PROTEIN REQUIREMENTS OF

DAIRY CALVES

by

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INTRODUCTION

Present recommendations for the protein allowances for dairy calves are based on comparatively few studies and relatively meager data obtained from feeding trials. Morrison's standards (24) are based primarily on eight studies. The latest recommended allowances of the National Research Council (26) are based on the studies by Ritzman and Colovos (30) and Lofgreen and associates (13). There is considerable variation in the above recommended allowances for dairy calves relative to the protein requirements (Table 1).

Morrison's present recommended allowances are a revision of his 1936 standard (23) which were more liberal for calves above 300 lb. bodyweight. Earlier recommended allowances by Armsby (2) were considerably higher than current recommendations.

Mitchell estimated the protein requirements by a factorial method, but this estimate has been modified at various times by numerous research workers (5, 6, 18, 22). These revisions have displayed a tremendous variation which exemplify the general confusion relative to the protein requirements of dairy calves.

Because of the normally high prices and limited supplies of protein feeds, definite minimum levels of intake which are adequate for proper growth of dairy calves should be established.

The purpose of this study was to secure more data relative to the minimum protein requirements of dairy calves for optimum growth by studying the effects of three levels of protein intake on growth and nitrogen retention when TDN and dry matter intakes were equal.

Table 1

Daily Allowances of Digestible Protein
for Growing Dairy Cattle

Bodyweight	Armsby	Morrison (1936)	Morrison (1948)[1]	N.R.C.[1]
lb.	lb.	lb.	lb.	lb.
100		.40	.40	.40
150		.52	.52	.50
200	.90	.62	.62	.60
300	1.07	.78	.77	
400	1.20	.90	.87	.80
500	1.31	.98	.92	
600	1.40	1.06	.95	.85

[1]Current recommended allowances.

REVIEW OF LITERATURE

Harris and Loosli (10) in feeding trials with dairy calves fed from 8 weeks to 16 weeks of age secured gains in bodyweight slightly above Ragsdale's standard with rations containing 18.8% crude protein. Those receiving 11.7% and 15.2% crude protein were slightly below normal and those receiving 8.3% made very poor growth. All rations were balanced in energy, fat, calcium, and phosphorus content.

Blaxter and Price (6) obtained poor growth with 700 lb. heifers fed a ration calculated to supply adequate digestible protein according to Mitchell's estimates. The addition of 0.5 lb. of protein to the ration proved to be of little value. However, the addition of 0.25 lb. of protein plus 0.25 lb. of starch resulted in normal growth.

Lofgreen and associates (13) in comparing different levels of protein intake failed to secure normal growth on the basis of either Mitchell's estimated minimum requirements or Morrison's 1936 recommended allowance when the TDN intake equalled Morrison's 1936 feeding standard. (These allowances were lower than the present standard). A 5% increase in TDN intake resulted in satisfactory growth. They found Mitchell's estimates to be approximately three-times too liberal for 150 lb. Holstein calves, but grossly inadequate for 700 lb. Holstein heifers.

Swanson and co-workers (34) found biological values of protein feeds depended primarily on the nutritive ratio of the ration and were poor indexes of the nutritive value of the feed protein. Biological values were about 45, 65 and 85 when the nutritive ratios were 1:4, 1:9, and 1:14 respectively. Proteins which gave widely different values when fed at the same concentration in the ration gave almost identical values when fed at the same nutritive ratio. The expected relationship between nitrogen utilization and nutritive ratio was disturbed when the ration was inadequate in TDN. Preferential use of protein for energy rather than as a source of nitrogen was indicated when feed intake was inadequate.

Blaxter and Mitchell (5) reported that the nitrogen required to replace fecal metabolic losses ranged from 25% of the absorbed nitrogen for 200 lb. Holstein heifers to 69.9% for 1200 lb. heifers. They concluded that ruminants which exist on feeds low in protein, low in digestibility, and high in fiber require more digestible protein to replace the fecal metabolic loss.

Maynard (18) indicated that as the nutritive ratio becomes wider the digestibility of all nutrients becomes lower, especially the apparent digestibility of protein.

Lofgreen and co-workers (14) fed Holstein heifers two levels of protein and energy to study the effects of energy on nitrogen retention. The low energy intake was the TDN allowance recommended in Morrison's 1936 standard and the high energy intake was 115% of this allowance. The low protein intake was the digestible crude protein allowance recommended in Morrison's 1936 standard and the high intake was 160% of this allowance. The low protein - low energy group retained 58.8% of the apparently digested nitrogen above maintenance needs compared to 78.7% for the low protein - high energy group. This increase was statistically important. At the high protein intake these values were 37.8% and 35.8% in the low and high energy groups, respectively.

The average daily gain in bodyweight was 1.2 lb. in the low energy groups and 1.4 lb. in the high energy groups with no significant difference between those calves on the low or high protein intake.

Ritzman and Colovos (30) showed that dairy calves from 1 to 4 months of age utilize protein and energy less efficiently as they become older. They found that 90% of the gain in bodyweight by calves fed for maximum growth was in the form of protein rich tissues.

Gullickson and Hanson (9) found no appreciable differences between linseed meal, cottonseed meal, corn gluten meal, soybean oil meal and ground soybeans as protein supplements for young calves.

Morrison (24) indicates that the quality of protein is of importance when milk is removed from the ration of dairy calves at the age of 7 to 9 weeks, but that animal protein is not necessary.

Norton and Eaton (25) secured satisfactory growth with dry calf starters containing 16% to 18% of soybean oil meal when milk was removed from the ration at the age of 7 to 9 weeks.

Carr et al. (7) reported calves fed skimmilk retained up to

18.1% more nitrogen than calves of the same age which were fed dry rations containing approximately the same amount of protein.

Ritzman et al. (31) reported that vitamin A deficient calves consumed more feed but made 50% less gain than calves receiving adequate supplies of vitamin A. Protein utilization decreased about 25% and digestion, absorption and ability to metabolize energy were depressed about equally.

Colovos et al. (8) found that both the digestion of the feed protein and retention of the absorbed nitrogen were lowered by vitamin D deficiency. The efficiency of energy utilization was also reduced.

Swett and associates (35) reported that Jerseys required more protein per unit of bodyweight for normal growth than Holsteins. Those animals receiving an excess of energy required less protein.

Ragsdale (28) found no difference between breeds in efficiency of feed utilization. Calves in this study received whole milk for 4 to 5 weeks followed by skimmilk until the age of 6 to 8 months.

Studies by Reid (29) indicate that Holstein heifers severely stunted by nutrient intakes limited to 65% of Morrison's recommended allowances from birth to the time of first calving apparently do not suffer permanent injury. Heifers fed in this manner made remarkable recovery in size and bodyweight when fed liberally during the first lactation. He reported slightly higher production from these heifers than from other heifers fed at or above normal recommended allowances from birth to time of first calving. These heifers were about equal in bodyweight with heifers fed normal allowances at the time of second calving.

Savage and McCay (33) suggested that maximum rate of attainment of adult body size may not result in optimum lifetime preformance.

Ragsdale (27) states that in general, individual animals may deviate from the standard approximately 10% or even 15% to 20% in liveweight and still be considered normal. Other measurements as a rule do not vary over 5% to 10% from normal animals.

Research workers (1, 4, 32) have shown that other animals utilize protein as a source of nitrogen more efficiently when their ration contains adequate energy. Observations of diabetic humans (17) have indicated that carbohydrates in the diet enhance nitrogen retention.

Considerable work has been done which shows that ruminants, including young dairy calves, may utilize urea as a portion of their nitrogen requirements.

Loosli and McCay (15) found that 2-month old calves were unable to grow on a 4.4% protein ration. When urea was added to give a calculated protein content of 16.2% to the ration, increases in bodyweight and height at withers were fairly satisfactory. Digestibility of dry matter and carbohydrates were increased considerably.

Hart *et al.* (11) concluded that the addition of ammonium carbonate or urea to a basal ration so as to increase the protein from 6% to an equivalent of 18% increased gains in bodyweight of dairy calves. Protein analyses of the carcasses indicated urea and ammonium carbonate fed calves stored considerably more protein. Calves receiving 43% of their nitrogen from urea were apparently normal. Higher levels of urea intake produced undesirable results.

Mills et al. (21) found that the addition of starch to rations containing urea supplied a suitable substrate for an active rumen flora. They noted a rapid hydrolysis of urea, a speedy disappearance of the ammonia thus formed and a marked rise in the protein content of the rumen.

Work and Henke (36) secured growth in dairy heifers superior to that on a low protein ration by the addition of 4% urea. However, they obtained greater gains in bodyweight on a normal protein mixture with equal calculated amounts of protein.

Bartlett and Cotton (3) secured 0.24 lb. more daily gain in bodyweight in dairy heifers when 0.177 lb. of urea was added daily to a limited protein ration. The same quantity of nitrogen in the form of protein resulted in slightly greater gains, but the differences were not significant.

Loosli et al. (16) demonstrated that rumen micro-organisms synthesize the ten essential amino acids by feeding sheep and goats purified rations with urea as the only appreciable source of nitrogen. The rations contained small amounts of amino acids. They found these amino acids in the rumen contents in amounts 9 to 20 times greater than in the ration. Lambs on the experimental ration made daily gains of 0.23 lb. bodyweight compared to 0.30 lb. for lambs on a control ration containing casein as the source of nitrogen. All lambs were in positive nitrogen balance. Calculated biological values were 56 for the urea ration and 82 for the casein ration.

McDonald (19) found that ammonia constitutes the main component of the non-protein nitrogen in the rumen fluid when the animal is fed a natural ration. He concluded from indirect evidence that ammonia represents an important intermediate in the digestion of dietary protein and its utilization by symbiotic micro-organisms.

McNaught and Smith (20) concluded that non-protein compounds usually dissolve quite readily in rumen fluid. They suggested that a portion of this non-protein nitrogen may pass through the rumen before the bacteria have an opportunity to utilize it. This may explain the finding that non-protein nitrogen is of less value to ruminants than its nitrogen equivalent in protein.

Huffman (12) reported ammonia formed from urea not utilized immediately by bacteria is absorbed through the rumen wall. In the presence of sufficient readily available carbohydrate, an active rumen flora will utilize the ammonia rapidly as a source of nitrogen and so prevent accumulation.

EXPERIMENTAL

Eighteen purebred Holstein, Guernsey and Ayrshire male and female calves from the Oklahoma Agricultural and Mechanical College herd were selected for a feeding trial to study the minimum protein requirements of dairy calves for optimum growth. All calves were removed from their dams 48 hours after birth, identified by neck strap numbers, and placed in individual tie-stalls with solid partitions. The stalls were located in the main dairy barn and each was equipped with a self-feeding hay rack, a drinking cup, and a bucket for starter. Sawdust or wood shavings were used for bedding.

The calves were turned in an open lot to exercise for approximately 2 hours daily during fair weather.

The calves were assigned to one of three groups in such a manner that all groups were balanced as nearly as possible with respect to breed, sex and birth weight. Groups I and II each contained 2 Holstein males, 1 Holstein female, 1 Guernsey female, 1 Ayrshire male and 1 Ayrshire female. Group III contained 2 Holstein males, 1 Holstein female, 1 Guernsey female and 2 Ayrshire females.

All calves were fed whole Holstein herd milk, from nipple pails, at the rate of 1 lb of milk per 10 lb. of bodyweight daily during the milk feeding period. Total milk consumption was limited to 450 lb. of milk per calf. Good quality prairie hay was fed *ad libitum* and a calf starter containing approximately 14% digestible protein and 72% TDN was fed daily. Daily feed consumption was recorded. As starter consumption increased it was diluted with beet pulp in the proportions indicated in Table 2. When daily consumption of the starter, beet pulp mixture approached 4.0 lb. they were gradually changed to their respective starters as indicated in Table 3.

All calves were weighed and measurements of height at withers and heart girth were made when they were removed from their dams, on the succeeding Saturday morning and weekly thereafter until the completion of the trial. These measurements were also taken at 180 days of age. All weights and measurements were taken at approximately the same time each Saturday and weekly records were started at this time.

When the calves regularly consumed all of the daily allowance of 4.0 lb. of starter and beet pulp in the proportions shown in Table 2 they were placed on the experiment. All calves remained on the experiment until they were 180 days of age, or for 16 weeks.

Weekly adjustments in the ration were made, in accordance with Table 2, on the basis of bodyweight. These amounts of starter and beet pulp when fed with the amount of prairie hay usually eaten by calves at these ages were calculated to supply 85.%, 100.0% and 115.0% of Morrison's (24) minimum protein allowances, for Groups I, II and III, respectively. In this manner, also, the calculated TDN and dry matter intake was equal in all three groups. The maximum daily allowance of starter was limited to 4.0 pounds.

Another group of calves consisting of three Holstein males and

Table 2

Daily Starter and Beet Pulp Allowances

Bodyweight	Group I		Group II		Group III	
	Starter No. 1	Beet pulp	Starter No. II	Beet pulp	Starter No. III	Beet pulp
lb.	lb.	lb.	lb.	lb.	lb.	lb.
150	2.1	1.9	2.3	1.7	2.4	1.6
160	2.1	1.9	2.3	1.7	2.4	1.6
175	2.5	1.5	2.6	1.4	2.6	1.4
185	2.6	1.4	2.7	1.3	2.8	1.2
195	3.0	1.0	2.9	1.1	3.0	1.0
205	3.0	1.0	3.0	1.0	3.0	1.0
220	3.4	0.6	3.2	0.8	3.2	0.8
230	3.4	0.6	3.3	0.7	3.3	0.7
240	3.5	0.5	3.4	0.6	3.4	0.6
250	3.5	0.5	3.4	0.6	3.4	0.6
260	3.5	0.5	3.6	0.4	3.5	0.5
275	3.6	0.4	3.6	0.4	3.6	0.4
285	3.7	0.3	3.8	0.2	3.8	0.2
295	3.8	0.2	3.8	0.2	3.8	0.2
305	3.9	0.1	3.9	0.1	3.9	0.1
315	3.9	0.1	3.9	0.1	3.9	0.1
325	4.0	0.0	4.0	0.0	4.0	0.0

Table 3

Calf Starter Formulas

Ingredients	Starter No. I	Starter No. II	Starter No. III
	lb.	lb.	lb.
Crimped oats	400	300	300
Cracked corn	600	600	600
Wheat bran	200	190	190
Cottonseed meal (41%)	200	410	610
Alfalfa meal	100	100	100
Omalass	400	300	100
Dried buttermilk	50	50	50
Trace mineral salt	20	20	20
Steamed bone meal	20	20	20
Ground limestone	20	20	20
Total	2010	2010	2010
[1]Total protein, per cent	15.31	17.88	20.75
[2]Digestible protein, per cent	11.74	14.26	16.78
[2]TDN, per cent	71.62	71.58	71.40

[1]Proximate analysis

[2]Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

three Guernsey males was selected for nitrogen balance trials and digestion studies. One Holstein and one Guernsey was assigned to each of these groups, I, II and III. Their treatment and feed intake was essentially the same as that of the animals in the feeding trial.

These calves were placed in metabolism stalls at approximately 90, 120 and 160 days of age. In each instance total collections of feces and urine were made for a 7-day period which was preceded by a 7-day preliminary period. Daily feed intakes were maintained as nearly constant as possible during the preliminary and collecting periods.

Daily feces collections were thoroughly mixed, weighed, and an aliquot taken each day for a composite sample. The samples were placed in 2-quart jars with tight fitting lids with thymol crystals added for preservative and refrigerated at approximately 37°F.

The daily urine collections were diluted to a constant weight, thoroughly mixed and an aliquot was taken each day for a composite sample. The daily samples were rendered slightly acid to litmus paper by adding concentrated H Cl, drop by drop, before they were placed in 2-quart jars with tight fitting lids and refrigerated.

RESULTS

Changes in body weight were the primary criteria used in evaluating the response of the calves to varying levels of protein intake. Bodyweight information is summarized in Table 4 and presented graphically in Figures 1, 2 and 3. Growth in Group I was retarded as evidenced both by a lower actual gain and per cent of expected gain based upon Ragsdale's standards. Groups II and III exhibited comparable bodyweight gains, although both groups were somewhat below expected growth. While the birthweights of all calves were slightly less than Ragsdale's standards, none of the groups of calves maintained this relationship during the trial. While the actual average birthweights were equal in all three groups, Group III was somewhat larger in relation to Ragsdale's standard because of some variation in sex. At the end of the trial Groups II and III were in the same relationship to one another as at birth, but Group I had fallen quite low in comparison. The Group III calves exhibited slightly better growth response during the feeding trial since they had suffered some weight disadvantage between birth and the initiation of the trial which they apparently regained during the observation period.

Skeletal growth as measured by height at withers and heart girth paralleled the relative changes that were observed with respect to bodyweight gains. Average gains in height at withers were 83, 92 and 91 per cent, and heart girth were 82, 96 and 100 per cent of that expected according to Ragsdale's standards, in Groups I,

Table 4

Growth Performance of Feeding Trial Calves
as Measured by Bodyweight

Description	Group I Bodyweight	Group I R.[1]	Group II Bodyweight	Group II R.[1]	Group III Bodyweight	Group III R.[1]
	lb.	%	lb.	%	lb.	%
Av. Birth weight	78	94.8	78	94.8	78	96.5
Av. initial bodyweight	165	96.5	160	98.1	156	93.5
Av. bodyweight at 180 days of age	280	83.0	311	92.2	300	90.2
Av. gain to 180 days of age	115	69.3	151	86.6	144	86.9
Av. final bodyweight	302	82.7	325	91.2	324	90.5
Av. gain on experiment	137	70.6	165	85.4	168	87.8
Av. daily gain	1.22	70.6	1.47	85.4	1.50	87.8

[1]Per cent of Ragsdale's standard.

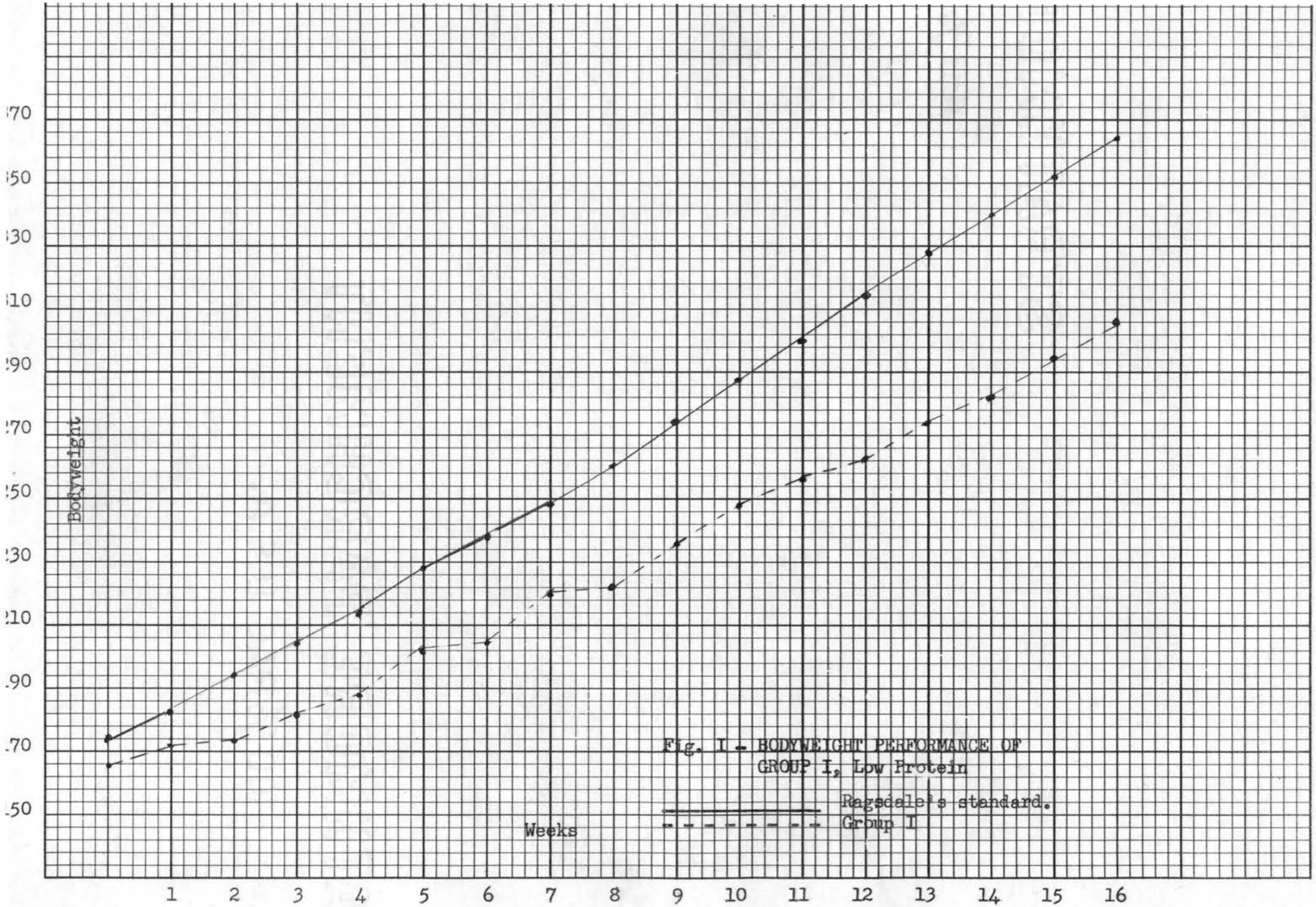

Fig. I - BODYWEIGHT PERFORMANCE OF GROUP I, Low Protein

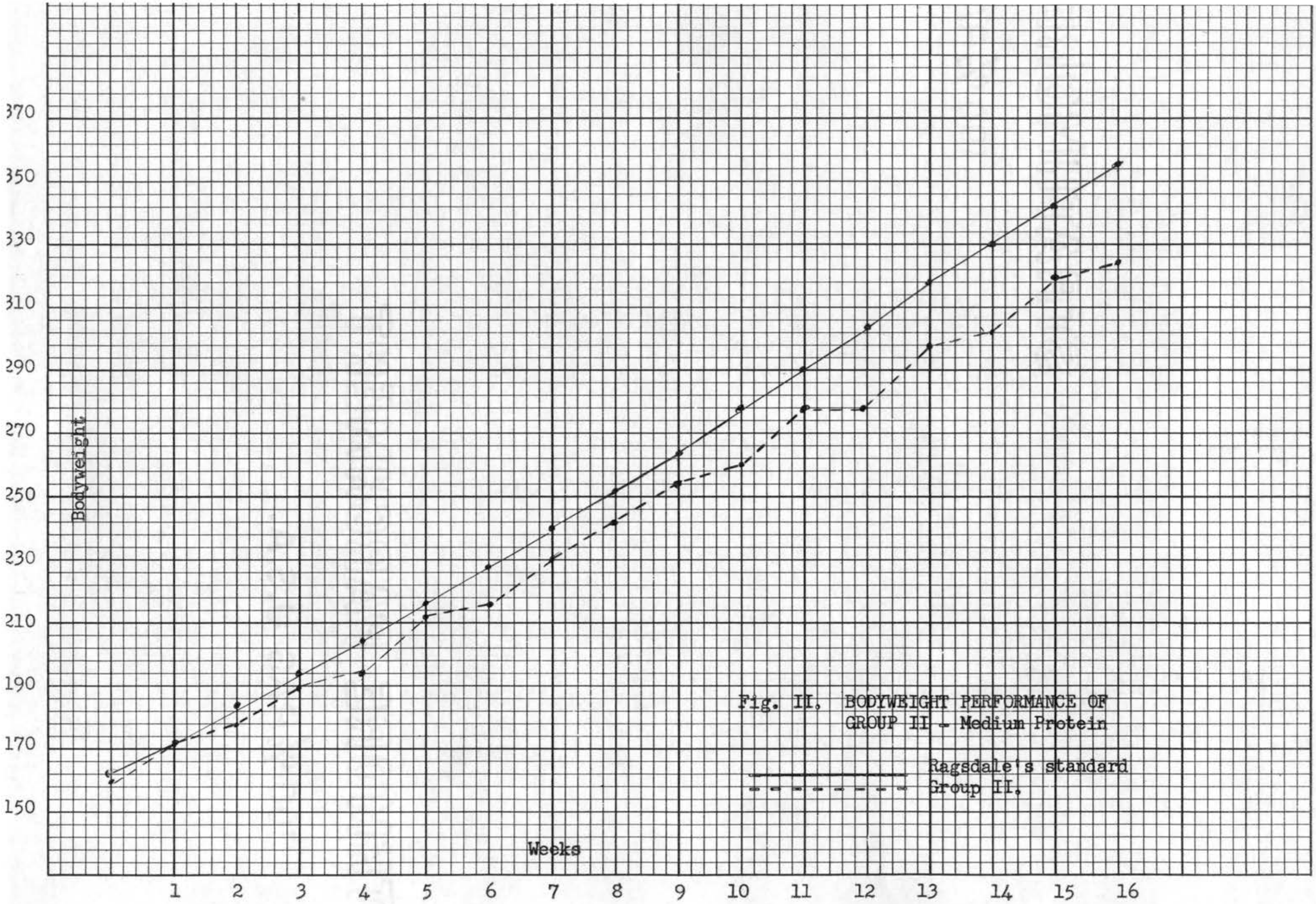

Fig. II. BODYWEIGHT PERFORMANCE OF GROUP II - Medium Protein

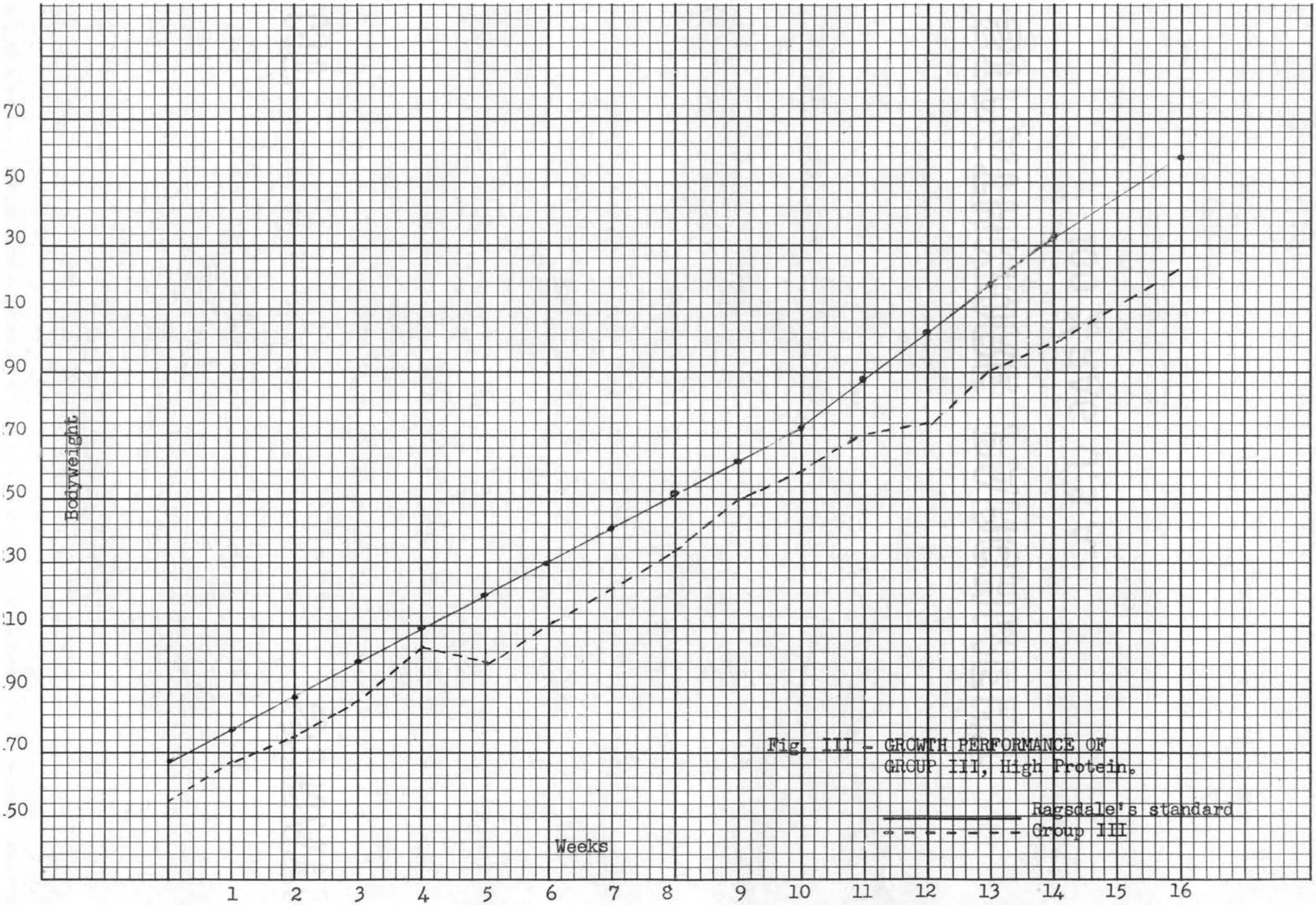

Fig. III - GROWTH PERFORMANCE OF GROUP III, High Protein.

II and III, respectively. In this respect, also, growth appeared comparable in Groups II and III while it was retarded in Group I, which received the lowest protein intake.

No differentiation could be made with any degree of accuracy between calves of the various treatment groups on the basis of general appearance. The appearance of all the calves seemed to be comparable to other calves which were being raised in the herd during the same period. The general health of all animals was good and could readily be classified as normal.

Average calculated daily protein intake was 3 per cent below the intended level in all three groups. This difference was due primarily to errors in the estimate of expected hay intake and expected growth and general variations of feeding habits of individual calves. The calculated average digestible protein intakes per pound of bodyweight gain were 0.375, 0.384, and 0.423 lb. which represented 82, 97 and 112 per cent of Morrison's minimum recommended allowances for Groups I, II and III, respectively.

Nitrogen retention as presented in Table 5 was positive in all instances with the exception of calf number G. 7 in the first trial. This individual went completely off feed during the last two days of the trial so that these data became invalidated. There was considerable individual variation with respect to the rate of nitrogen retention, but, with the possible exception of the last trial, there did not appear to be any advantage in terms of nitrogen retained

Table 5

Nitrogen Retention of Male Calves
at Three Levels of Protein Intake.

	Calf			Nitrogen Retention per day		
Group	No.	Age	Bodyweight	Total		Apparently digested
		da.	lb.	g.	g/cwt.	%
			Trial I			
I	G. 7	96	137	-3.22	-2.35	-72
	H. 19	98	229	19.36	8.45	65
II	G. 14	101	171	12.42	7.26	60
	H. 20	110	203	14.78	7.28	51
III	H. 2	103	224	19.34	8.63	47
	G. 16	100	153	12.80	8.37	50
			Trial II			
I	G. 7	126	171	11.89	6.95	64
	H. 19	128	275	17.19	6.25	63
II	G. 14	131	212	11.36	5.36	41
	H. 20	140	234	10.12	4.32	36
III	H. 2	133	273	16.96	6.21	43
	G. 16	130	191	19.38	10.15	52
			Trial III			
I	G. 7	164	205	10.77	5.25	50
	H. 19	166	316	14.76	4.67	51
II	G. 14	169	257	15.48	6.02	49
	H. 20	178	279	12.65	4.53	39
III	H. 2	171	324	20.33	6.27	43
	G. 16	168	255	19.66	7.71	48

per 100 lb. bodyweight in the high protein intake groups as compared to the low intake group. The efficiency of nitrogen retention as measured in terms of per cent retention of apparently digested nitrogen was generally in favor of the low protein intake calves. This difference became less apparent as the calves advanced in age.

The average apparent digestibility of protein was 48.06, 53.34 and 59.86 per cent in Groups I, II and III, respectively. The average apparent digestible protein intake was only 79 per cent of that calculated from the proximate analyses, using Morrison's average coefficients of digestibility. Apparent TDN intake was found to be 89 per cent of the calculated amount.

DISCUSSION

Some consideration should be given to the period from birth to the beginning of the feeding trial. During this time all calves were treated alike and their performance in this period might offer some indications relative to expected performance during the feeding trial.

The average gain in bodyweight from birth to initial weight on trial was 98, 101 and 91 per cent of that expected on the basis of Ragsdale's standards in Groups I, II and III, respectively. The relatively low rate of gain in Group III was apparently due primarily to the influence of calf number 32. This calf exhibited a gain of only 60% of that expected. It is apparent that this individual's lack of appetite for hay as indicated by low consumption prior to the trial (Appendix Table XVIII) lowered his nutrient intake sufficiently to account largely for the relatively low bodyweight gains. This calf also suffered from some respiratory disorder during this period. During the feeding trial number 32 displayed improved appetite and excellent growth response. On this basis it would appear reasonable to conclude that the three groups of calves were uniform from the standpoint of growth potential in spite of the fact that Group III displayed some slow growth prior to the trial.

The health and general well-being of the calves used in the experiment prior to being placed on trial was typical of calves at these ages. The incidence of scours was very low and the severity was considered very mild with each group being afflicted about equally.

The incidence of colds or respiratory disorders was very rare with only one calf, no. 32 in Group III, of such severity as to require medication. The duration of this case was only 4 days and apparent recovery was very rapid as judged by external appearance, general observation and resumption of bodyweight gains.

The average age at which milk was removed from the ration was 58.5, 57.0 and 58.3 days for Group I, II and III, respectively.

The appetites of the calves were also typical for young animals in that daily feed consumption was quite variable with some calves consuming more starter than hay while in the case of others the reverse was true. However, when milk was removed from the ration the average daily intakes of starter and hay increased rapidly with more uniform consumption of both. The average total feed intake for each group did not differ a great deal from one another, however, individual feed intakes were somewhat variable as shown in Appendix Tables I through XVIII.

Since variations in eating habits of young calves were anticipated no calf was placed on trial until it regularily consumed its allowance of starter and beet pulp. In this manner with uniform consumption of starter and beet pulp which furnished the major portion of the protein allowance, the intended protein intakes could be controlled quite rigidly in spite of variable hay intakes. It appeared that this plan would afford the most desirable conditions under which to study the effects upon growth of calves due to various protein intake levels.

While relatively wide individual variations were encountered with respect to the age at which calves consumed the intended levels of starter, the groups as a whole were quite uniform. This is shown by the fact that the average age on trial was 84, 78 and 83 days in Groups I, II and III, respectively.

FEEDING TRIAL

Results obtained in the feeding trial show that calves in Group I were retarded in growth as measured by bodyweight gains in comparison to Groups II and III. The average of Group I was greatly affected by calf no. 26 whose average daily gain was only 60.0% of Ragsdale's standard. This calf developed a bad feeding habit of lapping its starter and beet pulp out into the stall thus wasting an unknown portion. The other calves in Group I showed relatively uniform bodyweight increases from 67 to 79 per cent of that expected on the basis of Ragsdale's standards.

While Groups II and III exhibited comparable bodyweight gains, growth in Group III was apparently somewhat more uniform than in Group II.

Since increases in height at withers and heart girth paralled bodyweight gains it appears that differences in bodyweight gains represented growth rather than differences in fluid retention or fat deposition.

Growth in all calves was below that expected on the basis of Ragsdale's standards. A combination of several factors may have been responsible for this result. The intended TDN intake was minimal and this was complicated further by errors in estimating prospective appetites. TDN intakes were kept relatively low in order to enhance the expression of differences in growth response as related to varying protein intakes. Lofgreen et al. (14) have shown that high energy rations improves the utilization of protein, especially in the case of low protein rations.

The digestion trials indicated that the TDN values of the rations were over-estimated to some extent. Actual TDN intakes of the digestion trial calves were only 89% of those calculated on the basis of proximate analyses and Morrison's average digestion coefficients.

The average final bodyweights in this experiment were above those of heifers on low nutrient intake studies by Reid (29). His studies indicated that heifers retarded in growth will rapidly recover their approximate normal size if adequately fed. His studies have shown that these heifers have produced equally as well as heifers which had been fed at normal or above rates.

Despite the differences in growth among the calves in this study their health and general well-being was apparently normal. At 180 days of age accurate segregation of these calves into treatment groups on the basis of general appearance would have been impossible.

The rations were intended by calculation, using proximate analyses and Morrison's average digestion coefficients, to supply 85, 100, and 115 per cent of Morrison's minimum allowances of digestible protein for Groups I, II and III, respectively. However, actual feed consumption was such that these values were 3% lower for each group.

Further complications with respect to the intended protein intakes may have been introduced by over-estimation of the digestible protein value of the rations. On the average actual apparently digestible protein values obtained from the digestion trials were only 79% of the calculated values, based on proximate analyses and average digestion coefficients. While a relatively low performance might be expected from calves exposed to the stress of confinement in metabolism stalls it would not appear reasonable that this much difference would exist between these calves and normally managed animals.

On the basis of discrepancies between apparent digestibility values determined and those calculated and the variations in feed consumption it is possible that actual digestible protein intake of the feeding trial calves was as much as 20% below that which was intended. Further work will be required to clarify these values before final conclusions can be drawn.

DIGESTION AND NITROGEN RETENTION TRIALS

Calves involved in the nitrogen retention and digestion trials were all apparently normal, healthy calves and in good condition when placed in the metabolism stalls. Their daily feed consumption was very uniform throughout the trials with minimal refusals, (Appendix Tables XX, XXI, XXII). Starter was refused in only two instances. In the case of G. 7 the only refusals were on the last two days of collection period I at which time this calf was definitely off feed.

The other calf involved was H. 2 and his refusals of starter were small and irregular during period II and were probably influenced some by contamination of the starter by ragweed leaves from the hay.

The general appearance and health of the calves were maintained in relatively good condition while they were in the metabolism stalls with the exception of calf G. 7 which was off feed in period I. The urine of H. 20 appeared to have some blood contamination and the volume was abnormally high for one day during period I. However, it apparently had little influence on his performance with respect to his ability to digest nutrients. On the last two days of period II and the last day of period III his urine also appeared to be contaminated with blood. For this reason these samples were discarded and his urine values are based on only 5 and 6 days for periods II and III, respectively.

All calves displayed some evidence of having been under strain while in the metabolism stalls at the completion of each trial. Their performance was probably influenced accordingly.

Since calf G. 7 was definitely off feed the last two days of period I, a more accurate value of apparent digestibility would be shown if his data for this period were omitted. By so doing the average per cent apparent digestibility of protein in ration I would be changed from 48.06% to 49.79% and in all rations from 54.45% to 55.04%. Other minor abnormalities though not considered normal probably are typical or representative for calves of these ages.

The apparent digestibility of the protein in the rations tended to increase as the protein intakes were increased. However, this was according to expectation due to constant metabolic fecal loss of nitrogen. As the calves became older the apparent digestibility of protein tended to decrease. This was, also, as expected since the calves were consuming larger proportions of hay and consequently more dry matter in relation to the amount of protein.

Nitrogen retention was associated with rather extreme individual variability. The excretion of some bloody urine by calf no. H. 20 may explain his relatively low retention in the last two trials. No apparent explanations can be offered in behalf of other variations prevalent in all trials with all calves.

With the possible exception of Trial III, no relationship appeared to exist between the level of protein intake and nitrogen retention. The per cent retention of apparently digested nitrogen, however, appeared to be in favor of the low protein intake groups, but became somewhat less prevalent as the calves advanced in age.

SUMMARY

A feeding trial was conducted to study the growth response of young dairy calves when fed varying levels of digestible protein. Three groups of 6 calves each were designated as Groups I, II and III which received calculated allowances of 85, 100 and 115 per cent of Morrison's minimum recommended allowances of digestible protein, respectively. Rations consisted of prairie hay, beet pulp and starters containing 15.31, 17.88 and 20.75 per cent total protein as determined by proximate analysis for Groups I, II and III, respectively. The maximum daily allowance of starter was limited to four pounds. Dry matter and TDN intakes were essentially the same at all three levels of protein intake. The rations were adjusted weekly on the basis of bodyweight.

Changes in bodyweight were the primary criteria used in evaluating growth response, but height at withers and heart girth measurements were also determined.

Digestion and nitrogen retention trials were conducted with Holstein and Guernsey male calves to determine apparent digestibility of nutrients and nitrogen retention as effected by similar levels of protein intake as in the feeding trial.

The growth, as measured by gains in bodyweight in all three groups was below Ragsdale's standard. Group I was retarded in growth compared to Groups II and III, while the growth of Groups II and III were comparable. Changes in measurements of height at withers

and heart girth tended to parallel relative changes observed with respect to bodyweight.

More efficient utilization of protein appeared to be associated with the lower protein intakes.

Under the conditions of this study no advantage was apparent from the feeding of protein above the level calculated to equal Morrison's minimum protein allowance.

There were rather extreme variations in nitrogen retention between individual calves. The efficiency of nitrogen retention as measured in terms of per cent retention of apparently digested nitrogen was generally in favor of the low protein intake calves. Nitrogen retention per 100 lb. bodyweight did not appear to be influenced materially by the level of protein intake in this study.

Digestion data indicate that the average digestibility of protein in these rations was only 79%, and that of the TDN only 89% of calculated values determined by using proximate analyses and Morrison's average digestion coefficients.

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APPENDIX

APPENDIX

Table I

Calf No. 5, H. Male, Group I. - Born 10/1/53

Off milk at 50 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	86.6 lb.
Prairie hay	54.7 lb.	Beet pulp	2.9 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein.[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	100	106						
72	168	91	37.5	33.0	17.5	11.0	10.5	80
79	178	91	39.5	33.0	17.5	10.2	10.5	76
86	188	90	39.0	33.5	18.2	13.6	9.8	76
93	200	91	39.0	33.5	21.0	17.3	7.0	81
100	207	89	39.5	34.0	21.0	22.5	7.0	81
107	235	96	40.0	34.0	23.8	23.4	4.2	82
114	221	86	41.0	34.5	23.8	20.4	4.2	84
121	231	85	41.5	35.0	23.8	23.5	4.2	83
128	234	82	42.5	35.5	23.8	32.8	4.2	86
135	246	81	42.5	36.0	24.5	37.2	3.5	87
142	259	81	44.0	35.5	24.5	38.4	3.5	85
149	272	81	43.0	36.0	25.2	33.9	2.8	82
156	276	79	44.0	36.5	25.2	43.3	2.8	85
163	284	78	45.0	36.5	26.8	41.0	1.4	85
170	304	80	45.5	37.0	27.3	41.5	0.7	83
177	307	78	46.0	37.5	28.0	47.1	—	86
180	316	79	45.5	37.5				
184	328	81	46.0	38.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table II

Calf No. 10, A Female, Group I. - Born 10/10/53

Off milk at 64 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	105.9 lb.
Prairie hay	65.1 lb.	Beet pulp	16.5 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Diges-tible Protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	65	90						
91	163	103	35.5	32.0	14.7	10.3	13.3	74
98	177	105	36.5	32.0	17.5	11.4	9.8	76
105	156	88	36.5	33.0	17.5	6.9	9.9	81
112	172	92	37.0	33.0	17.5	11.7	10.5	79
119	181	92	38.0	33.5	18.2	20.1	9.8	81
126	192	92	39.5	34.0	21.0	21.9	7.0	85
133	204	94	39.5	34.0	21.0	29.5	7.0	85
140	217	95	41.0	35.0	23.8	26.0	4.2	87
144	226	94	41.0	35.0	23.8	32.2	4.2	88
154	230	92	42.0	35.5	24.5	27.5	3.5	86
161	244	93	42.5	35.5	24.5	32.9	3.5	85
168	238	87	42.0	35.0	24.5	35.0	3.5	88
175	270	95	43.0	36.0	25.2	32.6	2.8	82
180	268	91	44.0	36.5				
182	273	92	43.5	36.5	25.2	37.3	2.8	83
189	277	90	44.0	37.5	25.2	35.3	2.8	81
196	296	92	44.5	37.5	27.3	37.6	0.7	83
203	300	90	46.0	38.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table III

Calf No. 17, G. Female, Group I. - Born 10/12/53

Off milk at 67 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter 1	123.5 lb.
Prairie hay	70.1 lb.	Beet pulp	52.2 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	65	100						
110	146	91	36.0	32.0	14.7	5.9	13.3	78
117	148	88	37.5	32.5	14.7	13.3	13.3	81
124	158	88	38.5	33.0	14.7	13.6	13.3	77
131	166	88	38.5	33.0	15.0	8.5	9.0	68
138	166	83	38.5	33.0	17.5	13.9	10.5	82
145	174	83	39.5	32.5	17.5	14.7	10.5	80
152	169	77	40.0	34.0	18.2	17.2	9.8	84
159	200	88	40.5	34.0	21.0	22.0	6.1	82
166	200	84	41.5	34.0	21.0	22.7	7.0	86
173	217	87	41.5	35.0	23.8	24.3	4.2	86
180	225	87	42.0	36.0	23.8	26.5	4.2	85
187	230	85	42.0	36.0	23.8	25.7	4.2	84
194	242	86	43.5	36.0	24.5	28.2	3.5	84
201	247	85	44.5	36.5	24.5	32.8	3.5	85
208	257	85	44.5	36.5	24.5	26.4	3.5	80
215	265	85	45.0	37.0	25.2	23.8	2.8	79
222	269	83	44.5	37.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table IV

Calf No. 23, H Male, Group I. - Born 10/12/53

Off milk at 53 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	98.1 lb.
Prairie hay	55.0 lb.	Beet pulp	14.7 lb.

Weekly Growth Measurements and Feed Consumption

Growth						Feed Intake		
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	85	90						
68	170	96	36.5	32.5	17.5	4.5	10.5	76
75	182	96	36.5	33.0	18.7	8.7	9.8	78
82	188	94	37.5	34.0	18.2	9.0	9.8	74
89	196	92	38.0	34.0	21.0	16.9	7.0	82
96	216	96	39.0	34.0	23.8	19.2	4.2	84
103	210	88	39.5	34.5	23.8	27.4	4.2	89
110	215	86	40.0	35.0	23.8	19.7	4.2	85
117	230	87	41.5	35.5	23.8	32.5	4.2	87
124	232	84	42.5	35.5	23.8	34.2	4.2	87
131	251	86	42.0	35.5	24.5	38.9	3.5	87
138	267	86	43.5	36.0	25.2	44.1	2.8	87
145	282	87	43.0	37.0	25.9	41.9	2.1	84
152	273	80	44.0	36.5	25.9	37.3	2.1	84
159	300	85	45.0	37.0	27.3	36.9	0.9	82
166	300	81	45.5	37.5	27.3	46.9	0.7	85
173	317	83	45.5	38.0	27.3	36.1	0.7	80
180	317	79	46.0	38.5				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table V

Calf No. 26, H. Female, Group I. Born 11/4/53

Off milk at 55 days of age.
Total feed intake prior to experiment.
Whole milk 450.0 lb. Starter 102.8 lb.
Prairie hay 72.4 lb. Beet pulp 26.0 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	85	94						
80	172	97	36.5	33.5	17.5	8.8	10.5	77
87	178	95	37.0	33.5	17.5	9.1	10.5	76
94	170	85	38.0	33.5	15.0	12.2	9.0	68
101	170	81	38.0	34.0	17.5	17.1	10.5	82
108	187	84	38.0	34.0	18.2	13.3	9.8	76
115	196	83	38.0	35.0	21.0	21.4	7.0	84
122	216	87	39.0	35.0	23.8	25.8	4.2	87
129	207	80	39.5	35.5	23.8	28.1	4.2	90
136	227	83	41.0	35.0	23.8	28.7	4.2	86
143	232	82	41.5	35.5	23.8	30.4	4.2	85
150	249	84	41.0	36.0	24.5	28.4	3.5	83
157	245	79	42.0	36.0	24.5	27.4	3.5	83
164	253	78	42.0	36.5	24.5	30.6	3.5	83
171	265	78	43.0	37.0	24.5	32.7	3.5	81
178	277	79	43.5	37.0	25.2	39.7	2.8	83
180	277	78	43.5	37.5				
185	285	78	43.5	37.5	25.9	32.4	2.1	82
192	291	77	43.5	38.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table VI

Calf No. 29, A Male, Group I. - Born 10/24/53

Off milk at 62 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	96.6 lb.
Prairie hay	68.9 lb.	Beet pulp	18.4 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	70	86						
84	169	102	37.0	31.0	17.5	13.1	10.5	81
91	162	93	37.5	31.5	17.5	7.3	9.9	79
98	174	94	38.0	31.5	17.5	9.9	10.5	77
105	183	94	39.5	32.5	18.2	16.0	9.8	79
112	174	84	40.0	32.5	18.2	17.0	9.8	82
119	204	94	40.0	32.5	18.9	18.8	9.1	76
126	206	91	40.0	33.5	21.0	23.9	7.0	82
133	227	95	42.0	32.5	23.8	23.4	4.2	84
140	217	87	41.5	34.0	23.8	28.2	4.2	88
147	232	89	42.5	34.0	23.8	29.7	4.2	85
154	244	89	43.0	34.5	24.5	31.5	3.5	85
161	265	92	44.0	35.0	24.5	33.0	3.5	81
168	265	89	43.5	35.5	25.2	32.5	2.8	83
175	272	87	43.5	36.0	25.2	32.4	2.8	81
180	280	87	45.0	36.0				
182	283	87	45.5	36.0	25.9	33.0	2.1	81
189	287	85	45.5	37.0	25.9	43.9	2.1	84
196	306	87	46.0	36.5				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance

Table VII

Calf No. 3, A. Female, Group II. - Born 10/11/53

Off milk at 61 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	90.7 lb.
Prairie hay	54.8 lb.	Beet pulp	10.5 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb.	%R[1]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	70	97						
83	153	103	35.5	31.5	14.7	3.3	13.3	85
90	172	109	37.0	32.5	18.2	10.9	8.4	92
97	185	111	37.0	33.0	18.9	14.8	9.1	93
104	181	103	37.5	33.0	18.9	12.0	9.1	93
111	196	105	38.0	33.5	20.3	17.4	7.7	94
118	202	104	38.5	34.0	21.0	22.0	7.0	96
125	192	93	39.5	34.0	21.0	28.1	7.0	103
132	225	104	40.5	35.0	23.1	30.2	4.9	100
139	230	101	41.0	35.0	23.1	32.7	4.9	100
146	246	103	40.5	36.0	23.8	32.9	4.2	98
153	246	98	42.0	36.0	23.8	39.5	4.2	100
160	267	102	42.0	36.5	25.2	34.5	2.8	97
167	253	93	42.0	36.5	25.2	39.5	2.8	102
174	284	100	44.0	37.0	26.6	36.3	1.4	98
180	288	98	44.5	38.0				
181	293	99	44.5	37.5	26.6	41.4	1.4	98
188	300	98	45.0	38.0	27.3	38.6	0.7	97
195	306	96	46.0	38.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table VIII

Calf No. 6, H. Male, Group II. - Born 10/12/53

Off milk at 56 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	96.0 lb.
Prairie hay	52.6 lb.	Beet pulp	15.5 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	85	90						
68	171	96	36.5	32.0	17.5	7.5	10.5	90
75	192	102	38.0	33.0	20.3	15.7	7.7	95
82	194	96	38.0	33.5	20.3	20.4	7.7	97
89	221	104	38.5	33.5	22.4	24.1	5.6	97
96	241	107	40.0	34.0	23.8	29.7	4.2	98
103	241	101	40.5	34.5	23.8	31.8	4.2	99
110	254	102	41.0	35.0	23.8	33.1	4.2	96
117	262	100	42.5	34.5	25.2	41.4	2.8	101
124	279	101	43.0	35.0	25.9	37.8	2.1	98
131	286	98	42.5	36.0	26.6	45.5	1.4	101
138	295	95	44.0	36.0	26.6	45.9	1.4	99
145	313	96	44.0	36.0	27.3	46.9	0.7	98
152	311	91	44.5	36.5	27.3	49.4	0.7	99
159	346	97	44.5	37.0	28.0	46.1	-	95
166	346	94	46.5	37.5	28.0	53.4	-	98
173	376	98	46.5	38.0	28.0	52.7	-	94
180	380	95	48.0	38.5				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table IX

Calf No. 13, H. Female, Group II. - Born 10/9/53

Off milk at 57 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	101.3 lb.
Prairie hay	67.6 lb.	Beet pulp	28.7 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	75	83						
85	168	91	37.0	32.5	16.8	12.7	11.2	92
92	188	96	38.0	33.0	18.9	14.1	9.1	91
99	200	97	40.0	33.0	21.0	25.8	7.0	99
106	204	94	39.5	34.0	21.0	19.9	7.0	95
113	214	93	40.0	34.0	22.4	23.5	5.6	98
120	222	92	42.0	34.5	22.4	25.6	5.6	97
127	229	90	42.0	35.0	23.1	36.6	4.9	102
134	258	97	42.0	35.5	25.2	38.5	2.8	101
141	255	91	42.5	36.0	25.2	38.8	2.8	102
148	264	90	43.5	35.5	25.2	35.3	2.8	98
155	264	86	45.0	36.0	25.2	42.8	2.8	101
162	294	92	44.5	36.5	26.6	41.9	1.4	98
169	298	89	45.0	37.5	26.6	42.1	1.4	97
176	306	88	47.0	37.5	27.3	43.2	0.7	98
180	305	86	46.0	38.0				
183	311	86	46.0	38.5	27.3	41.2	0.7	96
190	321	86	46.5	39.0	28.0	42.6	-	97
197	326	84	46.5	39.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table X

Calf No. 22, H. Male, Group II. - Born 10/16/53

Off milk at 46 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	98.2 lb.
Prairie hay	52.7 lb.	Beet pulp	9.8 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	100	106						
64	163	95	36.0	32.5	14.7	-	13.3	80
71	173	95	37.0	33.5	18.2	9.2	9.8	92
78	184	95	37.5	33.5	18.9	13.6	9.1	92
85	206	100	38.0	34.0	21.0	13.8	7.0	92
92	210	96	38.5	34.5	21.7	24.5	6.3	98
99	222	97	41.0	34.0	22.4	22.1	5.6	96
106	207	85	40.0	34.0	22.4	6.7	5.6	93
113	214	84	40.0	34.5	22.4	32.4	5.6	101
120	240	89	42.5	35.0	23.8	38.6	4.2	102
127	258	91	42.5	35.0	25.2	48.6	2.8	105
134	271	90	42.5	35.5	25.2	47.2	2.8	101
141	280	89	43.0	35.5	26.6	47.8	1.4	103
148	285	86	44.5	36.5	26.6	46.5	1.4	101
155	308	89	45.0	36.5	27.3	44.8	0.7	98
162	308	85	45.5	37.0	27.3	49.2	0.7	96
169	334	89	45.0	37.0	28.0	49.1	-	98
176	335	86	46.0	38.0	20.0	36.6	-	98
180	340	85	46.5	37.5				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XI

Calf No. 27, A. Male, Group II. - Born 10/20/53

Off milk at 62 days of age.
Total feed intake prior to experiment.

Whole milk	457.5 lb.	Starter	92.4 lb.
Prairie hay	63.4 lb.	Beet pulp	19.8 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	75	93						
88	158	93	35.0	31.5	14.7	12.7	13.3	89
95	155	86	36.0	31.5	16.1	6.3	11.9	91
102	165	86	36.0	32.0	16.1	11.4	11.9	90
109	172	86	37.5	32.0	18.2	14.0	9.8	95
116	177	83	38.0	33.0	18.2	18.2	9.8	95
123	197	89	38.5	33.0	21.0	24.0	7.0	99
130	206	88	39.0	34.0	21.0	29.3	7.0	99
137	223	91	40.0	34.0	22.4	31.6	5.6	99
144	222	86	41.0	34.5	22.4	37.2	5.6	102
151	249	93	41.0	35.0	23.8	33.7	4.2	98
158	246	88	42.0	35.5	23.8	39.2	4.2	100
165	269	91	43.0	35.5	25.2	39.5	2.8	99
172	274	89	43.0	36.0	25.2	40.6	2.8	98
179	280	88	43.5	36.5	25.9	38.9	2.1	98
180	285	89	43.5	36.5				
186	294	89	44.5	37.0	26.6	40.9	1.4	97
193	306	88	44.5	37.5	27.3	46.4	0.7	99
200	310	86	46.0	38.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XII

Calf No. 28, G. Female, Group II. - Born 11/2/53

Off milk at 60 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	81.6 lb.
Prairie hay	38.8 lb.	Beet pulp	27.8 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Diges-tible protein[1]
days	lb	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	65	100						
82	146	117	36.0	32.5	16.1	4.2	11.9	95
89	158	120	36.5	32.5	16.1	5.4	11.9	90
96	157	111	38.0	33.0	16.1	11.6	11.9	93
103	156	104	38.0	33.5	16.1	13.1	11.9	95
110	180	113	38.0	34.0	18.9	15.7	9.1	95
117	189	112	38.5	34.0	19.6	17.1	8.4	94
124	197	110	40.0	33.5	20.3	23.0	7.7	97
131	197	105	40.0	35.0	20.3	24.6	7.7	97
138	228	115	41.0	35.0	23.1	27.3	4.9	98
145	223	107	41.5	35.5	23.1	30.4	4.9	101
152	242	111	42.5	36.0	23.8	32.0	4.2	99
159	245	107	42.5	36.0	23.8	28.9	4.2	97
166	247	103	43.5	37.0	23.8	32.5	4.2	98
173	262	105	44.5	37.0	24.5	34.7	3.5	97
180	270	104	44.5	37.0	25.2	41.4	2.8	99
187	288	107	45.5	37.5	26.6	36.4	1.4	98
194	292	104	45.5	38.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XIII

Calf No. 1, H. Male, Group III. - Born 9/29/53

Off milk at 51 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	111.7 lb.
Prairie hay	74.6 lb.	Beet pulp	12.3 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Diges- tible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	90	96						
81	201	101	39.0	34.0	21.0	18.0	7.0	110
88	204	97	39.5	34.5	21.0	18.2	7.0	109
95	219	98	39.0	35.5	22.4	22.4	5.6	111
102	234	99	40.0	35.0	23.1	30.6	4.9	113
109	252	102	40.5	35.0	23.8	27.5	4.2	109
116	254	97	42.0	36.0	24.4	29.1	4.2	112
123	261	95	41.5	36.0	24.5	46.5	3.5	116
130	264	91	43.5	36.0	24.5	36.9	3.5	112
137	276	90	44.5	36.5	25.2	42.9	2.8	113
144	297	92	44.5	37.5	26.6	42.2	1.4	112
151	313	93	45.0	37.0	27.3	48.9	0.7	113
158	325	92	46.5	38.0	28.0	51.4	-	114
165	324	88	47.0	38.5	28.0	54.6	-	116
172	359	94	47.5	38.5	28.0	55.4	-	111
179	362	91	48.5	39.0	28.0	53.7	-	110
180	367	92	49.0	39.0				
186	386	94	49.0	39.5	28.0	57.8	-	108
193	396	93	49.5	40.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XIV

Calf No. 8, H. Female, Group III. - Born 9/27/53

Off milk at 54 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	101.8 lb.
Prairie hay	65.5 lb.	Beet pulp	15.4 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb	$\%R^2$	in.	in.	lb.	lb.	lb.	$\%M^3$
Birth	80	89						
83	156	86	36.0	31.5	14.7	7.5	13.3	99
90	171	89	37.0	31.5	18.2	13.1	9.8	109
97	178	87	37.0	32.0	18.2	16.5	9.8	108
104	201	93	38.0	32.5	21.0	22.8	7.0	112
111	235	103	38.5	33.0	23.8	30.1	4.2	114
118	213	89	39.5	33.5	23.8	25.1	4.2	119
125	226	90	40.0	33.5	23.1	26.7	4.9	113
132	231	87	41.0	34.0	23.1	27.9	4.9	112
139	242	87	42.5	34.5	23.8	29.4	4.2	112
146	251	87	42.0	35.0	23.8	42.0	4.2	115
153	268	88	42.5	35.5	25.2	38.8	2.8	113
160	282	89	43.0	36.0	26.6	37.9	1.4	114
167	276	84	44.5	36.0	26.6	35.0	1.4	114
174	296	86	45.5	36.0	26.6	42.2	1.4	112
180	286	81	45.0	36.5				
181	288	81	45.0	36.5	26.6	45.5	1.4	115
188	324	88	45.0	36.0	28.0	45.0	-	112
195	325	85	46.5	37.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XV

Calf No. 25, A. Female, Group III. - Born 10/9/53

Off milk at 67 days of age.
Total feed prior to experiment.

Whole milk	450.0 lb.	Starter	89.7 lb.
Prairie hay	65.6 lb.	Beet pulp	9.4 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	70	97						
85	148	98	34.0	30.5	14.7	6.9	13.3	103
92	160	100	35.5	31.5	16.8	16.7	11.2	111
99	173	102	37.5	32.0	18.2	17.4	9.8	110
106	171	96	37.0	31.5	18.2	15.3	9.8	110
113	174	93	37.0	32.0	18.2	17.1	9.8	110
120	184	93	38.0	32.0	19.6	21.1	8.4	113
127	185	89	38.5	32.5	19.6	16.9	8.4	110
134	200	91	39.0	33.5	21.0	33.0	7.0	116
141	214	93	40.0	34.0	22.4	31.7	5.6	116
148	229	95	40.5	33.5	23.1	33.9	4.9	115
155	231	91	42.0	34.0	23.8	33.6	4.2	117
162	249	94	42.0	35.0	23.8	34.0	4.2	112
169	254	92	43.0	34.5	23.8	35.9	4.2	112
176	273	95	43.0	35.0	25.2	37.9	2.8	112
180	269	92	43.0	36.0				
183	278	93	43.0	36.0	25.9	38.7	2.1	113
190	286	92	45.0	37.0	26.6	37.7	1.4	113
197	299	93	45.5	36.5				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XVI

Calf No. 30, G. Female, Group III. - Born 11/9/53

Off milk at 64 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	77.0 lb.
Prairie hay	40.6 lb.	Beet pulp	30.0 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible Proetin[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	65	100						
89	136	103	34.5	33.5	16.8	7.2	11.2	121
96	149	106	36.5	34.0	16.8	6.7	11.2	111
103	155	103	35.0	34.0	16.8	6.4	11.2	108
110	151	94	37.0	34.0	16.8	9.8	11.2	111
117	167	99	38.0	34.5	18.2	16.1	9.8	113
124	163	91	38.5	35.0	18.2	17.8	9.8	115
131	196	104	38.0	36.0	21.0	20.1	7.0	112
138	200	100	39.5	36.5	21.0	23.8	7.0	112
145	211	101	39.0	36.5	21.7	25.5	6.3	112
152	218	100	41.0	37.0	22.4	24.9	5.6	112
159	227	100	41.0	37.0	23.8	24.5	4.2	114
166	231	97	41.5	37.5	23.8	26.8	4.2	114
173	239	96	42.0	37.5	23.8	31.4	4.2	114
180	255	98	43.5	38.5	24.5	26.0	3.5	110
187	252	93	43.0	38.5	24.5	15.1	3.5	106
194	256	91	43.0	38.0	26.3	33.0	3.5	121
201	270	93	45.0	39.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XVII

Calf No. 31, A. Female, Group III.- Born 11/9/53

Off milk at 64 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	86.4 lb.
Priaire hay	48.8 lb.	Beet pulp	37.3 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Diges-tible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	65	90						
89	142	91	36.0	32.0	16.8	7.2	11.2	116
96	151	91	37.0	31.5	16.8	9.7	11.2	111
103	167	95	37.5	31.5	18.2	12.7	9.8	111
110	172	93	37.5	32.5	18.2	20.8	9.8	113
117	186	96	38.5	33.0	19.6	21.4	8.4	112
124	191	94	39.0	33.5	21.0	26.2	7.0	117
131	210	98	40.5	34.0	21.0	28.5	7.0	112
138	216	96	40.5	35.0	22.4	31.8	5.6	116
145	237	100	42.0	35.0	23.8	30.1	4.2	114
152	245	99	42.5	35.5	23.8	30.9	4.2	112
159	253	98	42.5	36.0	24.5	32.7	3.5	113
166	265	98	43.5	36.0	24.5	32.6	3.5	110
173	276	98	44.0	37.0	25.2	43.0	2.8	113
180	288	98	45.0	37.0	26.6	35.7	1.4	112
187	298	98	45.5	37.0	27.3	29.7	0.7	109
194	295	93	45.0	37.0	26.6	47.5	1.4	114
201	311	95	46.0	38.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XVIII

Calf No. 32, H. Male, Group III.- Born 11/22/53.

Off milk at 50 days of age.
Total feed intake prior to experiment.

Whole milk	450.0 lb.	Starter	54.4 lb.
Prairie hay	18.3 lb.	Beet pulp	11.9 lb.

Weekly Growth Measurements and Feed Consumption

Growth					Feed Intake			
Age	Bodyweight		Heart girth	Height withers	Starter	Prairie hay	Beet pulp	Digestible protein[1]
days	lb.	%R[2]	in.	in.	lb.	lb.	lb.	%M[3]
Birth	100	106						
69	151	84	35.0	32.0	16.8	0.7	11.2	106
76	163	85	36.0	33.0	16.8	2.7	11.2	102
83	161	79	36.5	33.0	16.8	8.1	11.2	106
90	178	83	37.5	33.5	18.2	7.0	9.8	103
97	196	86	37.5	33.5	21.0	17.8	7.0	111
104	203	85	38.0	34.0	21.0	16.8	7.0	108
111	211	84	39.5	34.0	21.7	24.8	6.3	112
118	229	86	40.0	34.5	23.1	30.0	4.9	114
125	238	85	41.5	35.0	23.8	35.1	4.2	116
132	258	87	41.5	35.0	24.5	36.7	3.5	113
139	266	86	42.0	35.5	24.5	37.3	3.5	111
146	283	87	42.5	36.0	25.9	41.8	3.1	110
153	290	85	43.0	36.5	26.6	45.6	1.4	115
160	308	86	45.0	36.5	27.3	45.6	0.7	113
167	313	84	45.0	37.5	27.3	43.2	0.7	111
174	330	85	45.5	38.0	28.0	55.6	-	115
180	338	85	46.0	38.0				
181	344	86	46.0	38.0				

1. Calculated from proximate analysis of feeds and Morrison's average digestion coefficients.

2. Ragsdale's Standard.

3. Morrison's minimum allowance.

Table XIX

Air Dry Composition of Feeds

	Moisture	Ash	Protein	Ether Extract	Crude Fiber	N.F.E.
	%	%	%	%	%	%
Alfalfa meal	4.38	9.56	18.82	3.85	21.77	41.62
Wheat bran	10.62	6.00	13.94	4.64	9.91	54.89
Crimped oats	10.88	3.39	13.65	4.32	9.16	58.60
Omalass	2.57	6.77	11.16	2.14	5.60	71.76
Cracked corn	11.66	1.26	8.38	3.19	1.22	74.29
Dried buttermilk	8.14	10.25	38.44	6.38	--	36.79
Cottonseed meal	7.51	6.02	42.19	5.33	11.02	27.93

Table XX

Digestion Record
Collection dates December 30 - January 5, 1954
Protein Requirements of Calves

Calf No.	Fresh Material: Description	Daily Amount	Dry Matter	Composition of Dry Matter: Organic	Protein	Fat	Fiber	N.F.E.	Ash	N
		g.	%	%	%	%	%	%	%	%
All	Prairie hay	See	92.16	91.37	5.18	2.92	31.29	51.98	8.63	0.83
All	Beet pulp	Appendix	92.30	96.88	7.96	0.72	22.89	65.31	3.12	1.27
7-19	Conc. No. 1	Table XXIII	91.38	92.76	16.75	4.06	6.74	65.21	7.24	2.68
14-20	Conc. No. 2		91.35	92.61	19.57	3.94	7.35	61.75	7.39	3.13
2-16	Conc. No. 3		91.00	93.24	22.80	4.25	7.59	58.60	6.76	3.65
2	Hay refused	65	91.45	92.63	6.87	3.03	31.38	51.35	7.37	1.10
7	" "	149	90.68	92.85	5.45	3.04	32.81	51.55	7.15	0.87
7	Conc, BP. Hay ref.	428	90.48	93.07	15.27	3.44	11.59	62.77	6.93	2.44
14	Hay refused	233	91.64	91.46	6.18	2.60	30.40	52.28	8.54	0.99
16	" "	214	91.71	91.43	6.20	2.49	28.25	54.49	8.57	0.99
19	" "	104	91.02	90.00	8.48	3.83	22.85	54.84	10.00	1.36
20	" "	337	91.63	91.84	7.00	3.09	29.40	51.35	9.16	1.12
2	Feces	4210	26.83	88.68	13.88	2.29	22.62	49.89	11.32	2.22
7		2182	21.10	88.10	18.93	3.35	21.45	44.37	11.90	3.03
14		3091	20.47	89.48	19.03	2.17	20.72	47.56	10.52	3.04
16		2207	21.53	87.64	20.92	2.50	21.65	42.57	12.36	3.35
19		4516	24.30	87.89	12.65	2.29	21.78	51.17	12.11	2.02
20		2517	25.13	89.00	17.56	2.53	20.56	48.35	11.00	2.81
2	Urine	4179		Grams per liter - - - - - - - - - - - - - - - - -						5.24
7		4000								1.92
14		4000								2.08
16		4000								3.21
19		4000								2.56
20		5182								2.75

Table XXI

Digestion Record
Collection dates January 29 - February 4, 1954
Protein Requirements of Calves.

Calf No.	Fresh Material: Description	Daily Amount	Dry Matter	Composition of Dry Matter: Organic	Protein	Fat	Fiber	N.F.E.	Ash	N
		g.	%	%	%	%	%	%	%	%
All	Prairie Hay	See	89.76	91.61	5.50	2.45	32.02	51.64	8.39	0.88
All	Beet Pulp	Appendix			See previous analysis, trial 1					
7-19	Conc. No. 1	Table XXIII			"	"	"	"	"	
14-20	Conc. No. 2				"	"	"	"	"	
2-16	Conc. No. 3				"	"	"	"	"	
2	Feces	5998	24.10	87.02	14.00	2.83	23.52	46.67	12.98	2.24
7		3735	20.17	89.92	15.59	2.52	22.29	49.52	10.08	2.49
14		4846	23.80	87.51	15.29	2.80	22.31	47.11	12.49	2.45
16		3107	22.97	88.04	16.49	2.53	21.83	47.19	11.96	2.64
19		6433	22.70	87.82	12.14	2.65	22.34	50.69	12.18	1.94
20		3267	23.87	87.81	15.94	2.19	22.02	47.66	12.19	2.55
2	Urine	7000			Grams per liter - - - - - - - - - - -					3.25
7		"								0.95
14		"								2.32
16		"								2.51
19		"								1.45
20		"								2.55
2	Refused hay	45	90.72	91.47	6.05	2.81	29.81	52.80	8.53	0.97
7	" "	110	90.84	91.16	6.50	2.81	29.44	52.41	8.84	1.04
14	" "	26	90.32	93.50	5.08	2.61	35.44	50.37	6.50	0.81
16	No Sample	--	--	--	--	--	--	--	--	--
19	Refused hay	117	89.93	84.84	8.58	3.52	19.95	52.79	15.16	1.37
20	" "	97	90.54	90.19	9.91	3.27	26.20	50.81	9.81	1.59
20	" " conc.	110	86.21	86.47	25.84	4.04	8.54	48.05	13.53	4.13

Table XXII

Digestion Record
Collection dates March 8 - March 15, 1954
Protein Requirements of Calves.

Calf No.	Fresh Material: Description	Fresh Material: Daily Amount	Dry Matter	Percentage Composition of Dry Matter: Organic	Protein	Fat	Fiber	N.F.E.	Ash	N
		g.	%	%	%	%	%	%	%	%
All	Prairie hay	See	91.17	91.05	5.73	2.19	32.52	50.61	8.95	0.92
All	Beet pulp	Appendix			See previous analysis					
7-19	Conc. No. 1	Table XXIII			"	"	"			
14-20	Conc. No. 2				"	"	"			
2-16	Conc. No. 3				"	"	"			
2	Feces	6611	25.13	86.41	12.42	2.62	23.76	47.61	13.59	1.99
7		4885	23.27	88.71	13.84	2.27	23.10	49.50	11.29	2.21
14		6348	23.67	86.76	13.22	2.80	22.61	48.13	13.24	2.12
16		6199	22.00	87.05	13.59	2.43	22.93	48.10	12.95	2.17
19		7001	23.33	87.09	12.39	2.51	22.65	49.54	12.91	1.98
20		6453	22.87	87.19	13.29	2.52	22.15	49.23	12.81	2.13
2	Urine	7000			Grams per liter - - - - - - - - - - -					3.83
7		"								1.54
14		"								2.34
16		"								2.99
19		"								2.05
20		7902								2.47
2	Refused feeds	37	91.55	85.93	8.67	4.10	22.28	50.88	14.07	1.39
16		139	91.48	89.97	7.20	3.13	27.25	52.39	10.03	1.15
19		53	91.27	82.73	9.46	4.46	17.50	51.31	17.27	1.51
20		24	91.24	85.85	13.70	4.44	14.85	52.86	14.15	2.19

Table XXIII

Daily Feed Intake of Calves During
Nitrogen Retention Study

Group	Calf No.	Bodyweight	Prairie hay	Beet pulp	Starter
		lb	g.	g.	g.
			Trial I		
I	G. 7	137	513	324	396
	H. 19	229	1472	272	1544
II	G. 14	171	383	863	953
	H. 20	203	448	454	1362
III	H. 2	224	1569	272	1544
	G. 16	153	292	681	953
			Trial II		
I	G. 7	171	214	681	1135
	H. 19	275	1777	182	1634
II	G. 14	212	1271	363	1453
	H. 20	234	642	272	1434
III	H. 2	273	1992	182	1634
	G. 16	191	662	454	1362
			Trial III		
I	G. 7	205	953	454	1362
	H. 19	316	2126	45	1771
II	G. 14	257	1952	272	1544
	H. 20	279	1792	182	1634
III	H. 2	324	2505	45	1771
	G. 16	255	1904	272	1544

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