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WINTER RATIONS FOR DAIRY HEIFERS

by

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WINTER RATIONS FOR DAIRY HEIFERS.

INTRODUCTION.

In 1890 there were slightly less than 16,000,000 dairy cows in the United States and a trifle less than 63,000,000 people. In 1918 the number of dairy cows has increased to 23,284,000, but the human population has exceeded 101,000,000. In order to maintain the same number of cows per 1,000 population, there should now be 25,600,000 cows. These figures indicate that there is a shortage of about 2,600,000 dairy cows. This does not take into consideration the increased efficiency of cows in milk production, but there is no reason to believe that this increased efficiency will make up for so large a decrease in the proportion of dairy cows. Then too, there has been an increase in the consumption of milk and dairy products per capita since 1890, to say nothing of the large increase in exports.

The number of dairy cows that have been slaughtered in Europe since the war began is not definitely known but it is certain that the reduction in numbers has been very great. One evidence of this is the increased export trade of the United States in butter, cheese and condensed milk.

Before the war our exports of butter averaged about 4,000,000 pounds annually and our imports were only 1,000,000 pounds less than our exports. In 1916 our exports were over 13,000,000 pounds and for 1917 they were nearly 27,000,000 pounds. The increase in the exports of cheese and condensed milk during that time has been even greater.

Until at least the end of the war, and probably for several years afterwards, dairy products will be in enormous demand for export, and dairy cows will be required in almost unlimited numbers to restock the farms of Europe. If these needs are supplied, more dairy heifers should be raised, and the only logical place to raise them is on the dairy farms of this country.

Investigations indicate that it costs approximately \$75 to raise a dairy heifer to the age of two years. Under present conditions of high priced feed, this figure will more nearly equal \$100. Of

the total cost of raising, about 70 per cent is for feed, the most of which is fed during the winter months while the heifers are not on pasture. This makes the problem of winter feeding the most important item in the cost of raising dairy heifers.

However, the problem involves not only the cost but is also concerned with the important question of the effect of different planes of nutrition and the character of the ration on the growth and dairy qualities of the animals raised.

Comparatively little experimental data are as yet available concerning these problems of raising heifers. The purpose of the author in conducting the experiments reported in this thesis was to add to the data now available regarding the wintering of heifers, by testing the suitability of certain rations for this purpose.

REVIEW AND DISCUSSION OF LITERATURE.

In reviewing the literature relating to this subject, one is struck by the absence of definite knowledge as gained by investigational work. The greater portion of such experimental work as is reported on wintering heifers, was done with animals of the beef breeds. The results of such work may be applied, with some limitations, to dairy animals. Extensive investigations have been made relative to raising the dairy calf up to the time of weaning, but the feeding of heifers, from the time of weaning to the time of first calving, has not received much attention. The subject has been covered by different writers and rations have been suggested. The basis of such recommendations has been the observations of practical men and to only a limited extent have these observations been checked up in an experimental way.

FEEDING STANDARDS. There are three well-known feeding standards designed to set forth the feed requirements of growing cattle. The Wolff-Lehmann,⁽¹⁾ the Kellner,⁽²⁾ and the Armsby⁽³⁾ standards

are given in the following tables:

Table 1.

Wolff-Lehmann Standard for Growing Dairy Cattle

		Per Day Per 1000 Lbs. Live Weight				
Age in: Average :		Digestible Nutrients				
Months:	Live Wt.:	Dry	Crude	Carbo-		
	Per Head:	Matter	Protein	hydrates		Fats
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.
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 2.

The Kellner Standard for Growing Dairy Cattle.

		Per Day Per 1000 Lbs. Live Weight					
Age in: Live Wt.:		Digestible Nutrients					
Months: Per		Dry		Starch		Crude	
: Head		Matter		Protein		Protein	
: 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	

Table 3.

The Armsby Standard for Growing Dairy Cattle.

Beef Breeds				Dairy Breeds			
: Live		: Digestible		: Live		: Digest-	
: Weight		: Protein		: Weight		: ible	
Months:		: Value:		: Protein:		: Value	
: Lbs.		: Lbs.		: Lbs.		: Lbs.	
		: 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	

The Wolff-Lehmann standard gives the dry matter and digestible nutrients required per 1000 pounds live weight for animals weighing 150, 300, 500, 700 and 900 pounds respectively. The amount of dry matter is increased with the weight until 700 pounds is reached. While the digestible nutrients are decreased as the live weight increases, the digestible protein is decreased faster than the digestible carbohydrates. This results in a widening of the nutritive ratio as the animal grows older and increases in weight. This is in keeping with the general belief that young animals require more protein per unit of weight than mature animals.

Kellner based his feeding standard on what he called starch values. He assumed that to determine the true, net value of any feeding stuff, it was necessary to subtract the energy that was used in the various processes concerned with the digestion and assimilation of this feed from the total available energy furnished by the nutrients in the particular feed. By means of experiments with respiratory apparatus⁽⁴⁾ he found that one pound of digestible starch above maintenance would produce 0.248 pounds of body fat in the ox. Using one pound of digestible

starch as a unit, he computed the value of other feeds as compared with starch. This standard is not in general use in this country.

In the same general way, Armsby based his standard upon the digestible protein and net energy value of the feeds, representing the calorie value of the ration in "therms". A "therm" is 1000 calories.

The greatest variation noted in these standards is that of the protein requirements. Armsby bases the protein requirement on digestible true protein, while the Wolff-Lehmann and Kellner standards make use of the digestible crude protein. By true protein is meant amid-free protein. Some difference of opinion exists as to the real value of amid nitrogen for maintenance, growth or milk production. Experiments at the Wisconsin⁽⁵⁾ Station on dairy heifers and cows tend to show that the so-called amides of alfalfa hay and corn are of value, at least for growth of the animal. Armsby⁽³⁾ until recently, excluded it entirely from his calculations, but on the other hand, Henry and Morrison⁽⁶⁾ and Jordan⁽⁷⁾ give it full value in their tables on the composition of feeds.

USES OF FOOD. The uses to which a growing heifer may put its feed are as follows:-

1. Maintenance

2. Growth

3. Fattening.

The last use, fattening, is of minor importance in a study of growing heifers because that is a condition which practical dairymen try to avoid. This factor will not be considered except as it is related to growth.

Maintenance. By a maintenance ration is meant the amount of food which is required to maintain the animal at uniform weight and without using any feed in a productive way, such as for milk production or for gain in weight. Growth is necessarily eliminated. Maintenance is sometimes used in another sense to mean the total amount of food required, for example, by a horse to perform daily work or for a pig or calf to make normal growth. Its exact meaning is the minimum amount of food required to sustain life, and this meaning will be adhered to in this thesis.

Investigations show that at least one-half of all feed consumed by animals is used simply for maintaining the animal. Henry and Morrison⁽⁸⁾ state that to maintain an animal at rest the ration must supply

(a) fuel to maintain body temperature, (b) energy to carry on vital processes as the work of the lungs, heart, etc., (c) protein to repair the daily waste of nitrogenous tissue, and (d) mineral matter to replace the small but continuous loss of these materials from the body. Generally speaking, the first two factors are dependent to a considerable extent upon weather conditions and the temperament of the animal.

It is a well known fact that the maintenance requirements of cattle are higher in the winter than at any other season of the year. This is directly related to the housing of cattle from cold winds, snows and other forms of exposure. The Missouri Station,⁽⁹⁾ in conducting an experiment with beef steers relative to the maintenance requirements found that the cost of maintenance was least in the spring and greatest in the winter. During the other seasons it was intermediate. They also concluded that the cost of maintenance is high after a previous full fed period and the higher the previous plane of nutrition the greater this increase in cost. While condition alone had no effect, poor thrift and high cost seem to go together, while the cost decreases with increasing age.

In general, the nervous, restless animal will have a higher maintenance requirement than a quiet one. This is because of the fact that more energy is expended in muscular activity, resulting in more body fuel being used up. The Missouri Station⁽⁹⁾ found this to be true with beef cattle.

The maintenance requirements are, of course, greater for large animals than for small animals. However, Armsby⁽¹⁰⁾ has shown that the loss of heat and energy from the body is not proportional to size or weight of the animal but to the body surface exposed. From these results it is evident that a large animal requires somewhat less food for maintenance in proportion to its weight than does a smaller animal. Armsby⁽³⁾ gives the maintenance requirement of cattle as follows:

Table 4.

Maintenance Requirements of Cattle
Per Day and Head.

Live	:	Digestible	:	Net
Weight	:	Protein	:	Energy
Lbs.	:	Lbs.	:	Value
				Therms
150	:	0.15	:	1.7
250	:	0.20	:	2.4
500	:	0.30	:	3.8
750	:	0.40	:	4.95
1000	:	0.50	:	6.00
1250	:	0.60	:	7.00
1500	:	0.65	:	7.90

The protein and mineral requirements for maintenance will be discussed under the chapter on growth as will also the additional requirements of vitamins and growth accessories, which recent investigations have shown to be so essential.

Growth,- General Discussion. A discussion of rations for growing animals relates to a large extent to the use of food for constructive purposes. As the body of a young animal develops, its tissues

increase rapidly in protein and mineral matter. The skin, tendons, ligaments, muscles and internal organs are largely protein, together with the nervous system and the inner portion of the bones. During growth, all of these tissues and organs increase rapidly in size, while a great deal of the mineral matter is used in building the skeleton. Little growth occurs after maturity is reached, either ⁱⁿ/skeleton or organs. It is seen then, that growth requirements differ widely from maintenance requirements.

Measurements of Growth. Swett⁽¹¹⁾ states, "for satisfactory measurements of growth, at least two things must be considered - weight and skeletal measurements." He showed that for dairy animals not under extremely abnormal conditions, the height of withers can be used as a fairly accurate index of skeletal growth. Weight is not a satisfactory index of the growth of an animal because of the extreme fluctuations to which it is subject. Investigations show that the most satisfactory and accurate method of measuring the growth of dairy heifers is the height at withers and the weight.

Normal Growth. While much work has been done on determining the normal growth of many species of

animals, the most satisfactory figures for dairy cattle are those calculated by Burlingham and Gillette⁽¹²⁾ which are given in Table 5. These figures represent the calculations of standard growth for about 300 dairy heifers from birth to twenty-four months of age. It can be seen, that the Jersey attains approximately four-fifths, the Ayrshire three-fourths, and the Holstein two-thirds of total gain in height during the first year. Of the total weight at two years of age, the Jerseys made two-thirds and the Holsteins and Ayrshires approximately one-half the first year. The average daily gain in weight during the second year is $\frac{1.1 \text{ pounds}}{.6 \text{ pounds}}$ and .7 pounds for the Jerseys, Holsteins and Ayrshires respectively.

Table 5.

Standard Growth.

Age in: Months	Ayrshires			Jerseys			Holsteins	
	Withers:	Weight:		Withers:	Weight:		Withers:	Weight
	: Cent.	: Lbs.		: Cent.	: Lbs.		: Cent.	: Lbs.
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	:	96.3	: 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

Hunziker⁽¹³⁾ believes that a ration to be considered an unqualified success for dairy calves, should produce at least one pound of gain per day as an average for the first six months of the life of the calf. As the calves advance in age, the relation between their height and weight gradually changes. At thirty days of age, they should weigh approximately three pounds for each inch in height. This figure gradually increases until at six months of age, the calf should weigh approximately six and one-half pounds for each inch in height.

Brandt⁽¹⁴⁾ states that, "The average growth per diem by dairy cattle as measured by gain in weight is greater the first six month period of their lives and gradually decreases thereafter. Holstein cattle make greater gains per diem up to two years of age than do Jersey cattle."

Hulce and Nevins⁽¹⁵⁾ report that a growing dairy heifer should gain at least a pound a day during the first three months and should average slightly more than this from birth to one year. They give the following set of figures on three groups of heifers:

	Holstein	Holstein	Jersey
Weight at birth	92 lbs.	82 lbs.	56 lbs.
Weight at 1 year	532 "	564 "	472 "
Average daily gain	1.2 "	1.3 "	1.1 "

A comparison of the birth weight and daily gains of the two groups of Holstein calves, seems to indicate some relation between the birth weight and the rate of gain. On the other hand, Swett⁽¹¹⁾ is of the opinion that the birth weight of a calf seems to bear no direct relation to the rate of growth.

Growth Under Unfavorable Conditions. Results of investigations have been presented showing to what size or stature a dairy heifer should be at various ages. This work is based necessarily on favorable or at least normal conditions. The idea must not be gotten, however, that a dairy heifer, to be of normal stature at maturity, must grow steadily from birth, although there is a tendency for this to take place, even when conditions are unfavorable to a limited extent. This is of practical importance since, under practical conditions, at times feed is high or pastures are short, and it is almost impossible to supply growing heifers the amount of certain kinds of feed they should have. This is especially applicable to wintering

heifers, where the problem is to carry them through the winter with the least possible expense without injuring their future usefulness.

Our knowledge concerning the capacity of cattle to grow under adverse conditions is based mostly upon the work of Waters. He states⁽¹⁶⁾ "Some of our approved theories have been so extreme as to hold, in effect, that the animal must grow at its maximum rate practically every day from birth to complete maturity in order to reach its normal size or the full stature fixed by heredity-----. This assumes that the organism is utterly incapable of compensating for any retarded development at any time in its growth period, either by a subsequently increased rate of growth, or by extending, even in the slightest degree, the growth cycle, much less by growing for a time at least when so sparsely fed that no gain in weight occurs." He showed that steers would increase in height at withers on maintenance and while starving. In conclusion, he gives the following recourses for attaining normal size to which an animal may use:

1. By growing steadily from birth to maturity, as with a uniform and ample food supply.
 2. By storing fat in a period of abundant food
-

supply to assist in tiding over a limited period of sparse food supply without serious interruption of growth.

3. By prolonging somewhat the growth period.

4. By an increase in the rate of growth in a period of liberal feeding following a period of low nourishment and low gain. In other words, an animal that is below normal in size at a given age, through poor nourishment, apparently has the capacity, when liberally fed, to compensate for their loss in a measure at least, by an increased rate of gain.

5. By conserving the cost. Apparently the animal, when kept for a long period of time on a low nutritive plane, gets on a more economical basis than when more liberally fed. Thus a ration that was insufficient to sustain live weight at first may be capable later of maintaining the animal at a stationary body weight, and still later of causing an increase in weight.

Eckles,⁽¹⁷⁾ in comparing light fed and heavy fed heifers in respect to influence of the ration fed upon the rate of growth, found that animals receiving the light ration grew less rapidly but growth continued longer. However, the light fed group never reached quite the size of those receiving the heavier

ration when young. He states further, "The difference between a heavy and light ration for growing heifers shows more strongly upon the weight than upon the rate of skeleton growth."

This capacity to grow under adverse conditions has also been found to be true on other species of animals. Mendel,⁽¹⁸⁾ in experiments with rats and mice is quoted as follows: "We have secured clear evidence that the growth of rats and mice may be suppressed or held in abeyance for very long periods, even beyond the age at which any marked increment of size ordinarily occurs, without loss of the capacity of subsequent growth under appropriate conditions of diet."

CHARACTER OF RATION FOR GROWTH

Quality of the Proteins. Because of the scarcity and high price of proteins in animal feeds, it is of importance to know something of their nature and the process through which they go before being built into the tissues of the animal body or are eliminated as waste products through the urine.

At all times nitrogen is excreted from the animal body through the urine. In well fed animals this amount is comparatively large, depending largely upon the quantity of protein in the food. If the animal is being starved the excretion of nitrogen falls off rapidly at first until the supply of amino acids in the blood and tissues is lowered to the minimum. The nitrogen excretion in the urine then slowly decreases until it becomes constant, so long as heat and energy are furnished by the body fat. From this it can be seen that animals fed on a protein free ration cannot long survive. When only protein is fed to a fasting animal, in amounts equalling the quantity excreted during starvation, the amount excreted becomes greater, and, while the loss of nitrogen from the muscles and tissues is reduced, an equilibrium or balance is not reached. However, the protein given in the feed is not lost. It may be used as body fuel, thus saving the body fat; or the nitrogen may be split off from the molecules of protein or amino-acids and the non-nitrogenous material may be converted into glucose and later into glycogen or fat.

The question as to whether the function of protein in the body can be replaced by amides has been discussed under feeding standards.^{(1) (2) (3)} These feeding standards recommend certain amounts of digestible ^{and digestible crude} true/protein but do not take into consideration the quality or source of some of these proteins.

Investigations in recent years have shown that some of the proteins are well-balanced, containing adequate amounts of all the amino-acids needed by the animal for growth and maintenance. Others, as the principal ones of wheat, contain as much as forty percent of a single amino-acid, and only small amounts of some of the rest.

The most extensive investigations relative to the nutritive value of amino-acids to the animal, have been conducted by Osborne, Mendel, McCollum, Davis and others, and their results contain much valuable and enlightening information. Their method consists essentially in the feeding of isolated and purified proteins obtained from various sources, with basal rations which are otherwise adequate for maintenance or growth and of known composition. By this method it has been demonstrated that different proteins have different values in nutrition, and these differences

have been clearly shown to be due to variations in amino-acid content. The animals used in these experiments were rats and mice. Whether the data accumulating on the efficiency of proteins for growth with these animals will agree with those secured with dairy farm animals is problematic.

Of the results obtained by Osborne and Mendel, the most importance is attached to the demonstration that lysine is essential for growth.⁽¹⁹⁾ Gliadin, an alcohol-soluble protein of wheat, when fed to rats as the only protein, was capable of maintaining the animals for long periods at constant weight. Normal growth did not take place and, as a rule, only maintenance was secured. Upon the addition of lysine to the ration, normal growth was secured.

Zein, the alcohol-soluble protein of the corn kernel was likewise shown to be unable to support either growth⁽²⁰⁾ or maintenance.⁽²¹⁾ Analysis showed that this protein lacked the amino-acids glycocoll, tryptophane and lysine. The addition of tryptophane to the protein rendered it sufficient for long continued maintenance, while the addition of

lysine rendered it sufficient for fairly normal growth.⁽²²⁾ However, to obtain normal growth, it was shown that arginine, present only in small amounts in the zein, must be added.⁽²³⁾

Quite recently, Hogan⁽²⁴⁾ showed conclusively that lysine is indispensable for maintenance of young rats.

At the Kentucky station⁽²⁵⁾ it was likewise shown that lysine was the limiting factor in preventing growth of young chickens. Two lots of young chickens were fed, one lot on a grain ration containing lysine, the other lot a similar ration except that lysine was not included. Striking contrasts were gotten both in size and weight of the two groups.

McCollum, Simmonds and other⁽²⁶⁾ believe that the proteins of the maize kernel contain all the amino-acids essential for growth but that the proportions of some of them are such that they are not utilized to a high degree as the only source of protein. Quoting directly from them, they state, "When other factors affecting nutrition were properly adjusted, we have seen growth at about two-thirds the normal rate over a period of six or seven months on a diet in which all the protein was derived from 91

percent of ground maize in the ration." They later found that zein does not supplement the protein mixture in the wheat kernel or maize kernel so as to improve the rate of growth of young rats, but that it does supplement the proteins of the oat kernel in an efficient manner.⁽²⁷⁾ This is true regardless of the fact that zein lacks tryptophane and lysine and is one of the poorest proteins in cystine. It would seem to indicate that the proteins of the oat kernel are not lacking in these amino-acids, especially cystine.

In experiments relative to cystine, it was found⁽²⁸⁾ in quantitatively comparing casein, lactalbumin and edestin for growth on young rats, that to produce the same gain in body weight, 50 percent more casein than lactalbumin was required and 90 percent more of edestin. However, upon adding cystine to a casein ration, the cystine rendered the casein so much more efficient that on the average, 18 percent less protein produced 12.5 percent more growth. The replacement of cystine by alanine failed to give any nutritive advantage.

McCollum,⁽²⁹⁾ in working with hogs, found that the proteins of milk are superior to any other

proteins so far as growth is concerned, the pigs storing in their bodies over 60 percent of the milk proteins. Proteins of the cereal grains had an efficiency of only 23 to 28 percent, and of linseed meal, fed alone, only 18 percent. However, when three-fourths of the protein in the ration came from the corn and one-fourth from linseed meal, the efficiency was raised to 37 percent. From this it may be concluded 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. This is in accordance with results secured in many trials and in practice when linseed meal is fed as a supplement to corn for hogs. On the other hand, no better results were gotten when wheat and wheat embryo were combined than when each was fed separately. In this case, each feed is evidently deficient in the same amino-acids and they cannot supplement each other. This seems logical when we consider that the two feeds are derived from the same plant.

Hart and Humphrey, in 1915⁽³⁰⁾ and 1916,⁽³¹⁾ found in metabolism experiments with dairy cows that proteins from various sources are likewise of different worth for milk production. In these trials cows

were fed basal rations composed for the most part of the corn plant and which supplied but a small amount of digestible protein. To these rations various concentrates from the corn and wheat plants were added. In 1917⁽³²⁾ when clover hay was added to the basal ration, much higher efficiency as regards milk production was gotten.

While this experiment was conducted on mature, milk producing cows, there is no reason to believe that the results are not applicable to growing heifers receiving the same kind of feed. Indeed, there is evidence supporting the belief that with growing animals the results would be more striking. Osborne and Mendel⁽²³⁾ state in this connection, "When growth is not involved, the requirement of protein is smaller. In consequence, inequalities between the different proteins are likely to manifest themselves less conspicuously than when continued increments of body weight augment the demand for nitrogenous food-stuffs."

It is not definitely known just how far animals have the power of making amino-acids. Mathews⁽³³⁾ believes that glycocoll or glycine as it is now commonly called, can be synthesized in the animal body.

These experiments on the influence of isolated proteins with additions of certain amino-acids show that amino-acids like tryptophane, lysine, cystine and others are essential components of a complete ration. In experiments with growing animals it is necessary that the proteins in the diet should yield all the necessary amino-acids in adequate amounts. Individual proteins differ greatly in the amounts of the different amino-acids, in some, certain of them are entirely absent. The short-comings of one protein can be made good by supplementing it with another protein in which they do not exist to the same degree.

These investigations raise new problems relative to the economy of feeding. For example, corn generally forms the cheapest source of food for dairy animals. As the rate of growth is limited to a large extent by heredity⁽³⁴⁾ and not by nutritive conditions, it is not economy to furnish more protein and energy than is necessary for normal development. An incomplete but cheap protein can be supplemented by one which supplies the needed amino-acids.

Vitamines or Growth Accessories and Toxic Substances. Recent investigations have shown that

substances called vitamins or growth accessories are of equal importance with the quality of the proteins in promoting growth and maintenance in young animals. These substances are as yet unidentified dietary factors of which our knowledge is limited.⁽³⁵⁾ McCollum and his associates^{(36) (37)} classify them into two groups, namely fat soluble A and water soluble B and call them growth accessories. Others speak of them as vitamins.

The fat soluble A is soluble in fats and oils but is not extracted from foods by ether. Some of the sources of this unknown essential in human foods are milk and dairy products, eggs and meat, while the leaves of plants is the most abundant source in animal foods. The cereal grains probably all contain less of this fat-soluble A than milk and eggs and it is lacking in all extracted plant oils and fats such as olive, corn, wheat, soy bean and linseed oil.

The other class of diet necessities, water-soluble B, is soluble in water. It has been found that this substance is widely distributed in the vegetable foodstuffs as well as in meat, eggs and milk,

but it is not present in starch, sugar, plant fats and polished rice.

It has been known for a long time that the human disease called beri-beri, so common in oriental countries, is caused by a diet made up largely of polished rice. It was a matter of further knowledge that this condition could be cured by the addition of some rice polishings to the ration. Eijkman⁽³⁸⁾ discovered that the same disease which he called polyneuritis, could be produced in birds by the same means and could likewise be corrected by feeding rice polishings.

Funk⁽³⁵⁾ believes that beri-beri or polyneuritis has not been produced in any animals except man and birds and that only those animals in which the end product of metabolism is uric acid are affected by the disease.

In a comparison of three balanced rations restricted to the corn, wheat and oat plant respectively, Hart and others⁽³⁹⁾ found that the ration derived entirely from the wheat plant was markedly deficient for heifers. When the heifers fed this ration calved, the calves were either born dead or were very weak and undersized. This was not the case in the

other two rations composed of the corn and oat plant respectively, as the heifers fed these rations were strong and produced normal calves. However, the corn fed heifers were better in this respect. They ascribed the bad effects to be due to a toxic substance found in the wheat.

Later, Hart and others⁽⁴⁰⁾ found that swine were also susceptible to the effects of this toxic substance. When alfalfa hay constituted 20 to 25 percent of the ration and middlings 20 percent "the toxicity of the middlings was overcome, the inadequacy of the grains disappeared and the animals remained strong and vigorous."

While they are no doubt correct in ascribing these ill-effects to some toxic substance found in the wheat, it is possible, in view of later experiments, that the wheat lacks either the fat-soluble A or the water-soluble B or contains them in insufficient amounts. This belief is justified on the grounds that McCollum⁽⁴¹⁾ and his co-workers later fed proteins of the wheat kernel to rats and got the same general results, that is, they failed to raise young rats on this diet. In this case they attributed the failure

to a lack of water-soluble B in the wheat. Previous to this work they showed⁽⁴²⁾ that the wheat embryo contains both fat-soluble A and water-soluble B, the former present only in moderate amounts but the latter present in high concentration. It is a cause for regret that we know so little of the chemical nature of this toxic substance. It has not yet been determined whether the toxicity is due to some peculiarities in the chemical nature of the fats themselves (this substance is found in the fat extraction) or to something which is associated with the fats.

McCollum and Davis fed mixtures of casein,⁽⁴³⁾ a complete protein, together with carbohydrates and mineral matter to young rats. Normal growth was gotten for three or four months but then ceased. The addition of butterfat,⁽⁴⁴⁾ egg-yolk fat, kidney-fat, fat from corn or fat from the wheat germ, caused normal growth. However, the addition of lard, cottonseed oil or olive oil⁽⁴⁵⁾ did not increase the value of the basal ration of casein. Previously, Osborne and Mendel⁽⁴⁶⁾ demonstrated that cod-liver oil and oils of beef fat, added to this basal ration, produced normal growth, but were not as efficient for this purpose as was butterfat, because larger amounts were required for growth.

It has likewise been found that the maize kernel contains both fat-soluble A and water-soluble B, but the former is present in too small quantities for the maintenance of growth.⁽⁴⁷⁾ "Regardless of how satisfactory the maize kernel is supplemented in other respects, failure of perfect nutrition will supervene within a few months unless some foodstuff containing the fat-soluble A is supplied."

In summing up the work with rats in this connection, it is seen that when they are fed diets satisfactory in every way except for the absence of the factors fat-soluble A or water-soluble B, a gain in weight may take place for a period of two or three weeks. After this time there is no further increase but is followed by a rapid loss. Death follows in variable time unless these essentials are added. When the diet lacks water-soluble B but contains all other constituents, typical beri-beri results. There is loss in weight, lack of muscular control, especially in the hind limbs, and death occurs within a few hours unless the water-soluble B is supplied. Animals fed a diet properly constituted in every way except it is lacking in the fat-soluble A, may increase in weight during the first two weeks, at the end of which time

they begin to gradually fall off, become emaciated and suffer from edema of the eyelids. In both cases, recovery is quick upon the addition of the missing constituent of the diet.

Funk⁽³⁵⁾ extended these studies to chickens and found that practically all preparations that stimulated growth in rats failed to do so in young chickens. It will be of great importance when these experiments are extended to our important farm animals. At any rate, it is clear that the ration, in relation to growth, may conform to the best feeding standards in regard to its protein and energy content and in variety, and still be of such nature as to fail to nourish the animal properly. Such is generally the case when a single variety of seeds or feed from a single variety of plants make up the ration.

Mineral Matter. The importance of mineral elements in the food of growing animals is nearly always underestimated. This is largely because of the fact that they are present in such small quantities both in the feeds and in the animal body. Then too, the common belief that all animals, which receive leafy forage as the greater part of their

ration, consume and digest an abundance of mineral matter is shown not to be true by Forbes and others,⁽⁴⁸⁾ in relation to cows during liberal milk production. With rations of common farm feeds, chosen especially to provide maximum supplies of mineral nutrients, all calcium, magnesium and potassium balances were negative. From these results then, the question presents itself as to when does the cow make good these losses of minerals which take place during lactation. Obviously, she must either store them up in her body while growing or at a time when she is not producing milk.

The mineral elements are absolutely essential in the animal body. This is shown by the fact that by feeding rations free from mineral matter, animals die of mineral starvation. In fact, they perish sooner than if no feed at all is given.⁽⁴⁹⁾ The mineral elements control all the life processes. They are electrolytically active when in solution in the cell and are thus able to conduct charges of electricity through the body. This may be the true explanation of the growth of protoplasm. They are present in the bones, in all the tissues, in the blood and in all the liquids of the body.

The following table⁽⁵⁰⁾ shows the mineral elements present in some of our common cattle feeds:

Table 6.

Mineral Elements in Some Common Cattle Feeds.

	Parts in 1000, dry matter basis							
	Ash	K	Na	Ca	Mg	Fe	P	S
Blue Grass	:51.8:	18.14:	--	: 1.78:	1.01:	--	:2.24:	0.99
Timothy	:68.2:	19.64:	0.93:	3.98:	1.33:	0.40:	3.52:	.78
Red clover	:68.6:	18.38:	1.00:	17.12:	4.52:	.52:	2.89:	.89
Alfalfa	:73.8:	14.43:	.96:	24.46:	2.19:	.96:	2.74:	1.70
Bran	:61.6:	14.58:	.30:	1.27:	6.62:	.25:	1.35:	.02
Oats	:31.2:	4.64:	.39:	.80:	1.35:	.26:	3.49:	.22
Corn	:14.5:	3.59:	.12:	.23:	1.36:	.08:	2.87:	.04
Corn stover	:53.3:	16.06:	.47:	4.12:	1.84:	.86:	1.93:	1.13
Oil meal	:58.4:	11.79:	.63:	3.51:	5.58:	1.06:	8.06:	.76
Cottonseed meal	:74.8:	18.47:	--	: 2.36:	6.86:	.67:	15.01:	.37
Soy beans	:31.4:	11.62:	.23:	1.19:	1.69:	--	:5.03:	.34

We can see from this table that the grains are low in calcium whereas the leafy legumes have an unusually high amount, as have linseed oil meal and

cottonseed oil meal. The grasses and legumes contain only meagre amounts of phosphorus. Potassium is contained abundantly in all the feeds and never enters into practical feeding. The same can be said of the other minerals except calcium and phosphorus. Although highly necessary and not abundantly supplied, sodium is readily available and is commonly fed as ordinary salt.

The question of mineral nutrients for dairy heifers, limits itself then, to the consideration of calcium and phosphorus. Forbes and others⁽⁵¹⁾ point out that an insufficient supply of these elements in the ration results in malnutrition of the bones, especially in regions of infertile, sandy soils or where pastures are overstocked.

The work of the Wisconsin station⁽⁵²⁾ indicates that grains are deficient in calcium but rich in phosphorus: "Rations made up wholly of grains will supply to the growing animal an amount of calcium dangerously near a critical level of intake."

In experiments with hogs, Hart and McCollum⁽⁵³⁾ fed a ration consisting of the corn kernel 70 per cent and gluten feed 30 percent, supplemented with adequate inorganic salts, when distilled water only

was supplied. Without this addition of salt, early cessation of growth, loss of appetite, stiffness of joints, and roughness of coat resulted.

(54)

In another experiment two cows were fed, one a ration consisting of a mixture of corn grain and wheat straw supplemented with a salt mixture. To the other cow a similar ration was fed without the salt supplement. The effects of these two rations were somewhat noticeable in the appearance of the mothers, but to a more marked degree in their offspring. The cow receiving the salt mixture produced a normal, vigorous calf. The cow that did not receive the salt mixture did not produce a living calf.

Ordinarily, heifers fed a sufficient quantity of roughage will have enough mineral matter in the ration, but if the season is dry or for any other reason the feed is deficient in minerals, lime and phosphorus should be added to the ration.

Age as a Factor in the Utilization of Food.

Investigations show conclusively that young animals utilize their food to better advantage than do mature animals. Henry and Morrison⁽⁵⁵⁾ state that, "The gains made by well-nourished^{young} animals are relatively

much greater and more economical, based on weight and food consumed, than those of mature animals, even when fattening." They attribute the more rapid increase to several factors, viz., the flesh contains more water, the food is more digestible and concentrated, and more food is consumed in proportion to weight.

In this connection, Armsby⁽⁵⁶⁾ has compiled the following table which shows the gain of protein contained largely in the muscles by a growing ox at various ages, and which would seem to indicate that as maturity is approached, the quantity of protein built up in the body diminishes:

Table 7.

Gain in Protein by a Growing Ox at
Various Ages.

Average age: of animal in days		:	:Daily Gain of Protein to Body :Per 1000 lbs. :Computed on :live weight in :total protein in : Pounds :body - percent	
8	: Soxhlet :	:	3.994	: 2.347
15	: Soxhlet :	:	3.552	: 2.076
32	: Soxhlet :	:	2.755	: 1.693
50	: Neumann :	:	1.844	: 1.082
100	: De Vries:	:	1.892	: 0.711
840	: Jordan :	:	0.089	: 0.064

Proportion of Concentrates to Roughage. As has been shown in regard to some other qualities of a ration, the various feeding standards, also fall short in recommending the proportion of concentrates in a ration. They give a figure for total dry matter but that is as far as they go in this connection. As a ruminants stomach is well adapted to the handling of large quantities of roughage, it is the common practise to give heifers large quantities in their ration.

There are many instances in which young cattle have been raised on roughage alone, however, the general conclusion of most investigators is that they should have some grain in their ration. On the other hand, there are records of attempting to raise cattle on concentrates alone.

Sanborn⁽⁵⁷⁾ reports the feeding of a bull calf weighing 600 pounds for thirty-seven days without other food than bran and oats. The bull gained in weight during the trial and seemed healthy and in good spirits. In another trial of the same nature, the calf, in its craving for coarse food, ate the saw-dust used for bedding which resulted in its death.

Davenport⁽⁵⁸⁾ fed calves from birth, some on rations containing no roughage. In one case a calf was fed on milk until its desire for coarse feed was noticed, at which time all bedding was removed and shavings were substituted. The calf ate the shavings, dirt and bits of lumber, and at one time consumed as much as a half bushel of oats daily. When four months old, its joints and legs became swollen and stiff and it walked with a staggering gait. At five months of age there seemed to be a

disturbance in the nerve centers. The calf was killed and on post mortem, nothing peculiar was revealed in regard to its internal organs.

In the light of later investigations,⁽⁴⁰⁾ it is probable that this ration lacked one of the dietary accessories which are found in roughage, or the ill-effects may have been due to some toxic substance.

At the Nebraska station⁽⁵⁹⁾ two lots of Angus steers were fed, one receiving nothing but alfalfa and prairie hay, while the other lot received in addition four pounds of grain per day. The results are summarized as follows:

	:	:	:	:	Prai-:	:	Av.:	Av.:	Av.
	:	No.:	:	Alfal-:	rie:	:	Last:	First:	:
Lot	:	in	:	Time: fa hay:	Hay:	Grain:	Weight:	Weight:	Gain
	:	Lot	:	Days:	Lbs.:	Lbs.:	Lbs.:	Lbs.:	Lbs.
1	:	6	:	91	:	1237	:	250	:
	:		:		:	---	:	592	:
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Lot 1 required 14.87 pounds of hay for each pound of gain but made a gain of 1.1 pounds in weight daily on hay alone. Lot 2 required 8.9 pounds of food to make 1 pound of gain in weight.

The following fall these steers were weighed again to determine their summer gains, and it was found that those in Lot 1 gained 288 pounds in a period of 192 days while those in Lot 2 had gained only 234 pounds.

In later investigations ⁽⁶⁰⁾ these results were further borne out and the authors concluded as follows: "Calves which have been full fed during the winter are certain to lose a part of their grain 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 vitality is not economical."

A great deal of importance is attached to the observations of these and other investigators, that light winter-fed animals make greater summer pasture gains than heavy winter-fed animals. This is especially important at the present time when concentrates are so high in price. It would seem more economical to winter heifers with little or no grain and allow them to make greater and cheaper gains on pasture the following summer to make up what they failed to gain in the winter. It has been shown elsewhere in this thesis that such a practice will

not alter the size of the animal to any noticeable degree.

Wyllie,⁽⁶¹⁾ in studying the following summer's growth of winter-fed heifers, found that those heifers which made the least gains during the winter made the greatest gains the following summer. The bad effects of the light winter rations on growth disappeared after the heifers had been on pasture for the summer.

Burnett and Smith⁽⁵⁹⁾ wintered two lots of calves, one lot on sorghum hay and the other on alfalfa hay. Those wintered on sorghum hay gained less than those wintered on alfalfa hay but the summer gains following the trial were great enough with those receiving the sorghum hay as to place them on even weights with the alfalfa fed calves in the fall.

At the New Mexico station⁽⁶²⁾⁽⁶³⁾ it was shown that steers suitable for local market purposes could be raised on alfalfa alone.

Russel and others⁽⁶⁴⁾ fed two lots each of nine dairy heifers for 98 days. One lot was fed a ration consisting of 8 pounds alfalfa hay, 20 pounds silage and 2.5 pounds of concentrates (a mixture of

1.75 pounds cornmeal, 0.5 pounds of wheat bran and .25 pounds gluten feed). The other lot was fed 7 pounds of oat straw and 26 pounds corn silage per head daily with 3 pounds of protein rich concentrate (1 pound of cottonseed meal, 1.5 pounds gluten feed and .5 pounds wheat bran). The heifers ate only 4.5 pounds of straw per head daily. Those fed alfalfa hay and silage for roughage gained .97 pounds per head daily. Those fed straw and silage gained .93 pounds per head daily and were judged to be in just as thrifty condition as were the others. The feed for the first lot cost 12.4 cents per head daily, while that of the second lot cost only 10.3 cents per head daily. The results indicate that straw may often be satisfactorily and economically fed with silage and protein rich concentrates.

At the Storrs (Conn.) station⁽⁶⁵⁾ a ration consisting of 6 pounds of hay, 18 pounds of silage and 2 pounds of grain was fed to yearling heifers. This ration proved to be fairly satisfactory for the smaller yearlings but did not produce enough growth on the larger ones. The grain ration was increased the following winter to 3 pounds with better results.

Allison⁽⁶⁶⁾ showed that fattening cattle which received silage as the only roughage do not do well for longer periods than 90 days.

Skinner and Cochel⁽⁶⁷⁾ found that the addition of corn silage to a ration of shelled corn, cottonseed meal and clover hay, resulted in a more rapid and cheaper gain. The corn silage had a beneficial effect in causing the cattle to shed their winter coat earlier than those receiving the same ration without the corn silage. The use of silage also caused a smaller consumption of grain.

McCandish⁽⁶⁸⁾ believes that alfalfa and clover hays are excellent roughages to feed to dairy heifers and silage is useful in limited amounts. He states, "Fifteen to 20 pounds of it may be fed per day to dairy heifers during the winter, and this, with 7 or 8 pounds of alfalfa or clover hay and 2 to 3 pounds of grain, makes a good ration."

Variety, Succulence, Palatability and
Bulkiness.

From what has been cited in regard to the quality of the proteins, the vitamins and the

mineral matter, it is evident that a ration must consist of a variety of feeds. This is more strikingly shown by the following table, which gives the percentages of different protein retained by pigs when fed alone and when mixed. (29)

Table 8.

Nitrogen Retained From Various
Feeding Stuffs by Hogs.

Source of Protein	: No. : of : Trials	: Proportion of : Nitrogen re- : tained - percent
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	: 39.0

The above table indicates that in some cases nothing is gained by a combination as when corn, wheat and oats were combined. But, when corn was fed with linseed meal, the retention of nitrogen was materially increased above the figure gotten when each was fed alone. Evidently, they are both not deficient in the same amino-acids and one will tend to correct the deficiencies of the other.

At the Georgia Station,⁽⁶⁹⁾ in experiments relative to the associative digestibility of corn silage, cottonseed meal and starch with yearling steers, it was found that while the addition of starch caused a depression in the digestibility of the several nutrients, this depression could be largely overcome by the addition of cottonseed meal.

A ration is succulent when it is pleasant to the taste and has a slight laxative or tonic effect upon the digestive system of the animal, as does grass, silage, roots, and green feeds of any sort. It stimulates the appetite and helps to keep the animal in a thrifty condition. Little difficulty is experienced from this source when the ration contains any of the above feeds.

Eckles⁽⁷⁰⁾ states, "Such feed has a value outside of the actual nutrients it contains, on account of the favorable effect upon the digestion of the animal."

A feed is said to be palatable when its flavor is pleasant. Feeds differ in this respect. Some seem unpalatable because the animal will not eat them. Upon being taught to eat such feeds, they very often become highly palatable.

Armsby⁽⁷¹⁾ states, "There is some proof that the amount of digestive juices excreted depends upon the palatability of the feed."

Palatability, no doubt, influences the amount of feed consumed by an animal.

Talbot⁽⁷²⁾ is of the opinion that palatability may be the limiting factor which controls the quantity of some common feeds consumed by dairy heifers. For instance, heifers will consume more alfalfa hay than timothy hay and this is one reason why animals having access to alfalfa hay make more rapid gains.

In regard to bulkiness, Eckles⁽⁷³⁾ holds this opinion: "An animal that is fed too much grain in proportion to the amount of roughage may seem

hungry, while she really has a sufficient amount of nutrients, but so concentrated that it does not have sufficient bulk." This is evident in view of the fact that the dairy cow has a large, roomy stomach, especially adapted to the handling of bulky feeds.

Some breeders believe that if a heifer is raised largely on bulky feeds, it will have greater capacity for handling feed when mature. This idea was not borne out by investigations at the Missouri station. (17)

REVIEW OF RESULTS OF PREVIOUS INVESTIGATIONS

Investigations relative to winter rations for dairy heifers were begun at the Missouri Experiment Station in 1913 and have been carried on each winter since that time. Many feeds and combinations of feeds have been used, but most attention has been given to the problem of the proportion of grain to roughage in the rations.

Caine⁽⁷⁴⁾ started the investigations in 1913 and the work has been continued by Talbot,⁽⁷²⁾ Wylie,⁽⁶¹⁾ and Maughan.⁽⁷⁵⁾

The following table is a summary of the different rations used in these investigations:

Caine, 1913-14

Group I

Silage, ad-libitum.

Corn) equal parts, 2 pounds
Cottonseed meal)

Group II

Corn, 3 pounds

Clover hay, ad libitum.

Talbot, 1914-15

Group I

Corn, 2 pounds
Alfalfa hay, ad libitum.

Group II

Corn)
Cottonseed meal) equal parts, 2 pounds
Timothy hay, 2 pounds
Silage, ad libitum.

Group III

Alfalfa hay)
Corn silage) ratio 1 to 3, ad libitum.

Wylie, 1915-16

Group I

Corn, 2 pounds
Alfalfa hay)
Silage) ratio 1 to 3, ad libitum.

Group II

Corn, 3 pounds
Alfalfa hay, ad libitum.

Group III

Corn) Enough to make energy
Cottonseed meal) and protein equal ration
Timothy hay, 2 pounds
Silage, ad libitum.

Maughan, 1916-17.

Group I (medium ration)

Corn, 2 pounds
Alfalfa, 1 pound per cwt. of animal
silage, ad libitum.

Group II (heavy ration)

Corn, 1 pound per cwt. of animal
Alfalfa, 1 pound per cwt. of animal.
Silage, ad libitum

Group III (light ration)

Timothy hay, ad libitum
Silage, ad libitum
Corn, if necessary to make 1/4 pound
gain per day.

Results of Caine's Investigations. This experiment, which included but six animals, was begun in November and covered a period of 158 days. Caine concluded that a ration with silage as the roughage, while economical and adequate to carry heifers through the winter in a thrifty, growing condition, is hardly equal, judging from general appearances, to one in which clover hay furnishes the roughage.

The silage fed heifers seemingly needed some dry roughage. The nutrients received by this group were practically the same in amount as that

given the group receiving clover hay and were nearly sufficient for normal growth, but the animals appeared thinner than the clover fed group and were not in as thrifty condition.

Results of Talbot's Investigations. Talbot's first ration, consisting of 2 pounds of corn and alfalfa ad libitum was for the purpose of comparing the relative value of alfalfa fed with corn, with Caine's results on feeding clover with corn. Little difference was observed in their respective values, although the corn-alfalfa group made a little greater gain on less energy than did the corn-clover group.

Talbot's second ration was planned for the purpose of testing the advantage of adding some dry roughage (timothy hay) to a ration of the character fed by Caine, in which the roughage was all supplied by silage. His results showed that the dry roughage improved the ration.

In discussing his third ration consisting entirely of roughage, Talbot states that the heifers fed no grain used more protein and energy per pound gain than did those fed grain. In addition, all

animals in this group showed a loss in weight during one or more of the thirty day periods.

Talbot considered the ration of alfalfa and corn the most desirable. He states, "The main factor in the efficiency of this ration was the fact that the animals consumed more nutrients per day." He believed that all animals on experiment made normal growth. Taking the local cost of all foodstuffs, his group of heifers receiving silage were wintered with the least cost.

The results indicate the value of concentrates in a ration for wintering heifers.

Results of Wylie's Investigations. This work was continued by Wylie, the following year, who added 2 pounds of corn to the roughage ration as fed by Talbot.

He found that the addition of corn caused very much greater gains in weight. With the ration of roughage alone, Talbot got only 0.54 pounds average gains per day, while Wylie got 1.18 pounds gain per day by the addition of 2 pounds of corn. Then too, the amount of protein and energy used per pound gain was reduced one-half.

This substantiated the belief that a ration containing concentrates is superior to a ration consisting exclusively of roughage for dairy heifers.

Wylie further compared the results of feeding 3 pounds of corn with alfalfa ad libitum, to Talbot's results of feeding 2 pounds. He found that this addition of 1 pound of corn caused a decrease in the consumption of roughage to a marked degree, but that the gains in weight were not materially increased. He obtained an average daily gain in weight for the group of 0.9 pounds, while Talbot's group gained 0.82 pounds daily. This would seem to indicate that the addition of this extra pound of corn is not justified by the gains made. Wylie's heifers, which received this ration, varied in age from 9 to 17 months, while those fed by Talbot were somewhat younger. There is some evidence supporting the belief that younger heifers should receive more grain than older ones, although the individual gains made by the younger heifers of the same breed fed these two rations do not justify this opinion.

His comparison of grain and alfalfa, with and without silage (Groups I and II) resulted in a

gain of 1.18 pounds per day for the group receiving silage, and 0.9 pounds for the group without silage. This shows the advantage of having silage in a ration for dairy heifers.

Wylie's third ration was for the purpose of determining the value of silage, timothy hay and grain, as compared with his second ration consisting of alfalfa and grain. The nutrients were fed in approximately the same amounts, the amount of grain in the last ration being subject to variation in order to make the energy and protein equal to the second ration. The corn and alfalfa group made greater gains in weight, but he concluded that more animals should be used before definite conclusions can be made on this point.

His conclusion in regard to the three rations fed was that the corn, alfalfa and silage ration was the most efficient in the gains produced in proportion to the protein and energy received. The corn and alfalfa ration was the least efficient in this respect, while the timothy hay, silage and grain ration was intermediate to the others. From an economical standpoint, based on gain in weight, the

three rations stood in this same relation.

From a study of the records of growth on the heifers used by Talbot and Caine for the first summer following their respective experimental periods, Wylie showed that the animals which made extremely large gains on a winter ration usually made small gains when turned on pasture. When the gains made on winter rations were small, they were usually followed by large gains when the animals were pastured the following summer.

Results of Maughan's Investigations.

Maughan fed three rations for the purpose of comparing the efficiency and economy of light with heavy grain rations when fed with alfalfa and silage, and also to determine the results of feeding a ration of timothy hay and silage limited to the extent of producing one-fourth pound of gain daily.

In comparing the heavy and light rations when fed with alfalfa and silage, Maughan states, "It seems that the heavy grain 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."

From these results, it is apparent that heavy grain rations for dairy heifers has no particular advantage and is of unnecessary expense.

The heifers in Maughan's third group failed to consume large quantities of roughage, possibly because the ration was not palatable.

In summing up, Maughan is quoted as follows: "All things considered, a ration consisting of 2 pounds of corn and 1 pound of alfalfa per hundred pounds live weight and liberal amounts of silage will give better results than a ration with more grain."

PLAN OF EXPERIMENT AND EXPERIMENTAL METHOD

Plan of Experiment. This experiment on wintering dairy heifers is one of a series of the same nature begun by the Missouri Experiment Station in 1913 and continued each year since that time. Results of the former investigations are reviewed in the preceeding section of this thesis.

From a study of the results of these and other investigations it is believed that heifers should be raised mostly on roughage. Grain feeding should continue for some time after skimmilk feeding is stopped since the common practise of stopping the feeding of grain and skimmilk at the same time requires too great an increase in the consumption of roughness and the animal will not consume enough. As a result, growth is slow. From the age of probably ten months the animal should be fed on roughness almost exclusively until within possibly three months of calving when it is probably desirable to feed some grain.

The special object in view was to secure data concerning the extent to which normal growth may

be obtained from feeding roughage alone and under what condition of age it is necessary to feed concentrates in order to maintain normal growth. A secondary object was to determine in what proportions alfalfa hay and silage would be eaten when both were fed ad libitum.

Data were available showing the results of wintering heifers on alfalfa hay alone. In order to show the advantage of the addition of silage to alfalfa hay, a comparison was made of alfalfa hay alone with alfalfa hay and silage.

In addition, a study was made of the records of weight and growth made by the heifers used in the experiment conducted by Maughan for the summer following his wintering experiment. The object in this case was to determine to what extent the results of the different planes of nutrition during the winter would be overcome when the heifers were on pasture the following summer.

The feeding trial conducted by the author began the latter part of October and lasted 150 days.

Heifers Used. Eighteen heifers were used in this experiment, consisting of 9 Holsteins, 6 Jerseys and 3 Ayrshires. They were divided into three groups, irrespective of breed, but the younger

heifers were divided among the three groups.

Tables 9 and 10 give the essential facts concerning the age and breed of the animals used at the time the experiment was begun, together with a comparison of their height at winters, and weight, with the corresponding data for normal animals.

With the exception of Ayrshire heifer 324, all were below normal in weight and height at withers at this time. Poor pasture conditions during the previous summer were largely responsible for their small size, as the most of them were above normal weight at birth. Other than their small size, they were typical, pure-bred, dairy heifers and had been raised on skim milk.

The heifers were given a preliminary feeding period of ten days before the experiment proper was started in order to accustom them to the rations. Heifer 130 was not taken off of skim milk until two weeks before this experiment started and was not on pasture during the summer as were the rest.

Rations Fed. The following shows the rations for the three groups:

Table No. 9.

Data Concerning Heifers Used
in the Experiment.

*						
Herd No.	Breed	Age at Start	Weight at Birth	Av. birth weight same sex and breed	Sire	
		Mos.	Da.	Lbs.	Lbs.	
<u>Group I</u>						
271	:Holstein:	14	: 27	: 95	: 85	:Sir Korndyke
279	: "	8	: 12	: 95	: 85	: " "
280	: "	7	: 13	: 92	: 85	: " "
125	:Jersey	: 13	: 28	: 55	: 49	:Sult. Va. Lad
126	: "	: 9	: 27	: 50	: 49	:Sophie Dem.
130	: "	: 6	: 2	: 60	: 49	:Sult. Va. Lad
324	:Ayrshire:	13	: 18	: 67	: 74	:Sir Melrose Canary
<u>Group II</u>						
270	:Holstein:	17	: 27	: 97	: 85	:Sir Korndyke
272	: "	: 13	: 23	: 90	: 85	: " "
274	: "	: 9	: 12	: 100	: 85	: " "
278	: "	: 8	: 19	: 75	: 85	: " "
121	:Jersey	: 15	: 24	: 55	: 49	:Sult. Va. Lad
127	: "	: 9	: 19	: 45	: 49	: " " "
325	:Ayrshire:	12	: 18	: 65	: 74	:Sir Mel. Canary
<u>Group III</u>						
275	:Holstein:	8	: 29	: 105	: 85	:Sir Korndyke
276	: "	: 8	: 26	: 85	: 85	: " "
128	:Jersey	: 8	: 23	:	: 49	:Sult. Va. Lad
326	:Ayrshire:	11	: 11	: 52	: 74	:Sir Mel. Canary

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

Table No. 10.

Data Concerning Heifers Used
in the Experiment.
(Continued)

Herd No.	: Weight : at : Start : Lbs.	: Normal* : Weight : Lbs.	: Height : at : Start : Cms.	: Normal* : Height : Cms.
<u>Group I</u>				
271	: 590	: 620	: 118.1	: 118.5
279	: 391	: 416	: 105.1	: 106.6
280	: 303	: 380	: 99.9	: 104.8
125	: 446	: 527	: 110.1	: 111.5
126	: 324	: 405	: 100.6	: 105.0
130	: 257	: 265	: 96.6	: 94.5
324	: 564	: 525	: 111.8	: 109.5
<u>Group II</u>				
270	: 719	: 710	: 121.5	: 122.0
272	: 550	: 596	: 112.5	: 117.2
274	: 414	: 444	: 106.6	: 108.6
278	: 303	: 444	: 101.6	: 108.6
121	: 493	: 570	: 112.0	: 114.8
127	: 328	: 405	: 101.3	: 105.0
325	: 354	: 470	: 101.8	: 106.5
<u>Group III</u>				
275*	: 400	: 444	: 107.0	: 108.6
276	: 418	: 444	: 106.8	: 108.6
128	: 303	: 378	: 98.8	: 103.0
326	: 389	: 440	: 101.0	: 104.5

*Burlingham and Gillette, "The Normal Growth of Dairy Heifers." (See Table 5)(Figure taken from nearest month).

Group I

(Heifers under 1 year of age,
Corn, (2 pounds
(Heifers over 1 year of age,
1 pound
Alfalfa hay, limited to 6 pounds
Silage, ad libitum.

Group II

Alfalfa hay, limited to 6 pounds
Silage, ad libitum.

Group III

Alfalfa hay, ad libitum
Silage, ad libitum.

For Group I, it was originally planned to feed alfalfa hay at the rate of 1 pound per 100 pounds live weight, and corn if necessary to bring about normal growth. As these heifers were so far below normal growth at the start of the experiment, this was not considered advisable. The corn was fed with the idea of changing the amount as seemed necessary due to the rate of growth and age. Accordingly, it was found Number 130 was not making normal growth, so on January 5, her corn was increased to 3 pounds daily. It was found that she would not consume more than 6 pounds of alfalfa hay per day.

Likewise, those heifers in this group that reached the age of 1 year during the course of the experiment were cut down to 1 pound of corn daily, but the alfalfa was still limited to 6 pounds.

The object of limiting the alfalfa hay to 6 pounds daily for the heifers of the second group was to insure their consumption of more silage, the cheapest source of nutrients. These heifers appeared to be making normal growth or better during the experiment, so this ration was never changed.

It was likewise not considered necessary to make any change in the third ration.

Feeding Methods. All of the feeds were of good quality. The corn was fed in the form of corn meal. The alfalfa hay was cut in a feed cutter to avoid wasting and inaccuracy in records from feed thrown out of the boxes.

In the beginning, the rations were fed in equal parts, morning and evening. Later, the alfalfa hay was fed in the morning and the silage and grain at night. In case of those feeds fed ad libitum, an excess was avoided. If all was not eaten, the portion remaining in the boxes was weighed back and a note of the amount recorded on the

feeding sheet.

Water and salt were available in the lots at all times when the heifers were outside.

The feeding hours were regular, at six o'clock in the morning and four o'clock in the afternoon.

Records. Accurate records were kept on permanent feed sheets of all feeds consumed and refused. The quantity of each given was carefully weighed and recorded on feed sheets kept in the barns for that purpose. If any feed was not eaten, the amount was weighed back and recorded and was later subtracted from the original amount given. For the most part, the feed boxes contained three compartments for the corn, alfalfa hay and silage respectively, so as to avoid a mixing of the feeds while being eaten. However, in five of the stalls this was not possible and if there was a mixture to be weighed back, the relative amounts of each feed were estimated.

If a heifer went off feed or became sick, a note of the time and manner was made on the feed sheet under the proper number.

Each heifer was identified by a neck strap

on which was a brass plate with the animal's number, and each heifer was placed regularly in the same stall bearing a corresponding number.

Stabling. The heifers were stabled in two experimental barns built especially for experiments of this nature. Each heifer had an individual stall which was cleaned and bedded with straw daily. Occasionally a small amount of this straw was eaten. They were turned out into the lots about 9 o'clock in the morning where they remained until 4 o'clock in the afternoon unless the weather was disagreeable when they were turned out only long enough to drink.

Weights. Weights were taken on three successive days at the beginning of the experiment and at thirty-day intervals. An average was made of these three consecutive weights and this figure was used as the basis for calculations. At ten-day intervals a single weight was also taken. This latter weight was found to fluctuate considerably and could not be regarded as a true index of gain.

Measurements. The height at withers is the only measurement made of the growth in stature of the heifers used in this experiment, and was taken at the end of each thirty-day period. Previous investigations

at the Missouri Experiment Station have shown that the height at withers is directly correlated with other body measurements, and for this reason, this was the only body measurement taken.

The heifers were compelled to stand squarely on the scale platform and the height in centimeters was quickly taken at the highest point of the withers with a measuring rod. The heifers were then turned around and another measurement was taken at the same point on the withers. This was repeated until three measurements were taken. The figure used is the average of these three.

Calculations. The calculations in this thesis, relating to the composition of feeds used, other than mineral matter, are based on Armsby's⁽⁷¹⁾ tables. His figures for digestible crude protein are used instead of those for digestible true protein.

The mineral content of the feeds used are taken from tables given by Hart, Steenbock and Fuller.⁽⁵²⁾

The normal growth figures used are those compiled by Burlingham and Gillette.⁽¹²⁾

EXPERIMENTAL DATA AND DISCUSSION
OF RESULTS.

The data by 30 day periods for each of the eighteen animals used is given in Tables 11 to 19 inclusive. The data includes the kind and amount of feed consumed, the digestible crude protein, net energy value, and dry matter together with the weight and height at withers at the beginning of each period. The amount of corn fed the animals in Group I was not constant. In case of animals 271, 125 and 324 it was taken out of the ration entirely, due to the fact that these animals were judged to be making normal growth. In case of animal 279 the amount of corn was decreased to 1 pound per day. For animal 130 it was increased to 3 pounds per day, because she was the younger animal of the group and was not considered to be making normal growth.

A summary of Tables 11 to 19 is given in Table 20, showing the total amounts of the different feeds consumed by individual animals and by groups, together with the increase in weight and height at withers. It is seen that the animals in Group I,

Table No. 11.

Feed and Nutrients Consumed,
Height and Weight.

30 day: period:	Corn: Lbs.:	Alfalfa: Lbs.:	Silage: Lbs.:	Dig. : Crude : Protein:	Net : Energy: Value :	Dry : Matter:	Weight: Lbs.:	Height: Cms.
					Therms:	Lbs.:		

Holstein Heifer 271,
Group I

							590 :	118.1
1	:	60	:	180	:	520.2: 29.29 :	197.82: 355.04:	638 : 119.7
2	:	60	:	180	:	775.5: 32.10 :	238.41: 422.17:	688 : 120.0
3	:	58	:	178	:	805.0: 32.07 :	240.62: 426.31:	726 : 121.8
4	:		:	180	:	762.0: 27.46 :	182.92: 364.92:	740 : 122.8
5	:		:	180	:	919.0: 29.18 :	207.71: 406.21:	764 : 124.0
Total	:	178	:	898	:	3781.7:150.10 :	1067.31:1974.65:	:
Av.per	:		:		:			
day	:	1.19:	:	5.9	:	25.2: 1.00 :	7.11: 13.16:	:

Holstein Heifer 279,
Group I

							391 :	105.1
1	:	60	:	179	:	287.5: 26.63 :	160.47: 292.91:	439 : 108.3
2	:	60	:	155	:	288.5: 24.09 :	152.40: 271.23:	458 : 109.1
3	:	60	:	161.5:	:	388.5: 25.85 :	170.54: 303.47:	502 : 111.0
4	:	49	:	137.25	:	348.0: 22.03 :	145.99: 260.81:	534 : 113.0
5	:	30	:	147	:	378.0: 21.98 :	137.16: 260.60:	580 : 115.5
Total	:	259	:	779.7:	:	1690.5:120.58 :	766.56:1389.02:	:
Av.per	:		:		:			
day	:	1.73:	:	5.2:	:	11.2: .80 :	5.11: 9.26:	:

Table No. 12.

Feed and Nutrients Consumed,
Height and Weight.

	:	:	:	:	Dig.	:	Net	:	:	:
30 day:	Corn:	Alfalfa:	Silage:	Crude	Energy:	Dry	Weight:	Height		
period:	:	:	:	Protein:	Value	Matter:	:	:	:	:
:	Lbs.:	Lbs.:	Lbs.:	Lbs.:	Therms:	Lbs.:	Lbs.:	Cms.		

Holstein Heifer 280,
Group I

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Total : 300 : 814.5: 1409.2:125.67 : 770.61:1374.42: :
 Av.per
 day : 2 : 5.4: 9.3: 0.84 : 5.14: 9.16: :

Jersey Heifer 125,
Group I

									446	:	110.1					
1	:	60	:	175	:	446.5	:	27.95	:	184.37	:	331.06	:	475	:	112.8
2	:	60	:	146	:	712.0	:	27.80	:	216.66	:	374.38	:	508	:	112.3
3	:	58	:	145.5	:	561.5	:	25.93	:	190.77	:	332.56	:	540	:	114.5
4	:		:	156	:	396.7	:	20.89	:	116.47	:	246.95	:	547	:	113.5
5	:		:	180	:	536.0	:	24.96	:	146.82	:	305.48	:	565	:	116.1

Total : 178 : 802.5: 2652.7:127.53 : 855.09:1590.43: :
 Av.per
 day : 1.19: 5.3: 17.6: 0.85 : 5.70: 10.60: :

Table No. 13.

Feed and Nutrients Consumed,
Height and Weight.

				Dig.	Net			
30 day:	Corn:	Alfalfa:	Silage:	Crude	Energy:	Dry	Weight:	Height
period:				Protein:	Value	Matter:		
	Lbs.:	Lbs.:	Lbs.:	Lbs.:	Therms:	Lbs.:	Lbs.:	Cms.

Jersey Heifer 126,
Group I

							324	: 100.6
1	: 60	: 177	: 254.2	: 26.05	: 154.49	: 282.33	352	: 103.5
2	: 60	: 172.2	: 239.7	: 25.38	: 150.55	: 274.18	386	: 104.7
3	: 60	: 169.7	: 323.0	: 26.03	: 162.95	: 293.78	428	: 106.1
4	: 59	: 173.2	: 347.5	: 26.60	: 167.15	: 302.53	455	: 108.3
5	: 5	: 179.0	: 362.0	: 23.32	: 123.27	: 263.28	483	: 110.5
Total	: 244	: 871.2	: 1526.5	: 127.38	: 758.41	: 1416.10		:
Av. per								
day	: 1.6	: 5.8	: 10.1	: 0.86	: 5.06	: 9.40		:

Jersey Heifer 130,
Group I

							257	: 96.6
1	: 60	: 153.2	: 167.0	: 22.58	: 132.50	: 237.67	282	: 98.8
2	: 80	: 156.7	: 231.5	: 25.15	: 161.78	: 275.73	314	: 100.6
3	: 90	: 150.7	: 151.7	: 24.39	: 155.96	: 258.22	339	: 103.0
4	: 90	: 140.0	: 207.0	: 23.85	: 161.07	: 272.94	378	: 105.1
5	: 90	: 167.0	: 171.0	: 26.33	: 164.56	: 278.15	391	: 108.0
Total	: 410	: 767.7	: 928.2	: 122.30	: 775.87	: 1322.71		:
Av. per								
day	: 2.7	: 5.1	: 6.1	: 0.82	: 5.17	: 8.82		:

Table No. 14.

Feed and Nutrients Consumed,
Height and Weight.

30 day: period:	Corn: :	Alfalfa: :	Silage: :	Dig. : Crude : Protein:	Net : Energy: Value : Therms:	Dry : Matter:	Weight: :	Height: :
:	Lbs.:	Lbs.:	Lbs.:	Lbs.:	Lbs.:	Lbs.:	Lbs.:	Cms.

Ayrshire Heifer 324

Group I

							564 :	111.8
1	:	60 :	180.0:	529.0:	29.39 :	199.21: 357.33:	609 :	112.1
2	:	60 :	148.5:	674.0:	27.65 :	211.48: 366.68:	620 :	113.8
3	:	58 :	146.0:	415.0:	24.38 :	167.66: 294.49:	631 :	113.3
4	:	:	155.7:	382.0:	20.70 :	114.04: 242.81:	642 :	114.8
5	:	:	180.0:	556.0:	25.18 :	160.00: 310.74:	657 :	114.8
Total	:	178 :	810.2:	2556.0:	127.30 :	852.39:1572.05:	:	
Av.per	:	:	:	:	:	:	:	
day	:	1.2:	5.4:	17.0:	0.85 :	5.68: 10.48:	:	

Holstein Heifer 270,

Group II

							719 :	121.5
1	:	:	180 :	529.0:	24.88 :	145.71: 303.64:	760 :	122.7
2	:	:	180 :	811.0:	27.99 :	190.55: 377.80:	803 :	121.6
3	:	:	180 :	899.5:	28.97 :	204.64: 401.08:	845 :	122.0
4	:	:	179 :	921.0:	29.10 :	207.69: 403.82:	899 :	123.7
5	:	:	180 :	1088.0:	31.04 :	234.59: 450.66:	949 :	125.3
Total	:	:	899 :	4248.5:	141.98 :	983.18:1937.00:	:	
Av.per	:	:	:	:	:	:	:	
day	:	:	5.9 :	28.3:	0.95 :	6.56: 12.91:	:	

Table No. 15.

Feed and Nutrients Consumed,
Height and Weight.

30 day: period:	Alfalfa: Lbs.	Silage: Lbs.	Dig. : Crude : Protein: Lbs.	Net : Energy: Value : Therms:	Dry : Matter : Lbs.	Weight : Lbs.	Height : Cms.
Holstein Heifer 272, <u>Group II</u>							
1	: 180	: 531.5	: 24.91	: 146.10	: 304.29	550 : 588	112.5 112.5
2	: 180	: 795.0	: 27.82	: 188.00	: 373.60	627	: 113.6
3	: 165	: 783.0	: 27.15	: 184.39	: 365.87	645	: 115.6
4	: 179	: 621.0	: 25.80	: 159.99	: 326.92	677	: 116.5
5	: 180	: 772.0	: 27.56	: 184.34	: 367.55	699	: 116.7
Total	: 884	: 3502.5	: 133.24	: 862.82	: 1738.23	:	
Av. per day	: 5.8	: 23.3	: 0.89	: 5.75	: 11.59	:	
Holstein Heifer 274 <u>Group II</u>							
1	: 180.0	: 351.0	: 22.93	: 117.41	: 256.82	414 : 425	106.6 107.1
2	: 175.0	: 374.0	: 22.66	: 119.35	: 258.29	442	: 109.7
3	: 184.0	: 515.7	: 25.16	: 144.98	: 303.80	483	: 110.6
4	: 174.7	: 517.7	: 24.20	: 142.13	: 295.87	521	: 113.0
5	: 177.0	: 530.0	: 24.58	: 144.84	: 301.15	558.	: 114.7
Total	: 890.7	: 2288.5	: 119.53	: 668.71	: 1415.93	:	
Av. per day	: 5.9	: 15.2	: 0.79	: 4.46	: 9.44	:	

Table No. 16.

Feed and Nutrients Consumed,
Height and Weight.

30 day period:	Alfalfa:	Silage:	Dig. Crude Protein:	Net Energy Value:	Dry Matter:	Weight:	Height:
: Lbs.	: Lbs.	: Lbs.	: Therms	: Lbs.	: Lbs.	: Lbs.	: Cms.

Holstein Heifer 278,
Group II

1	: 177.5:	282.0:	21.91 :	105.58:	236.38:	303 : 332	: 101.6 : 103.0
2	: 169.0:	319.0:	21.41 :	108.56:	238.35:	368	: 105.3
3	: 157.2:	438.7:	21.49 :	123.57:	259.10:	399	: 107.8
4	: 166.2:	419.0:	22.23 :	123.51:	262.13:	425	: 108.8
5	: 174.5:	381.0:	22.68 :	120.29:	259.68:	453	: 111.0
Total	: 844.5:	1839.7:	109.72 :	581.51:	1255.64:		:
Av. per day	: 5.6:	12.2:	0.73 :	3.88:	8.37:		:

Jersey Heifer 121,
Group II

1	: 180.0:	416.0:	23.64 :	127.74:	283.91:	493 : 519	: 112.0 : 112.8
2	: 177.5:	623.2:	25.66 :	159.83:	326.14:	553	: 113.6
3	: 171.2:	655.5:	25.35 :	162.82:	328.90:	595	: 113.8
4	: 175.7:	626.0:	25.51 :	159.67:	325.28:	621	: 114.5
5	: 170.0:	591.0:	24.51 :	152.14:	310.80:	629	: 115.8
Total	: 874.5:	2911.7:	124.67 :	762.20:	1575.03:		:
Av. per day	: 5.8:	19.4:	0.83 :	5.08:	10.50:		:

Table No. 17.

Feed and Nutrients Consumed,
Height and Weight.

30 day period:	Alfalfa:	Silage:	Dig. Crude Protein:	Net Energy Value:	Dry Matter:	Weight:	Height:
:	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Lbs.	Cms.

Jersey Heifer 127,
Group II

						328	: 101.3
1	: 178.0:	271.0:	21.84	: 104.00:	233.95:	346	: 102.8
2	: 175.7:	366.2:	22.65	: 117.37:	256.94:	376	: 103.7
3	: 163.0:	455.2:	22.27	: 128.16:	268.70:	405	: 105.3
4	: 171.2:	373.5:	22.25	: 117.99:	254.74:	420	: 108.8
5	: 173.0:	392.0:	22.64	: 121.53:	261.21:	443	: 109.8

Total	: 861.0:	1858.0:	111.65	: 589.05:	1275.54:	:	
Av. per day	: 5.7:	12.3:	0.75	: 3.93:	8.50:	:	

Ayrshire Heifer 325
Group II

						354	: 101.8
1	: 174.7:	430.0:	23.24	: 127.17:	272.79:	387	: 102.0
2	: 159.5:	564.2:	23.11	: 144.29:	294.17:	425	: 104.5
3	: 159.2:	547.0:	22.89	: 141.47:	286.70:	449	: 106.3
4	: 179.0:	365.0:	22.98	: 119.29:	259.59:	467	: 107.7
5	: 176.5:	542.0:	24.65	: 146.57:	303.86:	515	: 108.8

Total	: 849.0:	2448.2:	116.87	: 678.79:	1417.11:	:	
Av. per day	: 5.6:	16.3:	0.78	: 4.53:	9.45:	:	

Table No. 18.

Feed and Nutrients Consumed,
Height and Weight.

30 day period:	Alfalfa:	Silage:	Dig. Crude Protein:	Net Energy Value:	Dry Matter:	Weight:	Height:
:	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Lbs.	Cms.
Holstein Heifer 275, <u>Group III</u>							
1	286.7:	314.7:	33.76 :	148.19:	344.86:	400 : 454	107.0 108.3
2	182.0:	387.0:	23.53 :	123.81:	268.11:	472	111.0
3	233.7:	471.2:	23.78 :	131.71:	279.87:	529	112.6
4	211.0:	464.0:	27.46 :	145.98:	314.88:	554	115.5
5	176.0:	510.0:	24.26 :	141.31:	294.99:	594	117.5
Total	1089.5:	2147.0:	132.79 :	691.00:	1502.71:		
Av. per day	7.2:	14.3:	0.89 :	4.61:	10.02:		
Holstein Heifer 276, <u>Group III</u>							
1	222.0:	367.0:	27.55 :	134.33:	299.42:	418 : 462	106.8 109.9
2	215.2:	517.0:	28.49 :	155.86:	332.64:	511	111.0
3	207.2:	497.5:	27.42 :	150.03:	320.25:	546	113.6
4	206.7:	537.0:	27.81 :	156.15:	330.19:	583	114.0
5	197.5:	579.0:	27.30 :	159.65:	332.79:	608	118.0
Total	1048.7:	2497.5:	138.57 :	756.02:	1615.29:		
Av. per day	6.9:	16.6:	0.92 :	5.04:	10.77:		

Table No. 19.

Feed and Nutrients Consumed,
Height and Weight.

30 day period:	Alfalfa:	Silage:	Crude Protein:	Net Energy Value:	Dry Matter:	Weight:	Height:
: Lbs.	: Lbs.	: Lbs.	: Lbs.	: Therms	: Lbs.	: Lbs.	: Cms.
<u>Jersey Heifer 128,</u>							
<u>Group III</u>							
						303	: 98.8
1	: 221.5:	223.0:	25.85:	111.26:	261.09:	339	: 100.1
2	: 185.0:	365.2:	23.62:	121.38:	265.14:	368.	: 102.7
3	: 192.0:	435.0:	25.13:	134.86:	289.88:	411	: 105.0
4	: 172.5:	425.0:	22.94:	126.61:	269.42:	438	: 106.6
5	: 151.2:	370.5:	20.10:	110.66:	235.68:	453	: 108.5
Total	: 922.2:	1818.7:	117.64:	604.77:	1321.21:		:
Av. per day	: 6.1:	12.1:	0.78:	4.03:	8.90:		:
<u>Ayrshire Heifer 326,</u>							
<u>Group III</u>							
						389	: 101.0
1	: 186.0:	386.0:	23.95:	125.04:	271.52:	396	: 101.0
2	: 189.0:	371.2:	24.10:	123.71:	270.38:	432	: 101.3
3	: 198.5:	580.0:	27.41:	160.16:	333.21:	471	: 104.3
4	: 154.0:	323.2:	18.87:	104.09:	225.70:	477	: 106.5
5	: 176.5:	535.5:	24.58:	145.54:	302.15:	512	: 107.7
Total	: 904.0:	2196.0:	118.91:	658.54:	1403.03:		:
Av. per day	: 6.0:	14.6:	0.79:	4.39:	9.36:		:

Table No. 20.

Total Feed Consumed and Gain in Weight and Height.

150 Days.

Herd No.	:	:	:	:	Weight		Height			
					Gain	Total	Gain	Total		
					per day	Gain	per day	Gain		
					Lbs.	Lbs.	Cms.	Cms.		
<u>Group I</u>										
271	:	178:	898.0:	3781.7:	1.16	:	173.3:	.039	:	5.8
279	:	259:	779.7:	1690.5:	1.28	:	191.0:	.069	:	10.4
280	:	300:	814.5:	1409.2:	1.29	:	194.0:	.068	:	10.3
125	:	175:	802.5:	2652.7:	0.79	:	119.0:	.040	:	6.0
126	:	244:	871.2:	1526.5:	1.06	:	159.7:	.066	:	9.9
130	:	410:	767.7:	928.2:	0.89	:	134.0:	.076	:	11.4
324	:	178:	810.2:	2556.0:	0.62	:	93.0:	.020	:	3.0
Average	:	249:	821.0:	2078.0:	1.01	:	152.0:	.054	:	8.1
Av. per day:	:	1.6:	5.4:	13.8:	:	:	1.0:	:	:	.054
<u>Group II</u>										
270	:	:	899.0:	4248.5:	1.53	:	229.6:	.026	:	3.8
272	:	:	884.0:	3502.5:	0.99	:	148.6:	.028	:	4.2
274	:	:	890.7:	2288.5:	0.96	:	144.3:	.054	:	8.1
278	:	:	844.5:	1839.7:	1.00	:	150.3:	.063	:	9.4
121	:	:	874.5:	2911.7:	0.90	:	135.7:	.026	:	3.8
127	:	:	861.0:	1858.0:	0.77	:	115.3:	.057	:	8.5
325	:	:	849.0:	2448.2:	1.07	:	161.0:	.047	:	7.0
Average	:	:	871.8:	2728.1:	1.00	:	154.9:	.043	:	6.4
Av. per day:	:	:	5.8:	18.1:	:	:	1.0:	:	:	.043
<u>Group III</u>										
275	:	:	1089.5:	2147.0:	1.30	:	194.7:	.070	:	10.5
276	:	:	1048.7:	2497.5:	1.26	:	189.3:	.077	:	11.5
128	:	:	922.2:	1818.7:	1.00	:	150.7:	.065	:	9.7
326	:	:	904.0:	2196.0:	0.82	:	123.3:	.045	:	6.7
Average	:	:	991.1:	2164.8:	1.09	:	164.5:	.064	:	9.6
Av. per day:	:	:	6.6:	14.4:	:	:	1.1:	:	:	.064

receiving corn in the ration consumed daily an average of 1.6 pounds of corn, 5.47 pounds of alfalfa and 13.8 pounds of silage. The average gain in weight was 152 pounds or an average daily gain of 1.01 pounds. In height at withers the average gain for the period was 8.1 centimeters.

Group II, receiving a ration of alfalfa, limited to 6 pounds and silage, ad-libitum, consumed an average of 5.8 pounds of alfalfa daily and 18.1 pounds of silage. The average gain in weight was 154.9 pounds, with an average of 1 pound a day. The average increase in height at withers was 6.4 centimeters.

Group III, receiving both alfalfa and silage ad-libitum, consumed an average of 6.6 pounds of alfalfa daily and 14.4 pounds of silage. The average gain in weight for the period was 164.5 pounds or a daily gain of 1.1 pounds. In height at withers, the average gain was 9.61 centimeters per animal.

By comparing Group I with Group III it is seen that the consumption of 1.6 pounds of corn a day decreased the amount of alfalfa consumed, but had no material effect on the consumption of silage. While the alfalfa was limited to 6 pounds daily to the animals

of Group I, it was found that in most cases they would not consume that amount until the corn was removed from the ration. The same may be said of silage. In Group I, receiving corn, the average daily consumption of silage was 13.8 pounds, but with Group II, without corn, the average daily consumption was 18.1 pounds, a difference of over 4 pounds. Between Groups II and III the daily consumption of alfalfa was 5.8 pounds and 6.6 pounds respectively. While the amount of alfalfa was limited to 6 pounds in case of Group II, this group consumed .8 pounds less a day as did Group III, receiving alfalfa ad libitum. However, Group II consumed on an average 3.7 pounds more of silage daily than did Group III. The average ages of the three groups were 10.5, 12.6, and 12 months respectively. It is probable that this younger age of Group I caused a smaller consumption of roughage. The three groups made an average daily gain of approximately 1 pound, which is considered a good gain for heifers of such age.

Table 21 gives the composition of the feeds used, both in digestible nutrients and in mineral matter.

Table No. 21

Composition of Feeds Used.*

Average Dry Matter, Digestible Crude Protein,

Digestible True Protein and Net Energy

Values per 100 Pounds for Ruminants.

Feed	:	:	:	:
	:	:	Digestible	:
	:	Dry	Crude	True
	Matter	Protein	Protein	Energy
	Lbs.	Lbs.	Lbs.	Value
				Therms
Corn, dent	: 89.5	: 7.5	: 7.0	: 89.16
Alfalfa, all analyses	: 91.4	: 10.6	: 7.1	: 34.23
Silage (corn)	: 26.3	: 1.1	: 0.6	: 15.90

Mineral Composition of Feeds Used.**

Feed	:	:	:	:
	:	CaO	:	P ₂ O ₅
	:	:	:	MgO
	:	Percent	:	Percent
				Percent
Corn	:	0.026	:	0.623
Alfalfa	:	4.310	:	0.610
Green Corn Fodder***	:	0.280	:	0.110
	:		:	0.220

*Bul. 143, Penn. Exp. Sta. 1916.

**Res. Bul. 30, Wis. Exp. Sta. 1914.

***Used for silage.

Protein and Energy Consumed.- Table 22 gives the total amounts of digestible crude protein and energy consumed by the individual animals and by groups together with the respective amounts of each a day and per pound gain in weight, including maintenance.

The average amount of digestible crude protein was found to be 128.69 pounds, 122.52 pounds, and 126.98 pounds for the three groups, or a daily average of .86 pounds, .82 pounds and .84 pounds respectively. This was a very uniform consumption. However, in comparing the protein consumption of the three groups on the basis of per pound gain in weight it is seen that Group I used .89 pounds, Group II .81 pounds and Group III only .79 pounds. To properly compare their increase in weight with the protein intake, the protein requirement for maintenance should be deducted (see Table 4). As the protein maintenance requirement is calculated on the basis of true protein while these figures are in terms of crude protein, such a comparison would not be fair. Group III, receiving alfalfa and silage ad-libitum consumed the least protein per pound gain, while Group II consumed slightly more. Group I, consumed the most, regardless of the

Table No. 22.

Protein and Energy Consumed

150 Days.

Herd No.	: Dig. :		: Dig. :		: Dig.Cr.:	
	: Crude :		: Crude :		:Protein :Energy	
	:Protein:	Energy	:Protein:	Energy	:per lb. :	:per lb.
	: Lbs. :	:Therms	:per day:	:per day:	: Gain :	: Gain
	:	:	: Lbs. :	: Therms:	: Lbs. :	: Therms
<u>Group I</u>						
271	: 150.10:	1067.31:	1.00 :	7.11 :	0.86 :	6.16
279	: 120.58:	766.56:	0.80 :	5.11 :	0.63 :	4.01
280	: 125.67:	770.61:	0.84 :	5.14 :	0.65 :	3.97
125	: 127.53:	855.09:	0.85 :	5.70 :	1.07 :	7.19
126	: 127.38:	758.41:	0.86 :	5.06 :	0.79 :	4.75
130	: 122.30:	775.87:	0.82 :	5.17 :	0.91 :	5.72
324	: 127.30:	852.39:	0.85 :	5.68 :	1.36 :	9.19
Average	: 128.69:	835.18:	0.86 :	5.77 :	0.89 :	5.86
<u>Group II</u>						
270	: 141.98:	983.18:	0.95 :	6.56 :	0.62 :	4.28
272	: 133.24:	862.82:	0.89 :	5.75 :	0.89 :	5.81
274	: 119.53:	668.71:	0.79 :	4.46 :	0.83 :	4.63
278	: 109.72:	581.51:	0.73 :	3.88 :	0.73 :	3.87
121	: 124.67:	762.20:	0.83 :	5.08 :	0.92 :	5.62
127	: 111.65:	589.05:	0.75 :	3.93 :	0.97 :	5.11
325	: 116.87:	678.79:	0.78 :	4.53 :	0.73 :	4.22
Average	: 122.52:	732.32:	0.82 :	4.88 :	0.81 :	4.79
<u>Group III</u>						
275	: 132.79:	691.00:	0.89 :	4.61 :	0.68 :	3.55
276	: 138.57:	756.02:	0.92 :	5.04 :	0.73 :	3.99
128	: 117.64:	604.77:	0.78 :	4.03 :	0.78 :	4.01
326	: 118.91:	658.54:	0.79 :	4.39 :	0.96 :	5.35
Average	: 126.98:	677.58:	0.84 :	4.52 :	0.79 :	4.22

fact that this group made the same gains in weight per day as did the other two groups.

The consumption of energy stands in the same relation as protein. Group I shows an average consumption of 835.18 therms, or 5.77 therms daily with 5.86 therms per pound gain in weight. Group II consumed 4.88 therms daily with an average of 4.79 therms per pound gain. Group III used 4.52 therms daily and only 4.22 therms per pound gain. While the average amounts of energy consumed by Groups II and III was less than that consumed by Group I, they evidently utilized this energy to better advantage as was the case with the protein.

Mineral Matter.- Table 23 shows the amounts of essential mineral nutrients supplied to the three groups of animals. Whether or not sufficient mineral matter was supplied is not definitely known, but it is believed that these elements, especially calcium, were present in sufficient amounts, since each group received alfalfa in the ration. As can be seen from Table 21, alfalfa contains a comparatively high per cent of the three elements, especially calcium. There is not enough variation in the amounts consumed by the three groups as to deem it worthy of further

Table No. 23.

Calcium, Phosphorus and Magnesium

Consumed by the Three Groups.

150 Days.

	:	CaO	:	P ₂ O ₅	:	MgO
	:	Lbs.	:	Lbs.	:	Lbs.
<u>Group I</u>	:		:		:	
Corn	:	.453	:	10.865	:	3.819
Alfalfa	:	247.566	:	35.038	:	29.868
Silage	:	40.726	:	15.999	:	31.999
Total	:	288.745	:	61.902	:	65.686
Average per animal	:	41.249	:	8.843	:	9.384
Average per day	:	0.275	:	0.059	:	0.062
<u>Group II</u>						
Alfalfa	:	263.028	:	37.226	:	31.734
Silage	:	53.472	:	21.006	:	42.013
Total	:	316.500	:	58.232	:	73.747
Average per animal	:	45.217	:	8.319	:	10.535
Average per day	:	0.301	:	0.055	:	0.070
<u>Group III</u>						
Alfalfa	:	170.869	:	24.183	:	20.183
Silage	:	24.246	:	9.525	:	19.050
Total	:	195.115	:	33.708	:	39.233
Average per animal	:	48.779	:	8.427	:	9.808
Average per day	:	0.325	:	0.056	:	0.067

consideration. While recent work has shown that the question is of great importance, little is known as to the mineral requirements of growing animals.

Quality of the Protein Supplied.- Our knowledge regarding the differences in amino-acid content of the common feeding stuffs is meagre, and we know still less about the amino acid requirements for growing heifers. However, a general statement can be made regarding the quality of the protein supplied by the different rations.

While it is probable that the proteins of corn contain all the amino-acids essential for growth of rats, it is believed that the proportions of some of them are such that they are not utilized to a high degree as the only source of protein.⁽²⁶⁾ Zein, the principal protein of the corn kernel lacks the amino-acids glycocoll, tryptophane and lysine and has only a small quantity of arginine.

The protein of alfalfa hay is believed to be one of the most complete proteins, and capable of supplementing the proteins of corn and other cereal grains in an efficient manner. This was strikingly shown at the Wisconsin Station in connection with

investigations concerning milk production by cows. (32)

Nothing definite is known in regard to the quality of the protein in silage, but presumably it is like that of the corn grain, not especially efficient.

It is believed that the three rations fed supplied the essential amino-acids, although the evidence supporting this statement is not conclusive. This efficiency is thought to be due to the alfalfa which was in the three rations. It must be borne in mind, however, that most of the investigations relative to the quality of the proteins have been confined to smaller experimental animals and whether these results can be applied to dairy heifers is problematic.

Vitamines or Growth Accessories.- There is likewise too little knowledge as to the vitamine content of the feeding stuffs used to justify a definite statement. It is known that alfalfa hay contains both the fat-soluble A and water-soluble B., the former in relatively large amounts. It is thought that the corn plant contains small amounts of both.

Toxicity.- Nothing is reported that would indicate the presence of any toxic substance in the

feeds fed.

Gains in Weight and Height.- Table 24 shows the individual and average gains in weight and height at withers for the three groups with the corresponding normal gains.

Group I made an average gain in weight of 152 pounds for the period, slightly exceeding the normal gain of 144 pounds. In height at withers the gain was 8.1 centimeters as compared with 7.9 centimeters for the normal. However, in comparing the individual gains, it is seen that animals 130 and 324 failed to make normal gains in weight by 40 and 15 pounds respectively and also fell behind the normal increase in height at withers. Animal 130 was the youngest animal on experiment, being but 6 months old at the time the experiment started. Some trouble was experienced in getting her accustomed to her ration at the start, due to the fact that she had just been taken off skim milk. This is probably the reason for her failure to make normal growth. The reason for Number 324 not making normal growth may lie in a discrepancy in the normal growth figures for Ayrshires. Fewer animals were used in these

Table No. 24.

Average Gains by Groups Compared
With Normal.

150 Days.

Herd No.	: Gain : Normal		: Gain : Normal	
	: in : gain in		: in : gain in	
	: Weight : Weight		: Height : Height	
	: Lbs. : Lbs.		: Cms. : Cms.	
<u>Group I</u>				
271	: 173	: 168	: 5.8	: 4.5
279	: 191	: 155	: 10.4	: 8.9
280	: 194	: 163	: 10.3	: 9.1
125	: 119	: 88	: 6.0	: 6.7
126	: 159	: 151	: 9.9	: 8.0
130	: 134	: 174	: 11.4	: 12.4
324	: 93	: 108	: 3.0	: 5.8
Average	: 152	: 144	: 8.1	: 7.9
<u>Group II</u>				
270	: 229	: 160	: 3.8	: 2.5
272	: 148	: 150	: 4.2	: 5.3
274	: 144	: 144	: 8.1	: 8.5
278	: 150	: 155	: 9.4	: 8.9
121	: 135	: 80	: 3.8	: 4.7
127	: 115	: 149	: 8.5	: 8.3
325	: 161	: 115	: 7.0	: 5.8
Average	: 155	: 136	: 6.4	: 6.3
<u>Group III</u>				
275	: 194	: 152	: 10.5	: 8.6
276	: 189	: 152	: 11.5	: 8.6
128	: 150	: 149	: 9.7	: 8.5
326	: 123	: 125	: 6.7	: 7.5
Average	: 164	: 145	: 9.6	: 8.3

calculations than for the other breeds and the figure given may be too high. However, 324 was 39 pounds above normal weight at the time the experiment started, and it is evident that some unknown factor is concerned. Other than having a somewhat rough appearance, she appeared to be doing well throughout the experiment.

Group II made an average gain in weight of 161 pounds as compared with a normal gain of 115 pounds. The corresponding gains in height at withers was 6.4 centimeters as compared with 6.3 centimeters. Here again, is seen that the three animals 272, 278 and 127 failed to make normal gains in both weight and height at withers.

Group III shows an average gain in weight of 164 pounds with a normal gain of 145 pounds. They exceeded the normal increase in height at withers by 1.3 centimeters.

It must be borne in mind that all of the animals except 324 and 270 were below normal in both weight and height at withers when the experiment was begun. This was due largely to the poor pasture conditions of the previous summer.

Charts 1, 2 and 3 show in graphic form the

Chart 1

INCREASE IN WEIGHT COMPARED
WITH NORMAL

Weight in
Pounds.

Group 1.

Chart 2

Weight in
Pounds.

INCREASE IN WEIGHT COMPARED
WITH NORMAL

Group 11.

Chart 3

INCREASE IN WEIGHT COMPARED
WITH NORMAL

Weight in
Pounds.

Group 111.

Chart 4

Weight in
Pounds.

RELATIVE GROWTH IN WEIGHT

Chart 5

RELATIVE GROWTH IN HEIGHT

Height in

AT WITHERS

Centimeters.

increase in weight of the three groups respectively as compared with normal. These charts show that while all of the groups were below normal weight at the start, the same ratio was maintained. In case of Group II the ratio was somewhat exceeded.

Charts 4 and 5 show graphically the relative growth in weight and height at withers respectively of the three groups.

Influence of Age and Breed.- Table 25 gives a comparison of the rations fed as influenced by the age and breed of the animals. Only the Holsteins and Jerseys are considered.

The average ages of the Holsteins in Group I, II and III were 10, 12.5 and 9 months respectively at the time the experiment was begun. The animals in Group I consumed less alfalfa and silage per day than did those in Groups II and III. The average gains in weight for the three groups were 186, 168 and 192 pounds respectively, all being considerably above normal. However, Group I made the greatest gain in weight with respect to normal. Groups I and III consumed .71 pounds of crude protein per pound gain while Group II consumed .75 pounds per pound gain. Group III consumed less energy per pound gain

Table No. 25.

Comparison of Experimental Rations
with Respect to Ages.

	: : Group : : I :	: : Group : : II :	: : Group : : III :
<u>Holsteins</u>			
Average age, months	: 10.0 :	12.5 :	9.0
Corn per day, lbs.	: 1.6 :	:	
Alfalfa per day, lbs.	: 5.5 :	5.7 :	7.1
Silage per day, lbs.	: 15.2 :	19.7 :	15.5
Gain in weight, lbs.	: 186.0 :	168.2 :	192.0
Normal gain, lbs.	: 140.0 :	131.0 :	152.0
Daily gain, lbs.	: 1.24:	1.12:	1.28
Increase in height, cms.	: 8.8 :	6.4 :	11.0
Normal increase, cms.	: 8.0 :	6.6 :	8.6
Lbs. Protein per lb. gain:	.71:	.75:	.71
Therms energy per lb.gain:	4.61:	4.59:	3.77
<u>Jerseys</u>			
Average age, months	: 10.0 :	13.0 :	9.0
Corn per day, lbs.	: 1.8 :	:	
Alfalfa per day, lbs.	: 5.4 :	5.8 :	6.1
Silage per day, lbs.	: 11.3 :	15.9 :	12.1
Gain in weight, lbs.	: 137.0 :	125.0 :	150.0
Normal gain, lbs.	: 151.0 :	100.0 :	149.0
Daily gain, lbs.	: .91:	.84:	1.0
Increase in height, cms.	: 9.1 :	6.1 :	9.7
Normal increase, cms.	: 8.0 :	7.4 :	8.5
Lbs. Protein per lb. gain:	.91:	.89:	.78
Therms energy per lb.gain:	5.06:	4.68:	4.03

than did the other groups.

For the Jerseys of the three groups the average age was 10, 13 and 9 months respectively. The respective gains in weight were 137, 125 and 150 pounds. Group I failed to make normal gain in weight by 14 pounds. The consumption of protein and energy per pound gain was lowest in case of Group III, and highest for Group I.

In comparing the two breeds it is seen that the Holsteins consumed more alfalfa and silage a day in every case than did the Jerseys. While the Holsteins and Jerseys of Group I received approximately the same amounts of corn and alfalfa a day the Holsteins consumed an average of 15.2 pounds of silage daily as compared with 11.3 pounds consumed by the Jerseys. The same may be said in regard to the animals in Groups II and III. In every case the Holsteins used less protein and energy per pound gain than did the Jerseys. This would seem to indicate that the Holsteins utilize their feed to better advantage than do Jerseys. However, more animals should be used before definite conclusions can be drawn.

Influence of Rations on General Appearance.- No material difference could be observed in the general appearance of the animals, considering them as groups. Individual differences were noticed at times, but these were of no material importance. The most outstanding fact regarding their general appearance as a whole, was the fact that they came through the winter in such a thrifty growing condition. But one animal, Number 270 of Group II, receiving alfalfa limited to 6 pounds daily and silage ad-libitum, showed signs of excessive fatness. This animal consumed as high as 37 pounds of silage daily and probably would have consumed more. Men of wide experience were of the opinion that a more thrifty, growing bunch of heifers were never wintered at this institution. The main fact is that no material difference could be noted in the appearance of the respective groups.

Plates 1 to 6 are photographs showing the appearance of the animals of the same and of different groups at the end of the experiment.

Comparative Cost of Experimental Rations.- Figuring corn at \$1.50 per bushel, alfalfa hay at \$30 per ton and silage at \$10 per ton, the average

feed cost of wintering the heifers of each group was as follows:

Group I

Corn	\$6.66
Alfalfa	12.33
Silage	<u>10.40</u>
Total	\$29.39

Group II

Alfalfa	\$13.07
Silage	<u>13.60</u>
Total	\$26.67

Group III

Alfalfa	\$14.87
Silage	<u>10.80</u>
Total	\$25.67

From these figures it is seen that the average feed cost per animal of Group I was materially higher than in the other groups; due to the fact that the ration for Group I contained corn while the other two did not. Then too, the feed cost per pound gain in weight was higher. For Group I this cost was 19 cents, while for Group II and Group III

it was 17 cents and $15\frac{1}{2}$ cents respectively. Considering everything, the cost of wintering the heifers in Group I was the most expensive.

Between Group II and Group III, there was but little difference in cost of wintering, however, Group III made the cheaper gains.

Due to the fact that alfalfa hay was limited to 6 pounds a day for Group II and fed ad-libitum to Group III, one would expect Group II to have received the cheaper ration, because, as a rule, alfalfa is a more expensive feed than silage. While Group III consumed slightly more alfalfa per day than did Group II, the latter group showed a much higher daily consumption of silage.

While the feed prices as given above represent approximately the average prices as paid during the course of this experiment, it must be borne in mind that they are extremely high. However, under normal conditions, the cost of wintering the three groups would probably have stood in about the same ratio.

Alfalfa Alone, Compared with Alfalfa and Silage.- Tables 26 and 27 show the value of adding silage to a ration of alfalfa alone, for Holsteins

Table No. 26.

Showing Value of Adding Silage
to a Ration of Alfalfa.

Holsteins.

Ration	:	: Alfalfa	:	Alfalfa
	:	:(ad libitum):	:	(6 lbs. daily
	:	:Alfalfa:	:	Silage
	:	:(ad libitum):	:	(ad libitum)
	:	:	:	:
No. of animals	:	11	:	2
Av. age, months	:	12.7:	:	9
Lbs. Alfalfa received, 150 days, av.	:	2217	:	1019
Lbs. Silage received, 150 days, av.	:	:	:	2322
Gain in wt. for period, av. lbs.	:	107	:	192
Normal Gain for period, lbs:	:	136	:	152
Av. daily gain, lbs.	:	0.72:	:	1.28
Normal daily gain, lbs.	:	0.90:	:	1.00
Dig. Cr. Protein per lb. gain, av. lbs.	:	2.19:	:	0.71
Therms energy per lb. gain, av.	:	7.07:	:	3.77
Dig. Cr. Protein a day, lbs:	:	1.57:	:	0.90
Therms energy a day,	:	5.06:	:	4.80

Table No. 27.

Showing Value of Adding Silage
to a Ration of Alfalfa.

Jerseys.

	:	:	Alfalfa	:	Alfalfa	
	:	:	:(ad libitum):	:	(6 lbs daily	
Ration	:	:	Alfalfa: Silage	:	Silage	
	:	:	:(ad libitum):	:	(ad libitum	
	:	:	:	:	:	
No. of animals	:	13	:	1	:	2
Av. age, months	:	13	:	9	:	13
Lbs. Alfalfa received, 150 days, av.	:	1813	:	922	:	867
Lbs. Silage received, 150 days, av.	:	:	:	1818	:	2384
Gain in Wt. for period, av. lbs.	:	69	:	150	:	126
Normal gain for period,lbs:	100	:	149	:	100	
Av. daily gain, lbs.	:	0.46:	1.00	:	0.84	
Normal daily gain, lbs.	:	0.67:	1.00	:	0.67	
Dig. Cr. Protein per lb. gain, av. lbs.	:	2.78:	0.78	:	0.93	
Therms energy per lb. gain, av.	:	8.99:	4.01	:	5.34	
Dig. Cr. Protein a day,lbs:	1.28:	0.78	:	0.79		
Therms energy a day,	:	4.13:	4.03	:	4.50	

and Jerseys. The figures on those heifers wintered on alfalfa alone were compiled from data at the Missouri Experiment Station, some of which has been previously published. The other figures are compiled from results of the present wintering experiment. For those groups receiving silage, the first group was fed both alfalfa and silage ad-libitum while the second group was limited to six pounds of alfalfa per day with silage fed ad-libitum. The length of the wintering period was 150 days.

The Holsteins wintered on alfalfa alone consumed an average of 2,217 pounds of alfalfa for the period while the two groups receiving silage consumed 1,019 and 879 pounds respectively. Where the alfalfa was fed ad-libitum the silage consumed amounted to 2,322 pounds, while with the group limited to 6 pounds of alfalfa a day the average consumption of silage was 2,939 pounds. This shows that limiting the amount of alfalfa fed, increases the consumption of silage.

The same results are found for the Jerseys, as seen in Table 27.

The most striking fact shown by these data with each basis of comparison, is that those animals wintered on alfalfa alone were materially inferior to those receiving both alfalfa and silage. In each case, those wintered on alfalfa alone failed to make normal growth in weight for the period while the others made more than normal. The consumption of protein per pound gain in weight was extremely high in case of those wintered on alfalfa alone, as compared with the others. It is evident that the greater portion of this protein was wasted. These animals were compelled to eat large quantities of the alfalfa in order to secure enough energy.

A comparison of the two breeds, Holstein and Jersey, raised on alfalfa alone indicates that the Holstein made greater and cheaper gains from the standpoint of the amount of nutrients consumed than did the Jerseys. While both breeds failed to make normal gains in weight, the Holsteins consumed 2.19 pounds of digestible crude protein and 7.07 therms of energy per pound gain, while the Jerseys consumed 2.78 pounds of digestible crude protein and 8.99 therms of energy per pound gain.

Figuring alfalfa hay at \$30 per ton and

silage at \$10 per ton, it cost approximately \$10 less to winter those animals receiving alfalfa and silage, than those receiving alfalfa alone.

Results of Winter Rations on Summer Gains.-

Table 28 shows a comparison of the winter and summer gains in weight and height at withers of three groups of heifers wintered in 1916-17 by Maughan.⁽⁷⁵⁾ The three groups of heifers were wintered on light, medium and heavy rations respectively. A review of this experiment is given in a previous section of this thesis.

The average winter gain for the group receiving the light ration was 55 pounds in weight and 6.4 centimeters in height, failing in both cases to make normal gains for the winter period. The following summer while on pasture, the average gain for the group was 142 pounds in weight and 6.7 centimeters in height. They failed to make normal gain in weight but exceeded the normal increase in height at withers. The average gain in weight per day for the winter was .37 pounds as compared with .88 pounds per day during the summer.

The group receiving the medium ration gained

Table No. 28.

Winter and Summer (Pasture) Gains
of Heifers Fed Light, Medium and
Heavy Winter Rations.

Herd No.	Winter 1916-17 (150 days)		Summer 1917 (162 days)	
	Weight	Height	Weight	Height
	Lbs.	Cms.	Lbs.	Cms.
<hr/>				
<u>Light Ration</u>	:	:	:	:
322	: 25	: 6.2	: 111	: 6.2
260	: 112	: 6.0	: 135	: 5.0
265	: 34	: 6.5	: 171	: 6.5
116	: 48	: 7.0	: 150	: 9.2
Total Gain	: 219	: 25.8	: 567	: 26.9
Average	: 55	: 6.4	: 142	: 6.7
Normal Gain	: 146	: 8.3	: 148	: 4.8
Av. per day	: 0.37:	: .04	: 0.88:	: .02
<u>Medium Ration</u>				
318	: 172	: 7.8	: 99	: 4.7
263	: 227	: 9.8	: 115	: 5.3
262	: 179	: 6.7	: 84	: 5.4
113	: 77	: 7.1	: 163	: 4.9
Total Gain	: 655	: 31.4	: 461	: 20.3
Average	: 164	: 7.8	: 115	: 5.0
Normal Gain	: 130	: 7.2	: 144	: 3.4
Av. per day	: 1.09:	: .052	: 0.71:	: .03
<u>Heavy Ration</u>				
320	: 249	: 8.9	: - 35*	: 5.1
264	: 257	: 11.4	: 9	: 6.2
258	: 253	: 8.2	: 89	: 3.9
117	: 101	: 11.1	: 81	: 6.3
Total Gain	: 860	: 39.6	: 144	: 21.5
Average	: 215	: 9.9	: 38	: 5.4
Normal Gain	: 149	: 7.4	: 153	: 5.0
Av. per day	: 1.43:	: .06	: 0.23:	: .03

* - denotes loss.

164 pounds in weight and 7.8 centimeters in height at withers for the winter period, slightly exceeding the normal figures in both cases. For the summer they failed to make normal gain in weight by 29 pounds, but slightly exceeded the normal increase in height at withers. The average gain per day was 1.09 pounds for the winter against .71 pounds for the following summer.

The group receiving the heavy winter ration exceeded the normal gain in weight by 66 pounds and the normal increase in height at withers by 2.5 centimeters. For the following summer the average gain in weight was only 38 pounds as compared with a normal gain of 153 pounds. They maintained the normal increase in height at withers. They made an average daily gain in weight of 1.43 pounds during the winter, but gained only .23 pounds a day during the following summer. The individual gains were likewise very small for the summer period. Animal 320 weighed 35 pounds less at the end of the summer than when she was taken off the wintering experiment. However, she maintained normal increase in height at withers.

A comparison of the three groups shows that the group receiving the heavy winter ration made the

least total pasture gains the following summer; the group receiving the light winter ration made the greatest; while the group receiving the medium winter ration made slightly less total gains. As compared on the basis of daily gain, they stand in the same relation. The same holds true for the increase in height at withers, although the difference is not so marked. While the group receiving the light winter ration made the greatest summer gains, the gains were not great enough to off set what was lost during the winter. Consequently this group was still far below normal at the end of summer. It could hardly be expected that this group would make this up in such a short period of time.

Chart 6 shows the increase in weight for the winter and summer periods in graphic form. As can be seen, the group receiving the medium winter ration presents the most uniform curve for both winter and summer gains. Judging from the gains in weight during both periods, this group of animals received the most desirable ration during the winter.

Chart 7 shows the corresponding increase in height. This shows that the height at withers

Weight in
Pounds

Chart 6

WINTER AND SUMMER(PASTURE)GAINS IN WEIGHT OF HEIFERS FED

Chart 7

Height in

Centimeters.

WINTER AND SUMMER(PASTURE) GAINS IN HEIGHT OF HEIFERS FED

is not affected to such a marked degree by the plane of nutrition during the winter and summer feeding periods as is the weight.

These results are of considerable importance. They show that it is not economical to winter heifers on a heavy grain ration so as to cause them to become excessively fat. They are almost sure to lose a portion of this flesh when turned on pasture the following summer. On the other hand, it is seen that it is poor practice to under-feed heifers during the winter so that they are under weight in the spring. While they may make excessive gains on pasture, this increased gain will not offset what they failed to make during the winter. As a result they are likely to be small and undersized. However, under present conditions of high priced feed it might be justifiable to under-feed heifers to a limited extent during the winter period and allow them to make up for this deficiency during the summer, when the feed is cheaper. If this practice is followed, it will take the heifers longer to mature. Consequently, the time of breeding should be delayed somewhat, in order that they may make up for this delay in growth. Investigations indicate that such a system of feeding

combined with late calving does not alter the size or dairy qualities of a cow when mature. However, if heifers are underfed during the winter and then allowed to calve at an early period, they are almost sure to be undersized at maturity.

SUMMARY AND CONCLUSIONS.

Summary.-The experiment herein reported is the fifth in a series of investigations of the same nature conducted at the Missouri Agricultural Experiment Station.

The special problem considered is the extent to which normal growth may be secured by feeding roughage alone and to what extent grain must be supplied in the ration to insure normal growth.

A secondary object was to determine in what proportions alfalfa hay and silage would be consumed when both were fed ad-libitum and to compare the efficiency of a ration of alfalfa and silage with a ration of alfalfa hay alone.

In addition, a study was made of the effects of different planes of nutrition during the winter on growth the following summer.

Eighteen pure bred dairy heifers of the Jersey, Holstein and Ayrshire breeds were fed for a period of 150 days. Some use is also made of data from previous investigations at this experiment station.

The animals were divided into three groups,
and received the following rations;

Group I.

Corn (Heifers under 1 year of age, 2 pounds.
(Heifers over 1 year of age, 1 pound.

Alfalfa Hay, limited to 6 pounds daily

Silage, ad-libitum.

Group II.

Alfalfa hay, limited to 6 pounds daily.

Silage, ad-libitum.

Group III.

Alfalfa hay, ad-libitum.

Silage, ad-libitum.

The average daily food consumed by the three
groups was as follows;

	Alfalfa	Silage	Corn
	Lbs.	Lbs.	Lbs.
Group I	5.4	13.8	1.6
Group II	5.8	18.1	---
Group III	6.6	14.4	---

As would be anticipated, there was a smaller consumption of both alfalfa and silage when corn was fed. Limiting the alfalfa to 6 pounds daily for Group II,

resulted in a somewhat greater consumption of silage, but the difference in the consumption of alfalfa by Groups II and III was not so marked as was expected.

The average amounts of digestible crude protein and therms of net energy consumed daily and per pound gain in weight for the three groups are as follows;

	Lbs. Dig. Cr. Protein		Therms Energy	
	Daily	Per lb. Gain	Daily	Per lb. Gain.
Group I	.86	.89	5.77	5.86
Group II	.82	.81	4.88	4.79
Group III	.84	.79	4.52	4.22

Groups II and III apparently used both protein and energy to better advantage than Group I. With a feeding period of only 5 months it is not possible to fully account for this variation in the use of food nutrients. It is not believed that it can be accounted for by any difference in the coefficient of digestibility. One possible explanation is that the gains made by Group I contained a larger proportion of fat which would require a greater food consumption for each unit of gain.

It is thought that the three rations

supplied all the essential amino-acids and dietary factors for normal growth, due to the fact that alfalfa hay was in the three rations.

The average gains made by the three groups in weight and height at withers are as follows;

	Weight Lbs.	Height Cms.
Group I	152	8.1
Group II	154	6.4
Group III	164	9.6

While the three groups were below normal both in weight and height at the beginning of the experiment, they maintained practically the same ratio throughout the experiment and are believed to have made normal growth.

The three groups of animals used averaged so nearly the same age that the data giving the average results by groups gives no basis for studying the relation of the age of the animals to the consumption of the rations used. However, a study of the data of individual animals does show some important facts. One Jersey heifer, 6 months old when the experiment started, failed to make normal gains in height when receiving 2 pounds of corn in the ration.

When the amount was increased to 3 pounds daily, normal gain was maintained. Two pounds of corn was sufficient for a Holstein heifer, one and one-half months older than the Jersey.

The Holstein heifers in each group used less protein and energy per pound gain in weight than did the Jerseys.

No material difference was noticeable in the general appearance of the groups at the end of the wintering period. Experienced men pronounced their condition as being excellent.

At current prices, Group I, receiving corn in the ration, was wintered at greater feed cost than the other groups. Between Group II and Group III, there was no material difference.

From every angle of comparison, the animals wintered on alfalfa alone were materially inferior to those wintered on alfalfa and silage.

Animals that were underfed during the winter period made greater gains in weight the following summer than did those which were overfed, but there was no material effect upon the increase in height at withers. However, the increased gains in weight made by the underfed group during the summer were not

great enough to offset what they failed to gain during the winter. Consequently, these animals were undersized at the end of the pasture season. The group wintered on a medium ration made normal gains for both winter and summer.

Conclusions.- From the age of probably 9 months, dairy heifers wintered on a good quality of alfalfa hay and silage will make normal growth and come through the winter in an excellent growing condition.

Between the ages of 6 and 9 months, it is advisable to supply at least 2 pounds of grain a day to this ration. The data indicates that for Jerseys, this amount should be 3 pounds, although the evidence is not conclusive.

When alfalfa hay and silage are fed ad libitum, the ratio in which they are consumed is somewhat greater than 1 : 2.

Limiting the amount of alfalfa hay to 6 pounds a day, increased the consumption of silage.

Heifers wintered on alfalfa hay and silage make greater and more economical gains than those wintered on alfalfa alone. A ration of alfalfa alone will not insure normal growth.

Heifers that have made gains far above normal during the winter season, as the result of heavy grain feeding, make small gains during the summer if on pasture. Heifers making considerably less than normal gains during the winter, as the result of rations received, make large gains on pasture.

Plate 1

Ayrshire Heifers From Groups 1, 11 and 111.

Photograph Taken at End of Experiment

Number 324, Group 1.

Number 325, Group 11.

Number 326, Group 111.

Plate 2

Jersey Heifers From Groups 1, 11 and 111.

Photograph Taken at End of Experiment.

Number 125, Group 1.

Number 127, Group 11.

Number 128, Group 111.

Plate 3

Holstein Heifers From Groups 1, 11 and 111.

Photograph Taken at End of Experiment

Number 270, Group 11.

Number 275, Group 111.

Number 279, Group 1.

Plate 4

An Ayrshire, a Jersey and a Holstein From Group 1.

Photograph Taken at End of Experiment.

Plate 5

An Ayrshire, a Jersey and a Holstein From Group 11.

Photograph Taken at End of Experiment.

Plate 6

An Ayrshire, a Jersey and a Holstein from Group 111.

Photograph Taken at End of Experiment.

DAIRY HUSBANDRY DEPARTMENT

EXPERIMENTAL DATA

Date February 1918

Subject

Winter Rations for Dairy Heifers.

Ration

Lot No.

Number of Animal	126 (*)			274(2)		127(2)		275(3)		128(3)		278(2)		279(1)		
RATION	Corn	alfalfa	silage	alfalfa	silage	alfalfa	silage	alfalfa	silage	alfalfa	silage	alfalfa	silage	Corn	alfalfa	silage
1	2	6	11	6	17	6	15	9	15	7	15	6	15	2	6	12
2	2	6	13	6	18	6	15	9	15	7	15	6	15	2	6	14
3	2	6	13	6	18 ⁽³⁾	6 ⁽²⁾	15 ⁽⁵⁾	9 ⁽³⁾	15	6 ⁽²⁾	15 ⁽³⁾	6	15 ⁽⁵⁾	2	6 ⁽²⁾	14
Weights	2	6	15	6	18	6	14	9	16	6	15	6	15	2	6	15
5	2	6	15	6	18	6	14	8	16	6	15	6	15	2	6	15
6	2	6	15	6	18	6	14	8	16	6	15	6	15	2	6	15
7	2	6	15	6	18	6	14	8	16	6	15	6	15	2	6	15
8	2	6	15	6	18	6	14	8	16	6	15	6	15	2	6	15
9	2	6	15	6	18	6	14	8	16	6	15	6	15	2	6	15
10	2	6 ⁽⁴⁾	15 ⁽¹²⁾	6 ⁽²⁾	18	6 ⁽⁴⁾	14 ⁽⁷⁾	8 ⁽⁵⁾	16	6 ⁽³⁾	15 ⁽¹⁾	6 ⁽⁹⁾	15 ⁽³⁾	2	6 ⁽¹²⁾	15
11	2	6	12	6	18	6	12	7	16	6	15	6	14	2	6	12
12	2	6	12	6	18	6	12	7	16	6	15	6	14	2	6	12
13	2	6	12	6	18	6	12	7	16	6	15	6	14	2	6	12
Weights	2	6	12	6	18	6	12	7	15	6	15	6	14	0	6 ⁽¹⁰⁾	5
15	2	6	12	6	18	6	12	6	15	6	15	6	14	0	6	5
16	2	6	12	6	18	6	12	6	15	6	15	6	14	0	6	7
17	2	6 ⁽²⁾	12 ⁽³⁾	6 ⁽²⁾	18 ⁽¹⁾	6 ⁽⁴⁾	12	6 ⁽¹⁾	15	6 ⁽³⁾	15	6 ⁽²⁾	14 ⁽²⁾	1	6 ⁽²⁾	8
18	2	6	12	6	18	6	12	6	15	6	15	6	14	1	6	8
19	2	6	11	6	17	6	12	6	16	6	15	6	12	1	6	9
20	2	6	11	6	17	6	12	6	16	6	15	6	12	1	3	9
21	2	6	11	6	17	6	12	6	16	6	15	6	12	2	3	12
22	2	6	10	6	17	6	12	6	14	6	15	6	12	2	3	10
Weights	2	6	10	6	17	6	12	6	14	0	10	6	12	1	3	10
24x	2	6	10 ⁽⁵⁾	6 ⁽¹⁾	17 ⁽²⁾	6 ⁽³⁾	12	6 ⁽⁷⁾	14	0 ⁽²⁾	10	6 ⁽⁴⁾	12 ⁽¹⁾	1	3 ⁽³⁾	10
25	1	6	10	6	17	6	12	6	14	0	10	6	12	1	3	10
26	1	6	10	6	17	6	14	6	15	0	12	6	12	1	3	11
27	1	6	10	6	17	6	14	6	15	4	12	6	12	1	3	12
28	1	6	10	6	17	6	14	6	15	4	12	6	12	1	3	12
29																
30																
31																
Remarks																

* Refer to group in which animal belongs.

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