of freshening the winter heifers had made the greater gains and on the average weighed sixty-nine pounds more than the summer heifers at the same age. For convenience the results are combined by periods of six months. It will be found that the winter heifers do not make as good average daily gains in all periods of six months as do the summer heifers but if the average daily gains from birth up to any point be considered it will be found that the winter heifers have always made the best daily gains. At the time of freshening, twenty-nine months of age, the average daily gains from birth were 1.09 pounds for the winter heifers and 1.01 pounds for the summer heifers, or an average for all heifers of 1.05 pounds.

Table IV

Average Daily Live Weight Gain per Heifer

Age Months	Winter Calves		Summer Calves		All Calves	
	For Six Months	For Total Period	For Six Months	For Total Period	For Six Months	For Total Months
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
0 - 6	1.38	1.38	1.36	1.36	1.37	1.37
6 - 12	1.40	1.39	1.28	1.32	1.35	1.36
12 - 18	1.05	1.26	.88	1.19	.96	1.23
18 - 24	.96	1.19	.98	1.13	.97	1.16
24 - 29	.59	1.09	.45	1.01	.53	1.05

To keep down the size of the paper and yet preserve clarity as far as possible, the amount of concentrates fed per heifer for each period of six months is given for each group and then the total amounts for each heifer are given in cumulative form up to the time of freshening. In addition all the feeds consumed are treated in the same way.

Table V

Average Amount of Concentrates Consumed by Heifers by Six Month Periods.

Age Months	Cracked Corn	Hominy Feed	Ground Oats	Wheat Bran	Oil Meal	Cottonseed Meal	Total
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
			Winter Calves				
0-6	139	16	79	63	36		333
6-12	468	29	179	154	77		907
12-18	407	18	118	112	59	9	723
18-24	235	2	59	70	48	5	419
24-29	345	4	100	106	88	20	663
			Summer Calves				
0-6	174	24	82	61	30		371
6-12	396	57	165	131	66		815
12-18	293	25	88	75	39	2	522
18-24	436	8	93	95	51	34	717
24-29	183	8	81	91	73		436
			All Calves				
0-6	154	19	80	62	34		349
6-12	439	41	174	145	73		872
12-18	361	20	106	97	51	6	641
18-24	314	4	74	82	49	16	541
24-29	280	5	92	99	77	13	566

Table IV

Average Cumulative Consumption of Concentrates by Heifers.

Age Months	Cracked Corn	Hominy Feed	Ground Oats	Wheat Bran	Oil Meal	Cottonseed Meal	Total
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
				Winter Calves			
0-6	139	16	79	63	36		333
0-12	607	45	258	217	113		1240
0-18	1014	63	376	329	172	9	1963
0-24	1249	65	435	399	220	14	3382
0-29	1594	69	535	505	308	34	3045
				Summer Calves			
0-6	174	24	82	61	30		371
0-12	570	81	247	192	96		1186
0-18	863	106	335	267	135	2	1708
0-24	1299	114	428	362	186	36	2425
0-29	1482	122	509	453	259	36	2861
				All Calves			
0-6	154	19	80	62	34		349
0-12	593	60	254	207	107		1221
0-18	954	80	360	304	158	6	1862
0-24	1270	84	434	386	207	22	2403
0-29	1550	89	526	485	284	35	2969

Table VII

Average Amount of Feed Consumed by Heifers by Six Month Periods

Age Months	Suck-ing	Whole Milk	Skim Milk	Concen-trates	Silage	Soil-ing	Pas-ture	Alf-alfa Hay	Cane Fodder	Corn Fodder
	Days	lbs.	lbs.	lbs.	lbs.	lbs.	Days	lbs.	lbs.	lbs.
Winter Calves										
0-6	3.5	1469	712	333	145		21	293		
6-12		57	1386	907	420	16	57	1182	38	21
12-18			7	723	957	51	53	1405	75	152
18-24				419	605	38	130	231	32	501
24-29				663	1959	179	62	463	70	239
Summer Calves										
0-6	3.5	1289	954	371	63		25	395		
6-12		26	1229	815	516	18	40	1126		
12-18				522	675		124	353	16	224
18-24				717	1739	16	54	245	202	735
24-29				436	1475	15	125	364	1	123
All Calves										
0-6	3.5	1391	809	349	113		22	334		
6-12		45	1323	872	470	17	50	1159	23	13
12-18			3	641	832	31	82	984	52	181
18-24				541	1059	28	100	237	101	594
24-29				566	1765	234	87	425	41	192

Table VIII

Average Cumulative Consumption of Feed by Heifers

Age Months	Sucking	Whole Milk	Skim Milk	Concentrates	Silage	Soiling	Pasture	Alfalfa Hay	Cane Fodder	Corn Fodder
	Days	lbs.	lbs.	lbs.	lbs.	lbs.	Days	lbs.	lbs.	lbs.
Winter Calves										
0-6	3.5	1459	712	333	145		21	293		
0-12	3.5	1516	2098	1240	565	16	78	1475	38	21
0-18	3.5	1516	2105	1963	1522	67	131	2880	113	173
0-24	3.5	1516	2105	3382	2127	105	261	3111	145	674
0-29	3.5	1516	2105	3045	4086	284	323	3574	215	913
Summer Calves										
0-6	3.5	1289	954	371	63		25	395		
0-12	3.5	1315	2183	1186	579	18	65	1521		
0-18	3.5	1315	2183	1708	1254	18	189	1874	16	224
0-24	3.5	1315	2183	2425	2993	34	243	2119	218	959
0-29	3.5	1315	2183	2861	4468	349	368	2483	219	1082
All Calves										
0-6	3.5	1391	809	349	113		22	334		
0-12	3.5	1436	2132	1221	583	17	72	1493	23	13
0-18	3.5	1436	2135	1862	1415	48	154	2477	75	194
0-24	3.5	1436	2135	2403	2474	76	254	2714	176	788
0-29	3.5	1436	2135	2969	4239	310	341	3139	217	980

The feed prices used were those current at the time of the preparation of the manuscript, November 1921. The home produced feeds were taken at farm values and did not include cost of marketing. Purchased feeds were taken on the basis of carload lots delivered.

The pasture costs were based on results previously published by Gillette, McCandlish and Kildee (2) which showed that the average duration of the pasturing season was 167 days in this district. Under the system of management maintained in this work it has been found that one acre of pasture will be sufficient for a heifer of one year old or over for the season. Consequently, by allowing $8.00 per acre for the pasture, which is a suitable allowance for the rental, manuring and maintenance of the pasture used, it will be found that the pasture costs for a heifer of twelve months of age or over will be five cents per day. It was more difficult to arrive at a cost for the pasture used by younger animals but it is believed that a charge of two and one-half cents per day for pasture for animals less than a year of age will be sufficient.

Table IX

Feed Prices

Feed	Price per Ton $
Cracked Corn	10.00
Hominy Feed	20.00
Ground Oats	15.00
Wheat Bran	20.00
Linseed Oil Meal O. P.	32.00
Cottonseed Meal	32.00
Alfalfa Hay	12.00
Cane Fodder	8.00
Corn Fodder	10.00
Corn Silage	4.50
Soiling	4.00
Whole Milk, per 100 lbs.	2.00
Skim Milk, per 100 lbs.	.25
Sucking, per day	.06
Pasture, per day	.05

From the prices furnished and the amount of feed consumed by the heifers the cost of concentrates by six month periods and the feed cost of production of the heifers, by six month periods and cumulative from birth to producing age have been prepared.

Table X

Average Concentrate Cost per Heifer by Six Month Periods

Age Months	Cracked Corn $	Hominy Feed $	Ground Oats $	Wheat Bran $	Oil Meal $	Cottonseed Meal $	Total $
				Winter Calves			
0 -6	.70	.16	.59	.63	.58		2.66
6- 12	2.34	.29	1.34	1.54	1.23		6.74
12- 18	2.04	.18	.89	1.12	1.00	.14	5.37
18- 24	1.18	.02	.44	.70	.77	.08	3.19
24- 29	1.73	.04	.75	1.06	1.41	.33	5.32
				Summer Calves			
0-6	.87	.24	.62	.61	.48		2.82
6-12	1.98	.57	1.24	1.31	1.06		6.16
12-18	1.47	.25	.66	.75	.62	.03	3.78
18-24	2.18	.08	.70	.95	.82	.54	5.27
24-29	.92	.08	.61	.91	1.17		3.69
				All Calves			
0-6	.77	.19	.60	.62	.54		2.72
6-12	2.20	.41	1.31	1.45	1.17		6.54
12-18	1.81	.20	.80	.97	.82	.10	4.70
18-24	1.58	.04	.56	.82	.78	.26	4.04
24-29	1.40	.05	.69	.99	1.23	.21	4.57

Table XI

Average Feed Cost per Heifer by Six Month Periods

Age Months	Sucking	Whole Milk	Skim Milk	Concentrates	Silage	Soiling	Pasture	Alfalfa Hay	Cane Fodder	Corn Fodder	Total Cost
	$	$	$	$	$	$	$	$	$	$	$
Winter Calves											
0-6	.21	29.18	1.78	2.66	.33		.53	1.76			36.45
6-12		1.14	3.47	6.74	.95	.03	1.43	7.09	.13	.11	21.09
12-18				5.37	2.15	.10	2.63	8.43	.30	.76	19.74
18-24				5.19	1.36	.08	6.50	1.39	.13	2.51	15.16
24-29				5.32	4.41	.36	3.10	2.78	.28	1.20	17.45
Summer Calves											
0-6	.21	25.78	2.39	2.82	.14		.63	2.37			34.34
6-12		.52	3.07	6.16	1.16	.04	1.00	6.76			18.71
12-18				3.78	1.52		6.20	2.12	.06	1.14	14.82
18-24				5.27	3.91	.03	2.70	1.47	.81	3.68	17.87
24-29				3.69	3.32	.63	6.25	2.18	.00	.62	16.69
All Calves											
0-6	.21	27.82	2.02	2.72	.25		.55	2.00			35.57
6-12		.90	3.31	6.54	1.06	.03	1.25	6.93	.09	.07	20.18
12-18			.01	4.70	1.87	.06	4.10	5.90	.21	.91	17.76
18-24				4.04	2.38	.06	5.00	1.42	.40	2.97	16.27
24-29				4.57	3.97	.47	4.35	2.55	.16	.96	17.03

Table XII

Average Cumulative Feed Cost per Heifer

Age Months	Sucking	Whole Milk	Skim Milk	Concentrates	Silage	Soiling	Pasture	Alfalfa Hay	Cane Fodder	Corn Fodder	Total Cost
	$	$	$	$	$	$	$	$	$	$	$
Winter Calves											
0-6	.21	29.18	1.78	2.66	.32		.53	1.76			36.45
0-12	.21	30.32	5.25	9.40	1.28	.03	1.96	8.85	.13	.11	57.54
0-18	.21	30.32	5.25	14.77	5.43	.13	4.59	7.28	.43	.87	77.28
0-24	.21	30.32	5.25	17.96	4.79	.21	11.09	18.67	.56	3.38	92.44
0-29	.21	30.32	5.25	23.28	9.20	.57	14.19	21.45	.84	4.58	109.89
Summer Calves											
0-6	.21	25.78	2.39	2.82	.14		.63	2.37			34.34
0-12	.21	26.30	5.46	8.98	1.30	.04	1.63	9.13			53.05
0-18	.21	26.30	5.46	12.76	2.82	.04	7.83	11.25	.06	1.14	67.87
0-24	.21	26.30	5.46	18.03	6.73	.07	10.53	12.72	.87	4.82	85.74
0-29	.21	26.30	5.46	21.72	10.05	.70	16.78	14.90	.87	5.44	102.43
All Calves											
0-6	.21	27.82	2.02	2.72	.25		.55	2.00			35.57
0-12	.21	28.72	5.33	9.26	1.31	.03	1.80	8.93	.09	.07	55.75
0-18	.21	28.72	5.34	13.96	3.18	.09	5.90	14.83	.30	.98	73.51
0-24	.21	28.72	5.34	18.00	5.56	.15	10.90	16.25	.70	3.95	89.78
0-29	.21	28.72	5.34	22.57	9.53	.62	15.25	18.80	.86	4.91	106.81

Results Obtained

As has already been noted the heifers used in this study were liberally fed and so the actual feed cost of production will tend to be above rather than below the general average cost of feed required for producing heifers. For the total of forty heifers the average feed cost of raising them from birth to the time of freshening at the average age of twenty-nine months was $106.81, while the same figures for the winter and summer heifers were $109.89 and $102.43 respectively.

In view of present prices this may seem a high cost of production but it should be remembered that these heifers were fed liberally and it is liberal feeding that pays. The man who is raising heifers to bring into his own herd can not afford to stint them on feed as it is only where they have been well grown and liberally fed that the greatest production can be expected from them.

This was well illustrated in the case of work with scrubs reported by McCandlish, Gillette and Kildee (4). A number of scrubs reared under poor condition had been obtained and put with the purebred herd. Previously these animals had been very poorly fed but when put with the purebred herd at Iowa State College they were given good feed and care. These scrubs can be divided into three age groups, heifers, four-year olds, and mature cows, according to the age at which they reached the station.

A summary of all the records made by the animals in the three groups, after a correction for age has been made, shows that those coming as mature cows had an average production of 3168.7 pounds of milk and 153.64 pounds of butterfat, while the four-year olds averaged 3597.7 pounds of milk and 166.36 pounds of butterfat, and the heifers 4036.1 pounds of milk and 191.21 pounds of fat. In other words, the cows that had not received good feed until they were mature, were the poorest producers and taking their production as the basis of comparison, it is found that the four-year olds produced 14 per cent more milk and 8 per cent more fat, while the heifer group produced 27 per cent more milk and 24 per cent more butterfat. This clearly shows that heifers must be well fed from birth to give maximum yields of milk and fat when they reach producing age.

The largest items in the feed cost of raising the heifers were whole milk, concentrates and alfalfa hay, and it was in these three items only that the higher cost was found for winter than for summer heifers, even though the feeds were charged at the same price at all times.

Whole milk is an expensive feed at all times but if heifers are to be raised well, its liberal use is justified in many cases. The winter heifers received more whole milk on the average than did the summer calves, as they were longer in being turned to pasture. The same facts hold true for the concentrates and the alfalfa hay. Though alfalfa hay is not advocated for calves in this section, yet it was necessary to feed it to all

classes of young stock, as it was grown for the milking herd and older heifers and the inclusion of clover hay production in the rotation would have rendered the farming operations more cumbersome.

Table XIII

Average Feed Cost per Pound of Live Weight Gain by Six Month Periods

Age Months	Winter Calves	Summer Calves	All Calves
	¢	¢	¢
0-6	14.6	14.0	14.4
6-12	8.5	8.1	8.3
12-18	10.9	9.4	10.3
18-24	8.8	10.2	9.4
24-29	19.8	24.9	21.6

Table XIV

Average Cumulative Feed Cost per Pound of Live Weight Gain

Age Months	Winter Calves	Summer Calves	All Calves
	¢	¢	¢
0 - 6	14.6	14.0	14.4
0 - 12	11.5	11.1	11.4
0- 18	11.4	10.7	11.1
0 - 24	10.9	10.6	10.7
0 - 29	11.7	11.7	11.7

It has been noted that the feed cost of growing fall and winter dropped calves to producing age was greater in this work than was the cost of growing spring and summer calves to producing age, though the average age of freshening was the same for both groups, twenty-nine months, and it is generally conceded that the raising of fall and winter calves is the more profitable proposition. There are certain factors regarding weather conditions and the amount of labour available which do render the raising of fall and winter calves the better proposition but here the feed cost only will be considered.

It will be found by studying the feed cost per pound of live weight gain that for each six month period, up to eighteen months of age, the feed cost per pound of gain was greater in the case of the winter heifers, but from that age until freshening the feed cost per pound of gain was lower in the case of the winter heifers. Of more importance however, is the fact that from birth to freshening, at the average of twenty-nine months the average feed cost per pound of live weight gain was the same for each group - 11.7 cents.

Consequently, the fall and winter dropped calves were the better proposition, as at the age of freshening they had reached a greater weight than the spring and summer born heifers, and had been produced at the same feed cost per pound.

Summary

As a result of the study of the feed cost of growing forty dairy heifers from birth to freshening, the following statements may be presented for consideration.

1. Of the forty heifers studied, twenty-four, dropped between October 1 and March 31, were classed as winter heifers, while the remaining sixteen, dropped between April 1 and September 30, were classed as summer heifers.

2. The average age of freshening in each lot was twenty-nine months; each month being a period of thirty days and not a calendar month.

3. The average birth weights were 68 pounds for the winter heifers, 64 pounds for the summer heifers and 67 pounds for all of the animals.

4. The average weights at freshening were 1010 pounds, 941 pounds and 982 pounds for the winter, summer and all groups respectively, while the average live weight gains from birth to freshening for these groups were 942 pounds, 877 pounds and 915 pounds.

5. For average daily live weight gains through the trial the winter heifers led with 1.09 pounds, while the summer heifers had 1.01 pounds, and the average for all was 1.05 pounds.

6. In total feed cost of production the ranking was winter heifers $109.89, summer heifers $102.43 and all heifers $106.81 each.

7. The average feed cost per pound of increase in live weight was 11.7 ¢ in all groups.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

V. MILK AS THE SOLE RATION FOR CALVES

Studies in the Growth and Nutrition of Dairy Calves

V. Milk as the Sole Ration for Calves

From time immemorial milk has been regarded as the feed best adapted to the complete nourishing of mammalia. It is the sole ration of all mammals during the earlier part of their post-natal development and is also recognized as an excellent staple in the diet of the adult human, especially in the case of invalids. On the farm it is used extensively in the feeding of young animals, and in the case of the hog it is fed in large quantities to more mature individuals.

Within the last decade much investigational work has been done concerning the nutritive value of milk and other feed stuffs. The major portion of this work has been conducted with laboratory animals and no attention has been paid to some of the factors which determine to a large extent the value of milk to certain types of livestock. The object of the work reported here was to determine the value of milk as the sole ration for calves.

Resume of Previous Work

The nutrients recognized as essential to the welfare of the animal organisms are carbohydrates, fats, proteins, ash, water and the food accessories or vitamines. The proximate composition of milk, showing the average amounts of the most abundant constituents present, is given in the first tabulation.

Table I.

Average Composition of Milk (16)

Constituent	%
Water	87.17
Fat	3.69
Casein	3.02
Albumen	.53
Sugar	4.88
Ash	.71

The proteins, fats and carbohydrates are present in the proportions that are recognized as being suited for the growth of young animals and the ash constituents are also abundant.

Within recent years it has been shown that all proteins are not of equal value for nutritional purposes as the nutritive value of a protein is determined by its amino-acid constitution. Some proteins are inadequate due to the fact that they do not contain all the amino-acids necessary for the life, growth and normal physiological development of animals. However, it has been shown by McCollum(11) that the milk proteins are adequate, that is, they will in the presence of a sufficiency of non-protein and inorganic nutrients, support life, promote growth, and foster all normal physiological functions.

The ash is another feed constituent which, tho present in sufficient quantities, may not be qualitatively suited to the requirements of the animal, but it has been proved by Osborne & Mendel (13) that the ash of milk satisfactorily meets the demands of the young growing animal, providing in the proper proportions all of the inorganic constituents needed for the proper functioning of the animal body.

Another factor recognized as limiting the nutritive value of feeds is the presence or absence of the vitamines, Fat-Soluble A Water-Soluble B and Water-Soluble C. The fact that Fat-Soluble A is present in abundance in milk has been proved many times as can be seen from the compilations of Blunt & Wang (1 and 2).

Milk is not too rich in Water-Soluble B, according to Osborne, Mendel, Ferry & Wakeman (14) but there should have been sufficient of it supplied, according to McCollum, Simmonds & Pitz (12), to satisfy the experimental animals. It is perhaps true however, that insufficient amounts of Water-Soluble C were present according to Chick, Hume, Skelton & Smith (3 and 4).

Thus far only work conducted with laboratory animals has been mentioned as this leads up to and helps to explain some of the results obtained on using rations from limited sources with farm livestock. In addition to its chemical character a ration must be of the proper physical nature before it supplies the needs of farm livestock.

In only a few instances have records been obtained of ruminants being fed for any considerable time on rations consisting entirely of feeds of the same physical character, but Sanborn (15) reports that in the case of both sheep and cattle fed on grain the stomachs weighed less than normal and this was most noticeable in the case of the rumen - the stomach compartment specially adapted for the handling of bulky material. Davenport (5) found that calves could not be raised on a ration consisting of milk alone or grain alone and he also noticed that as a rule no digestive disturbances accompanied such a ration.

Work of McCollum, reported by Henry (6) apparently showed that a sow pig was able to reach maturity and reproduce normally when fed milk alone.

Experimental Work

In the work reported here, two bull calves were used and they were fed on milk alone from birth until the time of their death. The animals are described in Table II.

Table II

Animals Used

Calf No.	355	366
Breeding	Grade Jersey	Grade Holstein
Date of Birth	9-25-16	12-17-16
Birth Weight	65 lbs.	90 lbs.

Both calves were allowed to remain with their dams for a few days after birth and were then put on a whole milk ration. The amount of milk fed was limited to what the calves seemed able to handle satisfactorily and tho they might possibly have become accustomed to larger quantities, it was deemed advisable to keep their consumption of milk comparable to that of other animals of similar weight in the herd and thus prevent digestive troubles as far as possible.

No roughage, grain or water was offered to either of the calves, and at first no salt was given, but from the time calf No. 355 was 70 days old, a salt roll was kept in fromt of him at all times and the same treatment was given calf No. 366 from the time he was 30 days old.

The calves were kept in a pen bedded at first with shavings and later with sand, as they showed a tendency to eat the shavings. Their feed consumption by ten-day periods is given in Table III.

Table III

Feed Consumption by Ten - Day Periods

Period No.	Calf No. 355		Calf No. 366	
	Milk lbs.	Salt lbs.	Milk lbs.	Salt lbs.
1	36		90	
2	90		90	
3	90		90	
4	90		90	.04
5	128		111	.05
6	120		129	.06
7	120		150	.04
8	126	.32	150	.03
9	146	.25	150	.11
10	150	.17	150	.21
11	150	.05	150	.10
12	150	.02	150	.05
13	150	.04	150	.04
14	150	.06	150	.03
15	141	.05	150	.03
16	120	.03	150	.02
17	120	.07	174	.03
18	120	.18	108	.03
19	123	.17		
20	142	.02		
21	99	.03		

In the first 10-day period calf No. 355 sucked for 6 days and No. 366 for 3 days. The last period for No. 355 contains only 8 days and that for No. 366 only 6 days, as No. 355 died when 208 days old, and No. 366 at the age of 176 days.

It will be noted that up until he was about 100 days old, No. 355 had an increasing capacity for milk, but from that time the appetite remained regular for a little over a month and then declined, tho there was an increase in milk consumption for a week or so before death. In the case of No. 366, maximum capacity was reached earlier and remained constant until about the same length of time before death, when it again increased.

The animal, No. 355, that received no salt until 70 days old, showed an enormous appetite for salt during the first 30 days in which it was available. From this time on his salt consumption decreased and with the exception of a short time between the ages of 170 and 190 days it did not again reach a marked elevation during the experiment. Calf No. 366 received salt earlier in his life and did not at any time have such an excessive consumption, tho between the ages of 80 to 110 days his consumption of salt was large.

There were no marked digestive disturbances, except in the case of calf No. 366, which was bloated for a few days before death, the bowels of the animals being usually laxative, tho not noticeably so. The faeces were rather foul smelling. The calves

showed by their actions that their rations were not entirely complete. They ate to a slight extent the shavings that were at first used as bedding, gnawed the wood in the walls of the pen, and licked the hair from each other. These substances, however, were not consumed in amounts sufficient to cause very noticeable digestive derangements.

Records of the live weights and body measurements of the calves obtained every thirty days are given in Table IV. The live weights given are the averages for three successive daily weighings. The body measurements taken were height at withers, depth of chest and width at hooks. For the sake of comparison, the measurements of the heifer calves in the herd fed normal rations are given. Difference in sex will not have much influence on these figures for comparative purposes owing to the sexual immaturity of the animals and also to the fact that calf No. 355 was castrated when 22 days old.

Table IV

Live Weights and Body Measurements

Age Days	eight lbs.	Height in.	Depth in.	Width in.	Weight lbs.	Height in.	Depth in.	Width in.	Weight lbs.	Height in.	Depth in.	Width in.
Birth	65				90				87			
30	76	29.9	12.6	7.1	103	28.0	14.3	7.5	90	28.7	11.4	6.7
60	107	31.1	13.0	7.5	139	30.3	14.8	7.9	120	30.7	12.8	7.5
90	132	32.3	13.8	7.9	165	32.7	14.7	8.7	163	32.9	14.2	8.5
120	145	33.9	15.0	8.3	174	35.0	15.7	8.7	211	34.8	15.4	9.4
150	144	35.0	15.4	8.3	172	35.4	15.7	9.1	262	36.4	16.7	10.2
180	137	34.6	15.0	8.3					314	38.4	17.9	11.2

It can be seen that the experimental animals grew fairly well until they were two to three months of age, but from this time on they did not thrive. They continued to gain slowly in weight for another thirty days, after which their live weights decreased gradually until the time of death. The body measurements appeared to increase about normally until the time the live weight increase ceased to be rapid and from this time on the measurements changed only slightly--in fact they were almost constant. A greater increase in height than is shown by the figures probably did occur, but owing to the fact that the animals began to go down on their pasterns about the time the live weight ceased to increase, the true height could not be accurately measured.

The increases in live weight and body measurements can be more easily appreciated when they are shown as percentages of the original figures, as in Table V. The increases in live weight from birth to the end of the last completed thirty-day period in the case of the experimental animals, and to the ages of five and six months in the case of the herd average, are expressed as percentages of the birth weights, while the body measurements are compared in the same way from the time the animals were thirty days of age.

Table V

Percentage Increase in Live Weight and Body Measurements

Calf	Age	Weight	Height	Depth	Width
	Months	%	%	%	%
Experimental					
No. 355	6	111	14	19	17
No. 366	5	91	27	11	21
Herd Average	6	369	34	57	67
	5	291	27	47	52
Percentage of Normal Rate of Increase					
No. 355	6	30	41	33	25
No. 366	5	31	100	23	40

During their lifetimes the experimental animals practically doubled their live weights, while during similar lengths of time calves normally fed attained weights more than four times as great as their birth weights. Similarly the increases in body measurements in the case of the calves fed milk alone were much less than normal, except in the case of the height of calf No. 366, which was normal. Of the increases in body measurement, the height was the most nearly normal, while width was farthest from it, and as a general rule the rates of growth in the body measurments showed less variation from normal than did the rate of gain in live weight.

In addition to the variations in weight and body measurements there were other abnormal symptoms which tho very appreciable were not capable of being directly measured or determined. The animals became very much emaciated and quite unthrifty in appearance. Their coats were long and staring and the hair fell out freely. Patches of the body became practically devoid of hair and sores were also apparent. As has already been mentioned, the animals were down on their pasterns and could not stand up properly and they walked with a very stiff gait.

One very noticeable feature of the experiment was the occurrence of fits. These fits were first apparent when the animals were between three and four months of age and continued to occur at frequent but irregular intervals up until about three weeks before the animals died. These fits were all very similar

and frequently started for no apparent reason and could almost always be induced by leading the animal around for a few minutes. The animal would fall down and bellow as if in pain; the jaws would stick open and the legs become rigid; the muscles became tense and hard; respiration slowed and in severe attacks entirely stopped. Where respiration did not stop the animal would recover in a few minutes, and where breathing ceased, artificial respiration had to be resorted to, to resuscitate the calf. The fits were practically identical with those of an epileptic nature.

Post-Mortem examination of both calves were made. The bones of No. 355 were very flexible as if insufficient ash were present; the leg bones could be bent comparatively easily, while the ribs had a very thin coating of hard material with a soft core. None of the bones were as rigid as would be expected in an animal of similar age. There was one atrophied kidney (perhaps congenital) with hypertrophy of the other. The mesenteric lymph glands were much enlarged and there was an apparent leucemia. The rumen was of normal size, but the walls were evidently atonic, due apparently to a development of lymphoid tissue. The omasum was smaller than would be expected, tho the two remaining compartments of the stomach appeared to be normal. The contents of the rumen resembled thin cottage cheese mixed with hair.

The bones of calf No. 366 appeared to be in fairly good con-

dition, tho one or two of the ribs might previously have been broken and healed. The mesenteric lymph glands were enlarged and both kidneys were in bad condition with cysts. All the stomach compartments were of about normal size, but there were streaks of dark brown or black pigment on the inner wall of the abomasum. The contents of the rumen were similar to those in the case of calf No. 355.

Discussion of Results

Whole milk, tho apparently giving good results until the animals are about three months old, very probably cannot be relied on as the sole ration for calves of greater age. Its inability to properly nourish older calves may be due to one or more of a number of factors.

Cattle and other ruminants begin to consume roughages at an early age and the lack of roughage may consequently give an explanation of the results obtained in this work. In addition the quantity and quality of the nutrients supplied may be of importance as well as the supply of nutrients.

In Table VI are given the requirements of young growing dairy calves according to the modified Wolff-Lehmann feeding standard as outlined by Henry & Morrison (7).

Table VI

Nutrients Required Daily by Young Growing Calves per 1000 pounds Live Weight

Weight	Dry Matter	Digestible Nutrients	
		Crude Protein	Total
lbs.	lbs.	lbs.	lbs.
150	23	4.0	22.0
300	24	3.0	18.3
500	27	2.0	15.8

From the data supplied the nutrients required by, and actually supplied to the experimental calves have been calculated. In this table the animals have been taken together rather than individually and the milk consumption is taken for all 30-day periods which were completed. It was assumed that the daily milk consumption of the calves while sucking was the same as in the succeeding days of the first 10-day period.

Table VII

Nutrients Required by and Supplied to Calves

Age	Average Live Weight	Milk Supplied	Nutrients Supplied			Nutrients Required		
				Digestible			Digestible	
			Dry Matter	Crude Protein	Total	Dry Matter	Crude Protein	Total
Days	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1-30	168	579	79	19	104	116	19	109
31-60	213	668	91	22	120	150	23	133
61-90	272	842	115	28	151	195	26	149
91-120	309	900	122	30	161	223	27	169
121-150	318	873	119	29	166	228	28	173

The actual surplus or deficit of nutrients supplied will be more valuable for comparative purposes and this is obtained by summarizing the data just presented.

Table VIII

Excess of Nutrients Supplied to Calves.

Age	Dry Matter	Digestible Nutrients	
		Crude Protein	Total
Days	lbs.	lbs.	lbs.
1-30	-37	0	5
31-60	-59	1	13
61-90	-80	-2	-2
91-120	-101	-3	-8
121-150	-147	-1	-7

Considerable variations are noticeable in the amounts of the nutrients supplied but the importance of these variations is perhaps best demonstrated when the oversupply or deficiency is expressed as a percentage of the actual amount required by the calves.

Table IX

Excess of Nutrients Supplied to Calves
Expressed as a Percentage of the Requirements

Age	Dry Matter	Digestible Nutrients	
		Crude Protein	Total
Days	%	%	%
1-30	-33	0	5
31-60	-39	4	10
61-90	-41	-8	-1
91-120	-45	-11	-5
121-150	-66	-1	-4

It is evident that from the beginning the calves were not receiving sufficient dry matter in their rations. The average amount of dry matter supplied in the first 30 days was 33% below that required by the animals and this deficiency continued to become greater until in the fifth 30-day period it amounted to 66%.

During the first two 30-day periods the calves received sufficient digestible crude protein and total digestible nutrients but from then on these constituents were deficient in the rations but never to such a great extent as was the dry matter. The calves were being given all the milk they could handle but were supplied with no bulky feed to supply them with the extra dry matter needed. The lack of this dry matter, which would have provided additional bulk, impaired the digestive powers of the animals and rendered them unable to handle sufficient milk to provide all the digestible nutrients they required. This in turn led to poor growth and development.

The digestive tract of a ruminant is large and capacious and before digestion can be normal, bulky feeds must be present to distend the digestive organs, stimulate peristalsis, separate the particles of more concentrated feeds and so allow of their being properly mixed with and acted on by the digestive fluids. Milk, being highly digestible and free from fibrous material, is not a "bulky" feed, tho its nutrients are present in a

rather large volume of water, and so it cannot, when fed alone, induce the digestive system of older ruminants to function properly, tho it is quite efficient with young calves, as in their case the rumen is relatively smaller in comparison with the rest of the digestive tract than it becomes ultimately.

Where digestion is retarded or hindered, as would occur when the digestive system became atonic due to the absence of roughage, the materials not completely acted on by the digestive juices would remain in the alimentary canal and undergo putrefactive changes. The products of such putrefaction are toxic and when absorbed from the alimentary canal can produce auto-intoxication, with symptoms similar to those found with the experimental animals in this case.

Another fact worthy of note is that these calves were at times, when averaging about 150 pounds in live weight, consuming over half as much salt per day as would a 1,000-pound animal. It has been found at this station that normally fed calves of similar weight will consume about .01 pounds of salt per day, while the experimental animals consumed as much as .03 pounds per day.

This excessive salt consumption may have been an attempt to correct digestive disturbances, or it may have been caused by other physiological demands, or it may simply have been due to the calves forming a pernicious habit.

That sodium chloride can produce tetanic convulsions such as were evident in the case of the experimental calves has been shown on several occasions. Loeb (8) demenstrated the contractions and final tetanus of muscles in contact with certain salt solutions and he later (9) showed that solutions of common salt could cause rhythmical twitchings and an increase in the concentration of sodium ions and can be counteracted by the addition of calcium salts. It has also been pointed out by MacCallum (10) that intravenous injections of solutions of sodium chloride increase peristalsis. There is a possibility, therefore, that the fits to which the experimental calves were subject may have been due in some way to excessive salt consumption.

It has been pointed out previously that the vitamines, Water-Soluble B and Water-Soluble C may not be present in milk in sufficient amounts for the continued well-being of the experimental animals. Further work is needed to determine whether each or all of these factors mentioned here were responsible for the unthriftiness, mal-nutrition and ultimate death of the animals used in this work.

Summary

From the evidence obtained in this work the following factors may be looked on as possible causes of milk being unable to supply all the nutritional wants of calves after they are a few weeks old.

1. The lack of bulk may arrest the development of the alimentary tract and prevent the proper digestion of the nutrients supplied by the milk.

2. Excessive consumption of salt, due to depraved appetite, or to an attempt on the part of the calves to correct nutritive disturbances, may have led to some of the distrubances noted.

3. The vitamines, Water-Soluble B and Water-Soluble C, may have been present in insufficient amounts and this may have induced the death of the calves.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

VI. THE ADDITION OF HAY AND GRAIN TO A MILK RATION FOR CALVES.

Studies in the Growth and Nutrition of Dairy Calves

VI. The Addition of Hay and Grain to a Milk Ration for Calves.

The necessity of investigating the effects of rations selected from limited sources is now recognized as of vital importance in arriving at a true idea of certain nutritional processes. In order to determine the true or relative value of any feed for a given class of animals, it is necessary that it be fed with a wide variety of other feeds and also as the sole constituent of the ration, if it is of such a nature as to render this possible. A thorough understanding of the physiological value of any feed can only be arrived at after a series of correlated investigations, the results of which can be studied as a group.

The work outlined here was undertaken to expand results reported in Paper V of this series and to determine the relative values of rations consisting of milk, milk and mixed grains, and milk and alfalfa hay for young calves.

RESUME OF PREVIOUS WORK

Investigations bearing directly on the problem under consideration are limited in number as little work of this character has been undertaken with farm live stock. There are however, reports of investigations with laboratory animals which

aid to some extent in the explanation of the results obtained.

The results available on the use of limited rations for ruminants are meagre. Plumb (20) fed one pen of calves on whole milk and two pens on skimmilk, for a period of two to three months without observing any bad effects from the limited ration. Sanborn (21) placed a calf weighing 180 pounds on a ration of milk and grain, and the animal is reported to have eaten the sawdust used as bedding and died of indigestion.

In an attempt to grow cattle without the use of roughages, Davenport (8) found that grain fed in amounts up to half a bushel daily to a five-months old calf did not satisfy the craving for feed. Disturbances of the nerve centers and swelling of the joints were noticed. A second calf, fed exclusively on skimmilk until seven months of age, when it was in quite poor condition, was then placed on coarse feed and recovered rapidly. A third individual, fed milk and grain, was extremely reduced in condition at five months of age, but recovered when allowed hay. A fourth calf, which received no roughage, died at three months of age. A post-mortem examination showed that the muscles were hard and firm and no internal fat was present.

That growth and reproduction were seriously affected by limiting the ration of dairy heifers to the products of a single cereal plant was found by Hart, McCollum, Humphrey & Steenbock (14,15). It was also reported in Paper V of this

series that calves could not exist for extended periods on a ration of whole milk alone.

In an investigation with hogs, Burnett (4 & 5) found that limiting the ration to corn markedly affected bone growth and development and the breaking strength of the bones of the legs. In the case of work done by McCollum and reported by Henry (16) it was found that a sow could be raised to maturity and reproduce normally with milk as the sole feed, though Evvard and Glatfelter (11) report that better success was obtained in the raising of orphan pigs where eggs, tomato juice or orange juice were added to the ration than where milk alone was fed.

It has been stated by Forbes (12) that the specific effects of feeds on growing animals are due largely to the mineral elements in the feed and especially to the relation between the calcium and magnesium, while the importance of the vitamines has been emphasized by many and the work of this character, though little of it with ruminants, has been summarized quite completely by Blunt & Wang (2 & 3). However, Dutcher, Kennedy & Eckles (10) report that the milk of cows on pasture is richer in water soluble C than is that of cows on winter feed.

EXPERIMENTAL WORK

In this work six calves were used, of which five were bulls and the other was presumed to be a freemartin as it was twinned with a bull. All but the freemartin were grades. The

calves were allowed to suck their dams for a few days after birth and were then put on the experimental rations. They were divided into three lots and information concerning the individuals is given in the first stable.

Table I

Animals Used

Lot No.	I		II		III	
Ration	Milk		Milk & Mixed Grain		Milk & Alfalfa Hay	
Calf No.	479	489	498	502	488	495
Breed	Grade Guernsey	Grade Holstein	Grade Jersey	Grade Guernsey	Grade Holstein	Holstein
Birth Weight Lbs.	76	85	51	68	66	65
Sucking Days	4	3	5	6	2	5

After the calves were taken from their dams, milk was fed to them three times daily in amounts indicated by their ability to handle it. Salt was accessible at all times and they had access to water for several hours daily though they were confined in pens. In addition, Lot II was allowed to consume at free will a grain mixture consisting of 5 parts cracked corn, 2 parts ground oats, 2 parts wheat bran and 2 parts old-process linseed oil meal by weight, while Lot III always had access to alfalfa hay.

Complete records of feed consumption were kept and these have been combined by 30-day periods throughout the various experiments. The weights of the animals were determined on three successive days in the middle of each period and from these the live weights at the end of each experimental period were determined. Body measurements were obtained in a similar manner though only taken on one day. In the final computations it was assumed that the milk consumed during the few days that the animals sucked their dams was the same in amount as that consumed in a like period after hand feeding was started.

The calves did not all start on experiment at the same time, due to differences in date of birth, but in the tabulations they are kept together on the age basis. The inequalities near the finish are due to the fact that the experiments were all closed about the same time irrespective of the ages of the calves. However, to avoid complications, the records for the

animals which lived throughout the work are given to the end of the last thirty-day period that was completed.

Rations

Lot I - Milk. The calves in this group were fed a ration of whole milk throughout the trial. When they became weak and low in condition, alfalfa hay was introduced into the ration. This introduction took place at the beginning of Period VIII for calf No. 479 and on the nineteenth day of Period VI in the case of calf No. 489. For a few days the allowance of hay was limited and then it was given at free will.

Lot II - Milk and Grain. This group received milk throughout the experiment and in the latter part of Period II the grain mixture was introduced and kept before the animals at all times. Calf No. 502 died on the sixteenth day of Period V after consuming little feed during the last two weeks of its life. At the beginning of the sixth period, alfalfa hay was given to Calf No. 498, at first in limited amounts, and later at free will.

Lot III - Milk and Alfalfa. These calves had milk throughout the experiment, and alfalfa hay was introduced in the latter part of the first period for calf No. 495 and in the early part of the second period for calf No. 498 and from then on was allowed at free will.

Table II

Feed Records

Feed	Whole Milk		Alfalfa Hay		Mixed Grain		Salt		Notes
Lot I - Milk Ration									
Calf No.	479	489	479	489	479	489	479	489	
Period	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
I	351	333					.01	.21	
II	450	489					.39	.09	
III	482	599					.10	.18	
IV	540	630					.10	.33	
V	630	630					.29	.27	
VI	630	630		x45			.26	.18	x Last 12
VII	630	630		149			.17	.10	days of Period
VIII	630	630	86	204			.10	.04	VI for Calf
IX	630		121				.15		No. 489
Lot II - Milk and Mixed Grain Ration									
Calf No.	498	502	498	502	498	502	498	502	
Period									x Calf No.
I	218	216					.04	.06	502 died on
II	246	267			2	10	.09	.08	the 16th day
III	270	270			26	32	.12	.06	of Period V
IV	270	270			60	50	.04	.02	and for two
V	270	x30			82	x2	.02	x.01	weeks prior to
VI	270		59		57		.08		this consumed
VII	270		108		30		.10		little feed
Lot III - Milk and Alfalfa Ration									
Calf No.	488	495	488	495	488	495	488	495	
Period									
I	298	307		9			.02	.04	
II	462	450	27	36			.02	.05	
III	450	450	73	96			.11	.08	
IV	450	450	184	168			.11	.11	
V	450	450	264	220			.19	.26	
VI	450		313				.45		

Growth of Calves

The records of the increase in live weight and body measurements of the calves are indications of the suitability of the rations for the calves. For this reason the birth weights of the calves and their weights at the end of each completed thirty-day period are given, as are the body measurements taken, height at withers, depth of chest and width at hooks.

In order that some idea may be gained as to the relative rates of increase in live weight and body measurements of the calves it is necessary that some standard be used with which they may be compared. For this purpose the averages of similar measurements obtained on 40 normally fed heifers are included. This should form a satisfactory basis of comparison as all the experimental calves were young and the bulls were castrated so that it is not probable that sexual development would cause the two groups of figures to vary relatively.

Table III
Live Weights and Body Measurements of Calves

Group	Normal	Lot I		Lot II		Lot III	
Calf No.		479	489	498	502	488	495
		Live Weight					
Period	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Birth	67	76	85	51	68	66	65
I	90	94	123	69	71	133	95
II	120	124	162	92	83	166	143
III	163	161	217	128	112	241	210
IV	211	177	271	165	113	322	266
V	262	212	315	187		399	339
VI	314	252	382	220		469	
VII	366	265	462	253			
VIII	413	289	530				
IX	452	323					
		Height at Withers					
Period	in.	in.	in.	in.	in.	in.	in.
I	28.7	30.4	29.9	26.5	28.1	29.1	28.6
II	30.7	31.5	32.5	27.5	29.0	31.4	30.7
III	32.9	33.3	35.0	29.4	30.4	33.5	32.2
IV	34.8	34.1	37.0	30.9	30.7	35.7	35.7
V	36.4	35.2	38.7	33.5		38.0	39.0
VI	38.4	36.4	40.5	35.0		40.8	
VII	39.8	40.2	42.6	36.2			
VIII	41.0	40.4	44.3				
IX	42.0	42.0					
		Depth of Chest					
Period							
I	11.4	12.1	13.0	10.2	11.0	12.1	11.9
II	12.8	13.5	14.0	11.5	11.3	13.9	13.0
III	14.2	14.9	16.0	13.1	13.2	15.8	15.1
IV	15.4	15.7	17.2	14.4	13.8	17.1	16.6
V	16.7	16.7	18.4	15.0		18.2	17.8
VI	17.9	17.8	19.3	15.5		20.0	
VII	18.7	18.7	20.3	16.2			
VIII	19.5	18.6	20.5				
IX	20.3	19.3					
		Width at Hooks					
Period							
I	6.7	6.5	7.4	5.9	6.3	6.8	6.9
II	7.5	7.3	8.6	7.0	6.9	7.8	8.0
III	8.5	8.0	9.8	8.1	7.1	9.0	9.6
IV	9.4	8.3	11.1	8.7	7.1	10.4	10.9
V	10.2	8.9	11.1	9.1		11.9	11.4
VI	11.2	9.8	11.4	10.0		13.0	
VII	11.8	9.9	12.4	10.4			
VIII	12.6	10.4	13.2				
IX	13.2	11.1					

Live Weights and Body Measurements. When Lot I is considered it is found that both animals is this group were heavier at birth than the average for the normal group. Calf No. 479 maintained its lead for only two months and then dropped below normal and continued to do so until alfalfa hay was introduced at the beginning of Period VIII when it started to regain in rate of growth, Calf No. 489, the heaviest of all, increased in live weight slowly and at the end of Period V was of the same weight as the normal calves were at the end of Period VI. During Period VI, alfalfa was introduced and it immediately started to gain rapidly.

Both animals in Lot II, though one was heavier and one lighter than the average for the normal group, fell far behind the normal weights as the work progressed. The calf No. 502 died, while No. 498 was given alfalfa at the end of Period V and when the trial closed at the end of Period VII it was beginning to approach the normal group in weight.

The alfalfa fed animals in Lot III, though slightly lower in birth weight than the average for the normal group, always exceeded the normal group in live weight from the end of Period I.

In regard to the body measurements it may be said that they did not vary uniformly though there was a very decided increase in the rates of growth of the calves in Lot III compared with the normal calves, while the calves in Lot II lagged behind the check. The calves in Lot I did not show a great variation from the check group.

Increase in Live Weight and Body Measurements. The animals in Lot III, fed alfalfa and milk throughout, showed a greater percentage increase in live weight and body measurements than did the normal group. In Lot II, calf No. 502 showed a slower percentage increase than normal and eventually died. The other animal in this lot, calf No. 498, showed slow percentage gains in height but the other measurements were near normal, while the percentage increase in body weight was accelerated by the introduction of alfalfa hay into the ration. In Lot I the percentage increases in live weight were good towards the start but started downwards and then recovered greatly on feeding alfalfa hay, the greatest recovery being in the case of the calf started on hay at the younger age. In the body measurements of this group the tendencies were quite similar.

Table IV

Percentage Increase in Live Weights and Body Measurements.

Group	Normal	Lot I		Lot II		Lot III	
Calf No.		479	489	498	502	488	495
	Increase in Live Weight						
Period	%	%	%	%	%	%	%
I	34	24	45	35	4	71	46
II	79	63	91	80	22	152	120
III	143	112	155	151	65	265	223
IV	215	120	219	224	66	388	309
V	291	179	271	267		505	421
VI	369	232	349	331		611	
VII	446	249	444	396			
VIII	516	280	524				
IX	575	325					
	Increase in Height at Withers						
Period							
II	7	4	9	4	3	8	8
III	15	10	20	11	8	15	13
IV	21	12	24	17	9	23	25
V	27	9	29	26		31	36
VI	34	20	36	32		40	
VII	39	32	43	37			
VIII	43	33	48				
IX	46	38					
	Increase in Depth of Chest						
Period							
II	12	12	8	13	3	15	9
III	25	23	23	28	20	31	27
IV	35	30	32	41	25	41	39
V	47	38	42	47		50	50
VI	51	47	48	52		65	
VII	64	55	56	59			
VIII	71	54	58				
IX	78	60					
	Increase in Width at Hooks						
Period							
II	12	12	16	19	10	15	16
III	27	23	32	37	13	32	39
IV	40	28	50	47	13	53	58
V	52	37	50	54		75	65
VI	67	51	54	69		91	
VII	76	52	58	76			
VIII	88	60	78				
IX	97	71					

Condition and Behavior of Calves.

Certain results brought about by the rations fed to the animals were most noted in physical characteristics, other than weight and body measurements, and in their body activities and general behavior.

Lot I - Milk. In the early part of Period III, calf No. 479 showed a ravenous appetite for shavings and started to eat hair from No. 489 and the faeces were very thin. The animal was quite thin but the muscles were firm. By the beginning of Period IV, No 479 began to lie down considerably. The faeces were watery and slate grey in color. The muscles were firm but there was no apparent body fat and the calf started to chew the wooden walls of the pen. In Period VI, No. 479 had taken practically all the hair from the back of No. 489 and attempted to cud. This was probably due to the hair and wood eaten.

In Period II, calf No. 489 showed a depraved appetite and in the early part of Period III became weak in the knees when led, and down in the front pasterns. Later in the period its gait became stilted and the legs were stiff at the knees and hocks. The skin was very sensitive and twitched when touched, especially along the spinal column. By Period V, calf No. 489 had become quite listless but was eratic to handle.

Within a few hours of the introduction of alfalfa hay to the ration, these calves were chewing the cud and continued to improve from that time on.

Lot II - Milk and Grain. The calves in this group may be treated separately. In the early part of Period III, calf No. 498 had a good appetite and was in good condition but showed a craving for roughage. It chewed its cud slightly, probably due to eating shavings used as bedding at that time, but they were removed. In the early part of Period V the leg joints became swollen and the calf could not stand straight. The knees were bowed outward and forward. The appetite was good but the faeces thin. When this calf was put on hay at the beginning of the sixth period, it began to improve and at the end of Period VII it was in good condition.

In the early part of Period II, calf No. 502 began to chew the boards of the pen and to cud to a small extent. At this time it had a good appetite though it was thin and its hair on end. Its vitality kept lowering until in the early part of Period V it began to bloat and this eventually became habitual and caused must pain. It became weak in the legs, unable to rise, eventually lost all control of the hind quarters, and died.

Lot III - Milk and Alfalfa Ration. The animals in this group were in good thrifty condition throughout the trial and always maintained a sleek glossy coat. Their faeces were normal though alfalfa hay in this section is sometimes not the best for calf raising as it at times tends to produce scours.

Post-Mortem Examination of Calf No. 502 in Lot II. A post-

mortem examination was conducted on calf No. 502 immediately after death, by Drs. B. A. Benbrook and H. D. Bergman of the Veterinary Division.

The Stomach. In the stomach as a whole the mucous membrane, folds and papilli were all apparently normal. The musculature of the wall of the rumen was not well developed. The rumen was about one-third undersized and distended with gas. The contents were dry and consisted mainly of oat hulls and some grain. The musculature of the wall of the reticulum was not normally developed, but the compartment approached nearer to normal than did the rumen. The omasum was also undersized. The abomasum was apparently fully developed and contained about a quart of fluid very similar in appearance to bile and contained a sediment of cinders showing that a depraved appetite had caused the calf to eat the cinders used for bedding in the latter part of the experiment. Derangement of the mechanism of the pylorus or hyperacidity of the stomach might explain the presence of the bile-like fluid in the abomasum.

The Intestine. Catarrhal enteritis was apparent throughout the intestinal tract. The contents of the small intestine were fluid and yellowish in color with small orange-yellow flaky bodies occuring in the fluid. This fluid was apparently largely secreted from the intestinal walls. The contents of the caecum appeared drier than normal. The amount of faeces in the rectum was also small.

The Glands. The liver was slightly enlarged, of lighter color than normal, soft, friable, and had a cloudy swelling, due to congestion. The gall bladder was about 4 times normal size and contained about 1½ pints of fluid. The bile was light yellow and flocculent, instead of greenish in color. Catarrhal infection caused swelling that almost entirely closed the openingof the bile duct into the duodenum and pressure on the gall bladder would force only a small amount of fluid into the duodenum. The wall of the gall bladder showed slight haemorrhages.

The kidneys showed no marked changes but the urine in the bladder was slightly cloudy and there was a slight congestion of the blood vessels in the bladder wall.

A hyperstatic condition existed in the principal lobe and most of the anterior lobes in the lower border of the right side of the lung. The remainder of the lung tissue was edematous.

Haemorrhages occurred in the epicardium and endocardium and were especially evident in the lining of the left ventricle. They were due to infection. The blood vessels in the walls of the gall bladder, in the walls of the bladder and in the mesentery, showed haemorrhages due to infection and weakening of the walls of the blood vessels. The blood was darker than normal and slow to coagulate. This was due to an infection destroying the enzyme thrombrokinase, which enters into the clotting process.

The spleen was enlarged, due to destruction of red blood cells in large quantities as the result of infection. The rapid destruction of red blood cells results in greater production of these cells in the bone marrow and consequently the bone marrow was slightly red instead of being the normal yellow color for a calf of this age.

General. The muscles were slightly yellow and edematous, possibly due to a leakage of blood serum. The knee and ankle joints appeared to be normal in both capsule and bone. The femur of the right hind leg was broken just below the hip joint and appeared to have been broken about two days before death. There was some haemorrhage and laceration about the broken part. The wall of the femur where broken was thinner than in a normal calf of the same age. A section of the radius, just below the left knee was taken for a breaking test.

Cause of Death. The immediate cause of death was a non-specific septicaemia arising from organisms normally present in the bovine body. Owing to the weakened condition of the calf these organisms were allowed to develop unduly. The immediate cause of death was this non-specific septicaemia which developed owing to the lowered vitality induced by undernutrition.

Breaking Test of Bone. The bone sample taken from the radius, just below the left knee of calf No. 502, was given both the breaking and crushing tests by Professor J. H. Griffith of the Engineering Division.

The sample of bone used was 6½ inches long and 2 9/16 inches at its smallest circumference. The bone had been removed from the body about a day before the breaking and crushing tests were made.

In the breaking test the bone was placed on blocks with a 5-inch span. A 5/8-inch bar laid crosswise sustained the force applied from above. The bone bent, cracked and finally broke with a variable load of from 190 to 640 pounds per square inch. The flexibility of the bone was largely due to the low content of ash constituents.

In the crushing test the weight was applied on the bone 2½ inches from the upper articulation by means of a 3/8-inch flat iron bar with rounded edges. The bone crushed with a load of 400 pounds per square inch. The bone was 3 inches in circumference at the crushing point, with the wall of the shaft varying around 3/32 of an inch in thickness at the point of crushing. The bone shaft at this point was 1 1/16 inches wide and 5/8 inch thick.

DISCUSSION OF RESULTS

It has been shown that milk as the sole ration for calves is unsuitable and that a ration of milk with a grain mixture of corn, oats, wheat bran and old-process linseed oil meal is even less valuable, while the addition of alfalfa hay to these two rations will render them quite well adapted to the needs of the growing calf. An explanation of the differences in the value of the rations is by no means easy.

The first point of note is the amount of nutrients consumed by the calves. From the feed data and the analyses given by Henry & Morrison (17) this information was obtained and from the same source the actual requirements of the calves were determined as in Paper V of this series. The percentage variation of the amount of nutrients consumed from the requirements of the calves were then obtained for each 30-day period.

Table V

Percentage Increase in Nutrients Provided in Addition to Requirements - Lot I

Calf No.	479			489		
	Dry Matter	Digestible Nutrients		Dry Matter	Digestible Nutrient	
		Crude Protein	Carbo. Equiv.		Crude Protein	Carbo. Equiv.
Period No. 1:	%	%	%	%	%	%
I	31	44	50	3	12	33
II	32	43	50	10	17	14
III	8	15	21	-31	5	11
IV	-30	5	12	-51	-17	-10
V	-29	8	13	-62	-22	-28
VI	-49	-13	-6	-52	69	-21
VII	-57	-12	-18	-28	122	4
VIII	-23	151	18	-24	283	1
IX	-20	218	17			

Table VI

Percentage Increase in Nutrients Provided in Addition to Requirements - Lot II

Calf No.	498			502		
	Dry Matter	Digestible Nutrients		Dry Matter	Digestible Nutrients	
		Crude Protein	Carbo. Equiv.		Crude Protein	Carbo. Equiv.
Period No. 1:	%	%	%	%	%	%
I	16	26	33	-1	9	12
II	4	8	14	39	32	47
III	29	14	27	58	39	53
IV	46	15	31	71	39	58
V	1	9	25			
VI	14	114	28			
VII	-5	165	22			
VIII						
IX						

Table VII

Percentage Increase in Nutrients Provided in Addition to Requirements - Lot III

Calf No.	488			495		
	Dry Matter	Digestible Nutrients		Dry Matter	Digestible Nutrients	
		Crude Protein	Carbo. Equiv.		Crude Protein	Carbo. Equiv.
Period No. 1:	%	%	%	%	%	%
I	7	14	20	47	88	57
II	47	111	47	86	187	82
III	47	143	26	36	253	65
IV	6	307	41	25	295	64
V	10	446	41	-4	364	24
VI	10	483	41			
VII						
VIII						
IX						

Lack of Bulk. To prevent confusion it should be stated that there is a distinction between the bulk of a feed and the dry matter it contains. The dry matter is simply the sum of the water-free constituents present. While the bulk of a ration is indicated by the weight of the feed which will fill a given unit of volume. Thus 100 pounds of corn and 100 pounds of alfalfa hay are of the same weight but the corn occupies considerably less space than the hay and so the alfalfa hay is classed as a bulky feed.

The calves in Lot I had an oversupply of digestible nutrients until the end of Period V in the case of calf No. 479 and until the end of Period III with calf No. 489. At those times the supplies of nutrients became deficient and continued to be so until alfalfa was added to the ration, even though the calves were receiving all the milk they could handle. The excess of nutrients that was at first supplied decreased gradually while the excess of dry matter decreased more rapidly and at an early stage in the experiment too little dry matter was being allowed, when milk alone was fed. As alfalfa was added to the ration the deficiency in the supply of dry matter gradually decreased and when the calves had come back into good condition the dry matter deficiency was rapidly disappearing. In other words, the bulky hay apparently aided in the recovery of the calves, in Lot I, due to the fact that the additional bulk helped to expand the rumen and other portions of the digestive tract and render the

calves capable of handling the nutrients with which they were provided. This necessary bulk was not present when the sole ration of the calves was milk.

It should be noted that calf No. 479 was always behind normal in live weight increase, but after alfalfa was added to the ration it came nearer to normal. Calf No. 489 was above normal at the start but decreased relatively in live weight until alfalfa was added in Period VI when it started to increase rapidly in live weight and at the end of the trial was above normal.

In Lot II where milk and grain were fed there were only a few times at which the supply of dry matter was deficient. There was a slight deficiency in the last period for calf No. 498 and in the first period for calf No. 502. The dry matter these calves received was not of a bulky character and calf No. 502 died in Period V, although it had an ample supply of nutrients throughout the trial.

In the case of calf No. 498 the fair excess of nutrients available at the start decreased irregularly until in Period V there was an excess of only 1% of dry matter in the ration. Alfalfa hay was then added and there was a great increase in digestible crude protein and also in other nutrients. The amount of dry matter was also increased though it went below the requirements in the last period, perhaps due to increasing capacity on the part of the calf.

The calf No. 502 was always below normal in live weight in-

crease while the calf No. 498 maintained a good rate of increase for a time but dropped below normal in Period V and then on the addition of alfalfa hay increased in live weight in a manner more nearly normal.

Evidently the addition of the grain mixture to the milk ration not only did not provide sufficient bulk but it had other bad effects as the calves did not do as well as those on milk alone. The addition of a bulky feed produced good results however.

The calves in Lot III were provided with plenty of bulk and, with but one exception, with plenty of dry matter, as they had a ration of milk and alfalfa hay from the start. In the rate of live weight increase they kept well ahead of the normal calves.

Thus far the data presented would indicate that the presence of sufficient bulk in the ration is absolutely necessary for young growing calves.

Quality of Ash. The quantity and the quality of the ash fed in the ration to animals has a considerable influence on the ultimate benefit of the feed to the animal and one of the important factors to note is the calcium-magnesium ratio in the rations of the various groups. For the determination of this ratio the figures on the lime and magnesia contents of feeds given by Henry & Morrison (17) are used.

Table VIII

Lime and Magnesia per 1000 lbs. of Feed.
After Henry & Morrison (17)

Feed	Milk[x]	Corn	Oats	Bran	Oil Meal	Alfalfa Hay
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Lime	1.8	.2	1.4	.9	5.1	19.5
Magnesia	.2	1.8	2.0	7.3	8.1	5.9

x Taken to be the same as in skim milk.

Table IX

Lime-Magnesia Ratio in Rations of Lot I

Calf No.	479	489	479	489	479	489
	Lime		Magnesia		Ratio	
Period	lbs.	lbs.	lbs.	lbs.	1:	
I	.63	.60	.07	.07	.1	.1
II	.81	.88	.09	.10	.1	.1
III	.87	1.08	.10	.12	.1	.1
IV	.97	1.13	.11	.13	.1	.1
V	1.13	1.13	.13	.13	.1	.1
VI	1.13	2.01	.13	.27	.1	.1
VII	1.13	4.04	.13	1.01	.1	.3
VIII	2.81	5.11	.64	1.33	.2	.3
IX	3.49		.84		.2	

Table X

Lime-Magnesia Ratio in Rations of Lot II

Calf No.	498	502	498	502	498	502
	Lime		Magnesia		Ratio	
Period	lbs.	lbs.	lbs.	lbs.	1:	
I	.39	.39	.04	.04	.1	.1
II	.44	.49	.06	.09	.1	.2
III	.53	.53	.15	.17	.3	.3
IV	.57	.56	.28	.25	.5	.4
V	.60		.37		.6	
VI	1.72		.62		.4	
VII	2.64		.81		.3	

Table XI

Lime-Magnesia Ratio in Rations of Lot III

Calf No.	488	495	488	495	488	495
	Lime		Magnesia		Ratio	
Period	lbs.	lbs.	lbs.	lbs.	1:	
I	.54	.73	.06	.11	.1	.2
II	1.36	1.51	.25	.30	.2	.2
III	2.23	2.68	.52	.66	.2	.2
IV	4.40	4.09	1.18	1.08	.3	.3
V	5.96	5.10	1.65	1.39	.3	.3
VI	6.91		1.94		.3	

In considering the ratio of the lime (Ca O) to magnesia (MgO) in the rations, the lime content is taken as unity. It was found in the case of Lot I that the ratio was 1: .1, or in other words, there was 10 times as much lime as magnesia in the ration when milk alone was fed. When alfalfa hay was added the ratio changed to 1: .2 or 1: .3, or in other words, there was 5 to 3 times as much lime as magnesia. In Lot III the ratios found were very similar in some respects to those in the later periods for Lot I, the ratio being generally 1: .2 or 1: .3.

With Lot II the lime-magnesia ratio changed to 1: .4 in the case of calf No. 502 just before its death and to 1: .6 for calf No. 498 in Period V. At this time calf No. 498 cut its grain consumption considerably and in the next period the ratio was 1: .4, while in the following period it was back to 1: .3 on the addition of alfalfa hay to the ration.

These results appear to be in accord with those of Forbes (12). When an excess of magnesium in proportion to the calcium is provided, the excess of magnesium is removed by a counteractive liberation of calcium from the tissues, especially the bone, and this may lead to malformation of the bones, especially of the legs. Such malformations of the legs were quite noticeable in the case of calf No. 498 before alfalfa was added to the ration, but on its addition the bones of the legs showed marked improvement. This would indicate that a ration of milk and the grains used is not only deficient in

bulk but also lacks the proper balance of lime and magnesia in the ash and is even less suited for growing calves than a ration of milk alone.

Vitamine Supply. Another very important factor so far as the nutrition of the calves in this study is concerned is the supply of vitamines, as there is a possibility that the calves might not have been provided with sufficient of them.

In considering all lots it may be said that butterfat is still regarded as the most important source of Fat-Soluble A and this is clearly demonstrated in the compilation of Blunt and Wang (3). It may be allowed therefore that the calves had sufficient of this vitamine.

Milk is not too rich in Water-Soluble B according to Osborne, Mendel, Ferry & Wakeman (19) but there should have been sufficient of it present to carry the various groups in good condition. It is perhaps also true that the Water-Soluble C present may have been sufficient according to Chick, Hume, Shelton & Smith (6 & 7).

When the other feeds in addition to milk are considered it is noted that the yellow corn fed to Lot II contained Fat-Soluble A according to Steenbock & Boutwell (22), although this was already present in the milk. The cereals provided would also furnish the calves with additional Water - Soluble B according to Osborne & Mendel (18) but the bran would be of no value in this respect according to Briggs (1). The oats

and other grains would not add any Water-Soluble C according to Harden & Zilva (13). As a consequence therefore, Lot II was probably provided with more Fat - Soluble A and Water-Soluble B than Lot I but they did not do as well and so the deficiencies of milk as the ration of Lot I cannot be attributed entirely to the lack of these vitamines.

In the third lot alfalfa hay was fed in addition to the milk and these calves did well and the animals in Lots I and II, which had reached a very low degree of vitality, recovered when alfalfa was fed. Alfalfa contains Fat-Soluble A according to Steenbock & Boutwell (22) but this was already present in the milk. Water-Soluble B occurs in considerable amounts in immature alfalfa but in less amounts when it is mature as has been stated by Osborne & Mendel (18) and undoubltedly much of this is lost in haymaking and storage and so it is doubtful if the alfalfa improved the ration so far as Water-Soluble B is concerned.

Alfalfa also contains Water-Soluble C but Chick, Hume, Shelton & Smith (7) and Delf & Shelton (9) state that when the living tissues are disorganized by drying the Water-Soluble C is destroyed. Consequently the alfalfa hay would apparently be of little value to the calves as a source of this vitamine. The alfalfa hay was the feed which produced the greatest growth and brought the calves that were below normal back to normal and yet it would appear that this was not entirely due to any vitamines which it might supply.

From the results obtained in this work it would appear that though milk is a poor ration for calves after they are a few weeks old, the addition of a grain mixture such as that used will give even poorer results. On the other hand, the feeding of alfalfa gave good results.

It would appear that the benefits of alfalfa do not lie entirely in the provision of more nutrients or in improving the vitamine supply. The alfalfa provides bulk which keeps the digestion tract of the calf distended and in proper condition for the handling of feed. The grain used produced bad effects by increasing the relative amount of magnesium as compared with calcium in the ration.

Summary

From the work reported here it would appear that the following deductions are possible:

1. Milk though a suitable ration for young calves cannot maintain ruminants indefinitely.

2. The addition of a grain mixture of corn, oats, bran and oil meal to a ration consisting solely of milk impairs the growth of the calves and leads to death even more rapidly than a ration of milk only.

3. The cause of the earlier death on the addition of the grains is probably due to the depletion of the body stores of calcium due to the fact that the grains contain more magnesium than calcium and calcium must consequently be drawn from the body, expecially the bones, to take care of this excess of magnesium.

4. The addition of alfalfa hay to a ration of milk or of milk, corn, oats, bran and oil meal will bring back to good growing condition animals which have fallen to a low place of nutrition on the rations mentioned.

5. Milk and alfalfa hay can be used to grow out calves satisfactorily.

6. The beneficial effects of the alfalfa hay are apparently not due absolutely to the nutrients it supplies as an abundance of nutrients had been provided in the other experimental rations.

7. It is apparently not probably that the alfalfa hay adds in appreciable amounts vitamines which might have been absent from the other rations used.

8. Where alfalfa is added to a ration of milk and the grain mixture used, it would appear that part of the beneficial effect of the alfalfa is due to the fact that it increased the calcium content as compared to the magnesium content of the ration and thus conserves the calcium stores of the body.

9. The main advantage derived from the alfalfa hay seems to be due to the fact that this feed, being bulky in character, helps to distend the digestive tract of the calf and so renders proper digestion possible.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

VII. THE USE OF THE SELF-FEEDER WITH YOUNG DAIRY CALVES.

Studies in the Growth and Nutrition of Dairy Calves

VII. The Use of the Self-Feeder With Young Dairy Calves.

Appetite, as an indicator of physiological needs, has been minimized by many investigators in the field of human and animal nutrition. From the beginning the whole animal kingdom has been controlled in its feeding problems only by appetite and environmental limitations of the feed supply. Consequently, even tho the role of appetite be not of great importance under artificial experimental conditions, yet, if the broad facts of the case, the continued existence and multiplication of man and other animals after countless aeons of feeding with appetite as their sole guide, be taken into consideration, it must be recognized as of some value.

Resume of Previous Work

The attention that has been given to the study of appetite can hardly be called critical. Evvard (1) has reviewed the literature on the subject and shown that appetite is a fairly reliable indicator of the physiological needs of the pig. A very limited amount ofwork has been done with cattle, but other material, not obtained with a view to studying the appetite of animals, may be reviewed here as of interest in connection with the work reported on the grinding of grain for calves.

It has been stated by Jordan (3) that the grinding of oats and corn increased their digestibility in the case of horses, the with sheep whole oats were as completely utilized as ground grain.

It has been found by Fain and Jarnagin (2) that, where corn meal and shelled corn were used to supplement skim milk for calves, the daily consumption of shelled corn was greater than that of corn meal, tho the rate of gain was greater and the amount of grain consumed per 100 pounds live weight gain less in the case of the shelled corn.

Kildee (4) also recommended whole oats in preference to ground oats for calves. Otis (5) found that calves fed shelled corn made larger gains and consumed less skim milk and hay, but slightly more grain per 100 pounds live weight gain, than did those fed corn chop. He also found that skim milk calves, two to three months old, consumed about 10 pounds of water per head daily.

In view of the work that has been done with the self-feeder as an adjuct in the management of other types of live stock this work was undertaken with young calves. The main object was to determine the ability of calves to select rations suited to their needs, to see their preferences for the various concentrates and obtain some knowledge of their demands for salt and water.

Experimental Work

Three calves, two heifers and a bull were used. All were in good growthy condition and information concerning them is given in Table I.

Table I. Animals Used.

Calf No.	411	413	414
Breed	Guernsey	Ayrshire	Holstein
Sex	M	F	F
Initial age, days	70	37	30
Initial weight, lbs.	146	110	110

From the time they were taken from their dams at about 3 days of age, until the beginning of the experiment, the calves had been fed whole milk. All had become accustomed to consuming small quantities of hay, while the bull, No. 411, was the only one familiar with grain.

The experiment lasted for two periods of 30 days each, and throughout this time the animals were given what milk was thought to be suited to their needs, skim milk being used to replace part of the whole milk as they became older. A supply of alfalfa hay, of medium quality, was kept before the animals at all times. A self-feeder in the pen contained the following feeds in separate compartments:

Shelled corn	Linseed oil meal (O. P.)
Cracked corn	Wheat bran
Whole oats	Corn gluten feed
Ground oats	Salt
Hominy feed	Charcoal

For a few hours each day fresh water was kept in front of the calves.

At the beginning of the experiment and at the end of each 30-day period the animals were weighed on each of three consecutive days. The average of the three consecutive weighings was taken as the live weight of the animals.

A daily record was kept of the amounts of milk, hay and water consumed and records of the other feeds used were obtained for each 30-day period. Moisture determinations were made on all feeds to allow of the computation of the total water

and dry matter consumption.

Discussion of Results

Milk consumption records were obtained for each animal and in Table II are given by 30-day periods. In Period I the bull was given more milk than the heifers, but during Period II each animal received 226 pounds of whole milk with an equal quantity of skim milk.

Table II. - Individual Milk Consumption (Arbitrarily Allowed)

Period No.		I		II		
Calf No.	411	413	414	411	413	414
Whole Milk, lbs.	276	294	294	226	226	226
Skim Milk, lbs.	84	42	42	226	226	226
Total Milk, lbs.	360	336	336	452	452	452

The total consumption for the group, of whole and skim milk, the various concentrates, hay, salt, charcoal and water are collected in Table III.

Table III. - Total Feed Consumption.

Period	I	II
Milk -	lbs.	lbs.
Whole	864	678
Skim	168	678
Concentrates -		
Shelled corn	1.3	108.6
Cracked corn	.0	.3
Whole oats	58.7	68.4
Ground oats	.4	.5
Hominy feed	.0	.3
Gluten feed	15.3	1.9
Wheat bran	13.3	17.3
Oil meal (O.P.)	62.7	75.6
Alfalfa hay	32.7	91.9
Salt	1.1	.3
Charcoal	.7	1.3
Water	384	689

The relative consumption of whole and ground grains can be more clearly appreciated when they are considered separately.

Table IV. - Consumption of Whole and Ground Grains

Period	I	II	Total
Whole Grain-	Lbs.	Lbs.	Lbs.
Corn	1.3	108.6	
Oats	58.7	68.4	237.0
Ground Grain-			
Corn	.0	.3	------
Oats	.4	.5	------
Hominy	.3	.0	1.5

From this evidence one fact is very apparent - the calves showed a decided preference for the whole rather than the ground grains. During Period I practically no corn was consumed but in Period II there were 108.6 pounds of whole corn and only .3 of a pound of cracked corn taken. The whole oats was consumed to the extent of 58.7 pounds in the first period and 68.4 pounds in the second period while never more than .5 of a pound of ground oats was consumed in 30 days. Hominy feed was also neglected in favor of the whole corn and oats. The total consumption of whole grain was 237 pounds while that of ground grain was 1.5 pounds.

Oil meal was the most favored of the nitrogenous concentrates, and the consumption of it increased as the experiment progressed. Wheat bran was a poor second while gluten feed appeared to be the least desirable, as only 1.9 pounds of it were consumed during Period II as compared with a consumption of 15.3 pounds in Period I. This decided decrease in consumption of gluten feed may perhaps be linked up with the increase in consumption of shelled corn, which in turn was probably due to another factor, the skim milk increase in the ration.

As the experiment progressed the daily allowance of skim milk was increased at the expense of the whole milk. This tended to narrow the nutritive ratio of the ration. The calves counteracted this, however, by increasing their con-

sumption of low protein concentrates from 60.4 pounds in Period I to 178.1 pounds in Period II, or 195%, while the increase in their consumption of high protein concentrates was relatively small, going from 91.3 pounds in Period I to 94.8 pounds in Period II, or only 4%.

The consumption of alfalfa hay, water and charcoal increased as the experiment progressed, while that of salt decreased.

Table V. - Average Daily Feed Per Calf.

Period	I	II
	Lbs.	Lbs.
Whole milk	9.60	7.53
Skim milk	1.87	7.53
Concentrates	1.69	3.03
Hay	.36	1.02
Salt	.012	.003
Charcoal	.008	.013
Water	4.27	7.66

From this it is apparent that the consumption of grain, hay and water increased very rapidly with the growth of the calves, the average daily requirements of water mounting from 4.27 pounds in Period I to 7.66 pounds in Period II.

Table VI. - Consumption of Dry Matter and Water.

Constituent	Dry Matter		Water	
Period	I	II	I	II
	Lbs.	Lbs.	Lbs.	Lbs.
Milk	127.8	153.3	904.2	1,202.7
Concentrates	133.6	230.4	18.1	42.5
Hay	27.7	77.9	5.0	14.0
Condiments	1.8	1.6	---	---
Water	-----	-----	384.	689.
Total	290.9	463.2	1,311.3	1,948.2

This again demonstrated the rapid increase in dry matter consumption from 290.9 pounds in Period I to 463.2 pounds in Period II, while the total consumption of water, as drinking water and in the feed, increased from 1311.3 pounds to 1948.2 pounds, or from 14.57 pounds per day in Period I to 21.65 pounds per day in Period II.

Table VII. - Live Weight Gains

Calf No.	411	413	414	Total	Average
Live Weight -	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Initial	146	110	110	366	122
Middle	209	158	164	530	177
Final	278	219	226	723	241
Live Weight Gains-					
Period I	63	48	54	165	55
Period II	69	61	62	192	64
Total	132	109	116	357	119
Average Daily Gains-					
Period I	2.10	1.60	1.80	5.50	1.83
Period II	2.30	2.03	2.07	6.40	2.13
Average	2.20	1.82	1.93	5.95	1.98

The live weight gains were very creditable, varying from 1.60 pounds to 2.30 pounds and averaging 1.98 pounds per head per day. The calves did not become too fat but remained in good growthy condition - that most desirable for young dairy calves. The feed requirements per one hundred pounds of live weight gain are relatively low.

Table VIII. - Feed Required for 100 Lbs. Live Weight Gain.

Period	I	II
	Lbs.	Lbs.
Whole milk	524	353
Skim milk	102	353
Grain	92	142
Hay	20	48
Water, drinking	233	359
Total dry matter	176	241
Total water	795	1,015

The calves showed distinct preferences for some of the grain preparations, but there is the question, how near did they come to balancing their rations in accordance with the concepts of modern feeding standards?

Table IX. - Actual and Expected Consumption of Nutrients by Calves.

Period	I		II	
Nutrients	Actual	Expected	Actual	Expected
Total dry matter, lbs.	209.9	267.9	463.2	412.8
Digestible crude protein, lbs.	66.4	43.8	94.1	60.9
Total digestible nutrients lbs.	292.8	230.1	425.1	327.9
Nutritive ratio	1:3.4	1:4.3	1:3.5	1:4.4

The consumption of dry matter and digestible nutrients by the calves is seen to be well above expectations but it has already been shown that the heavy feed consumption led to large and economical gains. According to the Modified Wolff-Lehmann Feeding Standard the feed for the calves should on the average have had a nutritive ratio of 1:4.3 in the first period and 1:4.4 in the second. However, the calves seemed to prefer a ration with a much narrower nutritive ratio. For the first and second periods the nutritive ratios of the rations were 1:3.4 and 1:3.5 respectively. In this choice of a narrower nutritive ratio the calves may have been correct. The calves grew rapidly and gained in weight but did not become too fat and this is the desirable method of growing out young dairy animals.

SUMMARY

This work is too limited in scope to allow of the making of definite recommendations but a few points of interest stand out clearly:

1. Young calves prefer whole corn and oats to the ground grains.

2. Hominy feed does not appear to be palatable to calves.

3. Linseed oil meal (O. P.) appears to be more palatable than wheat bran, while corn gluten feed is not in favor with calves.

4. Calves have the ability to vary their consumption of concentrates to comply with their needs. For example, when whole milk is replaced by skim milk the calves increase their relative consumption of low protein concentrate feeds such as corn and oats.

5. The calves used in this work consumed a ration of much narrower nutritive ratio than is generally recommended.

6. The calves maintained the nutritive ratio of their ration fairly constant though it became slightly wider as the calves advanced in age.

7. The consumption of hay increased materially as the calves became older.

8. Salt and charcoal were evidently desired by the calves.

9. Water is important, even for calves fed milk.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

VIII. RAISING DAIRY HEIFERS BY MEANS OF THE SELF-FEEDER.

Studies in the Growth and Nutrition of Dairy Calves. VIII. Raising Dairy Heifers by Means of the Self-Feeder.

The self-feeder is now recognized as a valuble adjuct in the feeding of hogs and also to some extent in fattening beef cattle. Its use with dairy cattle is still in the experimental stage, however, and the project reported here is supplementary to the work outlined in Paper VII of this series.

Resume of Previous Work

Part of the work on the use of self-feeders and problems intimately connected with their use has already been reviewed in Paper VII of this series but a few additional references may be given here.

Among the few references obtainable it is found that both Cook (1) and Nevens (4) reported good results where a grain mixture was provided in a self-feeder for calves. On the other hand, Hunt (3) found that cows in milk, when allowed access to a self-feeder, consumed so much grain that milk production was very uneconomical.

A report has already been given of the preference of young calves for whole grains and Hanly (2) obtained similar results, while Woll & Voorhies (5) found a slight advantage in feeding ground grain but the difference was not sufficient to pay for the grinding.

Experimental Work

The work outlined here was undertaken with the view of ascertaining the possibility of raising dairy heifer calves from birth to the age of first freshening with the aid of the self-feeder. The feeds used were very similar to those used in the earlier work reported in Paper VII of this series, with the exception that gluten feed and hominy meal, which had proved to be unpalatable, were excluded.

Three purebred heifer calves were used. All were in good growthy condition when put on the self-feeder at an average age of 27 days. Information concerning them is given in Table I and where necessary it is calculated to October 5, 1919, the day on which the trial started.

Table I

Animals Used

Calf No.	487	491	493	Average
Breed	Jersey	Ayrshire	Holstein	
Birth weight lbs.	64	60	80	68
Age, days	43	20	19	27

From the time of removal from their dams, until the beginning of the experiment, the calves had been receiving whole milk and were on pasture a few hours daily. In addition, calf No. 487 had also had a little hay and grain before the start of the trial.

Table II.

Previous Feed

Calf No.	487	491	493	Total	Average
Sucking, Days	1	6	5	12	4
Whole milk lbs.	359	103	103	565	188
Pasture, hours	328	104	104	536	179

All feed records were kept by 30-day periods and at the end of each period the animals were weighed on each of three successive days and the average of the three weighings was considered to be the weight of the animals at the end of the period. The height at withers, depth of chest and width at hooks was also determined for each animal.

The original intention was to carry the animals to the age of first freshening but as difficulties apparently arose regarding the breeding of the heifers, the trial had to be discontinued at the end of the twenty-second period.

At the beginning of the experiment the animals were all receiving whole milk, hand fed, and had before them at all times alfalfa hay and salt. The self-feeder kept in their pen contained the following concentrates.

Shelled Corn
Cracked Corn
Whole Oats
Ground Oats
Wheat Bran
Linseed Oil Meal O. P.

The calves were turned out daily for exercise and water and during the first 27 days they were on pasture for 8 hours daily. During the winter they were exercised and watered daily in the dry lot. When the pasture was ready in spring the heifers were turned out. The three animals were on a pasture of 2.09 acres and for shelter they had an open shed in which the self-feeder was kept.

The feeding of milk and alfalfa was discontinued during the eighth period and from the beginning of the ninth period to the end of the trial the animals were continuously on pasture but had access to the self-feeder at all times up to the end of Period XVIII. Periods XV to XX were in winter and during that time alfalfa hay was again fed and silage was also allowed. In this winter period however, the heifers also obtained some feed from the pasture. In the last two periods pasture alone was allowed.

Discussion of Results

The feed records were kept by 30-day periods but in order to study the early actions of the calves the record for the first 30 days was kept in 10-day periods. In considering this first period it is found that the calves took readily to the whole corn and whole oats and consumed considerably less of the ground feeds. They consumed a relatively liberal amount of wheat bran but only about half as much oil meal as whole corn or whole oats. Their consumption of grain was greater during the first 10 days than was their consumption of alfalfa hay, but during the second 10-day period they decreased their grain consumption. Evidently therefore, they took relatively too much grain during the first 10 days but immediately proceeded to correct it as their hay consumption exceeded their grain consumption for the 30-day period.

Table III

Feed Consumption During Period I.

Sub-Period	i	ii	iii	Total	Average per Heifer
	lbs.	lbs.	lbs.	lbs.	lbs.
Whole Milk	263	309	312	884	295
Whole Corn	3.2	5.6	1.9	10.7	3.6
Cracked Corn	0.0	0.9	0.9	1.8	0.6
Whole Oats	2.4	2.8	5.6	10.8	3.6
Ground Oats	1.2	0.5	3.2	4.9	1.6
Wheat Bran	4.0	1.9	1.4	7.3	2.4
Oil Meal	3.2	0.0	1.4	4.6	1.5
Alfalfa Hay	4.8	15.8	27.3	47.9	16.0

The milk feeding was at no time heavy, the animals being fed limited amounts twice daily, as it was felt best to allow the calves to choose their own feeds as much as possible. The fact that the calves did not lack for feed and developed well even on limited amounts of milk is shown by the live weight gains.

Table IV.

Individual Milk Consumption.

Calf No.	487		491		495		Total		Average	
Period No.	Whole Milk lbs.	Skim Milk lbs.	Whole Milk lbs.	Skim Milk lbs.	Whole Milk lbs.	Skim Milk lbs.	Whole Milk lbs.	Skim Milk lbs.	Whole Milk lbs.	Skim Milk lbs.
I	294		262		328		884		295	
II	302		302		392		996		332	
III	315		212	138	256	161	783	299	261	100
IV	315		180	180	210	210	705	390	235	130
V	315		180	180	210	210	705	390	235	130
VI	296	15	162	192	189	225	647	432	216	144
VII	120	199		260		336	120	795	40	265
VIII		90				90		180		60
Total	1957	304	1298	950	1585	1232	4840	2486	1613	829

In considering the total amounts of feed consumed it is found that cracked corn came first among the concentrates and was followed closely by whole corn, while whole oats was considerably behind, amounting to only about one-third of the whole corn. The amount of oil meal consumed was only about half that of whole oats while wheat bran was considerably lower and the ground oats consumed was but a very small amount. Roughly, there was one and a half times as much whole corn consumed as of all other concentrates combined, with the exception of cracked corn which was consumed in even larger amounts than the whole corn.

The total consumption of the various grains is perhaps not of as great interest as the changes which take place in the relative amounts of them consumed at various stages in the trial. During the first six periods when the amounts of whole milk fed exceeded the skim milk there was a steady increase in the amount of whole corn consumed while the cracked corn was consumed in insignificant amounts. The same holds true for both whole and ground oats, in fact the calves appear to have tried them at first and then decreased their consumption of them. The wheat bran also formed an insignificant part of the grain ration during this time, though the amount of oil meal used increased considerably with the exception of a very severe drop in the fifth period.

In the seventh period the skim milk fed exceeded the whole milk and in the eighth period skim milk alone was used for a time. The consumption of whole corn reached its peak in the seventh period, probably owing to its use for the replacements of the

butterfat removed from the ration, but in the eighth period it dropped. This drop in whole corn consumption was accompanied by an enormous increase in the amount of whole oats used. The bran consumption increased greatly during the seventh and eighth periods and that of oil meal also went up, while the amounts of cracked corn and ground oats consumed remained low.

Table V.

Total Feed Consumption by Thirty-Day Periods.

Period No.	Whole Milk lbs.	Skim Milk lbs.	Whole Corn lbs.	Cracked Corn lbs.	Whole Oats lbs.	Ground Oats lbs.	Wheat Bran lbs.	Oil Meal lbs.	Alfalfa Hay lbs.	Corn Silage lbs.	Salt lbs.
I	884		11	2	11	5	7	5	48		.31
II	996		24	6	44	15	1	2	133		.23
III	783	299	208	2	0	25	0	27	122		.24
IV	705	390	308	0	6	13	0	99	153		.09
V	705	390	466	0	9	11	2	7	129		.06
VI	647	433	577	5	1	6	2	96	144		.19
VII	120	795	651	8	1	7	43	111	149		.05
VIII		180	538	6	180	7	52	118	157		.60
IX			490	327	16	0	4	0			1.44
X			511	438	26	19	77	46			1.05
XI			343	612	0	0	33	17			1.04
XII			508	329	23	9	79	51			1.03
XIII			448	685	51	24	15	80			1.04
XIV			252	732	188	0	73	59			1.05
XV			31	835	172	33	0	91	242	674	.84
XVI			44	927	480	23	14	31	165	106	.70
XVII			1	913	399	0	0	21	199	192	.65
XVIII			412	584	235	0	16	13	254	219	.72
XIX									537	892	.83
XX									142	1425	1.20
XXI											1.16
XXII											1.01
Total	4840	2487	5823	6411	1842	197	418	874	2574	3508	15.58

The heifers were turned to pasture at the beginning of the ninth period and from there to the end of the fourteenth period they were under summer conditions and receiving no milk. Throughout this time the consumption of whole corn decreased and that of cracked corn increased. The consumption of oats in any form was low until the last thirty-day period of this section when the amount of whole oats consumed was large. The consumption of bran was somewhat irregular though with a tendency to increase when compared with the previous production. The oil meal consumption dropped to zero during the first thirty days on pasture and during summer was never high.

During the fifteenth to eighteenth periods corn silage and alfalfa hay were given at free will and during this time the whole corn consumption decreased and that of cracked corn increased until the last thirty days when there was a radical change in the opposite direction. The consumption of whole oats increased with the exception of the last period. Ground oats and bran were consumed in but small amounts and the consumption of oil meal though increased in the first thirty days declined towards the end.

From the time the calves were put on the trial until they went to pasture, 210 days later, they had free access to alfalfa hay and the consumption of this increased fairly readily. During the following summer they had no roughage but pasture but at the approach of winter they were given corn silage and alfalfa hay. These roughages were fed for six months and during

the first four grain was also being given. During the first period of feeding the silage was consumed in fair amounts but for the next three little of it was consumed as it frequently froze before the heifers would consume it. The consumption of hay remained fairly constant. For the two periods after the grain was removed the silage consumption increased greatly and there was an increase in hay consumption for one month but in the last month it was inhabited probably by the greater silage consumption and the freshening of the pasture. In the last two months of the trial the animals received pasture only.

The salt consumption increased irregularly from the start of the trial until the calves were weaned and put to pasture. At this stage there was a great increase in salt consumption and this was fairly well maintained until the introduction of alfalfa and silage at the beginning of winter when the salt consumption again fell and remained low until after the grain had been removed and the heifers were beginning to get fresh pasture again. At this time it again rose and remained so until the trial ended.

Table VI

Consumption of Whole and Ground Grains

Period No.	Whole Grain			Ground Grain			Amount of Whole Grain per Pound of Ground Grain
	Corn lbs.	Oats lbs.	Total lbs.	Corn lbs.	Oats lbs.	Total lbs.	lbs.
I	11	11	22	2	5	7	3.1
II	24	44	68	6	15	21	3.2
III	208	0	208	2	25	27	9.6
IV	308	6	314	0	13	13	24.2
V	466	9	475	0	11	11	43.2
VI	577	1	578	5	6	11	52.5
VII	651	1	652	8	7	15	43.5
VIII	538	180	718	6	7	13	55.2
IX	490	16	506	327	0	327	1.5
X	511	26	537	438	19	457	1.2
XI	343	0	343	612	0	612	.6
XII	508	23	531	329	9	338	1.2
XIII	448	51	499	685	24	709	.7
XIV	252	188	440	732	0	732	.6
XV	31	172	203	835	33	868	.2
XVI	44	480	524	927	23	950	.6
XVII	1	399	400	913	0	913	.4
XVIII	412	235	647	584	0	584	1.1

In comparing the amounts of whole corn and oats consumed with the amount of the ground grains utilized, it is found that from the beginning of the trial until the end of the eighth period, when the calves were weaned and put to pasture, that the amount of whole grain increased from 3.1 pounds per pound of ground grain consumed in the first period to 55.2 pounds per pound of ground of ground grain in the eighth period. During this time therefore the preference of the calves was for whole grains. From then on however, whether the calves were on pasture or on alfalfa and corn silage, there was no such marked preference for the whole grains. Sometimes they consumed more whole than ground grains and at other times considerably less.

Taking the two main groupings it is found that while the calves were receiving milk, grain and hay, they consumed 25.7 pounds of whole corn and oats for each pound of the ground grains, while the ratio was only .7 pound of the whole grains per pound of ground grains when the heifers were getting grain and were on pasture or being fed silage and alfalfa. At no time however, were ground oats consumed in appreciable amounts and it was only toward the end that whole oats were eaten in considerable quantities.

Table VII

Average Live Weights and Body Measurements

Time	Live Weights lbs.	Height in.	Depth in.	Width in.
Birth	68			
Start of Trial	80	28.1	11.3	6.2
End of Period I	113	29.6	12.5	7.4
II	155	31.6	14.0	8.2
III	220	34.3	15.6	9.3
IV	278	35.9	16.4	10.5
V	321	37.8	17.6	11.3
VI	398	39.4	18.7	12.1
VII	469	41.0	19.9	13.3
VIII	515	42.1	20.7	13.7
IX	568	42.9	21.5	14.4
X	622	43.7	22.2	15.2
XI	677	44.5	22.6	15.6
XII	733	45.2	23.0	16.0
XIII	787	46.0	23.8	16.4
XIV	842	46.8	24.2	17.2
XV	854	47.6	24.6	17.6
XVI	905	48.0	25.4	17.9
XVII	954	48.4	25.7	18.3
XVIII	984	48.8	25.7	18.7
XIX	973	49.1	25.7	19.1
XX	990	49.5	26.1	19.1
XXI	991	49.5	26.1	19.1
XXII	972	49.5	26.5	19.1

The average live weights of the heifers from the time of birth to the finish of the trial are given and the body measurements from the beginning of the trial. The calves used in this work were practically one month of age when the work was started and in order to get an idea of their relative rates of growth, they are compared with calves fed under normal conditions. This comparison is made on the percentage increase in live weight from birth and body measurements from one month of age. This method was used in Paper III of this series and the averages for the normally fed animals used in the work reported in that paper are used as a basis of comparison for the animals discussed here.

Table VII

Percentage Increase in Live Weight and Body Measurements.

Age Months	Heifers fed Normally				Heifers on Self-Feeder			
	Live Weight %	Height %	Depth %	Width %	Live Weight %	Height %	Depth %	Width %
6	309	34	57	67	372	35	56	82
12	731	54	92	118	896	58	100	155
18	988	64	112	146	1303	72	127	195
23	1171	68	121	164	1622	76	135	208

The calves used in the self-feeder trial were slightly below normal in live weight and body measurements at the start but they gained rapidly and at the end of the twenty-second period of the trial, when the self-fed heifers were twenty-three months of age they showed greater development in weight and all body measurements except width that the normally fed heifers did at the age of freshening, namely, twenty-nine months. Their growth in weight and body measurements at the first of the trial greatly exceeded that for the normally fed heifers.

Relative Increase in Growth of Self-fed Heifers as Compared with Normally Grown Heifers

Age Months	Live Weight %	Height %	Depth %	Width %
6	101	103	98	122
12	123	107	109	131
18	131	113	113	134
23	130	112	111	127

For further comparison the relative increases in live weight and body measurements of the self-fed heifers are compared with the same increases for the normally fed animals by six months periods. In other words, the average percentage increase in live weight of the self-fed heifers during their first six months is expressed as a percentage of the average percentage live weight increase during their first period of six months for the normally fed animals.

On examining the data by this method it is found that on the whole the self-fed heifers increased relatively more rapidly in live weight than they did in body measurements. This indicates in the best possible way the tendency for the self-fed heifers to lay on fat and get in higher condition than the normally fed animals.

When the body measurements alone are considered it is found that the greatest relative increase is in the width at the hooks and of the three measurements taken, this is the one most easily affected by condition. The height at withers and the depth of chest do not seem to be affected to such a great degree. All the body measurements were above normal, due to some extent to extra fleshing at the hooks, over the withers, and on the floor of the chest, but also undoubtedly to some extent due to increased skeletal growth.

It should be noted that from eighteen to twenty-three months of age there was a falling off in the relative increases in the live weights and body measurements of the self-

fed heifers. This was due to the fact that during the latter part of this period the heifers were on pasture only and lost in live weight and the outward evidences of condition.

Table X

Average Feed Cost of Growing Heifers

Age Months	Feed Cost by 6-Month Periods		Cumulative Feed Cost		Feed Cost per Pound of Gain by 6-Month Periods		Cumulative Feed Cost per Pound of Gain	
	Normal	Self-Fed	Normal	Self-fed	Normal	Self-Fed	Normal	Self-Fed
	$	$	$	$	¢	¢	¢	¢
0 - 6	35.57	35.81	35.57	35.81	14.4	14.1	14.4	14.1
6 -12	20.18	21.78	55.75	57.59	8.3	6.1	11.4	9.5
12 -18	17.76	20.92	73.51	78.51	10.3	7.6	11.1	8.9
18 -24	16.27	-----	89.78	-----	9.4	----	10.7	----
18 -23	-- --	8.72	-- --	87.23	- -	48.4	-- -	9.6

The feed cost of growing the self-feeders has been determined with the same feed costs as were used in Paper IV of this series in determining the cost of growing heifers for normally. The costs of growing the normal heifers to 24 months of age are given as they were originally calculated on that basis while the feed cost for the self-fed heifers is given to 23 months - the age of the heifers when the trial finished.

The feed costs of growing the normal and self-fed heifers do not vary as widely as might be expected, up to 18 months of age, but from there to the age of 23 or 24 months there is a difference which needs explanation. In the first six months of life the calves, as would be expected, show practically the same individual feed costs, but in the two succeeding six months periods, the self-fed heifers ate relatively more grain per head and so at eighteen months of age the total feed cost of growing the normal heifers was $73.51 and that for the self-fed heifers was $78.51 or $5 per head more. Up to this time the cost per pound of grain for the self-fed group was below normal, that for the normally fed heifers being 11.1 cents per pound and that for the self-fed animals 8.9 cents per pound. In Paper IV of this series the heifers were divided into winter and summer groups, according to the time at which they were dropped. As the self-fed heifers were in the winter group it is well to state that the normal cost per pound of live weight gain up to 18 months of age was 11.4 cents for the winter group.

From 18 to 24 months of age the feed cost for normally fed heifers was $16.26 while the feed cost for the self-fed heifers was $8.72. This marked difference in favor of the self-fed animals is due in great part to the fact that in the later part of this stage the self-fed animals were on pasture alone, while the other animals had been receiving grain. The normally fed winter heifers during the period of from 18 to 24 months of age had an average feed cost of $15.16.

From the age of 18 to 23 months the self-fed heifers showed little live weight gain, in fact at 23 months of age they weighed less than they did at 19 months of age. This is due to the fact that when grain was taken away from them completely and they were left to subsist on young grass alone, a considerable amount of shrink occurred and this had not been completely overcome at the end of the trial. Consequently, the feed cost per pound of gain during the last five months is exceptionally high. On the average the feed cost per pound of live weight gain from birth was 9.6 cents in the case of the self-fed heifers at 23 months of age and 10.7 per pound in the case of the normally grown heifers at 24 months of age.

There is apparently some difference in the feed cost per hundred pounds of live weight gain between heifers fed in the

ordinary method and those self-fed. This is true when they reach the age of about two years and the self-feeder would appear to have other advantages as the animals raised by this method need less attention when they have passed weaning age and grow heavier and larger.

In connection with the work with the heifers raised with the self-feeder a record was kept of the breeding of the animals and as was noted earlier the trial was discontinued owing to apparent difficulty in getting them bred.

Table XI

Breeding of Heifers

Heifer No.	Date of Breeding	Date of Successful Breeding	Fresh	Calf		Age at Freshening
				Sex	Weight	
					lbs.	Months
487	12/10/20 1/2/21	1/2/21	9/28/21	F	41	25
491	1/2/21 1/23/21 3/3/21	3/3/21	12/9/21	M	75	27
493	2/26/21 4/5/21 7/6/21 8/7/21	8/7/21	------	-	--	32
Average	3					28

The heifers, Nos. 487 and 491, were settled during the trial but owing to their condition it was a difficult matter to tell, in the early stages, whether or not they were pregnant. Later on, on examination, per rectum, they proved to be in calf. They freshened at ages which are normal for the breeds to which they belong. The heifer No. 487 was a Jersey, freshening at 25 months of age, and No. 491, an Ayrshire, freshening at 27 months. Throughout the trial the Jersey heifer was in relatively lower condition than the Ayrshire. The Holstein heifer, No. 493, was in the highest condition throughout the trial. As yet she has not freshened but on examination, per rectum, has shown that she is going to freshen to the breeding of August 7, 1921. This means that she will freshen at 32 months of age - a rather advanced age for a heifer of her development.

The animals were of different breeds and this induces a factor beyond control, but there should not be much difference in the freshening ages of Ayrshires and Holsteins and it can readily be seen that there was much more difficulty in getting the Holstein settled and this is very probably due to the exceedingly high condition she was in. She was only bred successfully after she had been on pasture alone for some time and lost in condition.

Summary

From this trial with a self-feeder in the raising of dairy heifers it is probably that the following suggestions may be made:

1. There is little difference in the feed cost of raising heifers to two years of age by the self-feeder method or by hand feeding where a liberal grain allowance is given.

2. The feed cost per pound of gain is lower with the self-fed heifers.

3. The heifers raised with a self-feeder will show the greater increases in live weights, height at withers, depth of chest and width.

4. The greatest relative increase will be in the live weight and though the skeletal measurements mentioned do show a true increase, this is further augmented by extra fleshing.

5. With self-fed heifers the extra conditioning may tend to delay breeding, or perhaps impair their breeding powers.

6. Ground oats and wheat bran are not palatable to heifers.

7. When the heifers are on a milk ration, whole corn is the grain consumed in greatest quantities; cracked corn and whole oats being used but little.

8. After weaning, and when under summer conditions, the consumption of cracked corn increased while that of whole corn decreased.

9. When the heifers were under winter conditions, after

they were a year old, cracked corn and whole oats were apparently the most palatable grains.

10. Linseed oil meal was evidently a palatable supplement though the quantities of it consumed varied from time to time.

11. Salt was consumed regularly. The largest amounts were used when pasture was available.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

IX. THE ADDITION OF TOMATOES TO A MILK RATION

Studies in the Growth and Nutrition of Dairy Calves

IX. The Addition of Toamtoes to a Milk Ration

In an effort to determine some of the fundamental principles underlying nutrition in general, and calf feeding in particular, a number of investigations have been under way for five years. In papers V and VI of this series, attention was given to the bulk supplied to young calves, though subsidiary problems also occurred. This paper simply includes further work on the influence of bulk on the value of the ration for a young growing calf, though at times other branches of the work have to be brought in.

Resumé of Previous Work

All of the work dealing directly with the provision of bulk in the ration of the calf has been reviewed in the two previous reports, but attention may be drawn here to recent work which is applicable to some extent to this problem.

In papers V and VI of this series it was found that milk alone was not a good ration for calves but a ration of milk and grain was even poorer as the grains added so much more magnesium to the ration that the calcium used in the removal of the magnesium had actually to be withdrawn from the body stores. The introduction of alfalfa hay to the ration caused rapid improvement in the lime-magnesia ratio and so lead to a positive

calcium balance. The bulk of the alfalfa hay was also of great value in bringing the digestion of the calves to normal as bulky feeds are necessary for the distension of the rumen and other parts of the digestive tract.

Since the compilation of the work by Eddy (1) on the distribution of the vitamines, it is easier to determine what influence the vitamines may have on the work reported in papers V and VI.

Table I

Distribution of Vitamines, from Eddy (1)

Source	Fat-Soluble A	Water-Soluble B	Water-Soluble C
Milk	x x x	x x x	x x
Alfalfa	x x x	x x x	?
Corn, White	x	x x x	?
Corn, yellow	0	x x x	?
Oats	x	x x x	0
Bran	0	x	0
Oil Meal	x x	x x x	
Tomatoes, canned			x x

x x x indicates abundance, x x relatively large amounts, x present in small amounts, 0 absent.

From this it is apparent that the milk was supplying as much Fat-Soluble A and Water-Soluble B and considerably more Water-Soluble C than any of the grains used or than the alfalfa. Consequently the recovery of the calves when fed alfalfa hay can not be looked on as due to any additional amounts of Water-Soluble C provided. This means that only the calcium content of the alfalfa hay or its bulky nature could have been of value in improving the ration of the calves.

On feeding grain and oat straw to goats for three months, Steenbock, and Hart (3) found that the calcium balance remained negative. Then there were indications of approaching collapse on the part of the animals, such as lack of appetite and loss of interest in their surroundings. Fresh grass was then fed to the animals and they recovered.

Later Hart, Steenbock and Hoppert (2) continued this work, using dry and milking goats. When fresh green oats were fed the calcium balance was positive but on feeding oat straw, the calcium balance was negative. When the fresh green oats were dried in a well lighted and well ventilated attic but out of direct sunlight, they still retained some of the properties which aided in calcium assimilation. It was also found that alfalfa hay kept up the calcium balance. Orange juice and cabbage had not this power so it can not be the antiscorbutic vitamine that aided calcium assimilation, but rather an antirichitic vitamine is also found in cod-liver oil.

Experimental Work

In the trial reported here two calves were used and although they were born some time apart, the records have been kept for each by thirty-day periods. Information concerning these animals is given in Table II. Calf No. 544 was twinned with a bull and was therefore presumed to be a free-martin, but a discussion of its sexual makeup will be taken up later. Calf No. 539 died at 180 days of age, being on a ration of milk alone, while No. 544 was killed after the completion of the fifteenth period. During the trial it had been fed milk, milk and canned tomatoes, and milk and alfalfa hay.

Table II

Animals Used

Calf No.	539	544
Breed	Grade Jersey	Holstein
Sex	Male	Free-martin
Date of Birth	11/3/20	12/26/20
Birth Weight, lbs.	55	65

The feed consumption for each calf is presented by thirty-day periods. Calf No. 539 was fed milk alone and died at 180 days of age. Calf No. 544 was fed milk alone until the end of period VII when his appetite had decreased. An allowance of 1 pound, 3 ounces of canned tomatoes was then given for five periods but as this did not produce the desired improvement, alfalfa hay was fed at free-will until the trial was closed.

Table III

Feed Consumption by Thirty-day Periods

Calf No.	544			539
Period No.	Whole Milk lbs.	Canned Tomatoes lbs.	Alfalfa Hay lbs.	Whole Milk lbs.
I	360			221
II	420			323
III	467			409
IV	624			495
V	765			645
VI	1181			675
VII	1125			
VIII	1125	36		
IX	1125	36		
X	1305	36		
XI	1310	36		
XII	1350	36		
XIII	1500		280	
XIV	1500		206	
XV	1500		285	

The live weights of the experimental calves were obtained at birth and at the end of each thirty-day period, by weighing on three consecutive days. The body measurements, height at withers, depth of chest, and width at hooks were obtained at the end of each period.

Table IV

Live Weight and Body Measurements

Age Days	Average for 40 Heifers				Calf No. 544				Calf No. 539			
	Weight lbs.	Height in.	Depth in.	Width in.	Weight lbs.	Height in.	Depth in.	Width in.	Weight lbs.	Height in.	Depth in.	Wid in.
Birth	67				65				55			
30	90	28.7	11.4	6.7	99	32.7	14.8	7.8	72	31.6	13.7	8.
60	120	30.7	12.8	7.5	150	33.3	15.1	8.6	91	32.6	14.1	8.
90	163	32.9	14.2	8.5	183	33.9	15.6	9.2	123	33.3	14.2	8.
120	211	34.8	15.4	9.4	251	34.5	16.0	9.4	165	35.1	15.3	8.
150	262	36.4	16.7	10.2	301	36.9	17.2	10.3	237	36.2	16.1	9.
180	314	38.4	17.9	11.2	390	39.0	18.2	11.5	250	37.0	16.5	9.
210	366	39.4	18.7	11.8	437	40.3	19.1	12.3				
240	413	41.0	19.5	12.6	479	41.5	20.3	12.9				
270	452	42.0	20.3	13.2	481	43.0	21.3	13.3				
300	486	42.7	20.9	13.6	537	46.9	21.5	13.9				
330	521	43.5	21.5	14.2	554	47.6	21.7	14.0				
360	557	44.3	21.9	14.6	630	48.2	22.1	14.8				
390	592	44.9	22.4	15.1	721	49.4	22.7	15.4				
420	628	45.5	22.8	15.4	750	50.0	24.3	16.0				
450	659	45.9	23.2	15.7	795	50.8	25.7	16.0				

Results Secured

If the increase in live weight and body measurement be taken each third month and expressed as percentages of the first measurements taken, they can be compared with the averages for a group of 40 heifers raised normally and reported in paper III of this series. In making this comparison in Table V it will be found that calf No. 539 shows a tendency throughout to be below normal in both live weight and body measurements. On the other hand, calf No. 544 always shows a higher rate of increase in live weight than is found in the normal group. However, this calf shows slow development in the body measurements until the alfalfa period is reached.

Table V

Percentage Increase in Live Weight and Body Measurements

Age Months	Average for 40 Heifers				Calf No. 544				Calf No. 539			
	Weight	Height	Depth	Width	Weight	Height	Depth	Width	Weight	Height	Depth	W
3	143	15	25	27	181	4	4	18	124	6	4	
6	369	34	57	67	500	19	12	47	364	14	21	2
9	575	46	78	97	640	31	44	71				
12	731	54	92	118	869	47	50	90				
15	884	60	104	134	1123	55	74	105				

It is well to study the requirements of the calves and the supply of nutrients supplied to them as this gives an idea of how far their rations meet their needs for nutrients, and other factors concerning the rations can be considered later. The nutrients required by and supplied to the calves have been calculated from the work of Henry & Morrison (4). To simplify matter however, the excess or deficit of nutrients supplied during each thirty-day period has been calculated for each calf.

Table IX

Percentage of Nutrients in Addition to Requirements Provided

Calf No.	544			539		
	Total Dry Matter	Digestible Nutrients		Total Dry Matter	Digestible Nutrients	
		Crude Protein	Total		Crude Protein	Total
Period	%	%	%	%	%	%
I	-56	60	64	11	20	25
II	-62	36	44	26	38	7
III	-68	13	17	23	31	38
IV	-68	10	16	10	17	24
V	-69	4	11	-39	4	10
VI	-78	40	38	-48	-10	-5
VII	-68	36	10			
VIII	-85	32	2			
IX	-85	28	-2			
X	-84	47	3			
XI	-85	36	-2			
XII	-86	29	-4			
XIII	-22	130	54			
XIV	-42	90	33			
XV	-25	108	40			

The calf No. 539 always had an oversupply of nutrients until the end of the fourth period. Then the supply of total dry matter dropped below normal and the supplies of digestible nutrients came down to near the actual requirements. In the next period the deficit of dry matter was even greater and the supply of digestible crude protein and digestible carbohydrate equivalent was below that required by the calf. The animal was given all the milk it could handle and yet could not obtain sufficient nutrients from it and the calf died at 180 days of age.

In the case of the larger calf No. 544, there was a deficit in the dry matter supply from the first period. This deficit varied irregularly but at the end of period VII, it was greater than at the beginning of the trial. At the start of the trial the calf consumed enough milk to provide a large excess of nutrients, but this excess decreased irregularly and reached a low point for total nutrients during period VII.

At the beginning of period VIII canned tomatoes were introduced into the ration and were fed with the milk for five periods, but during this time the deficit in dry matter consumed became greater. The amount of digestible protein consumed also decreased and where there had previously been an excess of total digestible nutrients a deficit became apparent.

At the beginning of period XIII the feeding of canned tomatoes was stopped and alfalfa hay was introduced into the ration. The deficit in dry matter was immediately largely reduced though it had

not entirely disappeared when the calf was slaughtered after 90 days on this ration. The supply of total digestible nutrients was also immediately converted from a deficit into a surplus and the supply of protein was also greatly augmented.

Behavior of the Calves

The calf No. 544 did not show any peculiarities in action until the fifth period when it started to chew the wooden walls of the pen and in period VI it showed signs of irritability or nervousness. These peculiarities continued to some extent until alfalfa was introduced into the ration. In period VII, just before the feeding of tomato juice was started, the calf was stiff in the joints and had a stilted gait. About this time the back of middle in the calf also became apparent. The eyes also did not appear normal; they were watery and dull. When the tomato juice was introduced the calf picked up, walked better and its eyes appeared to be well, but within two months it was back in the old condition and the leg joints became puffy. This lasted until the introduction of alfalfa hay to the ration when the calf started to regain a normal appearance and looked in good shape when the trial ended.

In the case of calf No. 539 somewhat similar conditions prevailed. It started chewing wood in the second period and by the third period was extremely nervous even when touched. It continued in this condition until its death at the end of Period VI.

Post -Mortem Examination of Calf No. 544.

The calf No. 544 was killed at the end of the fifteenth period and an autopsy was conducted by Dr. E. A. Benbrook of the Department of Veterinary Pathology and Bacteriology, while Dr. H. S. Murphy of

the Department of Veterinary Anatomy examined the sexual organs of the calf.

The animal was in fair condition and the abdomen was fairly well rounded yet flaccid. The condition of the skin was fair, though that in the region of the cheeks and jaws was dry, harsh, scaly and partly denuded of hair.

The Stomach

The rumen, reticulum and omasum appeared to be normal in size, whereas, the abomasum was voluminous for an animal of this size. The contents of the stomach compartments were about normal, but in the rumen there were two hair balls, one about 4 inches in diameter with a brown smooth coat and the other about 1½ inches in diameter and uncoated. The reticulum contained no foreign bodies except a small amount of sand and cinders. The mucosa of the abomasum was slightly catarrhal.

The Intestine

In both the large and small intestine the mucosa was somewhat catarrhal.

The Glands

The liver was enlarged by about one-third, was pale yellowish-red in color, mottled and friable. The gall bladder contained a number of concretions and the mucosa was slightly catarrhal. The pancreas was slightly enlarged. The spleen was slightly enlarged. The mesenteric chain of lumph nodes were all somewhat enlarged and the cortex in most cases was slightly reddened. In some petechial haemorrhages were noted. The remainder of the lymphatic system was

apparently normal so far as could be noted in the examination. The kidneys were slightly enlarged and pale. One kidney contained a retention cyst the size of a pea.

The thyroid glands were flattened and irregularly lobulated. The gland tissue was pale red in color and apparently interspersed with strands of connective tissue. The cut surface was shiny and rather sticky. The parathyroids were flattened and about the size of a pea. The thymus gland was large in its extra-thoracic position, extending up to the larynx, and most of the gland lobules showed petechial haemorrhages. The intra-thoracic portion of the gland was small.

The Skeletal Tissues

The skeleton showed no noticeable changes. Cross sections of the ribs above and near the sternum and of the left tibia appeared to be normal.

The Genital Organs

This animal as mentioned earlier was twinned with a bull, but from anatomical and histological examination, Dr. H. S. Murphy of the Department of Veterinary Anatomy was of the belief that the animal was potentially a bull though sexual development had been arrested.

Post-Mortem Examination of Calf No. 539

This animal was examined shortly after death by Dr. E. A. Benbrook of the Department of Veterinary Pathology and Bacteriology.

The Stomach

The rumen was about the size of the other three compartments

of the stomach and it contained a grey-brown opaque liquid. An oval uncoated hair ball about 2 inches long and 1 inch in diameter was found in the rumen. The abomasal mucosa showed haemorrhages.

The Intestine

The intestine showed no changes of importance.

The Glands

The liver showed a cloudy swelling and a few subcapsular haemorrhages, while the gall bladder contained a small amount of yellow cloudy bile. All of the lymph nodes were enlarged and congested and those of the viscera showed haemorrhages. The kidneys showed cloudy swellings and were congested. The thymus gland was large and showed haemorrhages throughout.

The Skeletal Tissues

The femur and humerus showed a peripherally red marrow but the osseous tissue was apparently normal. The joints of the legs were enlarged.

Cause of Death

The ultimate cause of death was haemorrhagic septicaemia which had a good opportunity for development owing to the lowered condition of the calf.

Discussion of Results

From the work presented in this and the two earlier pages in this series which deal with the problem of restricted rations for calves, it is apparent that milk is not suitable as the sole feed for calves when fed for any considerable time. From the amount of milk consumed by the calves on a ration of milk alone, it is

apparent that they were being supplied with sufficient digestible nutrients for a time, but later on in the trials they could not consume enough milk to provide all the digestible nutrients they required.

At a much earlier stage in the trials the dry matter provided by the milk rations fell below the requirements of the calves and so it would appear that the calves were not being supplied with enough dry matter, especially in the form of bulky constituents.

It has been sometimes believed that milk was at times deficient in the vitamine Water-Soluble C, but from the bibliography presented and the results of the trial reported here on the addition of tomato juice to a milk ration, it becomes apparent that the vitamines, Fat-Soluble A, Water-Soluble B and Water-Soluble C, were present in sufficient amounts and did not cause the inefficiency of milk when used as the sole ration.

The one point of importance brought out by the results reported here is that the addition of a roughage such as alfalfa hay to a milk ration will bring the calves through in good shape even though they have gone off badly on a ration of milk alone. There may be three factors which render such a roughage valuable in the ration.

It is to begin with bulky and thus renders possible the proper distention and development of the rumen and other portions of the alimentary tract even at an early age. It has already been shown in a previous paper in this series that the addition

to a milk ration of grains relatively rich in magnesium and poor in calcium will prevent the proper deposition of calcium in the skeletal tissues. Alfalfa hay is rich in calcium and so acids in maintaining the proper calcium balance.

AS has been shown in the resume' of previous work certain green plants, such as oats, contain an antirichitic vitamine which aids calcium assimilation. By careful curing part of this vitamine is retained. The alfalfa hay used in this tissue was of the second cutting and was put up rapidly without much exposure to direct sunlight, so there is a possibility that it contained some of this vitamine and was thus of greater value to the calf.

Summary

From the work reported here it would appear that

1. Milk can not be used as the sole ration for calves indefinitely.
2. A lack of the vitamines, Fat-Soluble A, Water-Soluble B and Water-Soluble C, is not a cause of the inefficiency of milk.
3. A bulky roughage appears to be necessary for the calf.
4. A roughage such as good pea-green alfalfa may also provide some of the antirichitic vitamine and add to the lime of the calf.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

X. SELF-FEEDING A GRAIN MIXTURE TO YOUNG CALVES

Studies in the Growth and Nutrition of Dairy Calves

X. Self-Feeding a Grain Mixture to Young Calves.

The use of the self-feeder in the raising of dairy calves has already been discussed in Papers VII and VIII of this series, so it will not be necessary to go into the history of the work here. In the two previous papers a trial of 60 days' duration with young calves was reported and also an attempt to raise heifers to producing age with the aid of the self-feeder. In each case the animals were given a choice of grains and were allowed alfalfa hay at free will while milk was hand fed.

Experimental Work

In the trial reported here 4 young calves, averaging 16 days in age, were used. Information concerning them is given in Table I and where necessary it is calculated to the day on which the trial started, namely, 6th of October, 1921.

Table I

Animals Used

Calf No.	565	570	572	573
Breed	Jersey	Ayrshire	Jersey	Ayrshire
Birth Weight, lbs.	51	55	41	58
Age, Days	32	18	8	8

The trial lasted for six periods of 30 days each. The calves were started on whole milk, hand fed, according to their apparent needs, and in the third period the substitution of skim milk started, though it was not absolutely completed until the last period.

Good alfalfa hay was kept before the calves at all times and they were provided with a mixture of 5 parts cracked corn, 2 parts ground oats, 2 parts wheat bran and 1 part old process linseed oil meal, by weight, in a self-feeder. Salt was provided at free will and the animals were watered twice daily.

Table II.

Total Feed Consumption for the Group

Period	Whole Milk	Skim Milk	Alfalfa Hay	Grain Mixture
	lbs.	lbs.	lbs.	lbs.
I	1056	----	27	39
II	1210	----	107	147
III	1206	140	160	319
IV	728	820	221	483
V	48	1770	162	623
VI	---	1880	180	806
Total	4248	4610	857	2417
Average per Calf	1062	1153	214	604
Dairy Average per Calf	5.9	6.4	1.2	3.4

It will be noted that the grain consumption is heavy, being at all times greater than the hay consumption. On the average each calf consumed 3.4 pounds of grain daily and only 1.2 pounds of alfalfa hay.

The live weight of each animal was obtained at the end of each 30-day period. The body measurements, height at withers, depth of chest and width at hooks were also determined. The animals showed excellent growth. This is more readily realized when the rates of grain are compared with those reported for normally fed heifers in Paper III of this series. The normally fed heifers have an advantage in age of 14 days in the comparison with the self-fed calves and yet at the end of the sixth 30-day period, when the trial ended, the self-fed heifers showed increases of 491%, 37%, 56% and 77% in live weight, height, depth and width respectively. The corresponding increases for the heifers fed normally were 309%, 34%, 57%, and 67%.

Table III.

Average Live Weights and Body Measurements

Time	Live Weight	Height	Depth	Width
	lbs.	in.	in.	in.
Start of Trial I	59	25.6	10.9	6.0
End of Period I	97	27.9	12.0	6.9
II	141	30.5	13.6	8.1
III	183	33.1	15.3	9.1
IV	239	34.6	16.9	10.0
V	297	36.2	17.7	11.0
VI	346	38.3	18.7	12.2

The self-fed heifers showed good gains, but the cost of the gains is a very important factor. Using the same feed costs as were used in the other papers of this series it is found that the cost of feed for the normally fed heifers up to six months of age was $35.57, and for the self-fed heifers that had a choice of gains it was $35.81, while for the heifers in the work reported here, where a grain mixture was used the cost was $29.96 or a considerable reduction.

If the cost per pound of live weight gain be considered it is found that it amounts to 14.4¢, 14.1¢ and 10.4¢ per pound for the various groups in the order mentioned above. This would indicate that calves can be raised economically when self-fed a mixture of grains. This is due largely to the fact that the amount of high priced feeds such as oil meal are limited and cheaper grains, such as oats, form a larger part of the ration.

Summary

From the work reported here it would appear that dairy calves can be fed economically until six months of age with a self-fed mixture of cracked corn, ground oats, wheat bran and linseed oil meal. The proportions of the feeds in the mixture can be adapted to ruling prices. Alfalfa hay can be self-fed and the milk hand fed according to the requirements of the individual calves.