

December 11, 1963

To the Graduate Council:

I am submitting herewith a thesis written by Hashim Maseehuddin entitled "Growth of Heifers as Affected by the Daily Frequency of Feeding Roughage Alone or Mixed Roughage and Concentrates." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

Eric W. Swanson
Major Professor

We have read this thesis and
recommend its acceptance:

L. T. Miles
W. W. Overcast
R. H. Lush

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate School

12370 52 MAR 2 1964

GROWTH OF HEIFERS AS AFFECTED BY THE DAILY FREQUENCY
OF FEEDING ROUGHAGE ALONE OR MIXED ROUGHAGE AND CONCENTRATES

A Thesis
Submitted to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
H. Maseehuddin
December 1963

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation and regards to Dr. E. W. Swanson who set up, advised, and guided this study; and to Dr. J. T. Miles who made the study possible, to Mr. Clyde Holmes and to the farm employees who helped with the weighing and feeding of the calves. My appreciation to Miss Virginia L. Guy who has typed this manuscript for me is also acknowledged.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION.	1
II. REVIEW OF LITERATURE.	2
Frequency of Feeding in Sheep	2
Frequency of Feeding in Dairy Cows.	3
Influence of Feeding on Growth Rate of Heifers.	4
Reasons for Faster Gains in Frequency of Feeding.	6
Concentration of Fatty Acids in the Rumen	7
Utilization of Fatty Acids.	8
Effect on Urea Nitrogen	8
Energy Values	9
Digestibility with Roughage and Concentrates.	9
Effect of Ration on Volatile Fatty Acids in the Rumen	11
Growth of Dairy Heifers	12
III. EXPERIMENTAL PROCEDURE.	14
Selection of Animals.	14
Weight of Animals	14
Feeding the Calves.	14
Digestibility Estimates	16
Rumen Samples	18
IV. RESULTS	
Feed Composition.	19
Apparent Digestibility.	19
Weight Gains of the Calves.	19

CHAPTER	PAGE
Utilization of Feed with Different Treatments	23
V. DISCUSSION.	30
VI. SUMMARY AND CONCLUSION.	34
REFERENCES	36
APPENDICES.	41

LIST OF TABLES

TABLE	PAGE
I. Allocation of the Calves with Different Treatments and the Average Weights of Calves in Pens Having Three Calves Each.	15
II. Composition and Digestibility of the Rations as Used in the First Half of the Twenty-Week Experiment (Dry Basis) . . .	20
III. Apparent Digestibility of Dry Matter and TDN of Different Rations and with Times of Feeding by Pens of Three Calves Each	21
IV. Average Weight Gains in 140 Days of the Experimental Period and the Average Rate of Gain for Three Heifers in Each Pen Comparing Hay and Grain with Hay Alone Fed Six Times and Two Times Daily.	24
V. Average Daily Rates of Gain in the First and Second Ten-Week Experimental Periods	
VI. Twenty Week Weight Gains, Feed Consumption, and Efficiency of Gains of Calves Fed Hay or Hay Plus Corn Six Times and Two Times Daily.	26
VII. Total and Average Daily Weight Gains and Feed and TDN Consumed with Hay or Hay Plus Corn Six Times and Two Times Daily.	27
VIII. Volatile Fatty Acid Proportions in the Ruminal Fluid of Calves Fed Different Daily Frequencies of Hay and Grain and Hay Alone	29

LIST OF FIGURES

FIGURE	PAGE
1. Growth Curves of Holstein Calves Fed Hay and Grain or Hay Alone, Each Comparing Six and Two Times Daily Feeding. . .	22

CHAPTER I

INTRODUCTION

During recent years it has been of interest to study the effects of frequency of feeding on the animal. Numerous studies with ruminants have shown that frequency of feeding affects the growth rate. The animal usually gains weight faster when fed at frequent intervals.

In previous studies of this type, the animals were fed hay alone or hay and limited concentrates. It has been postulated by some recent workers that the concentration of fatty acids in the rumen is affected by frequency of feeding. Particularly, the propionic to acetic acid ratio is very high. A similar effect can be obtained when the ratio of concentrates to hay increases in the ration.

In this investigation an attempt was made to study the effects of two rations on the growth of dairy heifers as influenced by frequency of feeding. In one ration the ratio of hay to grain was 1:1 to give a high propionic acid to acetic acid ratio. In the other ration only hay was fed to give normal ratios of the acids. Feeding frequencies of two times and six times daily were compared to determine how feeding frequency affects the efficiency of the utilization of the two rations.

CHAPTER II

REVIEW OF LITERATURE

Frequency of Feeding in Sheep

Gorden and Tribe (14) studied the effects of frequency of feeding on sheep. They separated the animals according to age and body weights into two groups. These were fed in a reversal type of experiment, eight times and once per day. The gain was 65.8 percent higher due to increased frequency of feeding. The feed was utilized less efficiently by the sheep fed once daily. The sheep fed eight times daily refused more feed than the others. They postulated that the total feed surface area open to attack by micro-organisms in the rumen might be larger for a longer time per unit of microbial activity than when the same quality and quantity of feed is given as one meal, resulting in a more efficient coefficient of digestibility.

Gorden and Tribe (14) theorized that the loss of energy due to fermentation is minimized by giving frequent feedings. If a large amount of feed is given at one time, then probably part of it remains longer in the rumino reticular cavity, and this delay results in larger energy losses. If feed is given in small amounts many times this energy loss is avoided. The even supply of substrates and supposedly even production of metabolites that may occur in frequent feeding systems gives rise to an alimentary environment better suited for an optimum growth of microorganisms and this may enable the animal to use the

metabolites more efficiently. The length of time spent in ruminating by animals under the two systems may also be different. It was observed that the rumination time for single fed sheep was longer.

Moirs and Somers (24) gave a single ration in five different ways. They tried to study the effect on ruminal bacterial population, metabolism within the rumen, overall nitrogen balance and dry matter digestibility. They found that the single feed gave the lowest dry matter digestibility and nitrogen retention. There was a fall in rumen pH, and lowest bacterial and the protozoal counts were noted. At the same time the highest ammonia nitrogen level and the lowest fatty acid concentration in the ruminal fluid was recorded with single feeding. They also found that other feeding schedules were as efficient as multiple feeding for digestibility and other functions; e.g., concentrates fed in the morning and roughage fed in the afternoon gave as good results as feeding the whole ration in four equal parts at two-hour intervals. These two methods of feeding gave the best results in their experiment on sheep.

Frequency of Feeding in Dairy Cows

Campbell and Merilan (5) investigated the effect of frequency of feeding on production characteristics and feed utilization. They found that more milk was produced when the cows were fed four times and seven times compared to two times daily. They sought information which might serve as a basis for selecting the optimum feeding intervals for desired milk production characteristics and efficiency of feed utilization. There was no appreciable change in four percent fat-corrected milk.

Although there was a significant difference between two times and four or seven times, total feed intake was least at two times but almost equal at four times and seven times feedings daily. Production of total milk solids corresponded to total milk with significant differences between two times and four times or seven times feeding. There was also an increase in milk fat in four times or seven times over the two times group. They attributed this to the more uniform level of volatile fatty acid production in the rumen due to more frequent feeding. The different feeding levels had no effect on body weight gains in lactating dairy cows.

Dawson and Kopland (8) studied dairy cows with once a day feeding compared to twice a day feeding. This experiment was done on a double reversal plan. They found that those fed two times ate ten percent more alfalfa and gave six percent more milk. The cows that were changed to once a day feeding dropped in milk production. More frequent feeding could possibly increase the amount of roughage consumed and thereby save grain.

Influence of Feeding on Growth Rate of Heifers

Gibbons (13) used seven sets of identical twin heifers for a trial of fifty days with a reversal treatment after fifty days. The rations given to each pair were the same and based on concentrate mixture, hay and brewer's grains. A second trial was conducted to exaggerate the treatments. The extra growth rate obtained by feeding a set amount of food in several meals as opposed to a single feed per day was very small. The difference in weight gains was not significant. When the amount of

feed is not restricted, the daily intake can be increased by feeding little and often and this in turn may affect the growth rate slightly.

Moirs and Somers (24) reported greater nitrogen retention from multiple feed treatment. There was enhanced conversion to microbial protein, the rate of ammonia formation and absorption from the rumen or both processes. Absorption of ammonia was related to concentration as urinary loss from single daily feedings was higher.

Putnam et al. (27) found that frequently fed animals had greater appetites and more rumen protozoa than the other groups. They found protozoal counts of 26.2×10^3 per milliliter and 14.1×10^3 per milliliter, respectively, in ten times and two times fed calves after eight weeks time.

Thomas and Mochrie (36) studied dairy heifers with one time, two times and four times per day feeding. Calves within each trio were fed equalized amounts of hay and grain. The calves ranged in weight from 241 to 587 pounds. A six-weeks period was used. The calves fed four times daily gained an average of 1.85 pounds daily, which was significantly higher than gains of calves in the other two groups. Rates of gain for calves fed once and twice daily, 1.16 and 1.22 pounds daily, did not differ significantly.

Mochrie et al. (22) studied frequency of feeding on animal response using two groups of four Holstein steers. The experiment was a reversal trial with two six-weeks periods. They found that the average daily gain for one time and four times feeding was 1.03 and 1.21 pounds, respectively. The difference in gains was significant. When they

compared first calf heifers in a similar experiment, they did not find significant differences for actual milk, milk fat, fat-corrected milk, percent fat, and live weights. Frequency of feeding increased feed utilization for growth but not for total energy output by lactating heifers.

Rakes et al. (30) compared dairy heifers with two times and ten times feeding per day during the same period of the day. The animals were fed chopped hay and maximum feed intake was established during a twenty-one day period. They reported increased weight gains due to frequency of feeding. Daily feed consumption was equal for both groups. There was a decrease in feed digestibility in the group that was frequently fed, but efficiency of feed utilization was much higher in the same group. A major part of rumination occurred in the night time and digestion too was more efficient in the night time.

Reasons for Faster Gains in Frequency of Feeding

Rakes et al. (30) suggested that when an animal is fed once or twice daily, large quantities of heat are produced at the same time. The animal can not efficiently utilize this heat for productive purposes. Thus it has to expend considerable energy getting rid of it. If the ration is given in small amounts at frequent intervals, heat production will be more uniform or constant. Under these conditions the animal is able to dispose of the small excess of heat with a minimum expenditure of energy, and more energy is available for productive purposes. Anything which influences propionic acid in the rumen influences the

net energy value of the ration. Rakes et al. (30) postulated that frequent feeding could increase the net energy value of the ration because of an effect on rumen fatty acids.

Hamilton (15) found that the thermogenic action of food varies depending upon the nature of disposal of absorbed nutrients. Thus, condition of animal, number of times fed per day, amount of feed at any one time or composition of feed may result in more efficient utilization of absorbed nutrients which results in lower thermogenic effect. According to Richardson and Mason (33) when a mixed diet was fed in small portions and given at two-hour intervals, heat production was the same as when a basal diet was fed at two-hour intervals. Lusk (21) suggested that if a mixed diet is so constituted as to conform to the exact needs of the tissues and is slowly introduced by absorption at frequent intervals, its specific dynamic effect is negligible.

Concentration of Fatty Acids in the Rumen

Putnam et al. (27) working with Angus heifer calves using the reversal treatment noticed significantly higher weight gains in frequently fed animals. The animals were fed ten times and two times a day. The frequently fed animals had greater appetites. They had a higher concentration of fatty acids in the ruminal fluid than those fed two times. Also they had more protozoa in the rumen than the other groups.

Knox and Ward (19) studied the rumen concentration of volatile fatty acids in fistulated Brown Swiss animals, feeding the animals two times and eight times a day. The mean ratio of acetic to propionic acid was higher in two times feeding than in eight times feeding. Also the

acetic to butyric acid ratio was higher in the animals fed two times daily.

Utilization of Fatty Acids

Armstrong and Blaxter (2) expressed the opinion that acetic acid is utilized less efficiently than other volatile fatty acids. Elliot and Loosli (11) found that the acetic to propionic acid ratio is closely related to efficiency with which digestible energy is converted to milk. They found a low acetic:propionic ratio associated with high milk production.

Knox and Ward (19) found that the rate of gain was related to total concentration of rumen volatile fatty acids. In their experiment eight times feeding showed a higher concentration of volatile fatty acids than two times feeding, which difference was more pronounced with time after feeding. They further explained that in two times feeding acetic acid was increased, which lowered volatile fatty acid utilization by the host. The lowered weight gains on two times feeding may be related to the pattern of total acid concentration throughout the day; and a lower acetic to propionic ratio might contribute to more efficient energy utilization, if values obtained for lactating cows can be extrapolated to animals on maintenance and growth rations.

Effect on Urea Nitrogen

Campbell et al. (4) conducted an experiment with forty Guernsey heifers five to ten months of age in four equal groups. They observed 14.4 per cent greater body weight gains in heifers fed six times daily

than in those fed two times, and 11.8 per cent less total digestible nutrients required per pound of body weight gain resulting from six times feeding. There was no statistical difference in growth and efficiency among groups fed protein and urea nitrogen when urea nitrogen was fed six times daily.

Energy Values

It is generally recognized that the digestible energy and total digestible nutrients systems over evaluate roughages relative to concentrates. The experiment by Elliot and Loosli (10) supports this statement. This is due to the difference in productive energy input. The net energy values of feeds decrease at a faster rate than the total digestible nutrients values (23); therefore, the net energy value of a unit of total digestible nutrients in concentrates is greater than that of the same unit in roughages.

The metabolizable energy value of corn meal was found to be essentially the same whether fed to steers as the only feed stuff or in combination with alfalfa hay (12) but heat increment values were much greater when corn was fed alone than when it was fed mixed with hay.

Digestibility with Roughage and Concentrates

Conrad and Hibbs (7) found the digestibility of cellulose to be less when a 2:3 ratio of hay to grain was fed than when either 4:1 or 3:2 ratios were given. The apparent digestibility of protein increased when higher proportions of grain concentrates were included in the rations.

They attributed the decrease in cellulose digestibility with 2:3 ratio of hay to grain. to the imbalance of microflora.

Phillips et al. (25) found that as the percentage of the corn in the ration increased, the apparent digestibility of the complete ration increased for all nutrients except crude protein in one case and crude fiber in the other.

In an experiment with Hereford and Angus yearling bulls by Dowe et al. (9) it was found as the corn in the ration increased, dry matter in the feces also increased, and the coefficient of digestibility was the same in all of the rations. The ratios of the corn to alfalfa on which the study was made were 1:1, 2:1, 3:1, 4:1 and 5:1.

Lassiter et al. (20) found the dry matter and crude protein digestibility increasing when they varied the ratio of hay to grain as 4:1, 1:1 and 1:4, respectively. The crude fiber digestibility was 54.2, 49.1 and 36.0 percent, respectively, with 4:1, 1:1 and 1:4 hay to grain ratios.

Kane et al. (18) investigated the effect of readily digestible carbohydrates on digestibility of alfalfa hay. When a twenty-day preliminary period was allowed, added carbohydrates had little effect on alfalfa digestibility. When no time was granted for adjustment to the starch addition, a highly significant depression of N-free extract and significant decreases in protein and dry matter digestibility were observed.

Putnam and Loosli (28) found as the proportion of concentrates in the ration became larger, the apparent digestibility coefficients for

dry matter, crude protein, ether extract, N-free extract, total carbohydrates, total digestible nutrients and dry matter intakes also increased. The apparent digestibility of the crude fiber decreased as the proportion of the concentrates in the ration increased.

Effect of Ration on Volatile Fatty Acids in the Rumen

Balch et al. (3) found with increasing concentrates in the ration, a higher fatty acid production in the rumen. Tyznik and Allen (37) found that high concentrates in the ration gave an increased propionic acid, decreased acetic acid and a constant concentration of butyric acid. Phillipson (26) found the concentration of acetic acid lower, that of propionic acid greater, and the ratio of acetic to propionic acid narrower in rumen fluid from a mixture of flaked maize and maize gluten feed in the proportion of 10:1 than from hay alone. This was done with lambs, and weight gains were adequate when supplemented by cobalt.

Card and Schultz (6) found a significant difference in the percentage of each of the acids due to ration.

Molar composition of rumen volatile fatty acids was studied by Elliot and Loosli (11) in three dietary ratios of hay to concentrates. As the proportion of concentrate in the ration increased, the relative proportion of acetic acid decreased. The efficiency with which digestible energy was converted to fat-corrected milk was highly correlated with the relative proportion of propionic acid in the rumen volatile fatty acids and with the ratio of acetate to propionate, as well as the crude fiber content of the ration.

Volatile fatty acids production was studied in vitro with brome grass hay, brome grass hay + grain and alfalfa hay and grain, by Hinder and Ward (17). It was found that rumen bacteria on a ration of hay and grain with excellent alfalfa produced the highest concentration of fatty acids.

Growth of Dairy Heifers

Reed et al. (31) found that the best feed mixture in their study for the growth of dairy heifers was 400 pounds of corn chops, 200 pounds of wheat bran and 100 pounds of linseed oil meal. They also found that alfalfa hay and corn silage failed to produce an entirely satisfactory development of Holstein heifers. The inadequate development was due to their inability to consume sufficient roughage to supply necessary energy.

Steenberg (35) found pronounced differences in growth, live weights and body size of animals with variations in levels of feeding. Ragsdale (29) found individual differences with which animals use their feed for growth but no breed differences in growth efficiency.

Stallcup et al. (34) concluded that heifers of normal body weight and size may be reared from six months to twenty-four months of age with not more than 900 pounds of grain provided that good roughage and pasture are in abundance.

Hibbs et al. (16) compared the performance of Jersey and Holstein calves raised according to the high roughage system of 3:2, hay to grain up to twelve weeks and 2:1 from twelve to twenty-four weeks of age. They found the growth to be slightly less than Ragsdale standards.

Hibbs et al. (16) found the efficiency of feed utilization, as measured by total digestible nutrients and net energy per pound of grain on a 2:1 hay to grain ratio, to be greater than on a 4:1 ratio. Quality and acceptability of ration is very important. Total digestible nutrients and net energy were utilized less efficiently in the group fed a 4:1 ratio of hay to grain, as there was much loss of energy due to heat increment coincident with the rumen production of volatile fatty acids, and a high proportion of acetic acid in relation to other volatile fatty acids.

CHAPTER III

EXPERIMENTAL PROCEDURE

Selection of Animals

Experimental animals were selected from a group of Holstein heifers, from four to seven months old, ranging in weight from 271 to 390 pounds. Twenty-four calves were selected and allocated to pens of three each. Calves were allocated to the pens so that a group of four pens each contained heifers of the same average weight. The four groups were allocated to the four treatments, and each treatment consisted of two pens. Heifers in four pens were similar in average weight. One of the two pens in each treatment contained older calves of heavier weights than the other pen. The initial assignment of heifers is shown in Table I.

Weights of Animals

The calves were weighed daily three times before starting the experiment. The average of these three weights was taken as the initial weight. After that they were weighed at weekly intervals for twenty weeks. The heifers were weighed in the forenoon about four hours after the first morning feed. At the end of the experiment they were weighed on three consecutive days and the average of those three weights was taken as the final weight.

Feeding the Calves

Pens I, III, V and VII were fed equal amounts of feed every day, and pens II, IV, VI and VIII were fed equal amounts but less than that

TABLE I

ALLOCATION OF THE CALVES WITH DIFFERENT TREATMENTS AND
THE AVERAGE WEIGHTS OF CALVES IN PENS HAVING THREE CALVES EACH

Group		Pen	Average Weight (lb)
A	Hay and grain, fed six times	I	357
		II	299
B	Hay and grain, fed two times	III	353
		IV	293
C	Hay alone, fed six times	V	359
		VI	293
D	Hay alone, fed two times	VII	358
		VIII	291

fed to the older calves in the former pens. The amount of feed was limited to slightly more than would be eaten by those fed only hay. The rations were alfalfa hay alone for two treatments, and a mixture of alfalfa hay and yellow corn in a ratio of 1:1 for two treatments. Alfalfa hay and corn in the latter ration were ground separately and mixed in an upright mechanical mixer. Alfalfa hay fed alone was chopped. The hay was purchased and was not uniform in quality. A large amount was chopped at one time, but this was not enough for the entire experiment; so a second lot of hay was chopped for the last few weeks of the feeding period.

The feeds were weighed into pails separately for each pen according to the ration assigned to each pen. From time to time the amount of feed was increased for all of the pens at the same time.

The frequently fed group was fed at 5 a.m., 8 a.m., 11 a.m., 2 p.m., 5 p.m. and 8 p.m. The control groups were fed at 5 a.m. and 5 p.m. Refused hay was weighed out once daily at 5 a.m. Daily feed records were maintained of the amount fed, refused, and consumed. The feeding trial was a continuous twenty-week period for each pen of heifers.

Digestibility Estimates

At the middle of the experiment, feed and fecal samples were collected. Grab fecal samples were mixed for each pen collecting from the three calves approximately equal amounts from each calf. The feces were thoroughly mixed, put in plastic bags, and placed in a freezer. They were thawed before analyses were made. Analyses for protein, ash,

moisture, ether extract and crude fiber were made on both feed and feces according to the method of the Association of Official Agricultural Chemists (1). The protein analyses were made on wet samples of feces. A sample of wet feces was also dried in a vacuum oven at 100°C to determine dry matter. The protein content was later corrected to a dry matter basis. The remaining portions of the fecal samples were dried in an oven air drier overnight. They were then placed in the laboratory for a few days to attain a constant air-dry weight. After that they were ground in a Wiley Mill. The analyses for different components were made on the air-dried feces.

Digestibility was estimated from the chromogen ratios of feed and feces. Analysis for chromogens were made as recommended by Reid et al. (32). The wet feces samples were used for chromogen analysis. Two hundred milliliters of 85 percent acetone was used to extract feed and fecal samples each time in a Waring blender. They were extracted for five minutes each for four times for feed and two times for feces. After each extraction the suspension was filtered. The combined extracts were then made to 500 or 1000 milliliters. They were kept in a refrigerator in the dark until reading was done on a spectrophotometer. Absorption at 406 microns was determined in a Beckman model DU spectrophotometer. Units of chromogen per milliliter were read from a previously prepared standard chart. Digestibility of a nutrient was determined by the following formula:

$$\text{Apparent digestibility} = 100 - \frac{(a \cdot x \text{ in feces})}{(b \cdot x \text{ in forages})} 100$$

where a is units of chromogen per gram of forage, b is units of chromogen per gram of feces, and x is the percentage of the nutrient in forage or feces.

Rumen Samples

Samples of ruminal fluid and ingesta were collected with a stomach tube and a vacuum pump. Individual samples of the three calves from each pen were combined and mixed to give one sample per pen. They were strained through a cheese cloth, centrifuged, and decanted. Fifty percent sulfuric acid was added to the centrifuged material at the rate of three percent of the sample (19). The acidified samples were preserved in a freezer at 10°F until analyzed for volatile fatty acids. The samples were thawed before analyses. Fatty acid determinations were made by a chromatographic separation technique as developed by Wiseman and Irvin (38). The ratios of acetic, propionic and butyric acid were determined in each sample.

CHAPTER IV

RESULTS

Feed Composition

The composition of the feeds, the average apparent digestibility of each nutrient and the total digestible nutrients (TDN) of the feeds are shown in Table II. The TDN of the mixture of hay and grain was higher than the TDN of hay alone. The hay contained 22,386 chromogen units per gram and the corn-hay mixture contained 11,688 units per gram. The apparent digestibility of protein was higher from the mixture of hay and grain. The crude fiber and ether extract were more digestible in the ration made up of hay alone.

Apparent Digestibility

In Table III is shown the average apparent digestibility of total dry matter from different treatments and the TDN for each pen calculated by the chromogen ratio formula suggested by Reid et al. (32). The digestibility of the hay and grain mixture averaged higher for the calves fed six times than for the calves fed two times daily. The apparent digestibility of the hay and grain fed by all of the calves irrespective of the times of feeding was about one and one-half times that of the hay alone.

Weight Gains of the Calves

In Figure 1 the weekly average body weights of the four groups of calves during the experimental period of twenty weeks are shown. Each

TABLE II

COMPOSITION AND DIGESTIBILITY OF THE RATIONS AS USED IN
THE FIRST HALF OF THE TWENTY-WEEK EXPERIMENT (DRY BASIS)

Nutrient	Hay + Grain		Hay Alone	
	Feed Composition	Apparent Digestibility	Feed Composition	Apparent Digestibility
	------(%)-----			
Protein	13.2	67.0	16.2	44.5
Crude fiber	19.0	36.3	35.7	39.8
Ether extract	3.1	71.3	1.8	87.2
Ash	4.9	--	8.1	--
NFE	59.8	79.0	38.2	47.0
TDN	67.9	--	42.9	--

TABLE III

APPARENT DIGESTIBILITY OF DRY MATTER AND TDN OF DIFFERENT
RATIONS AND WITH TIMES OF FEEDING BY PENS OF THREE CALVES EACH

Ration	Times Fed	Pen	Dry Matter Apparent Digestibility ------(%)-----	Dry Matter TDN
Hay + Grain	6	I	63.0	57.6
Hay + Grain	6	II	66.1	61.9
A, Average			64.6	59.8
Hay + Grain	2	III	61.3	61.6
Hay + Grain	2	IV	52.7	52.6
B, Average			57.0	57.1
Hay Alone	6	V	36.7	38.5
Hay Alone	6	VI	48.3	49.5
C, Average			42.5	44.0
Hay Alone	2	VII	47.1	47.3
Hay Alone	2	VIII	39.3	40.7
D, Average			43.2	44.0
Hay + Grain	2 + 6	I, II, III, IV	60.8	58.9
Hay Alone	2 + 6	V, VI, VII, VIII	43.3	44.0

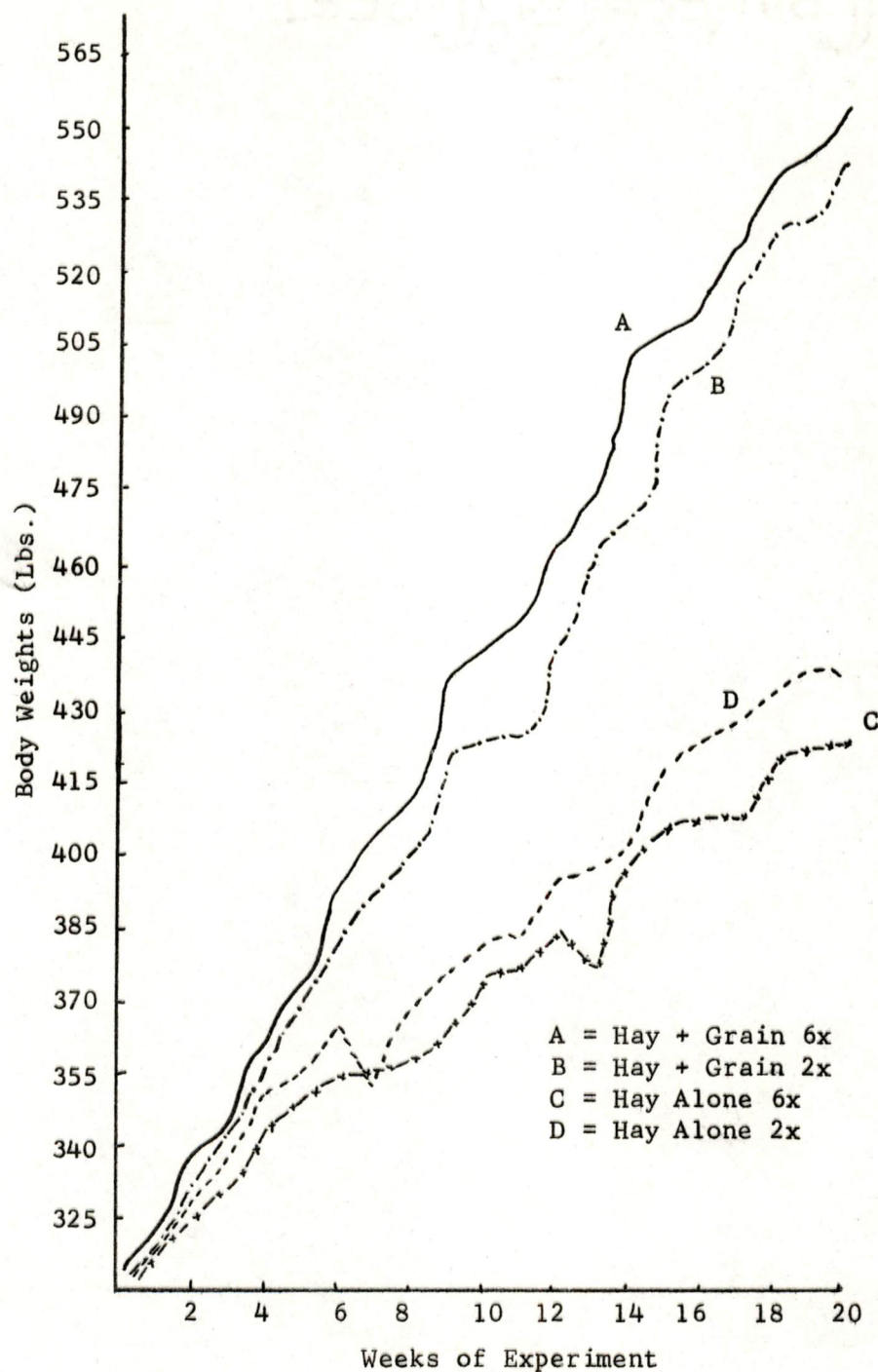


FIGURE 1

GROWTH CURVES OF HOLSTEIN CALVES FED HAY AND GRAIN OR HAY ALONE,
EACH COMPARING SIX AND TWO TIMES DAILY FEEDING

line represents the two pens of six calves with similar treatment of the rations. Calves in the A group showed a slight increase in growth over B, and groups A and B grew significantly faster than C and D. Gains of the calves fed hay alone were more variable and erratic than those of calves fed hay and grain. Unexplained sudden declines in body weights occurred in the seventh and thirteenth weeks in groups C and D, respectively.

The total gains per calf from the different treatments of hay alone and hay and grain are compared in Table IV. The average daily gains of the calves in each of the eight pens for twenty weeks are presented.

The daily rates of gain in different periods are shown in Table V. All of the treatments except B (Pen III and IV) showed a greater rate of gain in the first half than in the second half of the experimental period. Pens III and IV, fed hay and grain twice daily, gained more in the second than in the first half.

Utilization of Feed with Different Treatments

The amount of feed consumed and TDN values in relation to weight gains of the calves are shown in Table VI. TDN of each group was determined from feces analysis of that group only. The faster growing calves fed hay and grain consumed less feed and less TDN per pound of gain than did the slower growing calves fed only hay.

In Table VII is shown the total and average daily gain from each treatment. Also the gains are presented on rations of hay and grain and hay alone and from six times and two times daily feeding. The difference

TABLE IV

AVERAGE WEIGHT GAINS IN 140 DAYS OF THE EXPERIMENTAL PERIOD AND THE
AVERAGE RATE OF GAIN FOR THREE HEIFERS IN EACH PEN COMPARING HAY
AND GRAIN WITH HAY ALONE FED SIX TIMES AND TWO TIMES DAILY

Ration	Times Fed Per Day	Pen	Average 20-week Gain	Average Daily Gain
----- (lb) -----				
Hay + Grain	6	I	256	1.83
Hay + Grain	6	II	220	1.57
Hay + Grain	2	III	246	1.76
Hay + Grain	2	IV	220	1.57
Hay Alone	6	V	104	0.74
Hay Alone	6	VI	114	0.81
Hay Alone	2	VII	123	0.88
Hay Alone	2	VIII	129	0.92

TABLE V
AVERAGE DAILY RATES OF GAIN IN THE FIRST AND SECOND
TEN-WEEK EXPERIMENTAL PERIODS

Group	Pen	First Half 0-10 week	Second Half 10-20 week	Complete 0-20 week
------(lb)-----				
A	I	1.99	1.67	1.83
	II	1.70	1.44	1.57
Average	.	1.85	1.56	1.70
B	III	1.76	1.77	1.76
	IV	1.49	1.66	1.57
Average	.	1.62	1.72	1.67
C	V	1.01	0.47	0.74
	VI	0.79	0.84	0.81
Average	.	0.90	0.66	0.78
D	VII	1.11	0.64	0.88
	VIII	0.94	0.90	0.92
Average	.	1.03	0.77	0.90

TABLE VI

TWENTY WEEK WEIGHT GAINS, FEED CONSUMPTION, AND EFFICIENCY OF GAINS
OF CALVES FED HAY OR HAY PLUS CORN SIX TIMES AND TWO TIMES DAILY

Ration	Times Fed	Pen	Total		Feed		TDN		
			Gain	Feed	Per Pound Gain	Total TDN	Per Pound Gain	Total TDN	
----- (lb) -----									
Hay + Grain	6	I	256	1807.2	7.1	1041.3	4.1	4.1	
Hay + Grain	6	II	220	1664.5	7.6	1030.3	4.7	4.7	
Hay + Grain	2	III	246	1805.5	7.3	1112.2	4.5	4.5	
Hay + Grain	2	IV	220	1662.1	7.6	874.2	4.0	4.0	
Hay Alone	6	V	104	1687.3	16.2	649.6	6.2	6.2	
Hay Alone	6	VI	114	1528.0	13.4	756.4	6.7	6.7	
Hay Alone	2	VII	123	1803.7	14.7	853.1	6.9	6.9	
Hay Alone	2	VIII	129	1614.1	12.5	656.9	5.1	5.1	

TABLE VII

TOTAL AND AVERAGE DAILY WEIGHT GAINS AND FEED AND TDN CONSUMED
WITH HAY OR HAY PLUS CORN SIX TIMES AND TWO TIMES DAILY

Ration	Times Fed	Total Gain	Average Daily Gain	Feed Consumed Per Pound Gain	TDN Per Pound Gain
----- (lb) -----					
Hay + Grain	6	239	1.70	7.32	4.38
Hay + Grain	2	233	1.67	7.45	4.25
Hay Alone	6	109	0.78	14.81	6.44
Hay Alone	2	126	0.90	13.59	6.02
Hay + Grain	6 + 2	236	1.69	7.39	4.32
Hay Alone	6 + 2	118	0.84	14.20	6.23

in gains, due to rations, i.e., hay and grain compared to hay alone was significant ($P = .01$). The older group of calves gained more weight per day than the younger group fed the mixture of hay and grain. Gains from six times and two times daily feeding did not differ significantly.

The proportions of three volatile fatty acids in the ruminal fluid are shown in Table VIII. The ratio was calculated considering the three acids as 100 per cent. Other fatty acids such as formic, lactic and succinic were not separated from these three. The ratios of acetic to propionic were lower from feeding six times daily than from two times daily feeding from both hay and grain and hay alone. Differences in the acid ratios between the hay and grain ration and hay alone were not observed.

TABLE VIII

VOLATILE FATTY ACID PROPORTIONS IN THE RUMINAL FLUID OF CALVES FED
DIFFERENT DAILY FREQUENCIES OF HAY AND GRAIN AND HAY ALONE

Ration	Times Fed	Group	Pen	Volatile Fatty Acids			Ratio
				Acetic	Propionic	Butyric	Acetic to Propionic
--(molar % of the total)--							
Hay + Grain	6	A	I	76.3	15.1	8.6	5.1
Hay + Grain	6	A	II	73.0	14.1	12.6	5.2
A, Average				74.7	14.6	10.6	5.2
Hay + Grain	2	B	III	75.1	11.3	7.3	6.6
Hay + Grain	2	B	IV	79.9	11.4	8.7	7.0
B, Average				77.5	11.4	8.0	6.8
Hay Alone	6	C	V	78.2	17.3	5.8	4.4
Hay Alone	6	C	VI	81.0	13.1	5.9	6.2
C, Average				79.6	15.2	5.9	5.3
Hay Alone	2	D	VII	84.8	12.7	2.9	6.7
Hay Alone	2	D	VIII	81.3	11.3	7.4	7.2
D, Average				83.1	12.0	5.2	7.0

CHAPTER V

DISCUSSION

A problem in interpreting the feed-gain relationship was consumption of bedding. Bedding during the first ten weeks was composed of orchard grass clippings, and it was readily eaten by most of the calves. The calves fed only hay six times daily appeared to eat more bedding and to refuse more hay than the calves fed hay two times daily. The hay refusal seemed to increase each time the bedding was changed, and after there was no more bedding to eat, the calves ate more of their hay. For three full weeks after the calves fed all hay were bedded with sawdust in place of grass clippings, they ate a daily average of 2.8 pounds more hay than in the three full weeks before use of sawdust bedding (Appendix B). For comparison, the consumption in the last two three-week periods of the trial was 13.9 and 14.1 pounds. The amount of bedding consumed and its composition was not considered in calculating the digestibility of the rations. Since it did contribute to the feces, the undigested grass residue may have resulted in an underestimate of the digestibility of the hay.

The calves fed hay and grain left no refused feed. They also ate some grass bedding but the amount was probably much less than that eaten by the calves fed only hay.

The apparent digestibility of the dry matter, crude protein and nitrogen-free extract was higher in the groups fed hay and grain; but the digestibility of crude fiber and ether extract was higher on the hay

ration. These observations are in agreement with the crude fiber digestibility reported by Lassiter et al. (20) and Dowe et al. (9) and nitrogen-free extract digestibility observed by Dowe et al. (9).

The apparent digestibility of the dry matter of the hay and grain fed six times daily was somewhat higher than that fed two times daily. The group fed a ration of hay alone six times daily did not show higher digestibility than that fed two times daily. This possibly was due to the consumption of bedding material, discussed previously. A previous report (30) had showed higher efficiency of feed utilization in the calves fed several times daily even though there was more simultaneous refusal compared to the control group. The results of this experiment did not confirm that observation.

The graph of liveweights presented in the Figure 1 shows a faster growth in the calves fed hay and grain than in the calves fed hay alone. Also, the calves fed hay and grain six times daily gained slightly faster than those fed two times daily. The sudden fall in the growth curve (Figure 1) in the seventh and thirteenth weeks with calves fed hay alone two times and six times daily, respectively, shows that something affected their efficiency of feed utilization. This might have been due to the variable consumption of nutrients. This also could have been due to the calf weighing errors as affected by the time of the day, water consumption, heat or other factors which affected the calves fed all-hay differently than those fed hay and grain.

Although the superior first half weight gain of the calves fed hay and grain six times daily agrees with previous work done with sheep (14)

and calves (13, 30, 4), it was not statistically significant as in the study of Mochrie et al. (22) who made their study on Holstein steers. The average daily gains in their reversal trial experiment were 1.03 and 1.21 pounds. Gibbons (13) did not find a significant increase with identical twin heifers fed six times compared to once daily. Daily gains were 1.68 and 1.60 pounds, respectively. He postulated that when live-weight gain is small, a significant increase will more probably be obtained by increased feeding frequency. The gains of both groups fed hay and grain in this study may have been too large to show the difference due to the feeding frequency.

The higher average daily gains in the first half of the experiment than in the last half by the calves fed hay alone was probably due to consumption of an unknown amount of bedding in addition to hay ad libitum. In the last half, the calves in pens V and VII may have eaten more hay if they had been fed more, and this restriction could have reduced their growth rate.

The faster growing calves showed a higher efficiency of feed utilization and less TDN required per pound of gain than slow growing calves. The TDN values were calculated according to the apparent digestibility of the separate pens from only one determination. The error in the TDN figures was probably high because of variation in calves, as well as the bedding problem.

Variation in the ratio of acetic to propionic acids agrees with previous work (19) showing that frequent feeding produces a lower ratio of acetic to propionic acids. The fatty acid ratios for the younger

calves fed hay or hay plus grain two times daily was higher than that from the older calves of similar treatments. It is not known if this difference was significant or if it has been observed in animals of different ages or by other investigators.

In the study of Knox and Ward (19) the utilization of fatty acids was more efficient with eight times daily feeding. In this study there was a higher proportion of propionate with six times feeding both with hay and grain and with hay alone, but improved growth did not result from the hay ration. This could have been due to a different environment, such as summer rather than winter feeding.

The treatment of hay alone fed six times daily might have given a stimulating effect in winter when heat loss is less of a problem.

CHAPTER VI

SUMMARY AND CONCLUSION

Eight pens of three calves each were used in a study of the effect on growth rate of dairy heifers of rations containing hay alone and hay and grain. Each ration was fed six times and two times daily, allocating two pens for each treatment. The experiment was started in the early summer and carried out for a twenty-week period.

Alfalfa hay alone was given as one ration, and this with corn in the ratio of 1:1 constituted the other ration. Equal amounts of these two rations were fed six times and two times daily, divided equally among the daily feedings.

The dry matter apparent digestibility determined by the chromogen indicator method averaged 64.6 and 57.0 percent for hay plus grain with daily feeding of six times and two times, respectively, and averaged 42.5 and 43.2 percent for hay alone fed six times and two times daily.

The TDN calculated for each group averaged 59.8 and 57.1 percent for hay and grain fed six times and two times daily, respectively, and 44.0 and 44.0 percent for hay alone fed six times and two times daily.

The average daily gain from the hay plus grain ration was 1.70 and 1.67 pounds with six times and two times daily feeding, respectively, and 0.78 and 0.92 pounds from six and two times daily feeding, respectively, from hay alone. The difference in rate of gain from six times daily feeding was not significantly higher than from two times daily feeding.

The daily rate of gain was greater in the first half in all of the groups except the one fed two times daily with hay and grain. The older group had a superior gain per day on the hay and grain ration over the younger group.

The faster growing calves fed hay and grain with an average daily gain of 1.69 pounds consumed 7.39 pounds of feed and 4.32 pounds of TDN per pound of gain. The calves fed hay alone gained 0.81 pound daily and consumed 14.2 pounds of feed and 6.2 pounds of TDN per pound of gain.

The fatty acids in the ruminal fluid had a lower ratio of acetic to propionic acid in the groups that were fed six times daily with both rations than in those fed twice daily.

CRANES  CREST

REFERENCES

REFERENCES

- (1) Anonymous. Official Methods of Analysis of the Association of Official Agricultural Chemists. 9th Edition. 1960.
- (2) Armstrong, D. G. and Blaxter, K. L. The Utilization of Acetic, Propionic and Butyric Acids by Fattening Sheep. Brit. J. Nutrition, 11:413. 1957.
- (3) Balch, C. C., Balch, D. A., Bartlett, S., Bartrum, M. P., Johnson, V. W., Rowland, S. J. and Turner, J. Studies of the Secretion of Milk of Low Fat Content by Cows on Diets Low in Hay and High in Concentrates. VI. The Effect on the Physical and Biochemical Processes of the Reticulo-Rumen. J. Dairy Research, 22:270. 1955.
- (4) Campbell, J. R., Howe, W. M., Martz, F. A. and Merilan, C. P. Effects of Frequency of Feeding on Urea Utilization and Growth Characteristics in Dairy Heifers. J. Dairy Sci., 46:131. 1963.
- (5) Campbell, J. R. and Merilan, C. P. Effects of Frequency of Feeding on Production Characteristics and Feed Utilization in Lactating Dairy Cows. J. Dairy Sci., 44:664. 1961.
- (6) Card, C. S. and Schultz, L. H. Effect of the Ration on Volatile Fatty Acid Production in the Rumen. J. Dairy Sci., 36:599. 1953.
- (7) Conrad, H. R. and Hibbs, J. W. A High Roughage System for Raising Dairy Calves Based on the Early Development of Rumen Function. III. Effect of Rumen Inoculations and the Ratio of Hay to Grain on Digestion and Nitrogen Retention. J. Dairy Sci., 36:1326. 1953.
- (8) Dawson, J. R. and Kopland, D. V. Once a Day Versus Twice a Day Feeding for Dairy Cows. Circular No. 830. U.S.D.A. Washington, D. C. August 1949.
- (9) Dowe, T. W., Matsushima, J. and Arthaud, V. The Effects of the Corn Alfalfa Hay Ratio on the Digestibility of Different Nutrients by Cattle. J. Animal Sci., 14:340. 1955.
- (10) Elliot, J. M. and Loosli, J. K. Effect of Dietary Ratio of Hay to Concentrate on Milk Production, Ration Digestibility and Urinary Energy Losses. J. Dairy Sci., 42:836. 1959.
- (11) Elliot, J. M. and Loosli, J. K. Relationship of Milk Production Efficiency to the Relative Proportion of the Rumen Volatile Fatty Acids. J. Dairy Sci., 42:843. 1959.

- (12) Forbes, E. B., Braman, W. W., Kriss, M., Swift, R. W., Miller, R. C., French, R. B., Letonoff, T. V. and Sharpless, G. R. The Metabolizable Energy and Net Energy Values of Cornmeal Fed Exclusively and in Combination with Alfalfa Hay. *J. Agri. Research*, 43:1015. 1931.
- (13) Gibbons, J. Frequency of Feeding and Growth Rate of Young Cattle. *Agriculture*, 65:259. 1958.
- (14) Gordon, J. G. and Tribe, D. E. The Importance to Sheep of Frequent Feeding. *Brit. J. Nutrition*, 6:89. 1952.
- (15) Hamilton, T. S. Factors Affecting Thermogenic Action of Food. Rept. Conf. Energy Metabolism, Pennsylvania State. 1935.
- (16) Hibbs, J. W., Pounden, W. D. and Conrad, H. R. A High Roughage System for Raising Calves Based on the Early Development of Rumen Function. I. Effects of Variations in the Ration on Growth, Feed Consumption and Utilization. *J. Dairy Sci.*, 36:717. 1953.
- (17) Hinders, R. G. and Ward, G. M. Effect of Various Feeds on Volatile Acid Production. *J. Dairy Sci.*, 4:730. 1958.
- (18) Kane, E. A., Jacobson, W. C. and Damewood, P. M., Jr. Effect of Corn Starch on Digestibility of Alfalfa Hay. *J. Dairy Sci.*, 42:849. 1959.
- (19) Knox, K. L. and Ward, G. M. Rumen Concentration of Volatile Fatty Acids as Affected by Feeding Frequency. *J. Dairy Sci.*, 44:1550. 1961.
- (20) Lassiter, C. A., Huffman, C. F. and Duncan, C. W. Effect of Varying Hay-Grain Ratios and Levels of Feed Intake on Feed Utilization of Dairy Cows. *J. Dairy Sci.*, 40:611. 1957.
- (21) Lusk, G. The Specific Dynamic Action. *J. Nutrition*, 3:519. 1931.
- (22) Mochrie, R. D., Thomas, W. E. and Lucas, H. L. Influence of Frequency of Equalized Intakes on Animal Response. *J. Animal Sci.*, 15:1256. 1956.
- (23) Moore, L. A. Relationship Between T.D.N. and Energy Values of Feeds. *J. Dairy Sci.*, 36:93. 1953.
- (24) Moirs, R. J. and Somers, M. Ruminant Flora Studies. The Influence of Rate and Method of Feeding a Ration Upon its Digestibility, Ruminant Function and Upon Ruminant Population. *Australian J. Agr. Research*, 8:253. 1957.

- (25) Phillips, C. A., Hardin, S. D. and Thomas, W. E. The Effect of Corn Alfalfa Hay Ratio on the Digestibility of the Different Nutrients by Sheep. *J. Animal Sci.*, 10:424. 1951.
- (26) Phillipson, A. T. The Fatty Acids Present in the Rumen of Lambs Fed on a Flaked Maize Ration. *Brit. J. Nutrition*, 6:190. 1952.
- (27) Putnam, P. A., Gutierrez, J. and Davis, R. E. Effects of Frequency of Feeding Upon Rumen Volatile Fatty Acids, Protozoal Population and Weight Gains in Angus Heifer Calves. *J. Dairy Sci.*, 44:1364. 1961.
- (28) Putnam, P. A. and Loosli, J. K. Effect of Feeding Different Ratios of Roughage to Concentrate Upon Milk Production and Digestibility of the Ration. *J. Dairy Sci.*, 42:1070. 1959.
- (29) Ragsdale, A. C. Feed Consumption of Dairy Cattle During Growth. *Missouri Agr. Expt. Sta. Bull.*, 338. 1934.
- (30) Rakes, A. H., Hardison, W. A., Albert, J., Moore, W. E. C. and Graf, G. C. Response of Growing Dairy Heifers to Frequency of Feeding. *J. Dairy Sci.*, 40:1621. 1957.
- (31) Reed, O. E., Fitch, J. B. and Cave, H. W. The Relation of Feeding and Age of Calving to the Development of Dairy Heifers. *Kansas Agr. Expt. Sta. Bull.*, 233. 1924.
- (32) Reid, J. T., Woolfolk, P. G., Richards, C. R., Kaufman, R. W., Loosli, J. K., Turk, K. L., Miller, J. I. and Blaser, R. E. A New Indicator Method for the Determination of Digestibility and Consumption of Forages by Ruminants. *J. Dairy Sci.*, 33:60. 1950.
- (33) Richardson, H. B. and Mason, E. H. The Effects of Fasting in Diabetes as Compared with a Diet Designed to Replace the Foodstuffs Oxidized During a Fast. *J. Biol. Chem.*, 57:587. 1923.
- (34) Stallcup, O. T., Herman, H. A. and Ragsdale, A. C. The Growth of Dairy Heifers Raised Chiefly on Roughages. *Missouri Agr. Expt. Sta. Bull.*, 523. 1949.
- (35) Teichman, R., Eaton, H. D., Beall, G., Johnson, R. E., Lucas, H. L. Jr., and Moore, L. A. Effect of Previous Ration on Lactation Response to Substituting Corn for Alfalfa According to Net Energy and Total Digestible Nutrient System of Estimation. *J. Dairy Sci.*, 41:129. 1958.

CRANESFIELD CRIST

- (36) Thomas, W. E. and Mochrie, R. D. Effect of Frequency of Feeding Equalized Intake on Growth of Dairy Heifers. Proceed. Assoc. Southern Agr. Workers, 123-4. 1956.
- (37) Tyznik, W. and Allen, N. N. The Relation of Roughage Intake to the Fat Content of Milk and the Level of Fatty Acids in the Rumen. J. Dairy Sci., 34:493. 1951.
- (38) Wiseman, H. G. and Irvin, H. M. Agricultural and Food Chemistry, 5:213. 1957.

CRANES  CREST

APPENDICES

CRANES  CREST

APPENDIX A

TABLE IX

ANALYSIS OF VARIANCE

Source	D.F.	S.S.	Mean Square	F Value	
Total	23	108,682			
Rations (R) Hay Alone vs Hay Grain	1	83,544	83,544	69.04	***
Frequency (F) 6x vs 2x	1	216	216	.18	N.S.
R x F	1	726	726	.60	N.S.
Error	20	24,196	1210		

APPENDIX B

TABLE X

TOTAL WEEKLY FEED CONSUMPTION BY PENS OF THREE CALVES EACH FED
HAY AND GRAIN OR HAY ALONE SIX TIMES AND TWO TIMES DAILY ^a

Week.	Pens Fed Hay and Grain				Pens Fed Hay Alone			
	I	II	III	IV	V	VI	VII	VIII
------(lb)-----								
1	210	189	210	189	192	158	210	174
2	210	189	210	189	182	148	206	160
3	210	189	210	189	194	186	209	175
4	216	195	216	195	192	179	216	186
5	231	210	231	210	202	177	231	204
6	231	210	231	210	221	203	231	200
7	231	210	231	210	231	210	231	210
8	236	215	236	215	232	177	246	215
9	252	231	252	231	228	198	252	229
10	252	231	252	231	210	206	251	220
11 ^b	252	231	252	231	242	227	252	212
12	282	261	282	261	287	243	282	270
13	294	273	294	273	308	254	294	282
14	315	294	315	294	284	263	315	294
15	315	294	315	294	281	266	315	294
16	315	294	315	294	285	261	315	294
17	315	294	315	294	300	269	315	294
18	315	294	315	294	295	273	315	294
19	315	294	315	291	303	269	315	294
20	315	294	315	294	304	272	315	294
Total	5422	4994	5417	4986	5062	4584	5411	4842

^a All feed totals rounded to nearest whole pounds.

^b During the eleventh week the bedding which had formerly been straw and grass clippings was changed to sawdust, which was used from then to the end of the experiment.