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WINTER RATIONS FOR DAIRY HEIFERS.

by

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WINTER RATIONS FOR DAIRY HEIFERS.

-INTRODUCTION-

According to the January 1917 Crop Report of the Department of Agriculture the dairy cows in the United States number 22,768,000. This is an increase of 8.9 per cent during the past ten years. There is every reason to believe that the number will continue to increase, perhaps with greater rapidity in the future on account of the fact that dairy products seem an indispensable part of the human diet, and moreover because the cow is conceded to be the most economical producer of human food among domestic animals.

On the average it is probably safe to assume that dairy cows are milked not more than five years, after which they are replaced by younger animals. This being true it is necessary to raise approximately 4,500,000 cows each year in order to keep up the present numbers. Since the heifers do not come into milk until they are at least two years old, it is

necessary then that approximately 9,000,000 heifers be fed in the United States each year.

Furthermore, it is found by experience and observations of practical men, as well as by agricultural experiment stations, that at least one out of every four heifers which are raised to maturity are unprofitable. This tends to further increase the demand for cows to replace those discarded.

Several experiment stations have found that the cost of raising a dairy heifer to the age of two years is about \$75.00, and that nearly 70 per cent of this cost is for feed. Of the feed cost the greater part represents that required during the winter months when the animals are receiving dry feed, since pasture is still the cheapest feed in most parts of the United States. This makes the problem of winter rations the most important item of cost in the raising of the dairy heifer to maturity.

However, the problem of raising heifers not only involves the economic question of expense for feed, but also the equally important question of the effect of different planes of nutrition during the winter months on subsequent growth and usefulness.

Numerous experiments have been conducted with respect to the proper feed and care which calves and mature cows should receive, but on the other hand, very little has been done concerning the proper winter rations for dairy heifers between the period of skim milk feeding and the time of first calving.

It is a portion of this large problem of determining the best and most economical methods of wintering growing dairy heifers that forms the basis of this thesis.

The special object of these experiments is to compare the efficiency and economy of rations which are conducive to rapid growth with rations of such character as to admit of but limited growth.

11- REVIEW AND DISCUSSION OF LITERATURE.

The literature on raising dairy heifers past the age of skim milk feeding is indeed limited. It seems to have been generally assumed that if a heifer is given a good start as a calf that she requires little more attention until ready to calve. As a result we find very little experimental data concerning rations for growing dairy heifers after the time of weaning. Some experimental work has been conducted with beef cattle but these results have only a limited bearing on rations for dairy heifers inasmuch as their requirements for growth are different as was recognized by Armsby in preparing his feeding standard for growing animals which is reproduced in Table 1. The principles involved in feeding the growing steer must, however, be applicable to the feeding of the growing dairy heifer.

Feeding Standards for Growth of Dairy Heifers.- While

no single feeding standard for growing animals is universally accepted there are three standards especially well known. These are the Armsby,¹ the Wolff-Lehmann,² and the Kellner,³ which are given in Tables 1, 2, and 3.

Table 1.

Armsby's Standard For Growing Cattle.

Estimated Requirements Including Maintenance Per Head
Per Day.

Age	Beef Breeds.			Dairy Breeds.		
	Live Wt.	Dig. Pro.	Net Energy	Live Wt.	Dig. Pro.	Net Energy
Months	Pounds	Pounds	Therms	Pounds	Pounds	Therms
3	200	0.80	4.2	165	0.65	3.6
6	350	1.10	5.0	275	0.85	4.1
9	450	1.25	5.7	325	0.90	4.4
12	550	1.40	6.5	400	1.00	5.1
18	750	1.50	8.2	550	1.10	6.4
24	900	1.60	9.3	700	1.20	7.6
30	1000	1.60	9.9	800	1.20	8.2

Table 2.

Wolff-Lehmann Standard For Growing Dairy Cattle.

Age	Live Wt.	Per Day per 1000 pounds live weight.			
		Dry Matter		Digestible Nutrients.	
Months	Pounds	Pounds	Pounds	Pounds	Pounds
2-3	150	23	4.0	13.0	2.0
3-6	300	24	3.0	12.8	1.0
6-12	500	27	2.0	12.5	0.5
12-18	700	26	1.8	12.5	0.4
18-24	900	26	1.5	12.0	0.3

Table 3.

Kellner's Standard for Growing Dairy Cattle.

		Per Day per 1000 lbs. live weight.					

Age	Live Wt.	Dry Matter	Digestible Nutrients				

		Pro.	Starch	Equiv.	Crude	Pro.	Fat.

Months	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2-3	150	23	3.4	18.5	3.7	2.0	
3-6	300	24	2.8	14.7	3.1	1.0	
6-12	500	26	2.3	12.5	2.6	0.6	
12-18	700	26	1.8	10.5	2.2	0.4	
18-24	900	26	1.3	9.2	1.6	0.3	

Armsby's original standard was apparently based upon data obtained from growing steers and it was not until 1916 that he published a standard designed especially for dairy animals. On account of animals of the same age varying considerably in weight Armsby states that the weight rather than the age should be the controlling factor in using a feeding standard.

When studying these standards the wide variations in the various standards for animals of the same weight attracts attention at once. This is explained in part by the fact that Armsby calculates the protein requirement on the basis of "true" protein, i.e. digestible amid-free protein, while the others base their calculations on digestible crude pro-

tein. The starch values used by Kellner are based on the total digestible starch content of feeds. Armsby represents the total nutrients in terms of net energy, using the word "therm" to represent 1000 calories. Nutrients in the Wolff-Lehmann standard are shown only by the total dry matter. The requirement for fat and total dry matter are practically the same for the Wolff-Lehmann and the Kellner standards. It is noticed that as the animal grows older, the more nearly constant becomes the protein requirement. It is also interesting to note that in Armsby's recent bulletins he gives the composition of feeds in terms of digestible crude protein as well as "true" protein. Possibly the recent investigations by the Wisconsin Experiment Station have caused him to question his earlier position that the so called amids are not used by the animal.

Many experiments have been conducted to determine the accuracy of the various feeding standards for mature animals and as a result we have many modifications. However, very little has been done in finding whether or not the various standards apply with respect to dairy heifers.

Jordan⁴ conducted an experiment relative to the protein requirements of growing steers. His results bear out the figures in the various standards to the extent

that the protein requirement is greatest with the young animal in proportion to its weight and becomes more nearly constant as the animal approaches maturity. His work neither proved nor disproved the accuracy of any of the standards, but his results do show the general tendency of the protein requirement as set by the standards to be correct.

Flint⁵, in an attempt to determine the protein requirement for growing dairy heifers under one year of age, fed one lot twenty-five per cent less protein than is prescribed by the Wolff-Lehmann standard, a second two the prescribed amount, and a third twenty-five per cent more. His rations, however, were all found to be below standard in fat and carbohydrate content, and as a result nothing definite could be determined. He concluded, however, that the capacity for growth depends primarily upon the individual and so long as the protein supply is adequate to supply material for growth a larger quantity does not cause a greater rate of growth except only to a minor degree, while on the other hand, a deficient protein supply limits growth. He further showed that individuals vary in their requirement for protein. A normal ration for one animal is not necessarily a normal supply for another.

Maintenance Requirement of Animals.- In the process of nutrition the first function to which food is put is that of maintenance. Since the animal machine cannot be stopped when it is not in active use it requires a continual supply of food. This amount of feed which is required simply to support the animal is commonly designated as the "maintenance requirement", that is the amount required to maintain the animal when it is doing no work and producing nothing. In other words it is the least amount on which life can be permanently maintained.

The maintenance requirement is naturally greater for a larger than for a smaller animal. Experiments have shown, however, that this increase is not proportional to the weight of the animal, but approximately to the amount of surface which it exposes, so that the large animal requires less food for maintenance in proportion to its weight than does the smaller one. Table four gives the maintenance requirements according to Armsby.

Table 4.

Maintenance Requirements of Cattle per head and day.

Live Weight	Digestible Protein	Net Energy
pounds	pounds	therms
150	0.15	1.70
250	0.20	2.40
500	0.30	3.80
775-	0.40	4.95
1000	0.50	6.00
1250	0.60	7.00
1500	0.65	7.90

The activity of the animal is also a factor influencing maintenance, the greater the activity the higher the maintenance requirement. The third factor relates to the season of the year. Maintenance requirements are found to be lowest in the spring, highest in winter, and intermediate at the other seasons. The previous plane of nutrition likewise has an effect upon the maintenance requirement in that the higher the previous plane of nutrition the greater is the maintenance requirement. A fifth factor is time the animal has been on maintenance. After a longer period on maintenance the animal seems to be able to sustain itself on somewhat less feed. Here, however, the age and previous treatment are strong contributing factors.

Character of the Ration for Growth.

Effects of Feeding Concentrates Only.- It is a matter of general knowledge that animals can live and make growth on a ration of roughage alone. It is a recognized practice among many feeders to supply nothing but roughage the entire year round. While the ruminant's stomach is well suited to the handling of roughage it is found, however, that the feeding of roughage alone is not^{as}/economical as when a portion of the nutrients are in the form of concentrates.

7
Burnett and Smith fed two groups of steer calves for ninety-one days, one half receiving roughage only, and the other half receiving four pounds daily of grain in addition to the roughage. The grain fed group gained sixty pounds a month as compared with thirty-three pounds by the group receiving roughage alone. In summarizing their results they say, "The experiment shows that it is ordinarily more economical to feed a small grain ration even when good gains can be secured on hay alone."

8
Vernon and Scott conducted a similar experiment concerning which they have the following to say, "If we take an average of the three years feeding tests we find that the lots receiving a grain ration made a

slightly larger daily gain per 1000 pounds live weight than did the lot receiving alfalfa alone. It required nearly one pound more food for a pound of gain for those receiving only alfalfa hay than for the grain lot."

9

Eckles has shown that a heifer fed exclusively on roughage is slower in reaching maturity than one receiving some grain.

While the common practice has been to supply feed largely or entirely in the form of roughage, yet there is some data available with respect to the exclusive feeding of concentrates to ruminants.

10

Davenport attempted to raise calves to maturity on a ration entirely normal in variety and amount, but without any roughage whatever. Four calves were used and in each case it was found that the animal without roughage showed serious disturbances in health when from four to six months of age which resulted in their death.

11

Sanborn maintained a calf for six weeks in winter on grain and milk when, through its craving for roughage, it ate the sawdust used for bedding, which resulted in its death.

These and other experiments show that a young animal apparently cannot continue to grow normally on concentrates alone, in spite of the fact that large and even excessive amounts of concentrates are consumed in the desire to get the material that is apparently lacking. One calf used by Davenport¹⁰ consumed as much as fifty pounds of skim milk per day while another consumed more than one-half bushel of oats.

There is some evidence that with mature animals the necessity for roughage is not so marked.

Miller¹² successfully maintained mature cows eight weeks of each year on a ration of corn meal with no roughage whatever.

Proportion of Concentrates to Roughage.- In order to meet the requirements for dry matter as set forth by the various standards for growing dairy heifers it is usually found necessary to feed both concentrates and roughages. However, the proportion of each is not stated as it depends largely upon the particular feeds at hand.

Burnett and Smith¹³ fed one lot of calves of the beef type twice as much grain as was fed to a second lot. Considering the gains made when turned out to grass the

following summer, there was little difference in the growth of the two lots. They say, "For the entire year, with no grain while on grass, the results would go to show that a moderate grain ration in winter, not more than one third of a full feed, along with hay is most economical. Calves which have been full grain fed during the winter are certain to loose a part of their flesh when placed on green grass without grain. On the other hand, wintering without grain of any kind and allowing calves to run down in flesh and loose weight and vitality is not economical." In addition to grain each group received alfalfa and prairie hay.

The Iowa Station¹⁴ reports that when light grain rations are fed to growing beef cattle more roughage is consumed than when a medium or heavy grain ration is fed.

Kennedy, and others¹⁴ concluded that by judging from the gains made by the hogs which followed the various lots of cattle it would appear that cattle fed on light or medium rations made better use of their feed than did those fed on heavy grain rations.

Skinner and Cochel¹⁵ report that the class of dry roughage fed makes little difference due to the fact that

any form of dry roughage satisfies the desire of cattle for variety but the quantity consumed furnishes only a small proportion of food nutrients eaten. In proof of this they showed that oat straw was as efficient as clover for fattening cattle when fed in a ration of shelled corn, cottonseed meal and corn silage.

Allison¹⁶ found that when corn silage was the only roughage consumed steers failed to do well for longer periods than ninety days. His results showed that in comparison with clover, silage was equal to one half its own weight of clover.

Skinner and Cochel¹⁵ found that by adding silage to a ration for fattening cattle the consumption of shelled corn was decreased in amounts approximately equal to the amount of grain found in the silage.

They¹⁵ further found that more rapid and cheaper gains were secured by feeding a light grain ration than by feeding a heavy one; namely, two and five-tenths of cottonseed meal rather than four pounds per one thousand pounds live weight.

In a later experiment¹⁷ it was found that gains were made more economically both from the standpoint of feed consumed and cost when clover hay rather than alfalfa

fa hay was fed.

The Georgia Station¹⁸ in speaking of a normal ration for steers, refer to one in which seventy per cent of the net energy is supplied in the form of silage and thirty per cent in the form of concentrates. This, however, cannot be said of all rations as the per cent of nutrients in both concentrates and roughages vary with the nature and kind of each.

Henry and Morrison² say, "In the rations for growing and fattening animals and those at work or in milk a considerable part of the ration should consist of concentrates."

In dairy animals we find that the higher the production of milk the greater should be the per cent of concentrates in the ration.

Day¹⁹ of the Ontario Agricultural College, as a result of four years of work, shows the light or medium grain rations produce more economical gains than roughage alone.

Wide against Narrow Rations for Growth.- It is an accepted principle of nutrition that when a ration has too wide a nutritive ratio the digestibility of the feed is decreased. The effects upon growth, however, of

rations varying in their nutritive ratio seem to change with the age and size of the animal.

Jordan⁴ compared two rations, the first with a nutritive ratio of 1:5.2 and the second with 1:9.7. One steer in each lot was slaughtered at the age of 17 months, after the animals had been on trial for practically ten months, while the remaining two animals were continued until twenty-seven months old.

The results of the first lot of steers showed that those receiving a narrow ration gained 737 pounds while those with a wide ration gained only 552 pounds. The advantages of a narrow ration for the young growing animal is also shown by noting that steers on a narrow ration required but 495 pounds of digestible matter for 100 pounds of gain while the ones receiving a wide ration required 686 pounds of practically 40 per cent more.

However, when the remaining animals were slaughtered ten months later when at the age of 27 months the results were entirely reversed, in that those on the narrow ration slowed up in gains until they were surpassed in weight by those on the wider ration. Likewise, the requirements of digestible matter per 100 pounds were reversed, the group on the wide ration requiring

much less per 100 pounds gain.

²⁰
Caine, who fed rations high and low in protein, but with the same energy values, says, "An excessive supply of protein does not cause marked growth. A comparatively low amount of protein retards growth but does not check it permanently."

²¹ ²²
Both Talbot and Wylie showed that when heifers received enough protein for normal growth the gains were not materially increased by further increasing the protein.

²³
Dietrich found in working with pigs that "the factor of protein waste when ~~once~~ introduced apparently becomes such a fixed tendency or habit that it is eliminated or even materially reduced with great difficulty."

These data show that a ration having a narrow nutritive ratio is conducive to the rapid growth of the young animal, while on the other hand, when the animal is nearly mature the largest gains, which are then mostly fat, come from liberal feeding with rations high in carbohydrates and fat and rather limited in protein. That this principal is generally recognized is shown by the feeding standards which prescribe

the most protein in proportion to the weight in young animals.

Within recent years sufficient evidence has accumulated to indicate that the feeding problem during growth is not merely one of supplying the proper amounts of protein, fat, carbohydrate, and inorganic salts, but is a problem more far-reaching and one which demands that certain other indispensable substances be present.

Other Factors Influencing Growth.- Recent investigations have shown that several factors operate to make a diet a good or a poor one other than a liberal supply of protein and energy.

These new factors which must be given consideration are (1) the quality of the protein, (2) the vitamins, (3) the proper amount and proportion of the mineral constituents, and (4) the presence or absence of toxic substances.

(1) By the quality of the protein is meant the presence or absence of the essential amino acids. It appears that these amino acids must be present, for without them growth or even maintenance is impossible. Up to the present time twenty amino acids have been recognized in proteins.

Our knowledge regarding the composition of the proteins comes principally from the findings of Osborn and
24,25,26,27,28 29,30,31,32.
Mendel, and McCollum and his co-workers.

The former named investigators show that the economy of the different proteins as nutrients in growth appear to be closely bound up with their amino acid content.

³³
Nollau says, "It is probable that in the future protein feeding will be based on the amino acid content."

³⁴
Grindley and others show that the nutritive value of mixed proteins of food stuffs depends ultimately on the amino acids they contain.

³⁵
Osborn and Mendel, together with Hopkins, found that young rats would grow and develop normally when certain proteins as casein, edestin, or serum albumen were in the ration, provided butter fat, lard, some carbohydrate, and such salts as are found in milk were also present, while if such proteins as zein or gelatine were present with the same basal ration the animals would not continue to grow or indeed to live long. As a result of repeated and careful investigations it was found that zein failed to produce growth because it lacked certain amino acids, namely lysine and tryptophane. Likewise, gelatine failed also because it lacked certain amino acids. On the other hand it was found that growth resulted when casein, edestin, or serum albumen were fed because these proteins were complete in that they contained all the essential amino acids.

It was found also in the course of the experiment that the amount of protein which it was necessary to supply in the diet for the purpose of maintenance or growth varied with different proteins. The minimum amount necessary appeared to be determined by the amount²⁸ of some amino acid which was present in small amounts. In some proteins it was cystine, in others it was some other amino acid. However, it became necessary to add enough protein to supply the proper amount of the limiting amino acid in the ration in order to promote growth.

Some protein foods are especially high in certain amino acids, and when such a protein is taken as the sole source of amino acids for growth it is obvious that³⁶ a considerable part will be wasted. Mathews shows that the principal protein of wheat, namely gliadin, contains 42.8 per cent of a single amino acid, glutaminic acid, which, according to McCollum forms only 14 per cent of the body protein.

At present it appears that all the amino acids must be supplied to the animal direct in its ration since none can be synthesized except glycine as pointed out by³⁶ Mathews.

(2) The vitamins are unidentified dietary factors³⁷ of which our knowledge is as yet very limited. McCollum

32,38
and his co-workers prefer to classify the vitamins into two groups, namely fat-soluble A and water-soluble B until more is known concerning them, while other investigators designate them as the growth accessories.

However, it is generally agreed that these substances must be present in the diet of young animals in order to promote growth.

32
McCollum and Davis showed that when a ration was made up of purified proteins, carbohydrates and a salt mixture of appropriate composition it would not produce growth in animals. But if to each pound of the ration an ounce of egg yolk was added growth would proceed, and would again stop when the egg yolk was taken away and start when put back. They further showed that it was not alone the fats of the egg yolk that were needed but also other material in the egg yolk which was soluble in water and to which they gave the name water-soluble B. It was found widely distributed in the vegetable food stuffs as well as in meats, eggs and milk while it was absent from the starches, sugars, fats, and polished rice. To the substance in the fat of the egg, which seemed necessary and which is also found abundantly in butter fat and in alfalfa leaves they gave the name fat-soluble A.

(3) The mineral content of our feeds must also re-

ceive serious consideration as is shown by Forbes,^{39,40,41} and⁴² Hart and others. Forbes claims that the subject of mineral matter is our most important problem in nutrition today. The mineral elements most apt to be lacking are phosphorus and magnesium and especially calcium, which⁴⁰ is supplied abundantly by all legumes. Forbes shows that an insufficient supply of mineral matter, which is not uncommon after seasons of drought and overstocking of pastures which are poorly fertilized, causes malnutrition⁴¹ of the bones. He further shows that it is a common failure in cows not to breed after a season of forced milk production which might be accounted for by a mineral shortage. In fact, his recent investigations show that practically all cows at the time of highest production show a negative balance of mineral matter. The questions then naturally arise, When does the cow make good the mineral losses sustained during lactation?, and, To what extent should the growing heifer be supplied with mineral matter? Neither of these questions can be answered as yet, but it would appear that the young growing animal should be supplied with an abundance of mineral matter in order to make as complete a storage as possible for subsequent usefulness.

Another question yet to be solved relates to the

proper proportion in which the mineral nutrients should be supplied.

(4) The presence of possible poisonous constituents in the several feeds needs also^{to} receive serious consideration, as is pointed out by McCollum and others.³¹ In a comparison of balanced rations from the wheat plant with similar rations from the oat plant and corn plant it was²⁹ found by McCollum and others that the wheat ration was strikingly deficient and when the animals fed such a ration underwent the strain of reproduction the calves were either born dead or weak and materially undersized. Later investigation showed this deficiency to be due largely to the presence of a toxic substance in the wheat germ. Neither the exact nature nor the source of the toxic substance is at present understood.

Variety, Succulence, Palatability, and Bulkiness.-

From the preceeding discussion it is apparent that a variety of feeds in the ration would be of advantage in the way of increasing the probability that the growth factors missing in one feed would be supplied by another.

That variety is advantageous in the ration is shown by the following table which gives percentages of different² proteins retained when fed alone and when mixed.

Source of Protein	Number of Trials	Proportion of N in food retained
		per cent
Skim milk	1	66.2
Casein	1	50.8
Corn	4	23.7
Wheat	3	26.7
Oats	2	28.3
Linseed meal	1	17.0
Wheat embryo	1	39.0
Corn 1/3,oats 1/3,wheat 1/3	1	32.0
Corn 3/5,linseed meal 2/5	1	32.0
Corn 3/4,linseed meal 1/4	1	37.0
Wheat 1/2,wheat embryo 1/2	1	30.0

The above table shows that in some cases nothing is gained by a combination, as is the case of corn, wheat, and oats. On the other hand when corn was combined with linseed meal the retention of nitrogen was greatly increased over the figures secured for these food substances fed alone. From this we may assume that linseed meal and corn are not deficient in the same amino acids, and that when combined one tends to correct the deficiencies of the other.

43

Armsby, in referring to a proper ration, says, "From recent investigations it would seem well that care should be taken to see that grains of distinctly different species of plants should be used."

Another advantage from feeding a variety of feeds is the stimulating effect of such feeds upon the appetite of

the animal.

Not only do we need variety from the standpoint of proteins but also do we need variety in order to supply the proper mineral matter, and also the vitamins or growth accessories.

That succulence is of great value in a ration, whether supplied as pasturage, silage, soilage, or roots, is quite well understood by farmers as well as experimentors.

⁴⁴
Eckles says, "Such feed has a value outside of the actual nutrients it contains, on account of the favorable effect upon the digestion of the animal."

⁴⁵
Sanborn Found that the flesh of root-fed animals was in general more sappy or watery than the flesh of farm animals with no succulent food.

It is found that succulent feed tends toward rapid sturdy growth of the young of all animals, and when supplied throughout the year the best results follow.

⁴⁶
Henry points out that palatability is greatly influenced and controlled by familiarity and habit or custom. When corn silage is first placed before animals they care very little for it, but gradually become accustomed and their liking for it becomes very pronounced. ⁴⁶ Henry fed shelled corn and wheat bran to one lot of steers, while another lot received exactly the same ration except

the shelled corn was ground to a meal. After some weeks of successful feeding the rations for the two lots were reversed and immediately both lots showed a strong dislike for the new ration, eating so little at first that they shrank materially in weight. This shows that custom and habit, something entirely extraneous to the food, are possible factors in palatability.

Palatability may cause greater rations to be consumed and hence greater growth and production.

21

Talbot says that palatability may be the limiting factor which controls the amount consumed by the dairy heifer of some of the common feeds. For instance, it is a well known fact that an animal will consume more alfalfa hay than timothy hay and this is one reason why animals having free access to alfalfa make such rapid gains.

43

According to Armsby there is some proof that the amount of digestive juices excreted depends upon the palatability of the feed.

47

Jordan emphasizes the fact that a successful ration must be palatable. "An agreeable flavor is not a source of energy or of building material," he says, "but it tends to stimulate the digestive and assimilative functions of the animal to their highest efficiency, as is a requisite for the consumption of the necessary quantity of food."

When the roughage is unpalatable naturally the an-

imal tends to eat less of it even to the point of limiting the nutrients available for growth.

An animal seems to do better on a palatable ration than on one not so palatable even though both may supply the same amount of protein and net energy. Probably there is some connection between the specific make-up of the nutrients and palatability.

The bulkiness of the ration likewise has its effect on the growth of the animal, in that it is often the limiting factor in the amount consumed. Waters, Cochel,⁴¹ and Vestal⁴¹ say, however, that a certain amount of bulkiness must exist in the ration in order to distend the digestive tract and force out the ribs and hips when the animal is yet plastic, otherwise the body of the animal will never attain the desired conformation.

⁴⁸
On the other hand, Eckles⁴⁸ has shown that mature dairy animals which have been raised largely on roughage do not have a greater capacity for handling feed than those which received less roughage and more concentrates during their growing period.

It is also important from the standpoint of digestion that a ration should be light so as to allow the digestive juices to act more readily and more completely on the ingested food.

Growth Under Adverse Conditions.- That immature an-

imals continue to grow in skeleton even though they are underfed is shown by the results of Waters,⁴⁹ who kept three yearling steers at constant weight for twelve months and found that they all continued to grow as shown by an increase in height at withers, No. 1 gaining 9.9 per cent, No. 2, 6.8 per cent, and No. 3, 5.8 per cent. Corresponding to the increase in height at withers there was, however, a decrease in width of chest, the percentages being 12.1 per cent, 10.6 per cent, and 9.4 per cent respectively. The length of head increased and likewise did the depth of the body.

50

In other trials by Waters and Trowbridge, steers in a thrifty growing condition weighing 573 to 740 pounds were fed rations just sufficient to maintain their weight for various periods of time and were then slaughtered and the carcasses analyzed. Others were fed submaintenance on which they lost 0.5 pounds per day per head. Even the steers losing weight made steady growth in skeleton. A steer weighing 654 pounds when placed on the experiment lost 199 pounds in 12 months but nevertheless gained 3.6 inches in height at withers and 4.5 inches in length of body. While the carcass of the steer slaughtered and analyzed as a check animal at the beginning of the experiment contained 56.5 pounds of fatty tissue, that of an animal which had been given a ration just sufficient

to maintain its weight for 12 months contained only 24.3 pounds of fatty tissue, much of it having been replaced by water. An animal which had lost 0.5 pounds daily for a year had used up practically all of its fatty tissue for body fuel. Indeed only 0.4 pounds of fatty tissue could be separated from the entire carcass of the animal. Even the fat from the marrow of the bones had been largely replaced by a watery, ill-smelling liquid.

It is seen that the skeleton is not affected by poor nutrition until practically all the fat has been removed from the fatty tissues and the muscles. Waters⁴⁹ mentions that fat is withdrawn from the body in the reverse order from which it is laid on, that first deposited being the last to be absorbed.

⁴⁹
Waters further made a comparison between two eight-month-old steers, one on full feed and the other on maintenance, and found for the entire eight months that the steer on full feed increased in height more rapidly than the one on maintenance, but for a considerable time the poorly fed steer grew as rapidly as the other. Waters concludes that poorly fed animals will grow as rapidly as those on full feed for the first 70 to 120 days, depending upon the vigor of the individual and the previous condition of the animal. After this period he shows that the increase in height becomes less rapid ceasing altogether in from six months to one and one-half years. He had

one steer which grew for five months as rapidly as one on full feed and this steer was losing weight each day.

49

Waters concludes that the young animal may advance to normal size by any or all of the following ways:

- 1/ By growing steadily from birth to maturity.
2. By storing fat in a period of abundant feed supply to assist in tiding over a limited period of sparse food supply without serious interruption of growth.
3. By prolonging the growth period.
4. By an increase in the rate of growth during a period of liberal feeding following a period of low gain.
5. By conserving the cost.

Apparently the animal when kept for a long period on scanty food adjusts itself to a more economical basis than when more liberally fed. A ration which is at first insufficient to maintain the animal may be capable later of keeping the animal at a constant body weight and still later of causing gain.

While Waters experiments were all with beef animals they are nevertheless strikingly applicable to dairy animals.

51

Waters and others show that while a steer whose growth has been checked for a year or more may grow nearly as tall as one fed well all along, it is almost sure to have a smaller digestive capacity, narrower hips, flatter ribs, heavier shoulders and lighter hind quarters,

even when finished for market. However, a breeder who seeks to develop his animals toward an ideal type must supply ample feed during the entire growing period.

⁹
Eckles, however, concludes that the dairy characteristics of a dairy animal are a matter of inheritance and do not seem to be influenced to any great extent by over or under feeding.

⁴⁸
Eckles found in comparing the growth of light fed and heavy fed dairy heifers that the animals on a light ration were retarded somewhat in growth in height but they continued to grow for a longer time, so that at the age of six or seven years for Holsteins and five or six years for Jerseys, they come very close to equaling those receiving the heavy ration in height, but not entirely. The greatest difference found was 1.5 inches in height.

Growth Under Favorable Conditions.- Aside from the post natal retardation of the rate of growth lasting from two to five days as mentioned by Burlingham and Gillette,⁵⁴
⁵⁸ Brandt has shown that the average gain in weight of dairy heifers per day is greater the first six months of their lives and gradually decreases thereafter. This is also shown in the results of Skinner and Cochel⁵³ who show the amount of feed consumed and cost of gain per steer increases with the age of the animal.

The following table shows the average amount of feed consumed per pound gain by calves, yearlings and two-year-olds during the winter of 1908-09.

	Shelled Corn Pounds	Cottonseed meal Pounds	Clover hay Pounds
Calves	5.03	.83	2.92
Yearlings	6.21	1.07	3.20
Two-Year*Olds	7.63	1.32	4.12

This shows that it required 118 pounds more of shelled corn, 28 pounds more of clover hay, and 24 pounds more of cottonseed meal to produce 100 pounds gain on the yearlings than it did on the calves, or in terms of percentage, 23, 9, and 28 per cent respectively, with an average of 20 per cent more feed for a pound of gain on yearlings for a pound of gain.

A comparison between yearlings and two-year-olds showed that the two-year-olds required 24 per cent more than the yearlings for a pound of gain.

⁵²
Hunziker, in speaking of gains in weight, says that in order for a ration to be considered an unqualified success for dairy calves it should produce at least one pound of gain per day as an average for the first six months of the life of the calf. An average daily gain of one and one-half pounds is not uncommon although slightly above what the average dairyman may expect.

⁵³
Regarding gains in height, Hunziker says that the

rate of growth in height of dairy calves is rather uniform during the first six months of their life, the average monthly growth being 1.5 to 2 inches. As dairy animals advance in age the relation between height and weight gradually changes, as is shown by a calf at 30 days of age which should weight approximately three pounds for each inch in height, while a calf six months old weighs approximately 6.5 pounds for each inch in height and those 24 months old will even more than double this figure.

54

Burlingham and Gillette collected data concerning the normal growth of heifers of all the leading dairy breeds from birth until two years of age. This work seems to be the first of its kind which covers such a prolonged period. Table 34 shows their results, to which later reference will be made.

55

The Wolff-Lehmann Standard prescribes, for dairy cattle six to twelve months old and weighing 500 pounds, 1.6 pound digestible crude protein, 6.2 pounds digestible carbohydrates, and 0.25 pounds digestible fat.

1

From the recent table adopted by Armsby we observe that the figures for a heifer weighing 550 pounds are 1.10 pounds digestible true protein and 6.4 therms energy.

9

Eckles, in speaking of rations which are conducive to favorable growth for summer feeding of dairy heifers,

says that grass is sufficient as long as there is plenty of it. The winter ration should consist of a good quality of roughage with a small amount of grain. He says that a good ration is corn silage, clover or alfalfa, and a grain allowance of about two or three pounds daily per animal. More liberal rations, he says, will cause more rapid growth and earlier maturity but are too expensive.

56

Fitch, in outlining ideal feeds for calves more than six months old, also says that corn silage and alfalfa hay, together with some little grain, make an excellent ration. He advocates a grain mixture consisting of four parts of corn chop, two of bran, and one of oil meal.

57

Hill says, "The second winter calves should be fed liberally on alfalfa or clover hay, corn silage, and a moderate grain ration but without anything tending to fatten."

2

Henry and Morrison say that in winter there is no better ration for dairy heifers than legume hay, silage, and sufficient grain to keep them thrifty and growing without becoming fat.

48

Eckles, however, shows that the laying on of flesh or fat is not objectionable, in that a dairy heifer as soon as she freshens will loose the surplus body fat within a short time and show no more tendency to fatten later on in the lactation period than those raised on less abundant

allowance of concentrates.

58

Utilization of Rations by Different Breeds.- Brandt found that animals of different breeds require practically the same nutrients for a pound of growth and the amount required per pound increase in weight increases with the age of the animal.

21

Talbot found that Holstein heifers used in his experiment made greater gains per day than the Jerseys due to the fact they ate more. The gain in weight was found to follow the energy content of the ration more closely than the protein content, the animals making the largest gains receiving the most energy in their ration. He further showed that the Holsteins utilized their ration, when composed largely of roughage, to better advantage than the Jerseys.

22

Wylie found that the Ayrshires consumed slightly more nutrients for their size than did the Holsteins or Jerseys on the same ration. He further shows that the Holsteins consumed less protein and net energy per 1000 pounds live weight than the Jerseys, but made better gains, "thus apparently using their nutrients to better advantage than the Jerseys."

59

Severson found no difference between the Shorthorn breed and the Aberdeen Angus breed in the utilization of

of feeds or cost of maintenance.

While there is an apparent slight individual difference between heifers of different breeds yet in general there is no difference in the utilization of feed by the different breeds.

3

Kellner shows that different breeds of the same species of animals possess a power of equal utilization of feed.

62

Eckles also shows that the various dairy breeds all utilize their food practically the same. He found that the actual digestion coefficient on maintenance was slightly higher than when on full feed.

Cost of Raising Dairy Heifers.- To figure the cost of raising dairy heifers is rather difficult on account of wide variation in prices of feed.

However, a general idea can be received from some of the following reports.

60

The cost of raising dairy heifers on a Wisconsin farm that raised about twenty per year was kept for five years. The feed costs to raise a heifer to two years of age varied from \$39.00 to \$42.00. The total costs varied from \$60.00 to \$65.00 in different years.

61

The Office of Farm Management of the Bureau of Plant Industry kept records concerning the cost of raising 117

heifers in a Wisconsin Jersey Herd. The results are tabulated in the following table:

Table 5.

Cost of Raising 117 Jersey Heifers in Wisc.

	For 1 Year.	For 2 Years.
Value of Calf at Birth	\$ 7.04	\$ 7.04
Cost of Feed	24.67	40.83
Cost of Labor	4.45	7.81
Other Costs	6.36	13.73
Total Cost	42.52	69.41
Credit by Manure	3.00	8.00
Net Cost	39.52	61.41

This table shows a net cost of \$61.41 at two years of age in Wisconsin, 12.5 per cent of which was for labor, 22 per cent for other costs, and 65.5 per cent for feed. This cost was up to two years of age, and since heifers as a rule should not calve until 26 to 28 months of age, there would be a material addition to the above figure.

65

The Storrs Station found the total cost to two years of age to be \$66.00. The cost of feed for the two years was \$55.00.

64

Hayden shows the net total cost for Jerseys and Holsteins to be for the first year \$43.32, for the second year \$37.23, for the first and second years \$80.00, and

from birth to calving at 26½ months to be \$91.39. Of this amount the feed cost alone, up to two years of age for the two breeds, was found to be \$56.32, and from birth to 26½ months \$65.30. In this case the feed cost was about 70 per cent of the entire cost.

That the cost of feeding animals is not only affected by prices but also by the kind of a ration that is fed⁵³ is shown by Skinner and Cochel, who found a ration containing silage was more economical than one without silage, and also that a ration giving a variety of feeds seemed to be more economical than a ration consisting of only one or two or possibly three different feeds.

The prevailing prices of the feed used would also be a strong contributing factor.

⁵³ Skinner and Cochel show that corn silage is not only an economical feed but it is desirable in that it has a beneficial effect in causing cattle to shed their winter coat earlier than those receiving the same ration without corn silage.

²¹ Talbot, found in comparing corn and alfalfa, silage and timothy, and alfalfa and silage, that the most economical gains were made on corn and alfalfa due to the fact the heifers were able to eat more of this ration.

²² Wylie found that the cost of gains were reduced by adding silage to a corn and alfalfa ration.

Likewise, Tomhave and Hickman showed that there was a decided advantage in using corn silage for at least a portion of the ration if cattle are to be fed in an economical way.

Another factor, namely the one pertaining to the season of the year when the calf is dropped, plays an important part in the cost of raising dairy heifers, as is shown by Talbot²¹ who points out the striking difference in favor of fall calving as is shown in Table 6.

Table 6.

Feed	Spring Calving	Fall Calving
Whole Milk	90 Pounds	90 Pounds
Skim Milk	3001 "	3001 "
Corn	847 "	487 "
Alfalfa Hay	5099 "	2718. "
Pasture	6 Months	12 Months

Review of Parts I, II, and III of this Experiment.

Experiments on Winter Rations For Dairy Heifers were begun at the Missouri Experiment Station in 1913²⁰ when Caine compared the value of grain and clover with grain and silage as rations for dairy heifers during the winter months. His experiments covered 158 days and were begun in November.

He concluded that the silage fed heifers seemingly needed some dry roughage because their nutrients were practically the same as the clover group and were nearly sufficient for normal gains but the heifers appeared thin.

²¹
Talbot, the following year (1914-15), following up Caine's trials fed silage and grain and added timothy at the rate of two pounds per day. His results showed that the dry roughage improved the ration in that greater gains were produced with the same or slightly less nutrients.

Talbot also, in an attempt to show the relative value of alfalfa and clover when fed in a ration with corn, fed a group of heifers a ration consisting of two pounds of corn daily and all the alfalfa they would eat. The results were compared with those by Caine who, the previous year, fed corn and clover. Little if any difference was observed in the relative value

of alfalfa and clover when fed with grain, although the corn-alfalfa group made a slightly greater gain on less energy than did the corn-clover group.

Talbot's third ration consisted entirely of roughage. Alfalfa and silage were fed in the ratio of one to three to four animals for 150 days. In discussing the results Talbot states that the heifers with no grain used a greater amount of protein and energy for a pound of gain. Further, all animals in this lot showed a loss in weight during one or more of the thirty day periods. This lot averaged 569 pounds in weight and consumed an average of 6.55 pounds of alfalfa and 19.20 pounds of silage per day. The amount of digestible protein consumed each day was 0.623 pounds and the energy amounted to 5.435 therms, while the gains per day were 0.54 pounds. The protein consumed for a pound of gain was 1.41 pounds and the therms for a pound of gain were 12.35.

In comparing the three rations Talbot says, "The lot receiving corn and alfalfa made the greatest gains and this ration would be considered the best if preference could be made. The main factor in the efficiency of this ration was the fact that the animals consumed more nutrients per day." He shows that while Lot 1 (corn and alfalfa) produced the largest gains the

cost was higher. Lot 2 was not far behind Lot 1 in the gains made. Both lots showed better gains and the animals were in better condition at the end of the experiment than Lot 3, which received alfalfa and silage only.

His results show that in order to get the best and most economical results the growing heifer should receive some concentrates in her ration during the winter months.

22
Wylie the following year (1915-16), on the basis of Talbot's conclusions that the ration should contain some concentrates, fed a group of four heifers the same kind of roughage in the same proportion, namely alfalfa and silage one to three and in addition two pounds of corn.

He found that with the addition of corn very much greater gains in weight were made. In fact the addition of corn more than doubled the gains, and the amount of protein and energy used for a pound of gain was reduced one-half.

Evidently a ration containing concentrates is superior to a ration consisting exclusively of roughage.

Wylie further tested the effect of feeding three pounds of corn, rather than two pounds as had been fed the previous year, in a ration of corn, alfalfa and sil-

age, and also compared a ration of grain and alfalfa with and without silage.

Concerning the results Wylie says, "On the whole it may be said that the gains in weight for the two rations were approximately the same, and the cost per pound of gain was almost equal for the two rations."

His comparison of grain and alfalfa, with and without silage, resulted in a gain of 1.18 pounds per day for the group with silage, and of 0.90 pounds for the group without silage. This shows the pronounced value of silage in a ration, a value aside from the nutrients it contains. Undoubtedly silage should be a part of the ration for dairy heifers.

²²
Wylie fed another ration in which the object was to determine the efficiency of alfalfa and grain compared with silage and timothy and grain. Concerning the results Wylie says, "In comparing the results of the two groups receiving nutrients in approximately the same amounts the corn and alfalfa group received slightly more nutrients and made greater gains in weight but more animals should be used before definite conclusions can be made on this point."

In comparing the three rations fed, Wylie concludes that the ration of alfalfa, silage, and corn was the most efficient in gains produced in proport-

ion to the protein and energy consumed. The corn and alfalfa ration was the least efficient in this respect, while the timothy, silage and grain ration was intermediate to the others.

In proportion to live weight the group receiving corn and alfalfa consumed the most dry matter while those fed the timothy hay, silage, and grain consumed the least. The former was eaten in larger quantities probably on account of its greater palatability, while the small consumption of the latter was due in part to its being less palatable and to its greater bulk.

The experiments so far carried out do not furnish the data to justify a conclusion as to the amount of grain which it is economical to include in a winter ration.

Wyllie²² also studied the records of growth of the²⁰ heifers used by Caine and Talbot²¹ for the summers following the experimental periods. He found that the animals making the least growth during the winter made the most the following summer and as a result the effects of different rations as observed at the close of the experiment had entirely disappeared after the animals had been on pasture for the summer.

111. EXPERIMENTAL METHOD.

Plan of Experiment.

The experiment conducted by the writer is the fourth of a series of experiments pertaining to the wintering of dairy heifers begun in 1913 by the Missouri Experiment Station.

It was planned for the winter of 1916-17 to compare the efficiency and economy of light with heavy grain rations when fed with alfalfa and silage, and also to determine the results of using a ration of timothy hay and silage limited to the extent of producing one-fourth pound of gain daily.

It was further planned to continue the records of weight and growth in height during the summer months, when the animals would be on pasture, in order to determine to what extent the results of the different planes of nutrition during the winter would be overcome.

The results of the summer observations can not be inclosed in the present thesis.

The animals were to be placed on experiment Nov. 1, 1916 and continued for 150 days.

Rations Used.- The rations used in this experiment

were as follows:

Group 1 (medium Ration)

Corn, two pounds.

Alfalfa, one pound per hundred weight of animal.

Silage, all they would eat.

Group 11 (heavy ration)

Corn, one pound per hundred weight of animal.

Alfalfa " " " " " " "

Silage, all they would eat.

Group 111 (light ration)

Timothy, all they would eat.

Silage, all they would eat.

Corn, if necessary in order to make one-fourth pound gain per day.

It is noticed that for Groups 1 and 11 the amount of alfalfa is constant, while the amount of silage given is regulated to provide all the animals would consume. Group 111 was fed a ration very low in nutrients, and likewise very inexpensive. There is no definite ratio between the timothy and silage, each animal receiving as much as desired. This made it more typical of farm conditions. In an attempt to restrict the gains per heifer to 0.25 pounds per day it was found that some of the heifers required corn in addition to the roughage while others could gain this amount without corn. However, all the animals in this group were started on one pound of corn per day.

All of the feed used was of good quality. The animals were fed twice daily at regular intervals. The

feed for each animal was carefully weighed and recorded on a sheet kept for that purpose at the dairy barn. Any feed not eaten was weighed back and subtracted from the original weight. At the end of each 30 day period these sheets were taken to the dairy office and carefully copied into permanent record books where the original sheets were also preserved.

Water and salt were available at all times throughout the day in the yard where the animals were turned regularly for exercise.

Animals Used.- Twelve pure bred heifers were used in

this experiment consisting of Holsteins, Jerseys, and Ayrshires from the University Dairy Herd. They were divided into three groups, each containing two Holsteins, one Jersey and one Ayrshire. All were practically in the same condition of flesh when the experiment began as they had all been on the same kind of feed during the previous six months.

Tables 7 and 8 give details for each individual concerning the age, weight at birth, normal weight at birth, of heifers of the same breed, their sire, weight at beginning of experiment, normal weight, height at withers, and normal height at withers.

The animals were brought from the pasture October 24th and a preliminary feeding period begun. The weights were taken October 25th and they were observed to find if each took to its new ration. This they all did except No. 322, an Ayrshire in Group 111, which showed somewhat of a dislike for silage but it was found she did not refuse it entirely, and gradually increased the amount consumed and it was not necessary to replace her by another.

On November 1st the experiment was begun.

It was found almost impossible to get animals of the same age and weight notwithstanding there were many animals from which to choose, and as a result the average age of the groups were 12 months (367 days), 11 months (332 days), and $10\frac{1}{2}$ months (314 days) respectively, and their total weights were 1867, 1756, and 1561 pounds respectively, with an average of 467 pounds, 439 pounds, and 390 pounds per heifer.

Stabling.- All animals were provided with good shelter

throughout the winter. It was not found feasible to keep the Jerseys in the stanchions in the main dairy barn on account of their size and for this reason the Jerseys of Groups 1 and 11 were kept with all the animals of Group 111 in the experimental barn while the remaining animals of Groups 1 and 11 were kept in the main dairy barn.

Each heifer had an individual stall which was cleaned and bedded each day. All twelve animals were fed and cared for as nearly alike as possible.

Weights.- The heifers were weighed on three successive days at the beginning of the experiment. This was repeated each 30 days. At intervals of 10 days one weighing was made during the first three months, while during the last two months three weights were taken each 10 days on three successive days, a total of nine weights each 30 days.

Measurements.- Measurements of the height at withers were taken the first of each 30 day period. The animal was made to stand squarely on all four feet on a level platform and the measurement taken as quickly as possible so as to avoid any relaxation of the muscles which has been found to result in a lower reading. The reading was taken three times in succession after moving the animal about and the figure used is the average of the three measurements.

Other experiments at the Missouri Experiment Station have shown that there is a direct correlation between measurements of height at withers and the other measurements and for this reason the measurements taken were limited to the height at withers.

Feeding Standard.- All calculations throughout the

experiment relating to composition of feeds and requirements
for maintenance and growth were based on the tables given
by Armsby.

His standards for maintenance and growth give protein
in terms of digestible true protein only, while his tables
of feed analyses gives protein both as digestible crude
protein and digestible true protein.

The figures for digestible crude protein were used
in preference to those for the true protein.

Data concerning the heifers used in the experiment
is given in Tables 7 and 8, which follow.

Table 7.
DATA CONCERNING HEIFERS USED
IN THE EXPERIMENT.

Heifer No.	Breed	Age at Beginning of Exp.	Weight At Birth	Av. Birth Wt. of Females of same breed	Sire
		Mo. Da.	Pounds	Pounds	
Group 1					
318	Ayrshire	13---28	75	74	Capt. Moonstone
263	Holstein	10---21	107	85	Sir Korndyke
262	Holstein	11---24	95	85	Sir Korndyke
113	Jersey	10---10	55	49	Sultanas Va. Lad
Group 11					
320	Ayrshire	12---12	60	74	Capt. Moonstone
264	Holstein	10---0	100	85	Sir Korndyke
258	Holstein	14---26	95	85	Sir Korndyke
117	Jersey	6---21	30	49	Sultanas Va. Lad
Group 111					
322	Ayrshire	9-19	40	74	Capt. Moonstone
260	Holstein	12---18	90	85	Sir Korndyke
265	Holstein	9---16	97	85	Sir Korndyke
116	Jersey	7---30	55	49	Bessie Bates Lad

* Henry and Morrison, "Feeds and Feeding." 16th Edition,
page 424.

Table 8.
DATA CONCERNING HEIFERS USED
IN THE EXPERIMENT.
(continued)

Heifer No.	Weight at Beginning of Exper- iment.	Normal Weight *	Height at Withers at Beginning of Exp.	Normal Height at Withers *
	Pounds	Pounds	centimeters	centimeters
Group 1				
318	501	525	108.8	109.5
263	473	513	111.5	112.3
262	487	548	111.5	114.0
113	406	405	105.3	105.0
Group 11				
320	450	470	105.2	106.5
264	505	480	108.0	110.5
258	556	620	113.3	118.5
117	245	297	92.08	97.8
Group 111				
322	294	409	92.66	102.5
260	526	513	115.5	112.3
265	479	462	108.2	109.4
116	262	334	92.91	101.0

* Burlingham and Gillette, "The Normal Growth of Dairy Heifers." (See Table 34)

IV--EXPERIMENTAL DATA

and

DISCUSSION OF RESULTS.

The data in detail by 10 day periods for each of the twelve animals used will be found in Tables 9 to 20.

The data includes the feed consumed, the calculated digestible crude protein and net energy, and increase in height at withers and weight.

Table 21 gives the composition of timothy, alfalfa, silage, and corn according to Armsby's analyses.

A summary of the data in Tables 9 to 20 is given in Table 22. This table shows that Group I, receiving the medium ration, consumed daily an average of 2 pounds of corn, 5.27 pounds of alfalfa, and 17.80 pounds of silage. The average gains in weight were 1.09 pounds a day.

Group II, receiving a heavy ration, consumed 5.29 pounds of corn, 5.12 pounds of alfalfa, and 13.54 pounds of silage and made an average gain of 1.43 pounds a day.

Group III, fed the light ration, received 0.61 pounds of corn, 3.20 pounds of timothy, and 13.81 pounds of silage, and gained 0.36 pounds per day.

Table 9.
FEED CONSUMED, HEIGHT, AND WEIGHT.
Ayrshire Heifer 318.
Group 1.*

Ten Day Periods	Corn	Alfalfa	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
							501**
1	20	49	119	8.00	53.52	108.8	522
2	20	50	161	8.57	60.53		530
3	20	50	180	8.78	63.56		541***
4	20	55	180	9.31	65.27	108.6	547
5	20	55	190	9.42	66.86		570
6	20	55	200	9.53	68.45		583***
7	20	60	162	9.64	64.11	111.5	590
8	20	60	180	9.84	66.98		606
9	20	60	180	9.84	66.98		608***
10	20	60	185	9.89	67.78	113.5	623***
11	20	60	245	10.55	77.32		639***
12	20	60	271	10.84	81.45		649***
13	20	63.8	180	10.24	68.29	115.6	659***
14	20	65	235	10.97	77.44		672***
15	20	65	225	10.86	75.85		673***
						116.6	
Total	300	867.8	2893.	146.28	1024.39		
Av. per Day	2	5.78	19.2	.97	6.82		

* Ration.- Corn, 2 pounds; Alfalfa, 1 pound per hundred weight of animal; Silage, all they would clean up

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 10.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Holstein Heifer 263.

Group 1.*							
Ten Day	Dig. Net Energy			Height Weight			
Periods	Corn	Alfalfa	Silage	Crude			
				Pro.			
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
							473**
1	20	42.5	117.	7.29	50.97	111.5	483
2	20	45	161	8.04	58.82		495
3	20	45	180	8.25	61.85		507***
4	20	50	180	8.78	63.56	112.4	523
5	20	48	190	8.67	64.47		537
6	20	50	200	9.00	66.74		550***
7	20	55	160	9.09	62.09	115.8	562
8	20	53.5	180	9.15	64.76		576
9	20	55	180	9.31	65.27		587***
10	20	60	185	9.89	67.78	118.1	606***
11	20	60	245	10.55	77.32		622***
12	20	60	318	11.35	88.93		652***
13	20	64	259	11.13	80.92	119.6	669***
14	20	65	270	11.36	83.01		692***
15	20	65	254	11.18	80.46		700***
						121.3	
Total	300	818.0	3079.	143.04	1036.95		
Av. per Day.	2	5.45	20.5	.95	6.91		

* Ration.- Corn, 2 pounds; Alfalfa, 1 pound per hundred weight of animal; Silage, all they would eat.

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 11.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Holstein Heifer 262.

Group 1.*

Ten Day Periods	Corn	Alfalfa	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
							487**
1	20	50	117	8.08	53.54	111.5	494
2	20	50	163	8.59	60.85		515
3	20	50	180	8.78	63.56		522***
4	20	50	170	8.67	61.97	111.9	532
5	20	50	170	8.67	61.97		550
6	20	50	190	8.67	65.15		557***
7	20	55	160	9.09	62.09	114.8	569
8	20	55	180	9.31	65.27		596
9	20	55	180	9.31	65.27		590***
10	20	60	185	9.89	67.78	115.3	610***
11	20	60	238	10.47	76.21		621***
12	20	60	195	10.00	69.37		627***
13	20	62	210	10.38	72.44	117.6	646***
14	20	61	200	10.16	70.51		657***
15	20	65	195	10.53	71.08		666***
						118.2	
Total	300	833.	2733.	140.60	987.06		
Av. per Day.	2.	5.55	18.2	.93	6.58		

* Ration.-Corn, 2 pounds; Alfalfa, 1 pound per hundred weight of animal; Silage, all they would eat.

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 12.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Jersey Heifer 113.

Group 1.*

Ten Day Periods	Corn	Alfalfa	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
1	20	40	82.	6.64	44.55	105.3	406**
2	20	40	121.9	7.08	50.90		408
3	20	40	120	7.06	50.60		413
							425***
4	20	45	120	7.59	52.31	105.8	426
5	20	45	120	7.59	52.31		447
6	20	44.3	126	7.58	53.02		440***
7	20	39.7	139	7.03	53.51	107.7	447
8	20	45	140	7.81	55.49		452
9	20	45	87.5	7.25	47.14		454***
10	20	44.5	137	7.72	54.84	109.9	452***
11	20	41.8	160	7.69	57.58		466***
12	20	42.8	160	7.79	57.92		464***
13	20	45	158.5	8.01	58.43	110.9	478***
14	20	43	156.7	7.78	57.46		473***
15	20	45	177.0	8.21	61.37		483***
						112.4	
Total	300.	646.1	2005.6	112.83	807.43		
Av. per Day	2.	4.30	13.3	.75	5.38		

* Ration.-Corn, 2 pounds; Alfalfa, 1 pound per hundred weight of animal; Silage, all they would eat.

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 13.
FEED CONSUMED, HEIGHT, AND WEIGHT.
Ayrshire Heifer 320.
Group 11.*

Ten Day Periods	Corn	Alfalfa	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
1	45	45	119	9.45	74.44	105.2	450**
2	45	45	151	9.80	79.52		455
3	45	45	166	9.97	81.91		483
							502***
4	50	50	164	10.85	87.76	106.5	520
5	45.5	42	160.5	9.62	80.44		535
6	49.5	49.5	196	11.11	92.23		555***
7	55	54.5	93.5	10.93	82.56	108.8	565
8	55	54	169.5	11.71	94.46		587
9	55	55	145.3	11.55	90.95		596***
10	60	58.8	171	12.61	100.81	111.4	614***
11	60	60	190	12.95	104.24		636***
12	60	60	203	13.09	106.31		651***
13	65	60.8	155	13.02	103.41	112.9	656***
14	65	62.5	150	13.18	103.19		695***
15	65	62.0	110	12.65	96.66		699***
						114.1	
Total	820.	804.1	2343.8	172.49	1378.89		
Av. per Day	5.46	5.36	15.62	1.15	9.19		

* Ration.- Corn, 1 pound per hundred weight of animal;
Alfalfa, 1 " " " " "
Silage, all they would eat.

** Average of 3 weights on 3 successive days at beginning
of experiment.

*** Average of 3 weights on 3 successive days at end of
indicated ten day period.

Table 14.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Holstein Heifer 264.

Group 11.*

Ten Day Periods	Corn	Alfalfa	Silage	Dig. Crude	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
							505**
1	50	48.5	96	9.94	76.44	108.0	514
2	50	50	99	10.13	77.43		530
3	50	48.6	100	10.00	77.11		542***
4	55	53	104	10.88	83.70	110.6	565
5	55	55	130	11.38	88.52		585
6	55	55	150	11.60	91.70		605***
7	60	52.5	153.5	11.75	95.86	112.3	626
8	60	58.5	142	12.26	96.08		650
9	60	60	156	12.57	98.82		660***
10	65	63.6	185	13.65	109.13	116.4	682***
11	65	65	238	14.38	118.04		713***
12	65	65	235	14.35	117.56		727***
13	75	73.5	172	15.30	119.37	118.6	734***
14	75	67.8	140	14.35	112.33		761***
15	75	73	95	14.40	106.96		762***
						119.4	
Total	915.	889.	2195.5	186.94	1469.05		
Av. per Day	6.10	5.92	14.63	1.24	9.79		

* Ration.- Corn, 1 pound per hundred weight of animal;
Alfalfa, 1 " " " " " "
Silage, all they would eat.

** Average of 3 weights on 3 successive days at beginning
of experiment.

*** Average of 3 weights on 3 successive days.at end of
indicated ten day period.

Table 15.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Holstein Heifer 258.

Group 11.*

Ten Day Periods	Corn	Alfalfa	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
							556**
1	55	55	119	11.26	86.77	113.3	566
2	55	54	161	11.62	93.10		605
3	55	55	144	11.53	90.74		601***
4	60	60	140	12.40	96.28	115.9	617
5	60	60	150	12.51	97.87		648
6	60	60	170	12.73	101.05		671***
7	65	61.5	160	13.15	104.44	116.0	688
8	65	60.5	160	13.04	104.04		711
9	65	55.5	160	12.51	102.38		713***
10	70	69.5	185	14.65	115.61	118.5	747***
11	70	70	238	15.28	124.21		762***
12	70	70	176	14.60	114.35		777***
13	80	77	140	15.70	119.94	120.5	777***
14	80	77	150	15.81	121.53		811***
15	80	80	110	15.69	116.20		809***
						121.5	
Total	990.	965.	2363.	202.48	1588.51		
Av. per Day	6.60	6.43	15.70	1.35	10.59		

* Ration.- Corn, 1 pound per hundred weight of animal;
Alfalfa, 1 " " " " "
Silage, all they would eat.

** Average of 3 weights on 3 successive days at beginning
of experiment.

*** Average of 3 weights on 3 successive days at end of
indicated ten day period.

Table 16.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Jersey Heifer 117.

Group 11.*

Ten Day Periods	Corn	Alfalfa	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
1	25	25	70	5.29	41.97	92.08	245**
2	25	23.4	104	5.49	46.82		254
3	25	25	101.9	5.64	47.04		267
							276***
4	30	27.1	100	6.22	51.91	93.9	280
5	30	29.1	99.6	6.42	52.53		293
6	30	29.1	100	6.43	52.60		299***
7	30	22.9	88	5.64	48.56	97.3	302
8	30	27	67.3	5.85	46.68		300
9	30	30	76	6.26	49.08		310***
10	30	27.8	86	6.14	49.93	98.8	314***
11	30	28.6	102.5	6.40	52.83		325***
12	30	25	90.5	5.89	49.69		329***
13	35	31.6	66	6.70	52.51	101.8	334***
14	35	33.4	40	6.60	48.99		340***
15	35	34.5	40	6.72	49.37		346***
						103.2	
Total	450.	419.5	1231.8	91.69	740.51		
Av. per Day	3.	2.79	8.21	.61	4.93		

* Ration.- Corn, 1 pound per hundred weight of animal;
Alfalfa, 1 " " " " "
Silage, all they would eat.

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 17.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Ayrshire Heifer 322.

Group 111.*

Ten Day Periods	Corn	Timothy	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
1	10	15.5	14.3	1.37	17.85	92.66	294**
2	10	24	19.3	1.68	22.29		291
3	10	25	66.3	2.22	30.20		298
							290***
4	10	27	90.1	2.55	34.84	92.5	290
5	10	28.4	95	2.64	36.22		294
6	10	28	85.7	2.53	33.57		299***
7	10	23.5	58	2.09	28.33	92.6	295
8	10	29.6	82	2.54	34.67		292
9	10	30	96	2.70	37.07		292***
10	20	28	99.1	3.43	45.63	95.0	299***
11	20	18.8	107.2	3.24	42.96		304***
12	20	17.9	106.	3.20	42.38		305***
13	10	19	120	2.64	36.16	97.8	310***
14	0	20	131.9	2.04	29.57		315***
15	10	19.4	139	2.86	39.36		319***
						98.9	
Total	170.	354.1	1309.9	37.73	511.10		
Av. per Day	1.13	2.36	8.73	.25	3.40		

*

Ration.- Timothy, all they would eat; Silage, all they would eat, Corn, amount necessary to promote one-fourth pound gain per day.

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 18.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Holstein Heifer 260.

Group 111.*

Ten Day Periods	Corn	Timothy	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
							526**
1	10	29.5	111	2.85	39.24	115.3	548
2	10	39	167	3.75	52.23		568
3	10	45	180	4.08	56.88		573***
4	1	47	182	3.48	50.03	116.4	565
5	0	50	200	3.70	53.31		584
6	0	50	200	3.70	53.31		584***
7	0	49	200	3.67	52.87	118.6	582
8	0	50	200	3.70	53.31		588
9	0	52.5	200	3.77	54.38		597***
10	0	56.5	208	3.98	57.37	118.9	596***
11	0	50.9	230	4.05	58.46		617***
12	0	37.1	244	3.79	54.75		612***
13	0	37.7	259	3.98	57.39	120.3	632***
14	0	37	260	3.97	57.25		626***
15	0	40	274	4.21	60.77		638***
						121.3	
Total	31.	671.2	3115.	56.68	811.55		
Av. per Day	.20	4.47	20.76	.37	5.41		

* Ration.- Timothy, all they would eat; Silage, all they would eat; Corn, amount necessary to promote one-fourth pound gain per day.

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 19.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Holstein Heifer 265.

Group 111.*

Ten Day Periods	Corn	Timothy	Silage	Dig. Crude Pro.	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
							479**
1	10	29.5	113	2.87	39.56	108.2	490
2	10	39	163	3.71	51.59		500
3	10	40	160	3.71	51.55		498***
4	1	40	141.6	2.83	40.60	108.5	505
5	0	38.1	150	2.79	40.24		505
6	0	39	153	2.85	41.09		507***
7	0	37.4	160	2.88	41.52	110.0	505
8	0	40	160	2.96	42.64		495
9	0	40	160	2.96	42.64		488***
10	20	36	156.1	4.29	58.13	112.5	486***
11	20	39	141.9	4.23	57.17		491***
12	20	38.4	123.8	4.01	53.03		497***
13	10	36.8	147.7	3.47	48.23	115.0	504***
14	0	38.8	172.0	3.05	44.03		512***
15	0	40	192.9	3.32	47.87		513***
						114.7	
Total	101.	572.	2295.0	49.93	699.89		
Av. per Day.	.67	3.81	15.30	.33	4.66		

* Ration.- Timothy, all they would eat; Silage, all they would eat; Corn, amount necessary to promote one-fourth pound gain per day.

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 20.

FEED CONSUMED, HEIGHT, AND WEIGHT.

Jersey Heifer 116.

Group 111.*

Ten Day Periods	Corn	Timothy	Silage	Dig. Crude	Net Energy	Height	Weight
	lbs.	lbs.	lbs.	lbs.	therms	cm.	lbs.
1	10	15.5	67.8	1.96	26.35	92.91	262**
2	10	22.2	100	2.51	34.36		274
3	10	24	100	2.57	35.13		278
							280***
4	1	25.4	98.5	1.92	27.47	94.0	278
5	0	24.9	100	1.84	26.61		286
6	0	21.2	99.2	1.72	24.89		283***
7	0	19.2	77.2	1.42	20.52	95.2	285
8	0	22.6	99.6	1.77	25.55		285
9	0	25.6	94.8	1.81	26.08		284***
10	10	24.1	108	2.66	36.45	98.5	292***
11	10	17.2	111.5	2.49	34.04		300***
12	10	15.1	120	2.52	34.49		300***
13	10	20	119	2.65	36.44	99.0	304***
14	0	18.7	134.5	2.04	29.42		308***
15	0	17.8	135.9	2.02	29.26		310***
						100.0	
Total	71.	313.5	1566.0	31.90	447.06		
Av. per Day.	.47	2.09	10.44	.21	2.98		

* Ration.- Timothy, all they would eat; Silage, all they would eat; Corn, amount necessary to promote one-fourth pound gain per day.

** Average of 3 weights on 3 successive days at beginning of experiment.

*** Average of 3 weights on 3 successive days at end of indicated ten day period.

Table 21.

COMPOSITION OF FEED.USED.*

Average Figures for Dry Matter, Digestible Crude Protein, Digestible True Protein, and Net Energy Values Per 100 Pounds for Ruminants.

Feed	Dry Matter	Digestible		Net Energy Value
		Crude Protein	True Protein	
Timothy, all analyses	88.4	3.0	2.2	43.02
Alfalfa, all analyses	91.4	10.6	7.1	34.23
Silage (corn), well matured	26.3	1.1	0.6	15.90
Corn, dent	89.5	7.5	7.0	89.16

* Bul. 143, Pennsylvania Station, 1916.⁴³

Table 22.

TOTAL FEED CONSUMED BY HEIFERS
and
GAIN IN WEIGHT.

150 Days.

Heifer No.	Corn lbs.	Alfalfa lbs.	Silage lbs.	Timothy lbs.	Av.Gains per day. lbs.	Total Gains lbs.
318	300	867.8	2893.0		1.14	172
263	300	818.0	3079.0		1.51	227
262	300	833.0	2733.0		1.19	179
113	300	646.1	2005.6		0.51	77
Total	1200	3164.9	10710.6			655
Average	300	791.0	2677.1			164
Av. per Day	2.	5.27	17.80		1.09	
320	820	804.1	2343.8		1.66	249
264	915	889.0	2195.5		1.71	257
258	990	965.0	2363.0		1.68	253
117	450	419.5	1231.8		0.67	101
Total	3175	3077.6	8134.1			860
Average	794	769.4	2043.0			215
Av. per Day	5.29	5.12	13.54		1.43	
322	170		1309.9	354.1	0.16	25
260	31		3115.0	671.2	0.74	112
265	101		2295.0	572.0	0.22	34
116	71		1566.0	313.5	0.32	48
Total	373		8285.9	1910.8		215
Average	93		2071.1	477.0		55
Av. per Day	0.61		13.81	3.20	0.36	

Dry Matter Consumed.- The dry matter consumed by the three groups, together with the average weight and gain and dry matter per pound live weight and dry matter per pound gain are shown in Table 23. It is shown that the group which received the largest amount of grain consumed the most dry matter, while the group receiving the least grain consumed the least dry matter. The consumption of dry matter varied at large with the amount of grain consumed.

In general the gains in weight are closely associated with the consumption of dry matter both within and between the various groups.

The figures in Table 23 show that in proportion to the dry matter consumed by Groups 1 and 11 the Holsteins and Ayrshires made the most gains per 1000 pounds live weight and the Jerseys least. The Holsteins used their ration, when composed largely of roughage, to better advantage than the Jerseys. This seems to be born out by the results of the preceeding two years.

In Group 111 it appears that no such comparison can be made between the heifers because the underfeeding was so much below normal that individuality rather than breed was the controlling factor. This is strikingly brought forth in a comparison of No. 260 and No. 265 both of the same breed.

However, no definite conclusions can be drawn until more animals are used in the experiment.

Table 23.

DRY MATTER IN RATION
BY GROUPS.

	Group 1	Group 11	Group 111.
Ration	Medium	Heavy	Light
Average Dry Matter received per day	11.6 lbs.	12.9 lbs.	7.0 lbs.
Average weight	548.	546.	417.
Average daily gains	1.09	1.43	0.36
Dry Matter For a Pound live weight	3.2	3.6	2.5
Dry Matter for a Pound gain	2.9	2.5	6.9

Table 23 a.

DRY MATTER PER POUND LIVE WEIGHT.

	Group 1	Group 11	Group 111
Ayrshire	3.1	3.6	2.6
Holstein	3.1	3.5	2.4
Holstein	3.0	3.5	2.4
Jersey	3.5	3.7	2.6

Protein Consumed.- Tables 9 to 20 give the total digestible protein for each animal by ten day periods and the total for the groups appears in Table 22.

The total amount of digestible crude protein consumed was found to be 542 pounds, 653 pounds, and 176 pounds respectively, and the daily consumption per 1000 pounds live weight 1.64, 1.98, and 0.72 pounds respectively.

In order to properly compare their growth with their protein intake it is necessary to deduct the protein requirement for maintenance which is given in Table 4. This is calculated on the basis of digestible true protein only, so it becomes necessary to calculate the entire intake on the same basis. This is done by multiplying the total separate feeds consumed by the figure for digestible true protein as given in Table 21, which shows Group I to have consumed 372.9 pounds, Group II 489.5 pounds, and Group III 107.8 pounds of digestible true protein throughout the experiment.

It is found that Group I which weighed 548 pounds used 0.32 pounds true protein per day for maintenance or 48 pounds for the 150 days, Group II with an average weight of 546 pounds used also 0.32 pounds per day or 48 pounds per 150 days, and Group III with an average weight of 417 pounds used 0.27 pounds per day or 40 pounds per 150 days for maintenance.

Deducting maintenance from the total consumption we find Group 1 had 324.9 pounds, Group 11 441.5 pounds, and Group 111 67.8 pounds digestible true protein for growth.

Using these figures as the basis of our calculation we find that Group 1 consumed 0.49 pounds digestible true protein per pound gain while Group 11 consumed 0.51 and Group 111 consumed 0.31 pounds digestible true protein per pound gain.

This shows that the group on the low ration consumed the least protein per pound gain with Groups 1 and 11 receiving very much more.

Net Energy Consumed.- Tables 9 to 20 show the net energy in therms consumed.

It is shown by the tables that the energy consumed by the various groups was 3855 therms, 5176, and 2469 therms respectively.

Deducting maintenance according to the standard adopted by Armsby and reproduced in Table 4 it is found that the amount of energy available for growth was 3252 therms for Group 1, 4574 therms for Group 11 and 1968 therms for Group 111.

A comparison of the available energy with the total gains shows Group 1 to have consumed 4.96 therms, Group 11 5.31 therms, and Group 11 8.98 therms per pound gain.

While the total amount of energy consumed by Group 111 was materially less than was consumed by either of the other groups, yet per pound gain their energy intake was far in advance of the others.

Undoubtedly they used the small amount of protein received to better advantage. Whether it is due to the fact that a higher per cent of the protein was digested due to a small amount or whether the greater proportion of net energy present was conducive to better utilization of the feed is a question to which we cannot give a definite answer. However, Eckles⁵² Found that the coefficient of digestibility was higher when cows were on maintenance than when on full feed. Probably this would likewise apply to young growing heifers.

Table 24.

PROTEIN AND ENERGY RECEIVED.

By 30 Day Periods.

Heifer No. 318

GROUP I.

Period	Total Dig. Protein	Total Energy	Dig. Pro. per Day	Energy per Day	Dig.Pro. per 1000 pounds per day	Energy per 1000 pounds per day
	Pounds	Therms	lbs.	Therms	Pounds	Therms
1	25.35	177.61	.84	5.92	1.61	11.34
2	28.26	200.58	.94	6.68	1.67	11.90
3	29.32	198.07	.97	6.60	1.64	11.11
4	31.28	226.55	1.04	7.55	1.66	12.03
5	32.07	221.58	1.06	7.38	1.61	11.18
Total	146.28	1024.39	4.85	34.13	8.19	57.56
Average			.97	6.82	1.64	11.51

Heifer No. 263

Period	Total Dig. Protein	Total Energy	Dig. Pro. per Day	Energy per Day	Dig.Pro. per 1000 pounds per day	Energy per 1000 pounds per day
	Pounds	Therms	lbs.	Therms	Pounds	Therms
1	23.58	171.64	.78	5.72	1.59	11.67
2	26.45	194.77	.88	6.49	1.68	12.29
3	27.55	192.12	.91	6.40	1.60	11.26
4	31.79	234.03	1.05	7.80	1.69	12.60
5	33.67	244.39	1.12	8.14	1.65	12.04
Total	143.04	1036.95	4.74	34.55	8.21	59.86
Average			.95	6.91	1.63	11.97

Heifer No. 262

Period	Total Dig. Protein	Total Energy	Dig. Pro. per Day	Energy per Day	Dig.Pro. per 1000 pounds per day	Energy per 1000 pounds per day
	Pounds	Therms	lbs.	Therms	Pounds	Therms
1	25.45	177.95	.85	5.93	1.68	11.76
2	26.01	189.09	.86	6.30	1.59	11.68
3	27.71	192.63	.92	6.42	1.60	11.20
4	30.36	213.36	1.01	7.11	1.68	11.69
5	31.07	214.03	1.03	7.13	1.59	11.03
Total	140.60	987.06	4.67	32.89	8.14	57.36
Average			.93	6.58	1.62	11.47

Heifer No. 113

Period	Total Dig. Protein	Total Energy	Dig. Pro. per Day	Energy per Day	Dig.Pro. per 1000 pounds per day	Energy per 1000 pounds per day
	Pounds	Therms	lbs.	Therms	Pounds	Therms
1	20.78	146.05	.69	4.86	1.66	11.72
2	22.76	157.64	.76	5.25	1.75	12.13
3	22.09	156.14	.73	5.20	1.63	11.64
4	23.20	170.34	.77	5.67	1.69	12.36
5	24.00	177.26	.80	5.90	1.69	12.48
Total	112.83	807.43	3.75	26.88	8.42	60.34
Average			.75	5.38	1.68	12.07

Table 25.

PROTEIN AND ENERGY RECEIVED.

By 30 Day Periods.

Heifer No. 320

GROUP 11.

Period	Total Protein	Dig. Total Energy	Dig. Pro. per day	Energy per day	Dig. Pro. per 1000 pounds per day	Energy per 1000 pounds per day
	Pounds	Therms	lbs.	Therms	Pounds	Therms
1	29.22	235.87	.97	7.86	2.03	16.50
2	31.58	260.43	1.05	8.68	1.98	16.43
3	34.19	267.97	1.13	8.93	1.96	15.53
4	38.65	311.36	1.28	10.37	2.05	16.63
5	38.85	303.26	1.29	10.10	1.91	14.95
Total	172.49	1378.89	5.72	45.94	9.93	80.04
Average			1.14	9.19	1.99	16.01

Heifer No. 264

Period	Total Protein	Dig. Total Energy	Dig. Pro. per day	Energy per day	Dig. Pro. per 1000 pounds per day	Energy per 1000 pounds per day
	Pounds	Therms	lbs.	Therms	Pounds	Therms
1	30.07	230.98	1.00	7.69	1.91	14.71
2	33.86	263.92	1.12	8.79	1.95	15.35
3	36.58	290.76	1.21	9.69	1.91	15.34
4	42.38	344.73	1.41	11.49	2.03	16.59
5	44.05	338.66	1.46	11.28	1.96	15.17
Total	186.94	1469.05	6.20	48.94	9.76	77.16
Average			1.24	9.79	1.95	15.43

Heifer No. 258

Period	Total Protein	Dig. Total Energy	Dig. Pro. per day	Energy per day	Dig. Pro. per 1000 pounds per day	Energy per 1000 pounds per day
	Pounds	Therms	lbs.	Therms	Pounds	Therms
1	34.41	270.61	1.14	9.02	1.98	15.61
2	37.64	295.20	1.25	9.84	1.96	15.48
3	38.70	310.86	1.29	10.36	1.86	14.98
4	44.53	354.17	1.48	11.80	1.98	15.84
5	47.20	357.67	1.57	11.92	1.97	15.04
Total	202.48	1588.51	6.73	52.94	9.75	76.95
Average			1.34	10.59	1.95	15.40

Heifer No. 117

Period	Total Protein	Dig. Total Energy	Dig. Pro. per day	Energy per day	Dig. Pro. per 1000 pounds per day	Energy per 1000 pounds per day
	Pounds	Therms	lbs.	Therms	Pounds	Therms
1	16.42	135.83	.54	4.52	2.08	17.42
2	19.07	157.04	.63	5.23	2.20	18.24
3	17.75	144.32	.59	4.81	1.95	15.84
4	18.43	152.45	.61	5.08	1.92	15.94
5	20.02	150.87	.66	5.02	1.96	14.93
Total	91.69	740.51	3.03	24.66	10.11	82.37
Average			.61	4.93	2.02	16.48

By 30 Day Periods.

GROUP 111.

Heifer No. 260

Heifer No. 265

Heifer No. 116

1	7.04	95.84	.23	3.19	.86	11.78
2	5.48	78.97	.18	2.63	.64	9.36
3	5.00	72.15	.16	2.40	.58	8.49
4	7.67	104.98	.25	3.49	.87	11.96
5	6.71	95.12	.22	3.17	.73	10.41
Total	31.90	447.06	1.04	14.88	3.68	52.00
Average			.21	2.98	.73	10.40

Table 27.
PROTEIN AND ENERGY CONSUMED.
During 150 Days.

Group	Total Dig. Crude Pro.	Total Energy	Dig. Pro. per da	Energy per Day	Dig.Pro. per Day per 1000 pounds live wt.	Energy per Day per 1000 pounds live wt.
	Pounds	Therms	Pounds	Therms	Pounds	Therms
1						
318	146.28	1024.39	.97	6.82	1.64	11.51
263	143.04	1036.95	.95	6.91	1.63	11.97
262	140.60	987.06	.93	6.58	1.62	11.47
113	112.83	807.43	.75	5.38	1.68	12.07
Total	542.75	3855.83				
Average			.90	6.42	1.64	11.75
11						
320	172.49	1378.89	1.14	9.19	1.99	16.01
264	186.94	1469.05	1.24	9.79	1.95	15.43
258	202.48	1588.51	1.34	10.59	1.95	15.40
117	91.69	740.51	.61	4.93	2.02	16.48
Total	653.60	5176.96				
Average			1.08	8.62	1.98	15.83
111						
322	37.73	511.10	.25	3.40	.83	11.37
260	56.68	811.55	.37	5.41	.63	9.18
265	49.93	699.89	.33	4.66	.67	9.41
116	31.90	447.06	.21	2.98	.73	10.40
Total	176.24	2469.60				
Average			.29	4.11	.72	10.09

Mineral Matter.- Whether or not sufficient mineral matter was supplied to all the animals is an uncertainty but it appears that the groups receiving the legume in their ration should have been well supplied with mineral matter, especially calcium. With the group which received no legume it is doubtful if they received sufficient mineral nutrients.

While no conclusive work has been done relating to the amount of mineral matter required by growing animals, we do know that it is of prime importance that a liberal amount be supplied.

Table 28 shows a comparison of the amount of mineral nutrients consumed by the various groups, showing that Groups I and II received practically the same amount while Group III received little more than one-fourth as much as either of the others. The extremely small amount in the ration of Group III is accounted for principally by the absence of a legume in the ration.

While the small amount of mineral matter could have been possibly one of the limiting factors in the growth of the animals in this group, it is hardly probable that the deficiency would be marked in such a brief time. However, continued feeding on a similar ration would, in all probability, show marked effects from mineral deficiencies.

Table 28 A.

CALCIUM, PHOSPHORUS, AND MAGNESIUM

CONSUMED BY THE THREE GROUPS. -----
(150 Days)

	CaO	P ₂ O ₅	MgO	
	Pounds	Pounds	Pounds	
Group 1				
Corn	.312	7.476	2.628	
Alfalfa	136.407	19.305	16.457	
Silage	29.989	11.781	23.563	
Total	166.708	38.562	42.648	
Total of the 3				247.918
Group 11				
Corn	.825	19.780	6.953	
Alfalfa	132.644	18.773	16.003	
Silage	22.775	8.947	17.895	
Total	156.244	47.500	40.851	
Total of the 3				244.595
Group 111				
Corn	.096	2.323	.816	
Timothy	6.687	6.305	2.675	
Silage	23.200	9.114	18.228	
Total	29.983	17.742	21.719	69.444

Table 28 B.

MINERAL COMPOSITION OF FEEDS.*

Feed	CaO	P ₂ O ₅	MgO
	per cent	per cent	per cent
Corn	0.026	0.623	0.219
Alfalfa	4.310	0.610	0.520
Silage	0.280	0.110	0.220
Timothy	0.350	0.330	0.140

*Analyses taken from Wisc. Ag. Exp. Sta. Res. Bul.
30, 1914. (See Bibliography 42.)

Quality of Protein Supplied.- While our knowledge regarding the quality of protein in our common feeding stuffs is as yet very limited, yet some few generally accepted statements can be given concerning the protein supplied the three groups under study.

Although certain parts of the corn kernel are deficient in some of the essential protein constituents, yet when the entire kernel is consumed it is found to furnish all the essential amino acids. However, their proportion is at present considered not to be the most ideal.

Of the quality of the proteins in alfalfa, timothy, and silage, nothing can as yet be said conclusively. However, much work is being done on these particular feeds at the present time by Grindley and others.⁶⁶

Vitamines.- Likewise but little definite knowledge is available on the subject of vitamins relating to our common feeds. However, considering the feeds used in this experiment it has been shown by McCollum and Davis^{32,38} that alfalfa contains both fat-soluble A and water-soluble B, being especially well supplied with the former.

Nothing can as yet be said of the presence or absence of these desirable factors in the other feeds

used, namely corn, timothy, and silage.

Toxicity.- While the results at the Wisconsin
30,31,32
Experiment Station showed the presence of a toxic substance in the wheat germ, no similar findings have been recorded by these or other investigators relating to the toxic effects of any of the feeds used in this experiment, or in fact, of any other feeds other than wheat germ and cotton seed meal.

Gains in Weight.- Table 22 shows the total gains

for the three groups from November 1st to March 31st to be 655 pounds, 860 pounds, and 219 pounds respectively.

It is seen that Group 11 on the heavy ration, with one pound each of corn and alfalfa per hundred weight and all the silage the heifers would eat, made the greatest gains, while Group 1 on the same ration, except that the corn was reduced to two pounds per heifer regardless of their size, made the next greatest gains, with Group 111, on timothy and silage and some little corn, making the least gains.

Figures 4, 5, and 6 show, in a graphic form, the gains made by the various heifers in a comparison with normal gains as set forth in Table 34. It is shown that

Groups 1 and 11 made gains somewhat better than normal, having gained an average of 34 pounds and 66 pounds respectively more than normal. Group 111 failed to make normal growth, in fact at the end of the experiment the heifers were, on an average, 91 pounds below normal.

Table 32 shows a comparison of the various animals and groups. It is therein shown that the Jerseys in each group failed to make normal growth.

However, No. 117 in the group receiving the heavy ration seemed to be suffering from a dislocated hip and, in all probability, this interfered somewhat with her proper growth. Table 32 shows that she made 70 pounds less than normal gains. In fact she should have gained more than this, as all the other heifers in the same group gained from 85 to 129 pounds more than normal. Had her results been discarded, Group 11 would then have averaged much higher than is indicated.

Similar results, however, are found in Group 1 which also show the Jersey to have failed to make normal growth. Heifer No. 113 of this group was 74 pounds below normal in weight, slightly lower than No. 117. She appeared to be in perfect health, and consumed even more feed per 1000 pounds live weight than any of the other heifers in the group as is shown in Table 27, while her gains were less than one-half any of the others, as shown in Table

22. It is apparent that she failed to utilize her feed to as good advantage as the other members of the group.

Whether this difference is due to individuality or breed is still a question. However, the experiments during the previous three years along this same line at the Missouri Station seem to indicate that it is a breed difference, especially noticeable when the ration is largely roughage.

Tables 22 and 32 show that in all cases the Holsteins made the best gains, with the Ayrshires second, and the Jerseys last.

The average gains per day for each group for the 150 days were 1.09 pounds, 1.43 pounds, and 0.36 pounds, or on the basis of 1000 pounds live weight 1.98, 2.61, and 0.86 pounds respectively.

Figure 8 shows the relative gains in weight by the three groups in a graphic form.

Table 29.

COMPARISON OF WEIGHTS AND MEASUREMENTS

WITH NORMAL GROWTH.**

Heifer No. 318		GROUP 1.					
		Nov.1	Dec.1	Jan.1	Feb.1	Mar.1	Apr.1
		Age	Age	Age	Age	Age	Age
		14 mo.	15 mo.	16 mo.	17 mo.	18 mo.	19 mo.
Actual Weight*	501	541	583	608	649	673	
Normal Weight	525	550	570	590	610	632	
Actual Height*	108.8	108.6	111.5	113.5	115.6	116.6	
Normal Height	109.5	111.0	112.0	113.0	114.0	115.0	
Heifer No. 263							
		11 mo.	12 mo.	13 mo.	14 mo.	15 mo.	16 mo.
Actual Weight	473	507	550	587	652	700	
Normal Weight	513	548	574	596	620	648	
Actual Height	111.5	112.4	115.8	118.1	119.6	121.3	
Normal Height	112.3	114.0	115.8	117.2	118.5	119.8	
Heifer No. 262							
		12 mo.	13 mo.	14 mo.	15 mo.	16 mo.	17 mo.
Actual Weight	487	522	557	590	627	666	
Normal Weight	548	574	596	620	648	675	
Actual Height	111.5	111.9	114.8	115.3	117.6	118.2	
Normal Height	114.0	115.8	117.2	118.5	119.8	121.0	
Heifer No. 113							
		10 mo.	11 mo.	12 mo.	13 mo.	14 mo.	15 mo.
Actual Weight	406	425	440	454	464	483	
Normal Weight	405	439	468	498	527	556	
Actual Height	105.3	105.8	107.7	109.9	110.9	112.4	
Normal Height	105.0	106.9	108.5	110.0	111.5	113.0	
Av. Wt. of Group	467	499	532	559	598	630	
Av. Height	"	109.3	109.7	112.4	114.2	115.9	117.1

* Weight given in pounds and height in centimeters.

** See Table 34.

Table 30.

COMPARISON OF WEIGHTS AND MEASUREMENTS

WITH NORMAL GROWTH.**

Heifer No. 320		GROUP 11.					
		Nov.1	Dec.1	Jan.1	Feb.1	Mar.1	Apr.1
		Age	Age	Age	Age	Age	Age
		12 mo.	13 mo.	14 mo.	15 mo.	16 mo.	17 mo.
Actual Weight*	450	502	555	596	651	699	
Normal Weight	470	500	525	550	570	590	
Actual Height*	105.2	106.5	108.8	111.4	112.9	114.1	
Normal Height	106.5	108.0	109.5	111.0	112.0	113.0	

Heifer No. 264		10 mo.	11 mo.	12 mo.	13 mo.	14 mo.	15 mo.
Actual Weight	505	542	605	660	727	762	
Normal Weight	480	513	548	574	596	620	
Actual Height	108.0	110.6	112.3	116.4	118.6	119.4	
Normal Height	110.5	112.3	114.0	115.8	117.2	118.5	

Heifer No. 258		15 mo.	16 mo.	17 mo.	18 mo.	19 mo.	20 mo.
Actual Weight	556	601	671	713	777	809	
Normal Weight	620	648	675	710	746	788	
Actual Height	113.3	115.9	116.0	118.5	120.5	121.5	
Normal Height	118.5	119.8	121.0	122.0	122.5	123.0	

Heifer No. 117		7 mo.	8 mo.	9 mo.	10 mo.	11 mo.	12 mo.
Actual Weight	245	276	299	310	329	346	
Normal Weight	297	334	378	405	439	468	
Actual Height	92.08	93.9	97.3	98.8	101.8	103.2	
Normal Height	97.8	101.0	103.0	105.0	106.9	108.5	

Av.Wt.of Group	439	480	532	569	621	654	
Av.Height "	104.6	106.7	108.6	111.3	113.4	114.5	

* Weight given in pounds and height in centimeters.

** See Table 34.

Table 31.

COMPARISON OF WEIGHTS AND MEASUREMENTS

WITH NORMAL GROWTH.**

Heifer No. 322		GROUP 111.					
		Nov.1	Dec.1	Jan.1	Feb.1	Mar.1	Apr.1
		Age	Age	Age	Age	Age	Age
		10 mo.	11 mo.	12 mo.	13 mo.	14 mo.	15 mo.
Actual Weight*	294	290	299	292	305	319	
Normal Weight	409	440	470	500	525	550	
Actual Height*	92.66	92.5	92.6	95.0	97.8	98.9	
Normal Height	102.5	104.5	106.5	108.0	109.5	111.0	
Heifer No. 260		11 mo.	12 mo.	13 mo.	14 mo.	15 mo.	16 mo.
Actual Weight	526	573	584	597	612	638	
Normal Weight	513	548	574	596	620	648	
Actual Height	115.3	116.4	118.6	118.9	120.3	121.3	
Normal Height	112.3	114.0	115.8	117.2	118.5	119.8	
Heifer No. 265		9½ mo.	10½ mo.	11½ mo.	12½ mo.	13½ mo.	14½ mo.
Actual Weight	479	498	507	495	497	513	
Normal Weight	462	496	530	561	585	608	
Actual Height	108.2	108.5	110.0	112.5	115.0	114.7	
Normal Height	109.4	111.4	113.1	114.9	116.5	117.8	
Heifer No. 116		8 mo.	9 mo.	10 mo.	11 mo.	12 mo.	13 mo.
Actual Weight	262	280	283	284	300	310	
Normal Weight	334	378	405	439	468	498	
Actual Height	92.91	94.0	95.2	98.5	99.0	100.0	
Normal Height	101.0	103.0	105.0	106.9	108.5	110.0	
Av.Wt.of Group	390	410	418	415	428	445	
Av.Height "	102.2	102.8	104.1	106.2	108.0	108.7	

* Weight given in pounds and height in centimeters.

** See Table 34.

Table 32.

AVERAGE GAINS BY GROUPS COMPARED

WITH NORMAL GROWTH.

GROUP 1.						
Heifer No.	Gain in weight 150 days	Normal gain in weight 150 days	Increase above normal	Gain in height 150 days	Normal gain in height 150 days	Increase above normal
	Pounds	Pounds	Pounds	cm.	cm.	cm.
318	172	107	65	7.8	6.5	1.3
263	227	135	92	9.8	7.5	2.3
262	179	127	52	6.7	7.0	-0.3
113	77	151	-74	7.1	8.0	-0.9
Average	164	130	34	7.8	7.2	0.6

GROUP 11.						
320	249	120	129	8.9	6.5	2.4
264	257	140	117	11.4	8.0	3.4
258	253	168	85	8.2	4.5	3.7
117	101	171	-70	11.12	10.7	0.42
Average	215	149	66	9.90	7.4	2.5

GROUP 111.						
322	25	141	-116	6.24	8.5	-2.26
260	112	135	-23	6.0	7.5	-1.5
265	34	146	-112	6.5	8.4	-1.9
116	48	164	-116	7.09	9.0	-1.91
Average	55	146	- 91	6.45	8.35	-1.8

Table 33.
COMPARISON OF INDIVIDUAL GAINS IN
HEIGHT WITH NORMAL GAINS
FOR GROUP 111--EACH MONTH
FOR 180 DAYS.

	322	260	265	116	Average
1st Month					
Gain*	-0.16	1.1	0.3	1.09	0.58
Normal Gain	2.0	1.7	2.0	2.0	1.9
2nd Month					
Gain	0.1	2.2	1.5	1.2	1.25
Normal Gain	2.0	1.8	1.7	2.0	1.87
3rd Month					
Gain	2.4	0.3	1.5	3.3	1.87
Normal Gain	1.5	1.4	1.8	1.9	1.65
4th Month					
Gain	2.8	1.4	2.5	0.5	1.8
Normal Gain	1.5	1.3	1.4	1.6	1.45
5th Month					
Gain	1.1	1.0	-0.3	1.0	0.7
Normal Gain	1.5	1.3	1.3	1.5	1.4
6th Month					
Gain	0.4	2.0	0.8	2.3	1.35
Normal Gain	1.0	1.0	1.3	1.5	1.20

* Height given in terms of centimeters.

Table 34.

NORMAL GROWTH.*

Age in Months	Ayrshires		Jerseys		Holsteins	
	Withers	Weight	Withers	Weight	Withers	Weight
	cm.	Pounds	cm.	Pounds	cm.	Pounds
1	68.0	90	70.0	80	76.5	123
2	73.5	130	75.2	116	82.4	155
3	79.0	173	80.6	156	87.3	203
4	84.5	210	86.2	195	92.3	250
5	88.5	248	90.3	235	97.3	298
6	92.5	287	94.5	265	102.0	350
7	96.0	318	97.8	297	104.8	380
8	98.3	348	101.0	334	106.6	416
9	100.5	378	103.0	378	108.6	444
10	102.5	409	105.0	405	110.5	480
11	104.5	440	106.9	439	112.3	513
12	106.5	470	108.5	468	114.0	548
13	108.0	500	110.0	498	115.8	574
14	109.5	525	111.5	527	117.2	596
15	111.0	550	113.0	556	118.5	620
16	112.0	570	114.8	570	119.8	648
17	113.0	590	116.1	584	121.0	675
18	114.0	610	117.4	598	122.0	710
19	115.0	632	118.2	615	122.5	746
20	116.0	654	119.0	632	123.0	788
21	117.0	680	119.5	650	123.5	820
22	118.0	702	120.0	675	124.0	845
23	119.0	726	120.5	700	124.5	870
24	120.0	750	121.0	730	125.0	900

* Table from "The Normal Growth of Dairy Heifers" by Burlingham and Gillette. See 54.

Influence of Ration on Height.- Tables 9 to 20 inclusive give the height of the experimental heifers at 30 day intervals throughout the experiment, and Tables 29 to 33 show a comparison of these measurements with the normal for animals of the same age and breed.

Figures 1 to 3 show graphically a comparison of the gains made with normal gains in height. It is noted that nearly all the animals were below normal according to the standard when the experiment was begun. In fact all but No. 113 in Group 1 and No. 260 in Group 111 were below normal as given in Table 34. However, as the experiment proceeded it was evident that most of them were gaining on the standard and in some cases surpassing it. And at the close of the experiment, as shown in Figures 1 to 3, it was found that two of Group 1, two of Group 11 and one of Group 111 were above normal. In general, however, it may be said that they followed the normal growth fairly accurately.

While it was not expected that the rations fed Groups 1 and 11 would particularly affect their growth in height, yet it was a serious question as to Group 111. Table 32 shows that Group 1 gained 0.6 centimeters while Group 11 gained 2.5 centimeters more than normal, while Group 111 failed by 1.8 centimeters per animal to make normal gains. While No. 260 was slightly above normal at the end of the experiment yet she failed to make normal gains, but on

account of starting considerably above normal she could loose and still come out above normal as was the case.

Table 33 shows in detail the growth of the group receiving the light ration by months, and was made in order to see at what point the heifers in this group began to show retarded growth. Waters⁴⁹ pointed out that steers would make normal growth in height at withers for 70 to 120 days even on submaintenance.

It is noticed from a study of this table that the least average gains were made during the first month of the experiment, probably being due to the sudden change from a normal ration to one only slightly above maintenance. The second thirty-day period showed better gains than the first, while the third and the fourth months each showed gains above normal. However, the fifth month showed only one-half normal growth.

In an attempt to determine whether or not the results of this last month were a positive index to their retardation or that the results were only a slight variation within the possible limits of error in readings, it was decided to keep them on experiment thirty days longer, or until April 29th. Thereupon five or more careful measurements were taken and the average of the results showed that the gains were slightly above normal. However, No. 322 seemed to show a retardation ,

gaining less than one-half normal.

At the end of the six months it is found from Tables 32 and 33 that No. 322 was 35 per cent below normal, No. 260 6 per cent, No. 265 32 per cent, and No. 116 11 per cent below normal, with an average of 21 per cent. By comparing these results with the daily individual gains in weight as shown in Table 22 it is seen that the loss in height or retardation was proportional to the retardation in gains in weight.

On the whole it appears that by limiting gains to one-fourth pound per day for six months only very slightly retards growth in height. Just how long this could be continued is yet undetermined.

Comparison with the Standard Adopted by Armsby.-

Table 35 shows a comparison of the nutrients consumed by the various heifers individually and by groups with Armsby's Standard for growing dairy heifers. It is to be noted that the Standard adopted by Armsby gives protein in terms of digestible true protein while the protein intake of the experimental heifers is calculated in terms of digestible crude protein.

However, it is seen that Group 1 consumed the same amount of energy as prescribed but received less digestible crude protein than is called for in terms of true protein.

Group 11, on a heavy ration and making exceptional gains for dairy heifers, received more energy than called for, but they, likewise, received less protein than prescribed by the standard.

The heifers in Group 111 were underfed and hence failed to make normal gains, so it is difficult to compare them as the standard is for heifers receiving a normal ration. However, it may be said that the heifers in this group received much less than prescribed.

It is seen that the experimental heifers in Groups 1 and 11, although receiving less protein than is called for by Armsby's Standard, made excellent gains.

Table 35.
COMPARISON OF NUTRIENTS RECEIVED
WITH ARMSBY'S STANDARD.

No. of Heifer	Av.	Av. Wt.	Dig.	Energy	Armsby's Standard			
	Age		Crude	per	Age	Wt.	Dig.	Energy
thru-	out	Pro.	per	day			True	per
exp.		Day	Day				Pro.	day.
							daily	

	Mo.	Lbs.	Lbs.	Therms	Mo.	Lbs.	Lbs.	Therms

Group 1								
318	16	587	.97	6.82	18	550	1.10	6.4
263	13	586	.95	6.91	12	400	1.00	5.1
262	14	576	.93	6.58	12	400	1.00	5.1
113	13	444	.75	5.38	12	400	1.00	5.1
	--	---	---	---	--	---	---	---
Average	14	548	.90	6.42	13.5	437	1.02	5.4
Group 11								
320	15	574	1.14	9.19	12	400	1.00	5.1
264	12½	633	1.24	9.79	12	400	1.00	5.1
258	17	682	1.34	10.59	18	550	1.10	6.4
117	9	295	.61	4.93	9	325	0.90	4.4
Average	--	---	---	---	--	---	---	---
	13	546	1.08	8.62	13	419	1.00	5.2
Group 111								
322	12	306	.25	3.40	12	400	1.00	5.1
260	15	582	.37	5.41	12	400	1.00	5.1
265	12	496	.33	4.66	12	400	1.00	5.1
116	10½	286	.21	2.98	9	325	0.90	4.4
	---	---	---	---	--	---	---	---
Average	12	417	.29	4.11	11	381	0.97	4.9

Influence of Ration on General Appearance.- The most outstanding fact regarding the general appearance of the three groups was the extreme thinness and low vitality of the group receiving the light ration. They were noticeably less playful than the other groups and when weights and measurements were taken this group would continually object to being lead and seemed dull and stubborn, while the other animals always responded readily. All animals had been taught to lead when young so the difference was not due to training. On a rather cool day in March it was noticeable that they were suffering more from the cold as evidenced by shivering and humping their backs, while the other groups receiving the more liberal rations showed no discomfort from the weather.

The heifers in Group III failed to make normal growth by 1.8 centimeters in height and 91 pounds in weight. While the measurement at withers was the only measurement taken, it was apparent that all the animals in this group were also below normal in width of chest and development of the hind quarters. Contrary to the results of Waters and Trowbridge⁵⁰ the heifers showed no tendency toward an abnormal narrowness of the hips.

All the animals in this group showed a very rough

and thick coat. On a careful examination, the texture of the skin was found to be thick and tight and rather tough and leathery in all cases but one, that being a Jersey, which showed a thin skin yet tight and dry. This variation is probably to be ascribed to individuality. There was no evidence of any fat under the skin whatever.

On the other hand, Group 11, receiving the heavy ration including more than five pounds of corn a day for each animal, were extremely fat for dairy heifers and resembled beef animals in good, or extra good, condition. They gained 2.5 centimeters in height and 66 pounds in weight more than normal. Their skin was of fair quality, being slightly thick, however, and somewhat tight due to the excessive amount of fat underneath.

Group 1, receiving the medium ration which included two pounds of corn per day, can be considered as being in fully as good condition as desired by the practical dairyman after a season of indoor feeding when feeds were high in price. In fact they can be considered as being even slightly above the average heifer owned by successful dairymen.

The heifers in this group made perfectly normal gains, in fact, they gained 0.6 centimeters in height

and 34 pounds in weight more than normal. The condition of the skin was the best, being fine in texture, velvety, mellow and elastic. It was slightly thinner than that of the group receiving the heavy ration, and more pliable due to the absence of any excess fat.

Figures 7 and 8 show in graphic form the growth in height and weight of the three groups.

Plates 7, 8, and 9 are photographs showing a comparison of animals of the same breed at the end of the experiment under different planes of nutrition.

Plates 1 to 6 show the animals by groups at the beginning and at the end of the experiment.

Comparison of Results from the Experimental Rations.

Table 36 shows a comparison of the results of the experimental rations. It is noticed that while Group 1 received but twice as much digestible crude protein per 1000 pounds live weight as Group III, yet the heifers in this group gained three times as much in weight. When we consider the energy consumed we see that Group 1, while gaining three times as much in weight, consumed only about 50 per cent more energy.

Evidently most of the nutrients consumed by Group III were used for maintenance.

Group 11 consumed about two and one-half times as much protein and about twice as much energy as Group 111 per 1000 pounds live weight and gained four times as much in weight.

Table 36.

COMPARISON OF THE EXPERIMENTAL RATIONS.*

-1917-

	Group 1	Group 11	Group 111
Ration	Corn Alfalfa Silage	Corn Alfalfa Silage	Corn Timothy Silage
Corn Consumed	2.0	5.29	0.61
Alfalfa "	5.27	5.12	
Timothy "			3.20
Silage "	17.80	13.54	13.81
Average Weight	548.	546	417
Dig. Protein per Day	0.90	1.08	0.29
Dig. Protein per 1000 pounds live weight	1.64	1.98	0.72
Energy therms per Da.	6.42	8.62	4.11
Energy therms per 1000 pounds live wt.	11.75	15.83	10.09
Gains per day	1.09	1.43	0.36
Protein per pound gain including maintenance.	0.82	0.75	0.80
Protein per pound gain above maintenance	0.49	0.51	0.31
Therms energy per lb. gain, incl. main.	5.89	6.02	11.41
Therms energy per lb. gain, above main.	4.96	5.31	8.98

*Height given in terms of centimeters, other figures in terms of pounds.

To What Extent Can Grain Be Fed With Profit?- It

is shown in the foregoing discussion on protein and energy that the group receiving the heavy ration consumed 35 per cent more protein and 40 per cent more energy above maintenance than the group fed a medium ration and, according to Table 22, gained 51 pounds, or 31 per cent, more in weight.

Evidently the food was not used to as good advantage by the group receiving the heavy ration.

In order to make this extra gain of 51 pounds they consumed 3.29 pounds more corn per day or nearly 500 pounds more in the 150 days. However, the daily consumption of silage was decreased by 4.26 pounds or 639 pounds for the experimental period, while the consumption of alfalfa remained about the same for the two groups throughout the experiment.

Allowing \$1.00 per bushel for corn and \$6.00 a ton for silage, which were the current prices during this experimental period, it is seen that the additional gain was made at an added cost of \$7.00 or nearly 14 cents for each pound.

Such gains are found to be altogether too expensive when we see that a pound of gain above maintenance was made by the group receiving a medium ration at just one-half this amount.

However, there is another problem, one of even more serious consideration, namely, the problem of determining to what extent these gains will be affected when the heifers are turned out on pasture. It is highly probable, if not certain, that they will loose in weight, and this fat put on by expensive grain feeding will be used in place of cheap grass to partly maintain the animal. Their condition at the end of the experiment is one that can be maintained only by continued high grain feeding.

The writer estimates that each animal, when turned out on pasture and given no additional feed, will lose at least 50 pounds before there is a change in the direction of gains.

It is also pointed out in the foregoing discussion on protein and energy that the group receiving the heavy ration required 0.51 pounds protein for a pound of gain against 0.49 pounds by the group receiving the medium ration, and 5.31 therms energy compared with only 4.96 therms for the medium group. This further shows the greater economy in the medium ration.

On the basis of the foregoing it can be definitely said that the feeding of corn at the rate of one pound per hundred pounds live weight along with alfalfa and silage to dairy heifers is entirely impracticable.

A ration consisting of alfalfa, about one pound per hundred pounds live weight, and all the silage the heifers will eat, supplemented with some little grain, probable two or three pounds depending on current prices, will prove far superior from the standpoint of economy and, in all probability, equally as efficient as a ration high in grain.

That some little grain along with alfalfa and silage is advantageous and more economical and efficient than alfalfa and silage alone was shown by Wylie²² in 1915-16. A comparison of his results with those obtained by the author is found in Table 37, which shows that the addition of two pounds of grain to a ration of alfalfa and silage more than doubled the gains in weight per day, and produced a pound of gain with 5 therms of energy against 10 therms without corn, and 0.8 pounds protein compared with 1.6 pounds with alfalfa and silage alone.

Table 37.
SHOWING THE VALUE OF ADDING GRAIN
TO A RATION OF
ALFALFA AND SILAGE.

	1916	1916	1917
Ration	Alfalfa Silage	Corn Alfalfa Silage	Corn Alfalfa Silage
Corn Consumed**	-----	2.0	2.0
Alfalfa "	6.54	5.70	5.27
Silage "	19.21	17.02	17.80
Average Wt. of Group	569	634	548
Dig. Protein*per Day	0.90	0.94	0.90
Dig. Protein per 1000 Pounds live weight	1.58	1.48	1.64
Energy therms per day	5.43	6.55	6.42
Energy therms per 1000 Pounds live weight	9.55	10.33	11.75
Gains per day	0.54	1.18	1.09
Protein per pound Gain	1.66	0.80	0.82
Therms Energy per Pound Gain	10.06	5.54	5.89

* Protein always spoken of in terms of digestible crude protein in this thesis unless otherwise specified. When comparisons are made with results of previous investigators along this line, their results are changed to terms of crude protein.

** Figures are given in terms of pounds, unless otherwise specified.

Effects of Underfeeding.- The data given shows that Group III did little more than eat enough to supply the maintenance requirements. While the heifers in this group consumed about one-third as much protein and two-thirds as much energy as the group receiving the medium ration, yet this feed produced very little gain in weight. However, it did maintain life and carry the animals over a period when prices were extremely high on a very small relative cost, which is a great advantage if the animals are not materially affected.

However, it remains to be determined whether or not at the end of the pasture season these animals will have caught up with the others in weight and height. The gain in height made by these heifers was 1.8 centimeters which would not appear to be a serious retardation. If they succeed in regaining their normal condition when placed on pasture nothing has been lost but much gained in that the gain will be made on cheaper feed than used by the others. If they come very near to reaching the heifers in the other groups when full grown probably nothing has been lost if their hereditary combination for milk and fat production does not necessitate as large an animal as these would otherwise have become. It seems to be the

case on many dairy farms that the cows are larger than is necessary to meet the requirements for the small amount of milk and fat they produce. However, many of our dairy animals are slightly limited in their production by underfeeding, but heredity seems to be the greatest factor entering into the capacity of the animal to produce milk and fat.

It may be found that these heifers will be much slower in reaching maturity and hence their feeding period will be prolonged.

While these animals may be permanently retarded in growth we know from our present study of genetics that acquired characteristics are not transmitted, therefore the offspring from these animals, even should they remain slightly under size, will be normal in size and growth possibilities.

However, the definite and exact effects of underfeeding to the extent of allowing but one-fourth pound gain per day remains to be determined.

Tables 22 and 23 show that while the under fed group gained on an average 0.36 pounds per day there was a rather wide variation in individual gains, as shown by noting that the Ayrshire No. 322 gained but 0.16 pounds per day for the 150 days, while the Holstein No. 260 gained 0.74 pounds per day. No. 322 fail-

ed to gain, or in fact even to maintain herself, on timothy and silage and as a result had to be fed more than a pound of grain per day in order to make any gains whatsoever, while No. 260, on the other hand, gained 0.74 pounds per day in spite of the fact that grain was completely removed from her ration after the first month of the experiment.

As previously stated, Group III was underfed to the extent that individual differences were very noticeable. The greatest contrast is probably shown in the case of No's. 260 and 265, in that they were both of the same breed and began at practically the same weight. No. 260 persisted in consuming large quantities of feed even when no grain was available, while No. 265 failed to consume enough timothy and silage even for maintenance and it became necessary to add an average of two-thirds of a pound of corn per day to her ration in order to make even the small gain of 0.22 pounds a day.

However, in spite of the fact that No. 265 gained less than one-third as much as 260 in weight, yet in height she gained practically the same.

Cost of Wintering the Experimental Animals.- It is extremely difficult to find a satisfactory basis for

calculating the cost of rations in terms of money value since prices fluctuate within wide ranges from year to year and in different localities. It may be worthwhile, however, to calculate the actual cost of wintering the experimental animals at the current prices for feed. Silage has no definite market value but is assumed on the basis of the other feed prices to be worth \$6.00 a ton. The following prices represent the average current prices for the term covered by the experiment.

Corn	\$ 1.00 a bushel.
Alfalfa	18.00 a ton.
Timothy	14.00 a ton.
Silage	6.00 a ton.

On the basis of these prices, it is shown by the following table that the average cost of the feed for each heifer during the experiment which continued for 150 days, from Nov. 1, 1916 to Mar. 30, 1917, was \$20.00 for the heifers receiving the medium ration, \$27.00 for the heifers on a heavy grain ration, and \$11.00 for each heifer of the group receiving the light ration. In terms of percentage, we find that Group 1 cost 75 per cent as much as Group 11, while Group 111 cost only 41 per cent as much as Group 11.

Table 38.

COST OF RATION AND
COST OF A POUND GAIN.

	Group 1	Group 11	Group 111
Value of Corn	\$ 5.35	\$14.21	\$ 1.66
Value of Alfalfa	7.11	6.91	----
Value of Timothy	----	----	3.33
Value of Silage	8.01	6.12	6.21
Total Cost	20.47	27.24	11.20
Cost of one pound Gain including Maintenance	12.4 cents	12.6 cents	20.3 cents.

Application to Practical Conditions.- It is not to be overlooked that the cost of wintering the experimental animals for 1916-17 was abnormally high, due to the fact that a shortage of feed caused prices to range all the way from 50 to 100 per cent above normal.

Under ordinary conditions, heifers receiving a ration as Group 1 received, consisting of two pounds of corn and liberal amounts of alfalfa and silage, should cost about \$13.50 for five months feeding in the winter time, while heifers receiving the same ration, but with the corn increased to one pound per hundred pounds live weight, or about 5 to 7 pounds per day, would cost about \$18.00, and a heifer receiving timothy and silage and about one-half pound of corn per day in order to secure a daily gain of one-fourth pound, will cost about \$7.50.

A practical dairyman should secure a daily gain of approximately one pound in order to keep heifers in good condition.

A satisfactory and economical ration for dairy heifers would be one consisting of all the alfalfa and silage they will eat and about two pounds of corn a day.

Increasing the amount of corn to 5 or 7 pounds a day will cause slightly more rapid gains, but such

gains will be made at a material increased price over ordinary gains.

A heifer weighing about 500 or 600 pounds, in order to make one pound of gain daily, should receive about 0.8 to 0.9 pounds digestible crude protein and about 5.5 to 6.0 therms of energy a day.

Limiting the daily gains to one-fourth pound for the winter months causes the heifers to be thin and slightly undersize which, it is thought, will be overcome when placed on pasture. This, however, remains to be determined.

V--SUMMARY AND CONCLUSIONS.

Summary.-- This experiment is the fourth in a series of experiments the purpose of which is to compare the efficiency of various rations for wintering dairy heifers.

The object of this experiment was to determine the relative efficiency and economy of high as compared with low grain rations and also to determine the after effects of under-feeding.

Three groups of four heifers each were used. Each group consisted of one Ayrshire, two Holsteins, and one Jersey, all being pure breds.

Each animal in Group I received two pounds of corn, one pound of alfalfa per hundred pounds live weight, and all the silage she would eat.

Each heifer in Group II was fed one pound of corn per hundred pounds live weight, one pound of alfalfa per hundred pounds live weight, and all the silage she would eat.

The animals in Group III each received all the timothy and silage they would eat, and in case they

failed to make one-fourth pound gain each per day, corn was added in such amounts as was required.

The heifers were on experiment 150 days, beginning November 1, 1916.

On the average for the entire period each animal in Group 1 consumed 2 pounds of corn, 5.27 pounds of alfalfa, and 17.80 pounds of silage; Group 11 consumed 5.29 pounds of corn, 5.12 pounds of alfalfa, and 13.54 pounds of silage; while Group 111 consumed 0.61 pounds of corn, 3.20 pounds timothy, and 13.81 pounds silage.

In proportion to their live weight the consumption of dry matter varied in general with the grain consumed. Per pound live weight Group 1 consumed 3.2 pounds, Group 11 3.6 pounds, and Group 111 2.5 pounds dry matter.

Increased amounts of concentrates caused decreased amounts of roughage to be consumed. The reverse of this is not true, however.

The average gains per day were 1.09 pounds, 1.43 pounds, and 0.36 pounds respectively, or on the basis of 1000 pounds live weight they gained 1.98, 2.61, and 0.86 pounds per day.

The total gains by groups were 655 pounds, 860

pounds, and 219 pounds and the average weight was 548 pounds, 546 pounds, and 417 pounds respectively.

The average consumption of digestible true protein above maintenance per pound gain was 0.49 pounds for Group I, 0.51 pounds for Group II, and 0.31 pounds for Group III.

The average consumption of energy over and above maintenance per pound gain was 4.96 therms, 5.31 and 8.98 therms respectively.

It is apparent that Group III was limited by a lack of protein. In an attempt to secure protein the heifers had to eat unusually large amounts of energy. Groups I and II show that their gains follow more closely the energy intake than the protein intake above maintenance.

There was little difference in the amount of protein received per pound of gain by Groups I and II.

By comparing the nutrients received with Armsby's recent table we find that the heifers in Groups I and II followed the energy requirement fairly closely, but were below in the protein requirement. In fact, not even the high fed group received as much digestible crude protein as is called for by the Armsby Standard in terms of digestible true protein. The data at hand shows the heifers made perfectly normal gains

on less protein than is called for by this standard, but the energy used followed the standard very closely.

Groups 1 and 11 received practically the same amount of mineral matter while Group 111 received slightly more than 25 per cent as much as Group 1 or 11. Possibly this small amount of mineral matter had some bearing on the results obtained regarding this group, but in all probability, it is not noticed in so brief a period.

The various groups showed some difference in growth in height at withers, particularly in Groups 11 and 111. Group 1 gained but 0.6 centimeters more than normal, while Group 11 gained 2.5 centimeters more than normal, and Group 111, which were underfed, averaged 1.8 centimeters below normal.

Underfeeding to the extent of limiting gains to but one-fourth pound per day should not be practiced for periods more than the winter months apparently. However, definite data on this is not available.

Judging from the results by Waters⁴⁹ and Wylie²² it would seem safe to assume that when these heifers are placed on good pasture during the summer, the slight retardation in growth which they have suffered will be successfully overcome.

To what extent underfeeding of the growing animal during the winter may be practiced without serious affect is yet to be determined.

Group 111 failed to consume large quantities of roughage apparently because of the lack of palatability of the ration, the bulk seemed to have little or no effect.

In comparing heavy with light grain rations when fed with alfalfa and silage, it seems that the heavy feeding is altogether too expensive. Other than expense, however, there is no objection, but an advantage in that the animals grow somewhat faster in weight and height and hence reach maturity at a slightly earlier age.

However, this advantage is more than offset by the difference in costs. It would seem, therefore, that heavy grain rations for growing dairy heifers has no particular advantage and is associated with unnecessary expense.

All things considered, a ration consisting of two pounds of corn and one pound of alfalfa per hundred pounds live weight and liberal amounts of silage will give better results than a ration with more grain.

Conclusions.

A ration consisting of alfalfa and silage, supplemented with two pounds of corn daily, produced gains fully normal in height and weight and kept the animal in a thrifty condition.

Heavy grain rations caused the animals to become exceptionally fat for dairy heifers, but the cost of the additional gains was abnormally high.

Although there is considerable variation with individuals, ordinarily heifers will make little or no gains in weight on a ration of timothy hay and silage. The limiting factors seem to be palatability and low protein supply.

Limiting the daily gains to one-fourth pound a day for six months causes a marked retardation in growth in weight but only a slight retardation in growth in height.

It remains to be determined if this retardation will be overcome by a liberal pasture ration.

The results of the four years work go to show that for conditions in the corn belt states a ration

consisting of alfalfa, or some other legume, and silage for roughage, with about two pounds of corn make an excellent and satisfactory ration both from the standpoint of efficiency and economy.

The efficiency of this ration is to be attributed to the fact that it supplies sufficient protein of good quality, the necessary vitamins and mineral matter, especially calcium, and in addition is succulent and highly palatable.

Its economy is due to the use of silage and corn which are usually our cheapest sources of energy.

FIGURE 1.

GROWTH AS REPRESENTED BY HEIGHT AT WITHERS
COMPARED WITH NORMAL.

— Actual Gain
— Normal Gain

GROUP 1.

The figure shows that the heifers in this group on a medium ration followed the curve of normal growth rather closely. (See Table 29)

FIGURE 2.

— Actual Gain.
— Normal "

GROWTH AS PRESENTED BY HEIGHT AT WITHERS
COMPARED WITH NORMAL.

Height in
centimeters.

GROUP 11.

The figure shows that this group of heifers on a heavy ration exceeds the normal rate of growth. (See Table 30)

FIGURE 3.

— Actual Gain.
— Normal "

GROWTH AS REPRESENTED BY HEIGHT AT WITHERS
COMPARED WITH NORMAL.

GROUP 111.

(continued next page.)

FIGURE 3 (cont)

— Actual Gain.
 — Normal "

GROWTH AS REPRESENTED BY HEIGHT AT WITHERS
 COMPARED WITH NORMAL.

Height in
 Centimeters.

GROUP 111.

The figure shows that underfeeding to the extent of restricting gains to one-fourth pound per day caused only a slight retardation, which, however, becomes rather marked after four months. See Table 31.

FIGURE 4.

— Actual Gain.
— Normal "

GROWTH AS REPRESENTED BY WEIGHT
COMPARED WITH NORMAL.

Weight in
Pounds.

GROUP 1.

The figure shows that all the heifers in this group, except the Jersey, slightly exceeds the normal rate of growth in weight. (See Table 29)

FIGURE 5.

— Actual Gain.
— Normal "

GROWTH AS REPRESENTED BY WEIGHT
COMPARED WITH NORMAL.

The figure shows that all the heifers in this group, except the Jersey, made much greater gains in weight than normal.

(See Table 30)

FIGURE 6.

— Actual Gain.
— Normal "

Weight in Pounds.
GROWTH AS REPRESENTED BY WEIGHT
COMPARED WITH NORMAL.

GROUP 111.

The figure shows that all the heifers in this group failed to make normal growth. It is seen that they suffered greater loss in weight than in height. (See Figure 3 and Table 31)

FIGURE 7.

This figure represents relative gains made by the three groups for six months. It is noticed that Group 11, on heavy rations, gained most rapidly, while Group 111, on light rations, were slightly retarded. (See Tables 29 to 33.)

FIGURE 8.

RELATIVE GROWTH IN WEIGHT.

Group 1
Group 11
Group 111

Weight in
Pounds.

This figure represents gains made in weight by the three groups for six months. It is shown that Group 11 on heavy rations, gained most rapidly while Group 111 suffered pronounced retardation in growth in weight. Group 1 gained 1.09, Group 11 1.40, and Group 111, 0.35 pounds per day for the 180 days.

FIGURE 9.

RELATIVE AMOUNTS OF PROTEIN CONSUMED. — Group 1
 — Group 11
 — Group 111

Pounds of Protein.

This figure shows Group 11 to have received slightly more protein in its ration than Group 1, while Group 111 received very much less than either. See Tables 24 to 27.

FIGURE 10.

The figure shows that the difference in the energy intake by the various groups is not so pronounced as is the protein intake as shown in Figure 9. A comparison with Figures 8 and 9 shows the gains in weight to be more dependent on the amount of protein consumed than the energy consumed.

PLATE 1 a. No. 318 and No. 263 of Group 1.

At beginning of experiment.

November 1, 1916.

(continued)

PLATE 1 b. No. 262 and 113 of Group 1. AT Beginning of Experiment. Nov. 1, 1916.

MEDIUM RATION . Corn, two pounds each.
 Alfalfa, one pound per hundred pounds live weight.
 Silage, all they would eat.

Average weight of Group at beginning of experiment-- 467. pounds
 " height " " " " " " 109.3 centimeters.

PLATE 11 a. No. 320 and No. 264 of Group 11. experiment. Nov. 1, 1916.

At beginning of experiment.

November 1, 1916.

(continued)

104.6 centimeters.

PLATE 11 b. No. 258 and 117. At beginning of experiment. Nov. 1, 1916.

HEAVY RATION. Corn, one pound per hundred pounds live weight.

Alfalfa, one " " " " " "

Silage, all they would eat.

Average weight of group at beginning of experiment -- 439. pounds.

" height " " " " " " 104.6 centimeters.

PLATE 111 a. No. 322 and No. 260 of Group 111.

At beginning of Experiment.

November 1, 1916.

(continued)

PLATE 111 b. No. 265 and 116. At beginning of experiment. Nov. 1, 1916.

LIGHT RATION. Timothy, all they would eat.

Silage, all they would eat.

Corn, if necessary in order to make one-fourth pound gain per day.

Average weight at beginning of experiment.--	390.	pounds
" height " " " "	102.2	centimeters.

PLATE IV. Group 1. At end of experiment. March 30, 1917.

MEDIUM RATION. Corn, two pounds each.
 Alfalfa, one pound per hundred pounds live weight.
 Silage, all they would eat.

Av. Consumption.
 Corn, 2.0 Pounds.
 Alfalfa, 5.27 "
 Silage, 17.80 "

Average weight at end of experiment.-- 630 pounds.
 " height " " " " 117.1 centimeters.

Average gains per day for 150 days.-- 1.09 pounds.

PLATE V. Group 11. At end of experiment. March 30, 1917.

HEAVY RATION. Corn, one pound per hundred pounds live weight.
 Alfalfa, one " " " " "
 Silage, all they would eat.

Average Consumption.-
 Corn, *5.29 Pounds.*
 Alfalfa, *5.12* "
 Silage, *13.54* "

Average weight at end of experiment.-- *654.* pounds.
 " height " " " " *114.5* centimeters.

Average gain per day.-- 1.43 pounds.

PLATE VI. Group 111. At end of experiment. March 30, 1917. Average Consumption.-
 Timothy, 3.20 Pounds.
 LIGHT RATION. Timothy, all they would eat. Silage, 13.81 "
 Silage, all they would eat. Corn, 0.61 "
 Corn, if necessary in order to make one-fourth pound gain per day.

Average weight at end of experiment.-- 1145 pounds.
 " height " " " " 108.7 centimeters.

Average gain per day.-- 0.36 pounds.

PLATE VII.

March 30, 1917.

An Ayrshire from each group, at end of experiment.

No. 318--Group I--Medium Ration.
No. 320--Group II--Heavy Ration.
No. 322--Group III--Light Ration.

PLATE VIII.

March 30, 1917.

A Holstein from each group, at end of experiment.

No. 263--Group I---Medium Ration.
No. 264--Group II--Heavy Ration.
No. 265--Group III--Light Ration.

PLATE IX.

March 30, 1917.

A Jersey from each Group, at end of experiment.

No. 113--Group 1---Medium Ration.

No. 117--Group 11--Heavy Ration.

No. 116--Group 111-Light Ration.

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