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## Two Systems of Feeding Dairy Cows

### High Roughage and Low Grain versus Low Roughage and High Grain

By J. B. Lindsey and J. G. Archibald

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The amount of grain to be fed to cows is a question of perennial interest to farmers, particularly in a state like Massachusetts where grain is bought outright, while roughage is grown at home. Though much has been written on the subject, it has been largely opinion unsupported by experimental evidence. The experiment here reported was carried out to provide such evidence.

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# TWO SYSTEMS OF FEEDING DAIRY COWS: HIGH ROUGHAGE AND LOW GRAIN vs. LOW ROUGHAGE AND HIGH GRAIN FEEDING

By J. B. Lindsey, Research Professor, and J. G. Archibald,  
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## INTRODUCTION

The question of the proper amount of grain to feed to milking cows has always been one of great interest to farmers. Each individual farmer has his own opinion, and many have been the discussions centered around the problem at country store, Grange Hall, and other rural meeting places. Much, too, has been written on the subject in the farm press and elsewhere, both by practical farmers and by extension workers in dairy husbandry. Strangely enough, however, the various expressed opinions have had very little accurate experimental evidence behind them. About twenty years ago the Pennsylvania Experiment Station investigated the problem, but as the amounts of grain fed to two different groups of cows were not greatly different it left considerable to be done.<sup>1</sup>

It was decided, therefore, to conduct a long-time experiment on the subject at this station. This bulletin presents the results of the investigation, which was commenced October 1, 1928 and brought to a conclusion March 31, 1932, after having been conducted continuously for a period of three and one-half years.

## METHODS OF EXPERIMENTATION

The station herd of high grade Holstein cows was utilized throughout the entire period. The number of cows in the herd varied at any given time from ten to fourteen, which were divided equally and as uniformly as possible into two groups, referred to hereinafter as the high roughage and the low roughage group. All individuals were kept throughout the duration of the experiment (or for the length of time they remained in the herd) in the group to which they were originally assigned.

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<sup>1</sup>Note: After the investigation herein reported had been brought to a conclusion and the results had been prepared for publication, the authors received copies of a report\* of a somewhat similar investigation that recently had been conducted at the United States Dairy Experiment Station at Beltsville, Maryland.

The method of feeding described therein modifies the old rule of a pound of grain for so many pounds of milk, irrespective of other factors. It takes into account quality of roughage, capacity of the cow for roughage, level of milk production and fat test, and suggests the following rule, recognizing that it is applicable only where silage and a good quality of hay are available. For Jersey cows feed grain at the rate of 0.6 pound for each pound of milk produced above 10 pounds, and for Holstein cows feed 0.4 pound for each pound of milk above 16 pounds. The advantage claimed for this method is that it results in more economical feeding for two reasons: (1) Because cows will get enough nutrients from good roughage alone to provide for the maintenance of their bodies and also for the production of a certain amount of milk; (2) because one pound of grain does not contain sufficient nutrients for 3 pounds of milk. By the old rule, therefore, the low producers were overfed and the high producers were underfed. The modified rule overcomes this objection by regulating grain feeding according to a cow's capacity for roughage as well as by her milk production.

The method seems to have worked out quite satisfactorily but requires modification and care in its use for cows near the upper and lower limits of their production; it is worthy of trial by New England farmers who have corn silage and good quality hay available.

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\*Woodward, T. E., Shepherd, J. B., and Graves, R. R. Feeding and management investigations at the United States Dairy Experiment Station at Beltsville, Md. 1930 Report. U. S. Dept. Agr. Misc. Pub. 130. 24 p. 1932.

TABLE 1. —AVERAGE AMOUNTS OF ROUGHAGE\* AND GRAIN FED.

(Pounds daily per Cow)

	HIGH ROUGHAGE GROUP		LOW ROUGHAGE GROUP	
	Roughage	Grain	Roughage	Grain
Recommended . . . . .	25.1	6	19.5	11
Fed. . . . .	24.0	6	19.5	11
Actually eaten . . . . .	23.7	6	19.4	11

\*All roughage reduced to a hay basis and so reported. Because of considerable variations in the lengths of time the various roughages were fed, this was the only feasible method of handling the data.

The rations fed to both groups were of the same general character, the difference between the groups consisting in the proportion of roughage to concentrates. The high roughage group received grain at the average rate of one pound to 4½ pounds of milk, approximately thirty-five pounds of corn silage (November through April) and as much hay as they would clean up. The low roughage group received grain at the average rate of one pound to 2½ pounds of milk, approximately twenty pounds of corn silage (November through April) and as much hay as they would clean up. The amounts of grain were adjusted each month according to the milk yield. The rations in general were adjusted according to Haecker's standard whenever a change was made in the kind of roughage, e. g., from silage to rowen, or from rowen to green feed. Dry cows received 50 per cent in excess of the nutrients required for maintenance. The average amounts of grain and roughage for each group over the entire period appear in Table 1. When silage was not available, rowen and first crop hay were fed in equal or approximately equal amounts except during July, August, and September, when the rowen was replaced by such green crops as oats and peas, millet, and fodder corn<sup>2</sup>, five pounds of green feed being substituted for one pound of rowen. The hay was a mixed hay of good quality grown on the station grounds, containing at times considerable clover, but composed for the most part of timothy, red top, June grass, and sweet vernal grass. At any given time all feeds for both groups were from the same original lots. In order to keep the protein level for both groups approximately the same, it was necessary to feed to the high roughage group a grain mixture somewhat richer in protein than that fed to the low roughage group. This was done by varying the proportions of the several ingredients in the two mixtures. The formulas of the mixtures appear below.

	GRAIN MIXTURE	
	For high roughage	For low roughage
	group	group
	Per cent	Per cent
Wheat bran.....	20	20
Ground oats.....	15	25
Corn meal.....	15	30
Gluten feed.....	25	15
Cottonseed meal.....	25	10

These mixtures contained respectively about 17.9 and 12.8 per cent of digestible protein. The average composition of all feeds used in the experiment is shown in Table 2. Table 3 shows the total and average amounts of dry matter, digestible protein, and total digestible nutrients consumed in each group.

A study of Table 1 shows that while the average daily amount of feed recommended for the high roughage group was slightly in excess of that recommended for the low roughage group (.6 pound more), the amount fed was .5 pound less and the actual amount eaten was .7 pound less. This seeming discrepancy was due to the fact that considerable trouble was experienced from time to time in getting the cows in the high roughage group to eat sufficient roughage to meet their theoretical requirements according to Kellner's standard. A persistent effort was made to overcome this difficulty by offering the cows their theoretical quota of roughage for days at a time, even when it was evident that they were wasting considerable quantities of it, in the hope that in time they would become accustomed to the

<sup>2</sup>It would have been desirable to have had pasture for the cows during the summer, but as none was available within reasonable distance green feed was resorted to. It is not believed that under present farming conditions a system of green crops is economical for the average farmer.

relatively large amount of roughage and the relatively small amount of grain. Some of them did, but more did not, which accounts for the slightly lower feed consumption by this group.

TABLE 2.—AVERAGE COMPOSITION OF FEEDS  
(Per Cent)

Material	Number of lots	Water	Ash	Crude protein	Crude fiber	N-free extract	Crude fat
Hay.....	14	10.5	4.7	8.4	30.4	44.1	1.9
Rowen.....	7	11.8	6.4	11.8	23.9	42.9	3.2
Corn silage.....	3	75.9	1.1	2.1	6.0	14.2	0.7
Green oats and peas.....	3	84.9	1.6	2.6	4.4	6.1	0.4
Green millet.....	2	79.2	2.0	2.3	6.2	9.9	0.4
Green corn fodder.....	3	71.7	1.4	2.1	6.6	17.4	0.8
Green soy beans.....	1	62.9	4.0	6.9	10.1	15.3	0.8
High protein grain.....	12	11.0	5.2	22.7	7.8	48.7	4.6
Low protein grain.....	12	11.8	4.2	16.8	6.8	56.0	4.4

Table 3 shows that with respect to amounts of digestible protein eaten the two groups are not far apart, .09 pound per cow daily, or 3.8 per cent, in favor of the low roughage group. Respecting total digestible nutrients, this group ate on the average 1.09 pound, or 6.3 per cent, more daily than did the high roughage group. They ate also .46 pound, or 1.7 per cent, more dry matter daily per cow than did the high roughage group. These inequalities in feed intake are commented on in the general discussion toward the end of the bulletin.

### Records Kept

All cows were weighed at the first of each calendar month, the average of two weighings on consecutive days being taken unless the weights differed by more than twenty pounds, in which case a third weighing was made.

All milk was weighed, and a five-day composite sample was taken each month from each cow in milk and analyzed for total solids and fat.

All feeds were weighed for each animal each day and any feed refused was weighed and recorded. All feeds were sampled from time to time and complete fodder analyses were made according to the methods of the Association of Official Agricultural Chemists.

Summaries were made each month and at the end of the year for the whole year, so that cost of milk production at any given time was definitely ascertained.

Careful breeding records were kept and notes were made from time to time on the general appearance of the cows.

## RESULTS OF THE INVESTIGATION

### General Appearance

A summary appears in Table 4. The low roughage group maintained their general appearance on the whole better than did the high roughage group. This was due probably to the slightly greater intake of nutrients by the low roughage group. With the exception of two individuals, Nos. 35 and 88, which maintained an excellent appearance all through the experiment, the cows in the high roughage group showed a tendency to be rough coated and rather thin.

TABLE 3.—AMOUNTS OF FEED, DRY MATTER, TOTAL DIGESTIBLE NUTRIENTS, AND DIGESTIBLE PROTEIN CONSUMED.

	HIGH ROUGHAGE GROUP				LOW ROUGHAGE GROUP			
	Amount consumed	Dry Matter	Total digestible nutrients	Digestible protein	Amount consumed	Dry matter	Total digestible nutrients	Digestible protein
	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
Hay.....	74,781	66,929	39,724	3,455	67,204	60,148	35,699	3,105
Rowen.....	23,561	20,781	12,952	1,918	18,792	16,575	10,330	1,530
Corn silage.....	64,823	15,622	10,333	681	37,394	9,012	5,961	393
Green oats and peas.....	17,680	2,670	1,713	340	17,028	2,571	1,650	327
Green millet.....	10,497	2,183	1,395	154	8,285	1,723	1,101	122
Green Corn fodder.....	15,158	4,290	2,988	194	13,455	3,808	2,652	172
Green soy beans.....	235	87	53	13	180	67	41	10
High protein grain.....	31,950	28,436	22,391	5,729	.....	.....	.....	.....
Low protein grain.....	.....	.....	.....	.....	59,286	52,290	41,761	7,571
Total.....	.....	140,998	91,549	12,484	.....	146,194	99,195	13,230
Daily average per cow*.....	.....	26.64	17.30	2.36	.....	27.10	18.39	2.45

\*Obtained by dividing by 5293 and 5394 respectively, the number of cow days in the two groups.

TABLE 4.—GENERAL APPEARANCE OF COWS.

Cow No.	AGE AT		APPEARANCE	
	CONCLUSION		At the beginning or when included in the experiment	At the end or when withdrawn from the experiment
	Years	Months		
<b>High Roughage Group</b>				
35.....	10	7	Good	Excellent
71.....	8	3	Good	Good
88.....	7	2	Excellent	Excellent
98.....	4	.. (a)	Fair	Good
128.....	3	11 (b)	Fair	Good
137.....	3	7 (c)	Fair	Good
139.....	4	8	Good	Fair
143.....	3	3 (d)	Good	Fair
144.....	4	4	Excellent	Good
<b>Low Roughage Group</b>				
15.....	11	6 (e)	Good	Good
33.....	10	6	Good	Good
40.....	6	11 (f)	Fair	Fair
99.....	5	8 (g)	Fair	Good
121.....	4	6 (h)	Good	Excellent
126.....	5	6	Good	Good
138.....	4	8	Good	Excellent
141.....	4	7	Fair	Excellent

(a) Age when sold June 17, 1929. Very poor producer.

(b) Age when sold September 23, 1930. Aborted and had been a poor producer previously.

(c) Age when sold February 16, 1931. Reactor to tuberculin test.

(d) Age when sold February 16, 1931. Reactor to tuberculin test.

(e) Age when sold February 16, 1931. Old cow getting thin and lame.

(f) Age when sold July 15, 1929. Could not get her with calf.

(g) Age when sold February 16, 1931. Reactor to tuberculin test.

(h) Age when sold February 16, 1931. Reactor to tuberculin test.

### Body Weight

Because two-thirds of the individuals were immature when included in the experiment, maintenance of body weight could not be used as a criterion. It has been necessary to compare instead the relative gain in weight of the two groups, care being used to have weights for any one individual at beginning and end represent approximately the same stage of gestation. The weights are shown in Table 5.

With one exception<sup>3</sup> all the individuals gained in weight during the course of the experiment, the older cows making moderate gains, while the younger ones made normal to excellent growth. Taking the data in Table 5 at their face value it would seem that the low roughage ration was somewhat superior to the high roughage ration for maintenance and growth. It must be pointed out, however, that the average time interval between the two series of weights was twenty-seven months in this group while the average time interval for the high roughage group was twenty-two months. Assuming that had the time interval for the latter group also been twenty-seven months they would have continued to gain in weight at a rate equal to the average for the twenty-two month interval, the average individual gain would then have been 124 pounds and the percentage gain for the group 11.5 per cent. The above assumption may not be strictly justifiable, but no better means of adjustment is known and in fairness some allowance should be

<sup>3</sup> This cow was purchased for the experiment and at time of purchase was in show condition, carrying considerably more flesh than it is our practice to have our animals carry. Her failure to gain in weight is attributed to this reason. She was by no means thin when the experiment was completed.



TABLE 5.—CHANGES IN BODY WEIGHT.

Cow No.	WEIGHT IN POUNDS		GAIN	
	At beginning of, or when included in, the experiment	On a comparable date at or near end of, or at time of withdrawal from, the experiment	Pounds	Per cent
<b>High Roughage Group</b>				
35	1020	1070	50	4.9
71	1175	1295	120	10.2
88	1140	1180	40	3.5
98	1000	1145	145	14.5
128	1165	1200 (a)	35	3.0
137	1090	1300	210	19.3
139	990	1235	245	24.7
143	1040	1110	70	6.7
144	1065	1060	5 (b)	0.5 (b)
Averages	1076	1177	101	9.4
<b>Low Roughage Group</b>				
15	1210	1220	10	0.8
33	1190	1205	15	1.3
40	950	1005	55	5.8
99	960	1225	265	27.6
121	1115	1400	285	25.6
126	970	1060	90	9.3
138	1005	1375	370	36.8
141	1025	1220	195	19.0
Averages	1053	1214	161	15.3

(a) Actual weight not available; weight estimated from previous year's records.

(b) Loss.

made for the difference in time interval. Even after making this allowance, however, the low roughage group had some advantage insofar as gains in weight were concerned. These data bear out the general observation noted from time to time and referred to on p. 6 that the high roughage group showed a tendency to be rather thin, due probably in part to the slightly smaller amount of feed eaten.

### Milk Yield

Milk production records are available for fourteen complete lactation periods in each group. Records of partial lactation periods have not been included because there is no known method of correcting them so that they will be comparable. The complete records as reported in Table 6 have all been corrected to a 305-day basis with proper allowance made in each case for length of time a calf was carried during the lactation.<sup>4</sup>

The corrected daily milk yield per cow was almost exactly four pounds, or 14.4 per cent, more in the low roughage group than it was in the high roughage group. The number of lactations being the same, the total production was, of course, correspondingly higher in the low roughage group. It is to be expected that cows getting a liberal allowance of grain will milk more freely than if on a restricted

<sup>4</sup>These corrections were made by using the factors published by Gaines and Davidson in Illinois Experiment Station Bulletin No. 272, pages 25 and 34, Tables 7 and 8. Correction for age was unnecessary as the average age of both groups was approximately the same throughout the investigation.

allowance. The problem is concerned only in a minor sense with the amount of milk produced, the more important question being the relative economy of production, which is discussed later.

TABLE 6.—DATA RESPECTING MILK PRODUCTION.

	High Roughage Group	Low Roughage Group
Average daily milk yield per cow* . . . . . pounds	27.68	31.67
Total milk yield of each group* . . . . . pounds	118,207	135,244
Dry matter required to produce 100 pounds of milk . . . . . pounds	114	106
Digestible nutrients required to produce 100 pounds of milk . . . . . pounds	74	72
Average length of lactation period . . . . . days	325	311
Average length of dry period . . . . . days	91	81
Average length of time calf was carried during the lactation . . . . . days	182	200
Average number of productive days per calendar year . . . . . days	285	290

\*Corrected to a 305-day basis.

The high roughage group was slightly more persistent in milk flow as evidenced by an average lactation period two weeks longer than the average for the low roughage group. This can be attributed almost entirely to a shorter calf-carrying period during the lactation, the difference being eighteen days. The possible significance of the later breeding and resultant shorter calf-carrying period is discussed in the section dealing with reproduction. It may be noted at this point that both groups remained non-pregnant after calving somewhat longer than is usual and hence had somewhat shorter calf-carrying periods during the lactations. The slightly greater persistency in milk yield shown by the high roughage group is completely offset by a longer average dry period, the average number of productive days per calendar year being slightly higher for the low roughage group.

The low roughage group made slightly better use of their feed, eight pounds (7 per cent) less dry matter and two pounds (2.7 per cent) less digestible nutrients being required to produce one hundred pounds of milk.

### Feed Cost of Milk Production

The next question that naturally arises relates to the feed cost of production of the milk. This will vary with local conditions and relative costs of roughage and grain, and for any given time and place must of necessity be determined by the individual farmer. During the time this investigation was in progress the relation between grain prices and roughage prices was such that the feed cost of production was practically the same for both systems of feeding. With grain prices as low as they are at present (December, 1932), the low roughage system has an apparent advantage in immediate economy of production. It should be remembered, however, that where roughage is largely home-grown the high roughage system involves a considerably smaller cash outlay. Also, a farmer may be able to raise hay and silage for less than average prices. If so, the difference represents a profit on his labor which should be taken into consideration in calculating costs.

Costs should be figured not on the basis of actual cash outlay but on the cost of

a unit of milk produced. Reasonably accurate production records, such as are kept in herd improvement association work, can be used to ascertain this.

### Milk Production from Year to Year

The question is often asked concerning certain methods of feeding and management, "How do the cows hold up from year to year in production?" Unfortunately, only a small number of year to year comparisons are available from this study; five from the high roughage group, and seven from the low roughage group. These have been adjusted to a mature cow basis<sup>6</sup>, and the actual and percentage increments or decrements from year to year are shown in Table 7.

TABLE 7.—CHANGES IN MILK YIELD OF INDIVIDUAL COWS FROM YEAR TO YEAR.

Cow No.	Milk Yield* Pounds	Change from Year to Year	
		Pounds	Per Cent
<b>High Roughage Group</b>			
35	10,345		
	9,784	-561	-5.42
	9,921	+137	+1.40
71	8,139		
	9,370	+1231	+15.12
88	12,593		
	10,466	-2127	-16.89
139	8,890		
	10,575	+1685	+18.95
Average	9,950		
	10,023	+73	+0.73
<b>Low Roughage Group</b>			
33	12,250		
	13,172	+922	+7.53
99	11,201		
	10,590	-611	-5.45
121	10,458		
	12,077	+1619	+15.48
126	8,592		
	10,031	+1439	+16.75
	11,790	+1759	+17.54
138	10,490		
	13,771	+3281	+31.28
141	8,853		
	9,586	+733	+8.28
Average	10,268		
	11,574	+1306	+12.72

\*Corrected to a 305-day, farrow, mature cow basis.

Although both groups maintained their milk yield from year to year, the high roughage group did so only by a very narrow margin, while the low roughage group showed a substantial increase. Had there been available the same number of comparisons for both groups it is possible that there might not have been quite such a disparity between them in this respect. Because of the relatively few records caution should be used in interpreting this result.

<sup>6</sup> The adjustments have been made by using the factors for that purpose published by Turner, Ragsdale and Brody in Missouri Station Bulletin No. 221, page 8, Table 2.

### Composition of the Milk

As already noted on p. 6 the milk of all the cows was analyzed regularly for total solids and fat. A summary of the analyses appears in Table 8. Individuality plays such a large part in determining the average fat and solids test of a group of cows that it would not be fair to claim that any differences between the groups are due entirely to the experimental treatment. In addition, therefore, to the averages for the entire groups during the experiment, which are included largely as a matter of record, Table 8 also contains comparative data which show the average test for a corresponding period previous to the commencement of the experiment of such members of each group as were in the herd at that time and the average test for these same individuals during the course of the experiment. These individuals constitute approximately half of each group.

TABLE 8.—COMPOSITION OF THE MILK

	Total Solids (per cent)		Fat (per cent)	
	High Roughage Group	Low Roughage Group	High Roughage Group	Low Roughage Group
Entire herd throughout the experiment	11.77	12.33	3.52	3.81
Cows in herd for a corresponding period previous to the experiment:				
Before the experiment.....	12.14	11.81	3.71	3.58
During the experiment.....	11.70	11.79	3.54	3.62

Taken at its face value the first group of figures in Table 8 indicates some superiority in fat and total solids in the milk from the low roughage group. Part of this is apparent only, due largely to the presence in that group of a young cow (No. 126) that turned out to be an unusually high tester for a Holstein, her milk never testing less than 4 per cent fat and averaging 4.5 per cent over a three-year period. As there was not a corresponding high tester in the other group, part of the difference must be charged to this inequality. However, from the second and third sets of figures in the table it seems safe to conclude that part of the difference between the groups in this respect is due to the experimental treatment. While the fat and solids averages for the low roughage group were practically identical for the experimental period and a corresponding period immediately previous to the experiment, this was not the case for the high roughage group. This group showed a shrinkage of 0.44 per cent total solids and 0.17 per cent fat during the experimental period. These figures, representing a large number of individual tests, give evidence that low grain and high roughage feeding may tend to produce milk of slightly lower test as time passes. It does not necessarily follow that the composition of the milk can be substantially changed by any normal system of feeding.

### Reproductive Function

Two of the cases of retained placenta were in an individual that had had the same trouble twice previous to commencement of the experiment. The case of chronic metritis was also of long standing, having developed prior to the beginning of the experiment. Both cows that aborted reacted negatively to the blood test for infectious abortion.

TABLE 9.—DATA RESPECTING REPRODUCTION.

	High Roughage Group	Low Roughage Group
Days after calving before		
Appearance of first heat.....days	53	35
Next conception.....days	142	105
Regularity of oestrus:		
Good.....per cent	33	75
Fair.....per cent	45	25
Poor.....per cent	22	0
Number of services required.....	1.3	1.3
Percentage of breedings from one service.....	69	70
Irregularities:		
Retained placenta.....	3	0
Abortion.....	1 (a)	1 (b)
Other.....	1 (c)	1 (d)

(a) At 7 months.

(b) At 6½ months.

(c) 1 case of cervicitis.

(d) 1 case of chronic metritis.

It is evident that the low roughage group was somewhat nearer normal in its reproductive function than the high roughage group. This was true especially with regard to the cycle of oestrus and the length of time from calving to the next conception. The condition and weight at birth of the calves produced by both groups is summarized in Table 10.

TABLE 10.—DATA ON CALVES DROPPED DURING THE EXPERIMENT.

	High Roughage Group	Low Roughage Group
Sex distribution:		
Male.....per cent	84.6	60.0
Female.....per cent	15.4	40.0
Average weight at birth*.....pounds	98	98
Condition at birth:		
Very good.....per cent	31	20
Good.....per cent	61	60
Fair.....per cent	8	20

\*Corrected for unequal sex distribution; the average birth weight of all Holstein bull calves dropped in the station herd over a long period of years is 8 per cent higher than the average birth weight of Holstein heifer calves dropped in the herd for the same period.

Twenty-eight calves are represented in the summary in Table 10, thirteen in the high roughage group and fifteen in the low roughage group. Average birth weight was the same in both groups. At first glance it would seem, from the standpoint of condition at birth, that the calves in the high roughage group were on the whole more vigorous. However, it must be pointed out that all the "fair" individuals were heifers. It is common knowledge that bulls, as a rule, are more vigorous when born than heifers are, and part of the difference in this respect can probably be charged to the larger number of heifers in the low roughage group.

### DISCUSSION OF RESULTS

Viewing the results as a whole, the low roughage group of cows had a rather better record. They looked thriftier, put on more flesh, milked more freely, maintained their production better from year to year, maintained their average test better, and were more nearly normal in their reproductive function.

In searching for a reason for the better showing of this group the most obvious one is the slightly greater food intake noted on p. 5. This difference in intake of nutrients favors the low roughage group and because of it criticism might be made of the conduct of the experiment.

It must be pointed out, however, that the discrepancy is due in some measure at least to an inherent weakness in the high roughage system of feeding which has been brought out by the experiment; viz., that these cows would not, or could not, eat sufficient roughage to satisfy their theoretical requirements when the amount of grain fed was kept down to one pound for each  $4\frac{1}{2}$  pounds of milk daily. It is felt also that there must be other reasons for the better showing of the low roughage group. Superiority for milk production of the total digestible nutrients and possibly of the digestible protein in their ration is suggested as another cause. In the high roughage group 24 per cent of the total digestible nutrients and 46 per cent of the digestible protein consumed came from the grain, while in the low roughage group 42 per cent of the total digestible nutrients and 57 per cent of the digestible protein consumed came from the grain. Another factor not to be lost sight of is the additional energy required to digest the extra coarse fodder in the high roughage ration.

It is evident that cows will not produce to the limit of their ability on a high roughage system of feeding. Whether it is economical to have them do so will depend very largely on local conditions as to production and markets, and in a large measure the problem is one for the individual farmer to solve for himself.

If he is situated relatively far from market, with sufficient low-priced land to grow an abundance of rough feed, and if he has big hearty cows accustomed to consume readily large quantities of hay and other roughage; then the high roughage system is undoubtedly the one to adopt. If he is near a good market and the demand for milk is such that he is not unduly penalized for surplus production, if he has relatively little land and that high priced, and if he has cows of the smaller breeds; then undoubtedly liberal grain feeding is the practice to follow.

In between these extremes will be found the majority of New England farmers, and it is believed that in a great many cases the ratio of 1 pound of grain to  $3\frac{1}{2}$  pounds of milk is likely to prove the most satisfactory. Each farmer must study his own situation, weigh the facts, and decide for himself.

In conclusion, it must be emphasized that the high roughage system of feeding cannot prove satisfactory unless the roughage is of good quality, which means legume or mixed hay cut early and well cured, and corn silage that is sweet, well eared, and not watery.

### SUMMARY AND CONCLUSIONS

This bulletin reports the results of an investigation, three and one-half years in length, on the relative merits of two systems of feeding dairy cows. One of these systems involved the feeding of a relatively large amount of roughage and a relatively small amount of grain; the other involved the feeding of a relatively small

amount of roughage and a relatively large amount of grain. The station herd was divided into two groups which for convenience have been designated the high roughage and low roughage groups. The high roughage group received approximately one pound of grain for each  $4\frac{1}{2}$  pounds of milk produced, 35 pounds of silage, and as much hay as they would clean up. The low roughage group received approximately one pound of grain for each  $2\frac{1}{2}$  pounds of milk produced, 20 pounds of silage, and hay as above.

All feed was the same in composition at any given time for both groups, except that the grain mixture for the high roughage group was considerably richer in protein in order to keep the intake of protein at about the same level in both groups. In all other respects the treatment of the groups was identical.

Records were kept of general appearance of the cows, live weight, milk production, feed consumption, composition of the milk and of the feeds, and the reproductive function of the cows, including calf production.

The following results have been noted:

1. The cows in the low roughage group maintained their general appearance rather better than did those receiving a relatively large amount of roughage. The latter tended to be thinner and more rough coated.

2. The cows in the low roughage group made somewhat larger gains in weight.

3. The cows in the low roughage group produced more milk on both a daily and a yearly basis. Their lactations were slightly shorter but so also were their dry periods, so that their average productive period per calendar year was slightly higher.

4. The cows in the low roughage group made slightly better use of the feed they consumed as evidenced by the fact that they required 7 per cent less dry matter and 2.7 per cent less digestible nutrients to produce 100 pounds of milk.

5. Feed cost of milk production was practically the same for both groups. The high roughage system, however, involves a smaller cash outlay; and an additional saving may be effected where that system is used if the farmer is able to grow his roughages for less than the current market price.

6. The cows in the low roughage group maintained their milk production from year to year somewhat better than did those in the high roughage group.

7. The low roughage group maintained a uniform milk test as compared with their test previous to the commencement of the experiment, while the high roughage group fell off somewhat in this respect.

8. The low roughage group was somewhat nearer normal in reproductive function than the high roughage group.

The conclusion which has been reached from the results of this experiment is that in order to keep cows looking well and producing somewhere near the limit of their ability, reasonably liberal grain feeding must be practiced. Whether the practice will be economical depends largely on the particular set of conditions prevailing in different localities and on individual farms. With the facts in hand each farmer must make his own decision as to whether he will follow either of the systems outlined in these pages, or possibly a happy medium between the two.