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THE MINIMUM PROTEIN REQUIREMENT FOR GROWING
DAIRY HEIFERS.

by

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INTRODUCTION.

By minimum protein requirements of growing dairy heifers is meant the least quantity of protein in the ration which will allow normal growth to proceed. A study or investigation leading to a knowledge of the minimum amount of protein to be fed growing dairy heifers, to solve the fundamental problems should be conducted with animals receiving purified food substances, and every nutritional factor should be under complete control. It is obvious that this is entirely impractical with such large farm animals as dairy heifers. Consequently the results cannot be entirely satisfactory from a scientific standpoint, yet if such experiments are properly controlled they should give results of value both scientifically and practically. Thus these experiments may rightly be regarded as a stepping stone between the purely scientific and the purely practical.

From a scientific viewpoint such an investigation is important because it will enable future investigators in animal nutrition to conduct experiments on a more certain basis, for it should eliminate one of the important factors. It may also serve to throw some light on the practical application of work conducted with experimental animals.

From a practical view-point this study is probably more important. Protein is the most costly portion of an animal's ration. If we could determine the minimum amount of protein to be fed dairy heifers, and if these findings should be applied to practical feeding, an immense economic saving can be had by those who now over-feed with protein. Those who do not supply sufficient protein in the ration, might by using these standards, greatly improve the value and thrift of their dairy herd.

So well is the question of protein minimum recognized as a problem of importance that the United States Department of Agriculture has recently planned to institute a series of cooperatively conducted experiments at several experiment stations, including Missouri. The

object of these experiments is to determine the minimum amount of protein necessary for the maintenance and normal growth of dairy heifers.

This dissertation will be divided into two closely correlated parts:-

First, a comprehensive general discussion of the problem of protein minimum. It will include the records and results of investigations with both experimental and with farm animals.

Second, a discussion of the results obtained at this station together with the detailed records of some recent experiments.

GENERAL DISCUSSION OF PROTEIN MINIMUM.

The Chemistry of Proteins.- The proteins which occur universally in all plant and animal organisms, and are so essential in cell growth, are of extremely complex form. The quantitative composition of some of the known proteins may be expressed approximately as follows:-

C	50.0	to	55. %
H	6.5	"	7.3%
O	19.0	"	23.0%
N	15.0	"	17.0%
S.	0.3	"	2.4% Long (60)

In their complex composition and in some other respects, the proteins differ markedly from the fats and carbohydrates. Thus they cannot be elaborated except in the plant kingdom or at any rate, the fundamental structures in them appear to be formed in vegetable growth only. It is true that animals can modify and transform them but they cannot build them up from simple materials.

There has been considerable confusion between the terms proteins and proteids - the two being some-

times used synonymously and at other times to mean different things. However, as the result of the work and recommendations of a committee representing the American Society of Biological Chemists and the American Physiological Society, the word "protein" has been used to designate the whole group of substances which consist, so far as at present is known, essentially of combinations of amino acids and their derivatives (60).

Altho the proteins have all practically the same percentage composition, yet they differ widely in chemical structure. As has already been referred, the proteins are composed of a combination of amino acids. Each protein has its characteristic specific group of amino acids. Then again, each amino acid has its particular structure (13). Table I gives the analysis of certain common proteins. These analyses are not complete, nevertheless they illustrate the point that proteins from different sources differ in their amino acid content. They also illustrate the fact that the origin of a protein is a true criterion of its make-up.

TABLE I.
PERCENTAGE OF AMINO ACIDS FROM PROTEINS.

Amino Acids	Egg Albumin	Serum Globulin	Lactalbumin	Caseinogen Cows Milk	Edas-tin C.S.	Prot. of Maize	Zein Maize	Gluten from Wheat	Glia-din from Wheat	Herdein from Barley	Avan from Oats	Gelatin
	%	%	%	%	%	%	%	%	%	%	%	%
Glycine	0	3.5	0	0	1.20	.3	0	0.4	0.70	0	1.0	16.5
Alanine	2.1	2.2	2.50	1.50	4.50	----	9.8	0.3	2.70	1.40	2.5	0.8
Valine	---		0.90	7.20		----	1.9	---	0.40	1.40	1.8	1.0
Leucine	6.1	18.7	19.40	10.50	15.50	6.2	19.6	4.1	6.00	7.00	15.0	2.1
Phenylalanine	4.4	3.8	2.40	3.20	3.90	1.8	7.0	1.0	2.60	5.50	3.2	0.4
Tyrosine	1.1	2.5	0.90	4.50	2.30	3.8	10.1	1.9	2.40	4.00	1.5	0
Serine	---	---	----	0.50	0.40	----	1.0	---	0.20	0.10	---	0.4
Systine	0.3	1.5	----	0.10	---	----	---	---	0.40	---	---	---
Proline	2.3	2.8	4.00	6.70	2.30	5.0	9.0	4.0	7.06	13.73	5.4	5.2
Aspartic Acid	1.5	2.5	1.00	1.40	2.90	0.7	1.7	0.7	1.30	1.30	4.0	0.6
Glutamic Acid	8.0	8.5	10.10	15.60	17.20	12.7	26.2	24.0	37.33	41.30	18.4	0.9
Tryptophane	5.0		0.91	1.50			----		1.00		----	0
Arginine	2.1	---	-----	4.84	13.51	7.1	1.9	4.4	3.16	3.20	----	9.3
Lysine	2.1	---	-----	6.00	2.06	3.0	----	2.2	0	0	----	5.0
Histidine	----	---	-----	2.59	3.46	3.0	0.9	1.2	1.20	1.28	----	0.4
Ammonia	----	---	-----	1.60	----	2.1	3.6	2.5	5.11	4.87	----	0.4
Total	35.2	46.0	42.11	67.73	69.23	45.7	98.7	46.7	71.61	85.08	52.8	43.0

Taken from Plimmer's Tables (118)

THE METABOLISM OF PROTEINS.

Having looked into the chemical composition of the proteins, it might be well at this point to get a comprehensive idea of its metabolism in the animal body. There is now available an immense amount of data on the metabolism of protein, nevertheless of the actual process of protein metabolism very little is known definitely. Many theories of protein metabolism have been advanced and discarded - especially since 1867 when Voit (15) first advanced the view, "that the protein of the food after absorption, circulated in the tissue fluids - became "circulating protein" - and was utilized by the living tissues without first becoming an integral part of them." The protein from the tissue when worn out, was discarded and was replaced by the material from the "circulating" or food protein. Later, as the composition of the proteins were better understood, the theories began to differ, Kornauth (58) Gruber (35), Aberhalden (5 and 6). The idea began to prevail that the proteins were broken down into their constituent amino acids during the process of metabolism.

The generally accepted view today, is that the proteins are first broken down in the digestive tract, into simple amino acids. There are three steps:- 1. The pepsin of the gastric juice splits the proteins into proteoses and peptones.

2. The trypsin of the pancreatic juice acts on the proteins passing from the stomach and further reduces them to the proteoses, peptones, polypeptids and amino acids.

3. The erepsin of the intestinal juice acts on these simpler proteins formed and changes them finally into amino acids and possibly in some instances even into ammonia.

Thus we have a breaking down of the proteins into simple crystalline amino acids which in Abderhalden's words (1, and 4) are the building stones in protein metabolism. It is assumed that the animal has no synthetic power which enables it to build the amino acids needed from the complexes in the food, with the single exception of glycoll. Abderhalden (3) Cathcart (15) Folin (27) Van Slyke (110). The amino acids thus formed are absorbed into the blood from the intestines and as such are carried thruout the body. These absorbed amino

acids have been shown to rapidly disappear from the blood, Van Slyke (110). It must be concluded then that they are absorbed by the tissues of the body as they are supplied by the blood. Since the animal proteins are constituted of definite proportions of the various amino acids it must follow that the various tissues absorb just what acids they require, in the correct proportions. Amino acids not utilized by the tissues would consequently be wasted.

An important correlary to this generally accepted theory of protein metabolism was made by McCollum (63 and 68). He concludes from numerous experiments with rats and pigs that "there is apparently a difference in the metabolism and utilization of protein for growth and for maintenance." His experiments seem to indicate that there is a different "quality" of protein necessary for these two different processes. In maintenance, the protein is required only for a repair of old tissue, which McCollum thinks does not involve a complete replacement of the protein molecule but only of certain amino acids. In growth there is involved the

building of entirely new tissue, with the consequent building of the whole molecule. Experiments by Kaufman (56), Kellner (57) and Morgen (83 and 84) showing that non protein nitrogen is utilized very efficiently for maintenance but not at all or very poorly for growth or milk production, may serve to strengthen McCollum's theory.

The metabolism of protein is influenced by several factors which will be summarized here but not discussed.

1. The nature of the food taken in with the protein. Mendel and Lewis (79a) Cathcart (15 and 17) Van Slyke (111)

2. The caloric value of the diet, that is the quantity of carbohydrates and fat consumed with the protein. Mendel and Lewis (79b) Cathcart (15 and 16), Tsugi (108).

3. The rate and completeness of digestion and absorption. Cathcart (15).

4. Activity of the animal. Abderhalden (2)

5. The temperature of the environment.

Abderhalden (2) Cathcart (17).

6. The composition or quality of the proteins. Cathcart (15) Mendel and Lewis (79c).

The Use of Protein by the Animal.- The word protein is of Greek origin, meaning "of first importance". Because of the various and necessary uses it is put to in the body it really is of first importance. Protein enters into the complex structures of all the living cells. It is utilized in practically all of the organs and fluids of the body. Generally fasting animals withdraw from their body, first fat, second carbohydrates and glycogen and last protein. (Armsby 11) This indicates to some extent the importance of protein to the organism.

Theoretically the animal body has but two general uses for protein; the repair of protein tissue in mature animals and in growing animals, this and the building of new protein tissue as well. Practically, however, there are three uses;-

1. The repair of protein tissue.
 2. The formation of new protein tissue.
 3. Protein as a source of energy.
-

The repair of protein tissue takes place, probably as McCollum (62) indicates, in the replacing of the consumed amino acids. The nature of the process of the construction of new tissue is as yet not known. In the utilization of protein for energy, it probably is not used directly but is taken from the stored protein, Cathcart (15). Just what percent of energy should be supplied from the protein, is a question that concerns us deeply in this dissertation.

The Quality of Protein.- The importance of the quality of proteins in feeding animals is sufficiently great, that it warrants a thoro discussion here. As has already been indicated, the proteins are composed of combinations of amino acids which in metabolism are utilized to repair the protein tissue of the body, to build new protein tissues and for energy. The composition of the proteins fed is often very unlike that of the animal body, as may be gathered from Table I. It is plain then that the nearer the composition of the protein ingested is like that of the body protein, the more completely will it be utilized. This is borne out by numerous experiments. Abderhalden (1 and 4) states from

his work with rats and dogs, "the greater the similarity of the molecule of food protein to that of specific body protein, the greater will be the food value to the animal. --- Any one of the essential cleavage products which is present in the smallest amount in food protein, determines the value of the entire molecule to the animal."

In later experiments Mitchell (82) reports that Abderhalden was able to maintain dogs and rats on a mixture of amino acids for various periods of time. Mitchell himself duplicated these experiments with mice and obtained very satisfactory results. Many other workers have been able to maintain and even produce growth in experimental animals fed amino acids. Cathcart (15) Thayer (105).

Of great importance in this connection is the work of McCollum with isolated substances. He found that some proteins are capable of maintaining life and even producing growth by themselves whereas others are practically useless. He states (62) "protein from various sources differ widely from one another in their fundamental characters and therefore are not equivalent as nutriment for animals." In later work with the effect of the quality of proteins on milk production,

Hart and Humphrey (38, 40 and 41) found that there was a remarkable variation in the utilization of proteins from various sources. The efficiency of the proteins tested is as follows:- wheat 34 - 36%; corn 40%; milk 58 - 60%; gluten feed 46%; oil meal 60%; distillers grains 60%.

Russel (102) reporting McCollum's experiments with pigs finds that two unbalanced or deficient proteins may offset some of the deficiencies. Thus McCollum found his pigs would utilize the protein from milk - 60%; from grains - 23 - 28%; from linseed meal 18% and from three-fourths corn and one-fourth linseed meal - 37%. Hence the corn offsets the deficiency in the linseed meal.

The experiments of Osborne and Mendel with isolated food substances are extremely interesting when considering the subject of quality of proteins. Like other experiment^{ers}/ already referred to here, they found certain food substances lacking in the essential amino acid groups (87, 90, 93, etc). They have demonstrated beyond any doubt that the value of a protein depends upon its quality or its constituting amino acids.

From the conclusions of these most noted workers, we must assume quite correctly that the nearer the composition of a protein ingested resembles the body protein, the more thoroly is it utilized. An absence or limitation of one or several of the essential amino acids, curtails the value of the protein and may even render it entirely unsuitable for growth or tissue repair.

The Protein Minimum.

The Physiological Minimum.- There is no doubt that the body requires daily a certain supply of protein material to repair tissue waste. If there is no supply or the supply is limited, the break-down of the protein-tissue continues. There is then a loss of protein from the body tissues. The quantity of protein ingested sufficient to prevent the break-down of the body tissue or loss of protein from the body, is the physiological protein minimum.

The Actual Minimum:- Theoretically then, the protein requirement should equal in mature animals, the nitrogen excreted x 6.25 (the factor for protein). For growing or producing animals it should equal this plus the protein required for growth or production. This theoretical assumption, however, does not work out in practice. First, proteins differ widely in their amino acid make-up and consequently in their value for both maintenance and growth. Secondly, possibly because there is a definite limit to the intake of fat or carbohydrates on account of the mechanical difficulty in the digestion, or because of some other reasons, a certain proportion of the energy must be derived from the protein. The actual protein minimum then, is the total quantity of protein necessary for the repair of tissue, for the growth of new tissue and for supplementary energy. We must add that the protein minimum varies with the different proteins.

Trials With Experimental Animals.- At this point it may prove of some interest to summarize briefly some of the most important investigations in determining the protein minimum for experimental animals and for man. The first experiments of any great value were carried on by Michaud (81) with dogs. He attributed the previous failure of

Voit (112) and Korkunoff (from Cathcart 15) and others to get a nitrogen equilibrium to the fact that the proteins fed differed too markedly in composition from that of the tissue protein. Feeding a dog, dogs flesh he nearly reached the hunger minimum. He pointed out that a relative scale of minimum protein requirements should be made, based primarily on the quality of the proteins. Zisterer (117) agreed with the results of Michaud and made a comparative ratio for several protein materials, as regards their minimal requirements. His comparison is as follows; dog flesh 100; horse flesh 108; caseinogen 128; nutrose 121; edestin 153; gliadin 163. Thus an animal (presumably a dog) can subsist as well on the protein from 163 pounds of gliadin as from 108 pounds of horse flesh or from 100 pounds of dog flesh. Altho he concludes with Michaud that the requirement for protein is the lowest when it resembles most closely the tissue protein, he does not indicate just how much should be fed. We are led to believe, however, that for maintenance a dog should be fed "dog-protein" equivalent to 6.25 times the excreted nitrogen. It appears that if

some other protein is used this original maintenance requirement should be multiplied by the factors for that protein, as given above. Thus in using horse flesh multiply by 1.08, caseinogen 1.28, etc., to get the required amount to be injected. It is needless to say that a study of this, carried out far enough so that many foods could be included would prove an invaluable asset to the physiology of protein metabolism and to workers in problems of nutrition.

Considerable work has been done with the minimum protein for man. It is needless to go into detail regarding the recommendations other than to point out their extreme variability by summarizing them below (Cathcart, 15). This comparison is made on the basis of an 82 Kg (150 pound) man and also, were the requirements the same, for steers per 1000 Kg. live weight. It must be understood that the Armsby and Wolf-Lehman standards are for steers, and from them is figured the requirements for man, whereas for the others cited, it is just the opposite. These figures are of no more value here than to illustrate the variation in requirements, for they do not take into account the quality of proteins as having any bearing on the quantity necessary.

<u>Experimenter</u>	<u>Gms. per day</u> <u>per man</u>	<u>For Steers</u> <u>per 1000 Kg.</u> <u>Live Weight.</u>
Voit.	120	1.762
Chittenden.	60	.881
Hamill and Schryver	90	1.322
Cathcart	90	1.322
Melville (for soldiers)	190	3.017
Armsby (steers)	225	3.080
Wolf-Lehman(at medium work)	132	2.000
Wolf-Lehman(at heavy work)	189	2.800

In conclusion Cathcart's (15) words express precisely the present notion regarding the physiological protein minimum. "As regards the certainty of the protein minimum it may be definitely stated that there is no single minimum --- common to all men and all conditions." (This, of course, is as true for farm animals as it is for man). The fact that the quality of protein from different sources varies so widely and the fact that so many conditions enter into influence the metabolism of protein (page 10), makes this statement clearly obvious.

The Protein Minimum for Farm Animals.

What has already been considered of the protein minimum and the factors influencing it, applies as readily to farm animals as it does to experimental animals. This statement is based first; on Kellner's (57) view that, "the greatest digestive power is undoubtedly possessed by the ruminants"; second; on Armsby's (9) view that "it can hardly be assumed that the actual processes of metabolism in the body tissues are fundamentally different in the different species of mammals." However, it is well to consider here separately the protein requirements for farm animals, especially the growing dairy heifer.

Protein in Farm Feeds.- The first consideration that presents itself in discussing the proteins for farm animals, is the protein in the various farm feeds. Careful analyses have been made of the crude protein and the true protein (crude protein minus the non-protein nitrogen - amid free) in nearly all feeds. An excellent collection

of these analyses may be found in Henry's tables (48). Altho the available information is quite complete concerning the quantity of protein in the feeds, our knowledge of the quality of the protein even in the most essential feeds is very limited.

It is intended in this dissertation to discuss the quality of the protein in the feeds of which we already have some knowledge. Of the character of the proteins in the other feeds, it is impossible to give any definite information.

An examination of Table I will indicate somewhat the distribution of the amino acids in some of the proteins in a few of the feeds. Table II, given below indicates the distribution of the nitrogen in a few of the roughages.

TABLE II.
THE NITROGEN DISTRIBUTION IN ROUGHAGES
Percent of Total N.

Feed	Per Cent Total N.	Wat- er Sol. N. %	Acid- Amid H. %	Amino- Acid N. %	Remain- ing N.	Pep- tide N.	Ammonia N.
Corn Stover	0.86	65.5	25.6	25.7	11.2	----	3.05
Clover							
Hay	2.53	9.3	None	4.2	5.1	----	None
Alfalfa							
Hay	2.28	23.5	7.3	10.0	6.2	----	None
June							
Grass	1.76	16.3	1.28	16.4	2.1	----	1.50
(In bloom)							

From Hart and Bentley (37)

TABLE III.
PROTEIN FOR DAIRY AND BEEF HEIFERS COMPARED
Requirements in Kgs. per 1000 Kgs. Live Weight

Ages Mos.	Kellner		Lyden & Werner		Wolf		J. Kuhn		Wolf- Lehman	
	Dairy	Beef	Dairy	Beef	Dairy	Beef	Dairy	Beef	Dairy	Beef
6	3.1	4.0	3.0	4.0	3.0	3.5	2.5	3.5	3.0	3.5
9	2.9	3.6	2.5	3.5	2.5	3.0	2.2	2.8	2.0	2.5
12	2.6	3.2	2.0	3.0	2.0	2.5	1.8	2.4	1.8	2.0

From the above analyses and from those of Ames and Boltz (8) for alfalfa as given below, we find that a considerable portion of the nitrogen in the feeds is of the non-protein form.

Forms of Nitrogen in Alfalfa Hay.

<u>N.</u>	<u>Percent of Total</u>	<u>Percent Amide</u>	<u>Percent Protein</u>	<u>Protein N percent of Total</u>
1st Cutting	3.03	1.01	2.02	66.66
2nd Cutting	2.43	.55	1.88	72.28

The question immediately arises, is this non-protein nitrogen used by the ruminants and especially by growing dairy heifers? Armsby in his feeding standards precludes all but true or amid-free protein(9). Kellner (57), however, proves that non-protein nitrogen has a distinct place as a "protein sparer". The same view is also held at the Danish Research Laboratory (56) where it has been shown with milch cows that a part of the maintenance nitrogen can be of the amid form, the less the amount of protein present, the better the utilization of the amid nitrogen. Morgen (83 and 84) has shown in experiments with sheep and goats that non-protein nitrogen can take

the place of a part of the true protein in both growth and maintenance. He believes also that ammonia nitrogen ingested, is changed by bacteria in the stomach, into a higher form of nitrogen and then utilized as such. Hart, Humphrey and Morrison cite numerous experiments (43) to bear out the contention that the non-protein forms of nitrogen are used by the animal for maintenance and even for milk production. They conducted experiments with growing heifers and found that nitrogen retention in animals maintained almost entirely on the nitrogen from alfalfa hay was about the same as for animals maintained similarly on the nitrogen from the corn kernel. In alfalfa the non-protein nitrogen equals about 33 %; in corn about 6 %. Hence their results indicate that for maintenance and growth the protein from corn in a ration of 1:8.2 equals the protein from alfalfa on a ration of 1:12.4, or else that the amid form of nitrogen is utilized and the alfalfa ration is 1:9. The authors later concluded that on the basis of total nitrogen ingested, that from alfalfa is equal to the nitrogen from corn for the growth of dairy heifers. They also noticed that the animals were very wasteful in the use of nitrogen, which they believed to be evidence that "the quality of

the protein in the ration was not very good."

From what has been shown we must conclude that at least for maintenance of young-stock, non-protein nitrogen is useful, in that it takes the place of the true proteins. Consequently a large part of the nitrogen necessary for repair can be drawn from the non-protein form, and as some other work above cited indicates, it can be used also for tissue building to a slight extent.

Corn:- With this grain as with other cereals, we find certain deficiencies. The average water free analysis for the kernel is taken as 11.33 % crude protein, 82.26 % carbohydrates, 4.81 % fat and 1.54 % ash (Henry 48). The composition of the protein is given by Osborne (88) as follows:-

Zein		58 %
Maize glutelin		36 %
Globulius	)	
	)	
Albumius	)	6 %
	)	
Proteoses	)	

An examination of Table I shows that the zein of the corn kernel is entirely lacking in glycine, trypto-

phane and lysine. It is not only probable but it is certain as will be shown, that tryptophane and lysine are the limiting amino acids in the corn grain.

Even as far back as 1909, Michaud (81) found in experiments with dogs that the protein from corn is only 30 % efficient. Later, working with rats, Osborne and Mendel found that zein is inadequate for growth (87 and 94), pointing out that in all probability lysine was the limiting amino acid. In glutelin they report 2.93 % lysine and zein 0. Since glutelin constitutes 36 % of the total protein in maize, the percentage of lysine is consequently very small. They also found that tryptophane added to zein greatly improved its ability to maintain growth (88). They believe that this deficiency in the composition can be met when feeding farm animals, by the addition of a small amount of lactalbumin. Working with chickens they found that chicks fed corn gluten plus lactalbumin, developed normally. If corn gluten alone was fed, it was found to be totally inadequate (90). In their latest work, Osborne and Mendel conclude that the best results in any case where corn is fed are obtained when tryptophane and lysine are added to the ration (91).

Hogan with rats (52) found that tryptophane was the first limiting factor and lysine the second limiting factor in corn feeding. Evvard (22) working with brood sows found that the protein from corn alone tended to produce in the offspring, lessened vigor, less weight and smaller litters. Comparing the protein from cereals and from milk for growth of pigs McCollum (63) believes that zein is utilized for growth to some extent but not for maintenance. In further work with pigs McCollum and Simmonds obtained two-thirds normal growth when they fed 91 % of the protein in the ration from maize kernel. They state, "the protein of the maize kernel contains all of the amino acids essential to growth but the proportions are not adequate."

In conclusion we must draw the inference from this mass of evidence, that the protein from the maize kernel is inadequate. It is limited first in tryptophane and second in lysine. Its relative value for growth and maintenance together should not be taken as higher than 40 %.

Other Grains.- In general it must be said here that the deficiencies evident in corn protein hold to a large extent for all of the common grains, wheat, oats and barley.

Michaud (81) found wheat protein to be 40 % efficient for dogs. Osborne and Mendel (94) were able to maintain rats for some time on gliadin and glutenin from wheat. They found the gliadin to contain 16 % and the glutenin 1.92 % lysine (87). Mendel and Fine (78) believe that if it were not for the mechanical factors involved, the utilization of the protein from corn, wheat, oats and barley would be about equal. McCollum in pig feeding experiments (63) found the grains to be 23 - 28 % efficient for growth and maintenance. Hart and Humphrey found the wheat kernel to be 34 % efficient (40 and 41). McCollum and Simmonds (70 and 71) showed that zein does not supplement the total protein with wheat or maize kernel and that it does supplement the protein of the oat kernel. Gelatin supplements both the oat and wheat kernel. From this they conclude that tyrosine and tryptophane and possibly cystine are the limiting amino acids in the protein of corn, oats and wheat.

We can deduce then in conclusion that the proteins from cereal grains are probably as inadequate as the protein from corn. It is at least certain that no satisfactory growth has as yet been obtained, by feeding

any mixture of grains.

Other Concentrates.- Not very much work has been done in determining the protein quality of the common important concentrates. The work of Hart and Humphrey (38, 41, 44 and 46) with milch cows indicates that the efficiency of gluten feed protein is about 46 %; oil meal 80 %; and distillers grains 80 %. Osborne and Mendel (90) working with chickens found that cotton seed meal when added to corn gluten was just as efficient and could produce as good growth as lactalbumin added to corn gluten. Richardson and Green (97 and 98) find that cotton seed meal contains all of the amino acids necessary for normal growth. A protein content in the ration of 18 %, derived wholly from cotton seed meal is adequate for normal growth. Hence we must conclude that the protein of cotton seed meal is "adequate."

Milk Products.- Skimmilk and skimmilk powder prove to be the most valuable products for feeding young growing animals. Michaud has shown milk protein to be 99 % efficient with dogs (81) McCollum (63) with pigs proves it to be the best supplement for corn, supplying all of the missing amino acids. Osborne and Mendel (90) also show this

to be true with rats and chickens. They showed in other experiments (89) that the lact-albumin foods in every case produced the largest gains. For the same growth as with lactalbumin 50 % more casein or 90 % more edestin is necessary. We can see then that the protein from milk is practically a "complete protein", being of animal origin it has a composition not very much unlike the animal tissues.

Roughages.- As yet very little is known concerning the quality of protein in the roughages. Hart, McCollum and Steenbock (42) conducted interesting experiments with dairy heifers in which they fed four lots of four animals each on rations derived entirely from the corn plant, the wheat plant, the oat plant and a mixture of the three. The order of excellence was corn, oats, the mixture of the three, and wheat. These rations affected not only the development of the heifers but also the offspring and the milk production. Conditions approaching normal were reached by the corn-fed heifers only. These results, the authors believe cannot be attributed so much to the difference in proteins as to the presence of some unknown toxic substance in some part of the plant. The

protein of alfalfa has been given considerable attention, especially as regards the utilization of its amid content (page 20). We find that the total nitrogen from alfalfa is as efficient as the total nitrogen from corn, despite the fact that alfalfa has about 33 % non-protein nitrogen. Consequently the total nitrogen from alfalfa should not be taken as over 40 % efficient (page 25).

PROTEIN FEEDING STANDARDS FOR FARM ANIMALS.

It is not the purpose in this paper to discuss the various feeding standards in detail. All that will be undertaken here is a discussion of the protein requirements as set forth by the various feeding standards.

As already mentioned (page 10) the protein is needed by growing animals for maintenance and growth and possibly for energy. There is nothing to hinder our belief, that for maintenance the growing animal requires as much protein in proportion to its size and weight as does the mature animal. This quantity has been quite accurately determined by many workers and is now taken to

be about .52 pounds true protein per 1000 pounds live weight (Armsby 11). But it is impossible to determine just how much protein is needed for the other two requirements apart from the protein needed for maintenance.

There is considerable variation in the quantity of protein recommended by the different investigators. Many of the experiments conducted do not apply to dairy heifers since the data was taken with growing beef animals. The most noted authorities concede that the requirements for growing beef animals differ from those for growing dairy animals on account of the difference in the rate of gain. This is well illustrated in Table III. Because of the variation in the requirements between beef and dairy breeds, it is intended to ignore here all experimental work carried on with beef breeds and to consider only the requirements for dairy heifers.

Table III indicates briefly the recommendations of some of the German investigators. It is interesting to note the variation in protein requirement for dairy heifers. An extremely low figure was that obtained by

Fingerling (25), who recommends 1.5 pounds true protein per 1000 pounds live weight for dairy heifers from 5 to 9 months old. He was able to maintain heifers and produce growth on as low as 1.345 pounds of true protein per 1000 pounds live weight. He concludes that for heifers from 5 to 9 months old 1.5 pounds true protein is just as efficient as 3.31 pounds of true protein per 1000 pounds of live weight, provided they have the same supply of carbohydrates -- 12 to 13 pounds per 1000 pounds of live weight. A supply of protein above 1.5 pounds only caused a larger loss thru the feces and urine and so a consequent waste.

Wolf-Lehman Standard.- The standard set down by Wolf-Lehman for growing dairy heifers at different ages, is given below (Henry 48).

TABLE IV.

THE WOLF-LEHMAN STANDARD FOR GROWING DAIRY HEIFERS

Age	Average Live Weight	Digestible Crude Protein Pounds Per 1000 Lbs. Live Weight	Per Animal
Mos.	Lbs.		
2 - 3	150	4.0	.60
3 - 6	300	3.0	.90
6 -12	500	2.0	1.00
12-18	700	1.8	1.26
18-24	900	1.5	1.35

TABLE V.

KELLNER STANDARD FOR GROWING DAIRY HEIFERS

Age	Live Weight	Digestible Crude Protein Pounds Per 1000 Lbs. Live Weight	Per Animal
Mos.	Lbs.		
2 - 3	150	3.4	.51
3 - 6	300	2.8	.84
6 -12	500	2.3	1.15
12-18	700	1.8	1.26
18-24	900	1.3	1.17

From this we see that the protein requirement per 1000 pounds live weight is assumed to decrease with an increase in age. As might be expected, with an increase in weight, the total protein per animal increases.

Kellner Standard.- Kellner's (57) standard ration gives the following for protein requirements. The total requirements in this standard are lower than those of the Wolf-Lehman but not quite so low as those of Kuhn, Fingerling, etc.

Armsby Standard.- Armsby's tables (9), calculated on the basis of true protein are as follows.

TABLE VI.

ARMSBY STANDARD FOR GROWING DAIRY
HEIFERS

Age	Live	True	Energy
Mos.	Weight	Dig.	Value
	Lbs.	Protein	Therms
		Lbs.	
3	275	1.10	5.0
6	425	1.30	6.0
12	650	1.65	7.0
18	850	1.70	7.5
24	1000	1.75	8.0
30	1100	1.65	8.0

It must be taken into consideration that the results in this table were obtained from feeding trials with beef steers and consequently are somewhat high for dairy heifers. The requirements are much higher than any yet given.

Flints Experiments.- Some very instructive experiments were conducted by P. M. Flint of Georgia (26) on the protein requirements of dairy heifers. He used grade Jerseys under one year old. When started, the animals were from 3 to 5 months old. The heifers were divided into three lots. For a preliminary trial of 30 days all of the lots were fed according to the Wolf-Lehman standards. Then for a period of 88 days lot II was fed the same Wolf-Lehman standard; lot I received 25 % less protein and lot III 25 % more protein. The other factors in the ration remained as called for by the above standard.

It can be seen from these tables that the gain was directly in proportion to the amount of protein fed.

The experimenter further determined the metabolism of the protein by means of the nitrogen balance. Two animals were used from each lot.

TABLE VI.

FLINT'S EXPERIMENTS - PERIOD I. (88 days)

Lot	Average Weight Daily	Dig. Prot. per 1000 Pounds	Daily Gain Pounds
I	223.5	2.15	.48
II	198.9	3.02	.60
III	216.1	3.70	.80

FLINT'S EXPERIMENTS - PERIOD II. (88 days)

Lot	Average Weight Daily	Dig. Prot. per 1000 Pounds	Daily Gain Pounds
I	299.1	1.86	.54
II	280.9	2.63	.74
III	312.5	3.23	1.01

It appears from these experiments that the nitrogen retention is not very much affected by the quantity of protein injected, for there is apparently no greater retention in the heifers receiving a 25 % deficiency than there is in the heifers receiving a 25 % excess of protein. Flint concludes that the minimum amount of protein given (lot I, 25 % below the Wolf-Lehman standard), is adequate for normal growth. He states further, "Growth capacity depends primarily upon the individual, so long as the protein supply is adequate to supply the material for growth. A larger quantity does not cause a greater rate of growth except only in a minor degree." Another important conclusion which can be drawn from Flint's work is that individuals vary in their protein requirements, the variation in this case being considerably augmented by the use of animals of different breeds and by figuring their requirements on the basis of age.

Other Investigations.- Besides these experiments reported, there are very few others recorded, which have been conducted with dairy heifers. A few Jersey heifers which were included in some feeding tests by

TABLE VIII.

FLINT'S EXPERIMENTS - NITROGEN BALANCE.

Lot	Average Weight	Dig. Prot.	Protein Metabol- ized	Reten- tion per 1000 Lbs.	Gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
I a	250.1	.54	.24	1.20	.74
I b	206.2	.48	.17	1.50	1.02
II a	257.8	.72	.29	1.67	1.27
II b	266.9	.69	.36	1.45	.90
III a	222.5	.84	.54	1.35	1.32
III b	209.0	.82	.58	1.10	1.11

TABLE IX.

GEORGESON'S RESULTS WITH DAIRY HEIFERS

No. of Heifer	Age	Weight	Daily Dig. Prot.	Daily Gain
	Mos.	Lbs.	Lbs.	Lbs.
4	13.86	603	.975	1.33
5	14.69	575	1.185	1.15
6	13.50	586	.948	1.27
7	<u>13.01</u>	<u>524</u>	<u>1.051</u>	<u>1.09</u>
Average	13.76	572	1.040	1.21

Georgeson (33) may be included here for comparison. The heifers were about one year old when started and were fed 147 days. Their results were not tabulated. Table IX gives the ages, weights, protein fed and daily gain.

The amount of digestible protein consumed daily was figured for the above from the daily feed given the heifers (Henry's tables used). As can be seen, the protein fed was below that recommended by the Wolf-Lehman standard. The gain in weight was above normal.

From what has been shown here it appears that the recommendations regarding the quantity of protein necessary for normal growth vary widely. Table IX comparing directly, the different standards illustrates this point to advantage. While there is considerable variation in the standards it would be concluded that feeding a quantity of protein in excess of that set forth is unnecessary and a waste of food. Surely there must be some good reason for this difference of opinion. If we look closely into the work of the various investigators who established these standards we find that at the time when their^{work}/was carried out all of the factors controlling the utilization of protein now recognized

were not understood. It is easily conceivable that the lack of knowledge at the time, concerning the quality of protein alone, may be a satisfactory explanation for this variation.

TABLE X.

A COMPARISON OF THE RECOMMENDATIONS OF FEEDING
STANDARDS AND EXPERIMENTS FOR GROWING DAIRY HEIFERS

Standard or Experi- menter	Pounds of Digestible Protein per 1000 Lbs. Live Weight					
	3 mos.	6 mos.	9 mos.	12 mos.	18 mos.	24 mo
Lydtin & Werner	-----	3.0	2.5	2.00	-----	-----
Wolf	-----	3.0	2.5	2.20	-----	-----
J. Kuhn	-----	2.5	2.2	1.80	-----	-----
Fingerling	-----	1.5	---	----	-----	-----
Wolf-Lehman	4.0	3.0	2.0	1.80	1.5	-----
Kellner	3.4	2.8	2.3	1.80	1.3	-----
Armsby (True Prot.)	1.1	1.3	----	1.65	1.7	1.75
Flint (Low)	-----	2.0	----	----	-----	-----

EXPERIMENTS AT THE MISSOURI STATION.

As far as is known, no experiments have been conducted to determine the quantity of protein necessary to produce normal growth in dairy heifers, where practically all of the nutritional factors outside of quantity of protein were supplied and where a satisfactory basis of comparison in determining normal growth was used. First let us consider briefly, each of the nutritional factors which must be present.

1. Energy.— The growing heifer must have a sufficient supply of energy producing material, carbohydrates and fat, in order to produce satisfactory growth. Probably the most satisfactory method for expressing this requirement is that given by Armsby (Table VI).

In figuring the rations for the experimental animals at this station, the weight rather than the age was used as a basis. The requirements are based on the results obtained in a number of experiments with growing animals. Wherever the total energy in the feeds supplied (by Armsby's Tables) did not come up to the requirements, the deficiency was supplied by adding a suitable amount of sugar and starch. It was the

aim in every case to doubtlessly supply a sufficient amount of energy in the ration.

2. Mineral Requirements.— But little definite knowledge is available regarding the mineral requirements of animals and especially growing heifers. We know little regarding the quantity of minerals to supply and even less of the proportion in which the elements should be supplied. It is generally conceded that Ca and P. are ordinarily the main elements to which attention should be given, altho Mg. and K. also deserve considerable notice (Forbes, 29 and 30). With experimental animals, the mineral content of milk is often taken as a basis in figuring the mineral requirements necessary for normal growth. Milk contains, CaO .14 %; P_2O_5 .17 %; MgO. .017 % and K_2O .175 %. We know that the minerals in the milk must be in a highly available form. Furthermore we do not know whether the amount supplied is sufficient or whether it is superabundant. Consequently, it is inconceivable how such a basis can be used for such large animals as dairy heifers. The assumed requirement for dairy cows in full production, varies from 75 to 100 gms. CaO per day and from 50

to 75 gms. P_2O_5 per day. (Forbes, 29 and 30). The other minerals are supposed to be well supplied by any ordinary system of feeding so that their importance is negligible.

Based on McCollum's work with pigs (64) a calf about six months old should receive as a supplement to the daily ration about one ounce of rock phosphate - - $Ca_3(PO_4)_2$ (56 gms.). This would yield about 8.4 gms. of P_2O_5 and about 11.2 gms. of CaO . Again, Gouin and Andouard (in Henry, 45) and Kellner (in Forbes, 30) recommend an addition of from 60 to 90 gms. of bone meal to the ration of the growing heifer. There is, however, no record of how much the mineral content of the ration should vary with the variation in age or weight. Consequently it is advisable in an experiment to determine the minimum protein requirements to supply all of the minerals in a quantity, probably far above the actual requirements and so be on the safe side of this respect.

The minerals in the experimental ration used were supplied; first, by feeds rich in mineral matter as alfalfa, bran, skim milk, etc; second, in some cases by feeding mineral supplements as bone meal, potassium citrate and magnesium citrate.

3. Quality of Proteins.- This subject has already received considerable attention in this paper and consequently very little can be added here. It was the aim in this experiment to supply an adequate protein mixture in every case. This aim was satiated by providing a combination of feeds, the protein quality of which we know to be either adequate or nearly so. In this connection skim milk powder, which has already been shown in this paper to be excellent from the standpoint of protein quality, was used in several of the rations.

4. Fat Soluble A.- McCollum has shown by numerous experiments (66, 68, 69 and 72) that a substance of unknown composition which he terms "fat soluble A" is absolutely essential for the growth of animals. Animals deprived of this "vitamin," show a swelling of the eyelids, a marked soreness of the eyes and in six or seven weeks become blind. If this necessary dietary factor is withheld longer, the animal finally dies. If a small amount of butter fat is fed, the animal quickly recovers, unless the deprivation has gone too far. The fat soluble A is very abundant in butter fat and is also found in some quantities in the leaves of plants, especially in alfalfa. It is wholly absent in vegetable fats and in the grains.

Water Soluble B.- Another "vitamin" discovered by McCollum and which is just as important in the ration is the "water soluble B". Fortunately this substance is relatively more abundant, for it is found in sufficient quantities in the cereal grains, in skim milk, etc. An ordinary ration in which some grain is fed is sure to supply enough of the water soluble B.

5. Toxic Substances.- Important experiments with dairy heifers by Hart, McCollum, et al., already discussed here (page 30) show that rations made up entirely of either the oat plant, the wheat plant or a mixture of which they form a large part, proved toxic and affected the individuals and their offspring. McCollum, Simmonds and Pitz (70) found that a high percentage of protein from the wheat kernel, when fed in the ration had a bad effect on the offspring - causing blindness or death. They thought this to be due to some cumulative toxic substance. The same investigators (73) found that oats produce a bad effect on growth, possibly as a result of the absorption of putrefactive substances from the intestines. Osborne and Mendel (92) found that cotton seed meal "has a diliterious effect due to some ether soluble substance in the

seed" which can be removed and which acts either as a toxin or makes the food unpalatable."

This discussion makes it evident then that some attention should be paid to toxicity. We must be careful to render the ration free, as far as possible, from any large amount of toxin-producing feeds. To be sure, small quantities of these feeds in the ration cannot carry with them sufficient quantities of toxins to be harmful.

Growth Normal.- In order to compare the growth of animals it is necessary to have some definite basis of comparison. Too many experiments have proven valueless because the comparison was based either on guess work or on a check animal. A far superior basis for comparing growth is now in use at this station. It is a growth curve, one for Jerseys and one for Holsteins, compiled from the records of a considerable number of young animals. By constructing a plot so that the coordinate represents the weight or height at withers and the abscissa the age in months it can readily be determined how an animal compares with the normal for either weight or height. In experiments where a great deal depends upon comparing the growth of animals, such a growth curve is invaluable.

Riford's Work.- In the fall of 1913 experiments were started to determine the minimum amount of protein necessary to produce normal growth of dairy heifers, from the age of six months to the time of birth of the first calf. The then known factors outside of protein quantity, were as far as possible eliminated from the ration. The plan followed in feeding was:-

1. The ration was calculated for the animals each month, a month in advance.
2. The maintenance was figured according to weight rather than age, by Armsby's standard.
3. A comparison with the growth normal showed how much a normal animal at its age should gain per day.
4. The energy value of protein was assumed to be 1.016 therms per pound.
5. From tables of average net energy for maintenance and per pound of growth for dairy of Holstein or Jersey breeds, the energy in addition to that for maintenance was determined.

When about six months old the animals were placed on experiment. Previous to that time they were kept the same as the rest of the young stock of the herd. When placed on experiment the animals were kept "practically the full time in small box stalls with board floors

(previous to 1914). Shavings were supplied for bedding. In good weather they were allowed the run of a dry yard during the day. They were kept muzzled at all times when not in their stalls to preclude any possibility of obtaining feed and also because they showed a tendency to eat dirt". Later, November, 1914, the heifers were kept in a barn built especially for experimental purposes. The heifers had each a single box stall with a cinder floor. Shavings only were used for bedding. During warm days the animals were turned out, muzzled, into a dry yard. Clear fresh water and salt were available at all times. In later work, several changes to be discussed presently, were made in the care of animals. The animals were fed twice daily, morning and evening. The feed was weighed out at each feeding, recorded and feed not consumed was weighed back and the amount recorded. Measurements, which are described in Riford's dissertation, were taken every thirty days. Weights, "until December 1914, the heifers were weighed weekly. Once each month the animals were weighed on three consecutive days and the average for the three days taken as the weight for the middle day". Later, 1914, the weights were taken every ten days and three-day weights every thirty days. Still later(1916)

only the three day weights were taken every thirty days.

Riford in his dissertation discussed the pure-bred Jersey heifers No. 91 and No. 94. At time of entering the experiment 91 was a little below normal in weight and height at withers; whereas 94 was almost normal in weight and above normal in height at withers. Heifer 91 was kept on a high protein ration, 25 % of the energy for growth being furnished by the protein. Her ration was alfalfa hay as a roughage and as a concentrate, a grain mixture of corn, bran and cottonseed meal during the first half of the experiment for later the cottonseed meal and bran were left out. Heifer 94 received timothy as a roughage and corn only as a concentrate. In period 20, 21 and 22, this heifer received alfalfa and starch and sugar (11 pounds corn starch to 3 pounds sugar) instead of timothy and corn. She also received a mineral supplement of bone meal and calcium carbonate.

Development of Heifers.- Heifer 91, on high protein, was somewhat below normal in weight when started on the experiment. This sub-normal position she maintained thruout the experiment without very much variation. The same may be said of her increase in height. Thruout the ex-

periment she was active and in good flesh. From these facts Riford concluded that heifer 91 developed normally.

Heifer 94 on low protein did not develop normally. When started she was very near the normal in weight. Up to period 19 her curve showed a steady deviation from the normal. After 19 it increased slightly but even at the end of the experiment the weight was about 120 pounds below normal. At six months of age 94 was above normal in height. Up to period 19 there was the same deviation from the normal in height as was noted in weight. After period 19 she gained rapidly in height but she never did catch up to the normal. Her condition thruout the experiment was such as to show a decided lack of thrift. When 14 months old she became blind and has remained so ever since.

Riford's Conclusions.- Riford concludes that 91 which received the high protein ration, developed normally. She apparently had a sufficient quantity of protein in her ration and all of the other dietary factors were eliminated. Heifer 94 did not develop normally mainly because of an inadequate amount of protein in her ration. The nutritional factors discussed were:-

1. Protein content of the ration.
2. Energy value of the ration.
3. Mineral content of the ration.
4. The Protein quality.

New Considerations.- It is highly probable that if we should review the experiments with heifers 91 and 94 in the light of our present knowledge, several new considerations of value might present themselves. Since Riford drew his conclusions several new nutritional factors have arisen. They have each been discussed in this paper in detail (pages 44 - 49).

There is no doubt that No. 91 developed normally and 94 subnormally. It now remains to be seen whether or not this difference in development can be entirely ascribed to the quantity of protein in the ration. Was the development of 94 limited by the quantity of protein? Were each of the remaining six nutritional factors satisfied? These are the questions to be answered.

1. Energy.- Riford's Chart I showing a comparison between the energy supplied in the ration fed 91 and 94 and his conclusions indicate beyond any doubt

that the energy was sufficient.

2. Mineral Content.-- Table XI and Charts I and II, comparing the mineral content of the rations fed 91 and 94 with the minerals in the rations of a few other animals which it is reasonable to believe were sufficiently supplied as regards this nutritional factor, show that both 91 and 94 probably did not receive enough CaO. Especially low in this respect is the ration fed 94. An important fact to permit the inference that the mineral make-up of the rations was insufficient, was the constant desire of both heifers to eat dirt. So great was this desire that both animals were muzzled when in the yard. Riford mentions that the ration fed 94 might be insufficient from a mineral standpoint. We may conclude then that in minerals, particularly CaO, it is barely possible that 91's ration was poor, but it is quite clear that the ration received by 94 was insufficient in this respect.

3. Protein quality.-- Considerable has lately been added to the knowledge of quality of proteins. It appears from this that the ration received by 91; alfalfa, corn, bran and cottonseed meal had a sufficient amino acid supply. Experiments at Wisconsin (101,102) indicate that such a combination furnishes the highest efficiency

for milk production. Theoretically, and it may be assumed from what we know also practically, there is not very much difference between the amino acid requirements for growth or for milk production. Both involve the building of new tissue. Hence it is safe to say that 91 received an adequate mixture of amino acids. With heifer 94, however, it is different. Riford admits the possibility that this animal did not receive an efficient supply of protein. Seventy-five percent of the protein of her ration was from corn, which has been conclusively shown to be only 40 % efficient (page 25) and 25 % of the protein from timothy hay, the protein quality of which is unknown. But it is unreasonable to believe that the amino acids in timothy are of sufficiently high quality to compensate the low value in corn and bring it up to the high level of efficiency maintained with 91. Consequently we will have to conclude that the quality of protein was not excluded from the ration of 94 as a nutritional factor.

4. Fat-Soluble A.- When Riford made his study, the importance of "vitamins" in the ration was not yet recognized. This phase then, demands our particular attention. It appears that the ration fed 91 happened

to have a sufficient supply of the fat soluble A, which is found fairly abundantly in alfalfa hay. In the case of 94, however, which was maintained for the first 19 periods on timothy and corn, it is not so sure that this "vitamin" was adequately supplied. Corn has been shown to contain very little of the fat soluble A (McCollum, Simmonds and Pitz, 69). The only other source is the leafy portion of the timothy, the vitamin content of which we know nothing. Two general indications point to the conclusion that 94 did not receive an adequate supply of fat soluble A.

1. In the eight periods of the experiment heifer 94 went blind. No cause for this blindness could be found. McCollum's experiments show (page 47) that blindness is one of the first symptoms of a lack of fat soluble A in the ration. The calf to which 94 gave birth also was blind and died soon after birth.

2. When alfalfa replaced timothy in the last few periods, 94 showed remarkable gains in weight and height. Riford reports of this change thus, "Her coat assumed a smooth appearance. She showed better spirits and was more active. From lack of evidence

we cannot consider the improved condition of the heifer following the change in ration as due to any one or to all of the factors included in the change". It is safe to conclude in view of our increased knowledge of "vitamins" that 94 was limited by an insufficient supply of fat soluble A.

5. Water soluble B.- This "vitamin" which is fairly abundant in the seed coats of the cereals, was sufficient in the ration fed 91. It was supplied by the corn, the cottonseed meal and the bran. With 94, the only apparent source was corn and in the last few periods when the corn was replaced by the starch and sugar it was practically absent from the ration. Whether this absence had anything to do with causing the death of her calf it is impossible to state. The fact that 94 gained so much during her last few periods indicates that the absence of the water soluble B had no visible effects on the animal.

6. Toxic Substances.- It is safe to conclude that the ration fed 91 did not contain toxins, sufficient to affect the animal. Altho not quite so certain with 94 because her ration was limited to two sources, it may be reasonable to conclude the same for this animal as well.

General Conclusions.- It appears that the ration fed 91 had an abundance of protein - a quantity about equal to the Wolf-Lehman standard. Altho the mineral content may have been somewhat weak all of the nutritional factors were doubtlessly supplied.

Heifer 94 probably did not receive a sufficient quantity of protein and in addition there is considerable doubt whether the following nutritional factors were supplied.

1. Mineral content.
2. Protein quality.
3. Vitamin - fat soluble A, Water soluble B.

Consequently the low plane of protein of her ration cannot be taken as the absolute cause of her lack of development.

TABLE XI.

MINERAL CONTENT IN DAILY RATIONS OF HEIFERS

Period	CaO	P O ₂ 5	MgO.	K ₂ O
	Gms.	Gms.	Gms.	Gms.
<u>No. 250</u>				
3	31.204	20.950	3.238	38.869
11	37.289	29.073	8.044	62.224
18	40.422	32.018	8.834	71.753
25	66.810	39.124	13.402	79.353
<u>No. 253</u>				
4	50.027	23.801	6.775	35.738
11	59.648	27.843	8.672	48.146
17	68.791	32.323	11.510	57.910
24	60.971	29.573	8.995	50.830
<u>No. 103</u>				
4	40.756	28.866	6.413	56.373
10	35.892	25.349	7.410	42.876
14	37.224	26.727	8.263	65.747
19	38.094	27.642	8.581	68.533
<u>No. 91</u>				
1	23.966	26.710	-----	-----
6	34.882	43.800	-----	-----
18	47.352	28.204	-----	-----
22	44.047	27.784	-----	-----
<u>No. 94</u>				
1	39.990	10.919	-----	-----
6	26.759	22.412	-----	-----
18	37.210	31.473	-----	-----
22	28.829	12.004	-----	-----

TABLE XI. (CON'T.)

MINERAL CONTENT IN DAILY RATIONS OF HEIFERS

Period	CaO	P ₂ O ₅	MgO.	K ₂ O
	Gms.	Gms.	Gms.	Gms.
<u>No. 115</u>				
1	5.147	15.664	5.076	33.715
8	25.947	18.249	8.448	42.328
15	31.268	32.781	7.354	74.496
<u>No. 114</u>				
1	15.577	14.494	5.913	29.089
10	41.853	30.575	7.467	40.748
19	67.538	39.061	13.600	91.283
<u>No. 269</u>				
2	29.420	31.638	11.703	45.684
11	37.112	38.571	11.987	62.400
<u>No. 267</u>				
2	36.170	21.497	7.603	57.913
11	37.149	34.407	13.459	62.144
18	41.389	40.350	14.992	83.916
<u>No. 266</u>				
2	23.032	10.513	5.653	39.606
9	24.192	20.195	7.866	43.972
18	25.125	21.203	8.374	50.746

5-1-1915

Chart I
Curves showing CaO
intake of heifers
daily by periods

- No. 253
- No. 250
- No. 91
- No. 94
- No. 103

Periods

GRAMS

Periods

TABLE XII.

MINERAL CONTENT OF FEEDS

Lb. per 100 Lbs.

Feed	CaO	P ₂ O ₅	MgO	K ₂ O
Corn	.014	.471	.135	.169
Timothy	.207	.222	.112	1.492
Alfalfa	1.484	.550	.303	1.416
Bran	.213	2.553	.767	1.048
C. S. Meal	.228	1.345	.168	.825
Skimmilk Pwd.	1.731	1.539	.246	2.499
Oats	.140	.810	.200	.560
Bone Meal	33.695	21.958	----	-----
CaCO ₃	47.600	-----	----	-----
K Citrate	-----	-----	----	16.000
Mg.Citrate	-----	-----	5.700	-----

Note.- This table was compiled from Riford's figures and from compositions of feeds given in Henry's tables.

FURTHER EXPERIMENTS.

With the object of determining more definitely what the actual protein minimum for the growth of dairy heifers should be, several other animals have from time to time been placed on experiment. With our increased knowledge of the nutritional requirements of animals it has been possible to use a ration that supplies these factors with reasonable certainty. It has also been the intention in these later experiments, to compare somewhat the effect on growth of the source of protein.

At the present writing there is available data on the following heifers besides 91 and 94 which have been discussed in Riford's thesis and in this paper.

Heifer No.	Breed	Percent of Energy for Growth from Protein	Condition of Data
250	Holstein	8 %	Complete
253	Holstein	15 %	Complete
103	Jersey	15 %	Complete
114	Jersey	15 and 25 %	Incomplete
115	Jersey	15 %	Incomplete
266	Holstein	15 %	Incomplete
267	Holstein	25 %	Incomplete
129	Jersey	15 %	Incomplete
132	Jersey	20 %	Incomplete
273	Holstein	20 %	Incomplete
277	Holstein	35 %	Incomplete
120	Jersey	8 %	Incomplete
269	Holstein	25 %	Incomplete

In this part of the dissertation it is intended to discuss in some detail the results obtained with the animals on which complete records are now available and to consider in as much detail as is possible the data on the heifers still in the experiment. The same eliminative process of reasoning that was employed in reviewing Riford's work will be used here.

Feeding and Care:- The same method as that described by Riford and already explained here, was used in the feeding and care of the experimental animals. At present all of the animals are kept in a barn especially built for the purpose. During cold weather they are kept tied in stanchions; during warm weather and also at night, the heifers are allowed the freedom of a small gravel yard where they have free access to water. They are not muzzled and they show no tendency to eat dirt as was described by Riford.

The rations for the heifers are figured in advance every thirty days. If not enough energy is supplied by the roughage and concentrates, starch and sugar are added in a quantity sufficient to furnish the desired energy value. The mineral content of the rations are reinforced if it seems advisable, by the addition of bone meal, calcium carbonate, magnesium citrate and potassium citrate. The animals are fed twice daily.

Measurements and Weights:- Every thirty days on three consecutive days the weights of the animals are taken. Up to July 13, 1916, the twenty-one measurements enumerated by Riford were taken. Beginning on that date a new measurement "the width of thurls" was added. This new measurement was included because it was noticed that when an animal failed to develop normally her width of thurls was greater than her width of hips. A normal animal is several centimeters wider at the hips than at the thurls. Whether an insufficient protein supply is the cause of this peculiar development or whether it is due merely to a checking of the growth, it is impossible to state at this time. More attention will be given this point later.

Heifer No. 250.

In December 1914, Holstein heifer No. 250 was placed on experiment on a low protein plane, practically to compare as nearly as possible to the quantity in the ration fed No. 94. Table XIII gives the average daily quantity of feed given this

animal for the 28 periods she was on experiment. For the first 23 periods the protein was supplied by the timothy hay and skim milk powder. During the remainder of the experiment alfalfa was added. The plane of protein was maintained at about the same level thruout the experiment except during periods 7 and 19 when it was materially raised to note the effect.

Growth:- As may be seen from Table XIV and Chart III, 250 made a very irregular gain in weight. During periods 7, 11, 19 and 23 there was either no growth at all or else a falling off in weight. When put on experiment 250 was practically of normal weight. She then fell off in weight very rapidly until in period 12 she was over 200 pounds below normal. From period 12 to 18 she stayed at about the same distance from the normal. In the following few periods there occurred another drop and then a slight gain to the end of the experiment. When this heifer was taken off the experiment she weighed only about 70 per cent of the normal. There can be no doubt then that 250 did not develop normally in weight.

In skeletal growth somewhat different results were noted. In height at withers, Chart IV, 250 was a little below normal at the start. Up to period 7 there was only a very slight falling off; from 7 to 14 the growth was rather slow, the lowest point being reached in period 12 when the heifer was 5.5 centimeters below the normal. After period 14 there began a rather intermittent approach to the normal until at the end of the experiment she was a little above normal height. The increase in heart girth followed along quite generally with the increase in height. At the end of the experiment she probably had a normal heart girth. The width of hips however did not develop normally and she showed that same peculiar condition noted with 94, in which animal there is a greater width of thurls than of hips, Chart V.

Observations on 250:- Thruout the experiment 250 was observed to be in good spirits and to eat her feed well. She was always noted to be a little thin and was not able to stand the cold as well as

the other heifers. In the 18th period when her protein was increased she improved greatly in looks and made considerable gains. Since being taken off the experiment she made an excellent showing in milk production, She was placed on official test and yielded about 15,000 pounds of milk within the year.

Summary on 250:- From the observations and from a study of the tables and charts for this animal we must conclude that 250 made a normal growth in height but she was subnormal in width of hips and in weight. It now remains to be determined whether the protein was the limiting factor.

1. Energy in the Ration.- An examination of Table XV and Chart VI shows that the energy supplied 250 was at every period except 21, considerably above the Armsby standard. Chart VII showing the relation between the energy furnished daily in the ration and the increase in weight by 30 day periods, proves quite conclusively that a sufficient energy value was supplied this animal for, an increase in the daily energy value of the ration produced no increase

in the rate of gain. Likewise, a lowering of the energy value did not decrease the rate of growth. We can safely conclude then that the energy factor was sufficiently supplied in the ration of 250.

2. Mineral Matter.- Table XI and charts I and II show that the feed of this heifer had a rich mineral content. In CaO her ration was richer than that furnished 94 and but a little below that of 91. It is difficult to conclude definitely that 250 received sufficient minerals in her ration. The fact that considerable mineral supplements in the form of bone meal, potassium and magnesium citrates were furnished and that the animal showed no special cravings for mineral matter may lead us to conclude that she was not limited by this nutritional factor. True, she grew normally in height but like 94 which probably did not receive sufficient CaO her posterior development, the relation between the width of hips and width of thurls was abnormal.

3. Quality of Proteins.- In the first 23 periods the proteins were furnished by timothy hay and skim milk powder; in the last 5 periods alfalfa hay was added. We know quite definitely that skim-milk protein contains an adequate mixture of amino acids. This, together with the unknown proteins from timothy and alfalfa hay may be assumed to constitute a mixture of fairly high quality.

4. Fat Soluble A.- During the first 23 periods the only possible sources from which the fat soluble A could come were from the leaves of the timothy hay, of which we know nothing, and from the very little butter fat in the skim milk powder. There is no sure evidence available to show that this growth accessory entered in as a limiting factor in 250's growth. The only possible inference that it may have limited the growth is noted when we examine closely Table XIII and compare it with the growth curves, Charts III and IV. We find that when the skim milk powder was increased in the feed during periods 14 to 20, there occurred also a more rapid skeletal and weight growth. Again when alfalfa, which

we know definitely contains considerable of the fat soluble A, was added there followed a rapid gain in weight. But these results may have been due to other nutritional factors. The results from period 14 to 20 may have been due to a greater utilization of the protein in consequence of the increase in quantity of an adequate protein. This may also have entered in as a factor when alfalfa was added, and also the mineral content was much improved. Besides, the animal was advancing in the gestation period at that time. Because of these considerations we cannot conclude definitely that the fat soluble A was the limiting factor in the growth of 250.

5. Water Soluble B.- This growth accessory was doubtlessly supplied thruout the experiment by the skim milk powder if by none of the other feeds in her ration.

6. Toxins.- As far as we know, toxins played no part in limiting the growth of this animal.

7. quantity of Protein.- It is essential at this point to consider the quantity of protein in 250's ration as a possible explanation of her subnormal development. Table XV and Chart VIII show that this animal was maintained on plane of protein intake far below the Armsby and Wolf-Lehman standards; on an average about 50 per cent of these recommendations. Chart IX showing the relation between the protein fed and the increase in weight, shows that in general an increased gain was secured with an increase of the quantity of protein in the ration. In the 18th period 250 was placed on a high protein plane and she immediately responded by making better gains.

Conclusions on 250.- From what has been pointed out here we are reasonably sure that all of the nutrititional factors with the exception of protein purposely limited were supplied in sufficient quantities unless it was CaO, which it is possible was close to the lower limit. It at least is clear that the only serious deficiency was the quantity of the proteins. It has been shown to be directly responsible (if not by itself then in part) for the subnormal

TABLE XIII.

FEED CONSUMED DAILY

Average by 30 Day Periods

No. 250

Period	Alfal- fa	Tim- othy	Starch and Sugar	Skim Milk Powder	Bone Meal	CaCO ₃	K.Cit- rate	Mg.Cit- rate
	Lbs.	Lbs.	Lbs.	Lbs.	Gms.	Gms.	Gms.	Gms.
1	-----	3.59	3.43	1.04	25.0	8.3	-----	-----
2	-----	3.45	3.50	1.22	38.3	10.0	-----	-----
3	-----	3.72	3.50	1.25	40.0	10.0	-----	-----
4	-----	3.60	3.50	1.25	65.0	5.0	15	30
5	-----	3.54	3.51	1.12	65.0	-----	30	60
6	-----	3.73	3.40	1.12	65.0	-----	30	60
7	-----	3.73	3.59	1.17	65.0	-----	30	60
8	-----	5.95	2.90	1.08	65.0	-----	30	60
9	-----	6.00	3.00	1.09	65.0	-----	30	60
10	-----	6.50	3.00	1.13	65.0	-----	30	60
11	-----	6.50	3.10	1.18	65.0	-----	30	60
12	-----	7.17	2.97	1.14	65.0	-----	30	60
13	-----	7.42	3.20	1.19	65.0	-----	30	60
14	-----	7.42	3.30	1.29	65.0	-----	30	60
15	-----	7.40	3.60	1.39	65.0	-----	30	60
16	-----	7.42	3.77	1.42	65.0	-----	30	60
17	-----	7.42	3.92	1.47	65.0	-----	30	60
18	-----	7.42	3.90	1.47	65.0	-----	30	60
19	-----	7.25	3.67	1.37	62.8	-----	29	58
20	-----	7.42	3.80	1.43	65.0	-----	30	60
21	-----	7.42	3.30	1.30	65.0	-----	30	60
22	-----	7.42	5.27	1.22	65.0	-----	30	60
23	-----	7.42	5.00	1.28	65.0	-----	30	60
24	3.87	4.12	5.00	1.28	65.0	-----	30	60
25	4.00	4.00	5.00	1.28	65.0	-----	30	60
26	4.00	4.00	5.00	1.28	65.0	-----	30	60
27	4.00	4.00	5.00	1.28	65.0	-----	30	60
28	4.00	4.00	5.00	1.28	65.0	-----	30	60

TABLE XIV.
WEIGHTS AND MEASUREMENTS AND
AVERAGE DAILY GAINS BY 30 DAY PERIODS
No. 250

Period	Weight	Height at Withers	Width of Hips	Width of Thurls	Heart Girth	Daily Gain	Lbs. Prot. per Lb. Gain	Therms per Lb. Gain
	Lbs.	Cms.	Cms.	Cms.	Cms.	Lbs.		
1	344	99.8	28.8	----	119.0	.967	.423	5.61
2	373	102.3	29.5	----	120.0	.433	1.038	12.94
3	386	105.0	31.0	----	122.0	.567	.857	10.16
4	403	107.8	32.0	----	125.0	.100	4.890	57.10
5	406	108.4	32.5	----	127.0	.300	1.470	18.60
6	415	110.5	33.0	----	132.0	.167	2.742	33.84
7	420	112.0	33.3	----	133.0	----	----	----
8	420	112.3	33.5	----	135.0	.667	8.988	90.90
9	440	113.4	34.3	----	140.0	.200	2.375	30.80
10	446	114.8	34.5	----	138.0	.667	7.781	9.63
11	466	115.8	35.3	----	140.5	----	----	----
12	458	115.8	35.5	----	141.0	1.433	3.710	4.66
13	501	116.5	36.0	----	143.0	.933	.597	7.57
14	529	117.8	36.8	----	145.0	.967	.613	7.51
15	558	120.5	37.8	----	143.5	.733	.840	10.25
16	580	121.5	38.3	----	144.0	.667	.964	11.68
17	600	122.7	39.5	----	146.0	.900	.726	9.84
18	627	124.3	40.0	----	148.0	.067	9.765	119.40
19	629	124.7	40.3	----	150.0	----	----	----
20	624	124.5	41.0	42.5	149.0	.400	.482	5.58
21	666	125.7	41.5	43.5	151.0	.167	3.786	43.62
22	671	127.0	42.0	43.8	151.0	.533	.384	5.73
23	777	127.0	42.3	43.5	154.0	----	----	----
24	692	126.7	42.0	44.0	157.0	1.033	.518	8.24
25	723	128.1	43.0	44.5	158.0	1.733	.308	4.90
26	775	128.3	44.0	45.0	162.0	1.700	.314	5.00
27	826	130.5	45.0	45.0	167.0	1.333	----	6.38
28	866	130.6	45.0	45.5	169.0	1.533	----	5.55

TABLE XV.

NUTRIMENTS RECEIVED DAILY BY 250

Average by 30 Day Periods

Period	Age at Beginning of Period	Average Weight	Dig. Prot.	Armsby's Dig. Prot. by Age	Net Energy	Armsby's Net Energy by Age
	Days	Lbs.	Lbs.	Lbs.	Therms	Therms
1	209	344	.409	.867	5.43	4.200
2	239	373	.450	.883	5.61	4.300
3	269	386	.486	.900	5.76	4.400
4	299	403	.489	.933	5.71	4.633
5	329	406	.441	.967	5.58	4.866
6	359	415	.457	1.000	5.64	5.100
7	389	420	.485	1.007	5.85	5.317
8	419	420	.401	1.033	6.06	5.533
9	449	440	.475	1.050	6.16	5.750
10	479	446	.521	1.066	6.42	5.966
11	509	466	.550	1.083	6.55	6.183
12	539	458	.533	1.100	6.69	6.400
13	569	501	.558	1.117	7.07	6.600
14	599	529	.593	1.133	7.26	6.800
15	629	558	.616	1.150	7.52	7.000
16	659	580	.643	1.166	7.79	7.200
17	689	600	.654	1.183	7.96	7.400
18	719	627	.651	1.200	7.96	7.600
19	749	629	.615	1.200	7.55	7.700
20	779	624	.676	1.200	7.82	7.800
21	809	666	.631	1.200	7.27	7.900
22	839	671	.589	1.200	8.79	8.000
23	869	717	.609	1.200	8.64	8.100
24	899	692	.536	1.200	8.52	8.200
25	929	723	.534	-----	8.51	-----
26	959	775	.534	-----	8.51	-----
27	989	826	-----	-----	8.51	-----
28	1019	866	-----	-----	8.51	-----

Pounds

Chart III
Curves showing increase
in weight of No. 250 and
the normal weight

— No. 250
— Normal

Periods

Centimeters

Periods

Cms.

Therms

PLATE A - FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

DEPARTMENT OF ENGINEERING, UNIVERSITY OF MO.

Periods

Pounds

Therms

Chart VII
Curves showing the increase
in weight and the energy
furnished daily in the ration
No 250
Energy Therms
Growth lbs.

Periods

Pounds

Periods

lbs. Protein

Pounds

Periods

development of 250. We must conclude then from the experiment with this animal, that a low protein plane, where only 8 per cent of the energy for growth is derived from the protein, is inadequate for the best development and growth of Holstein heifers.

Heifer No. 253.

Commencing June, 1915, Holstein heifer 253 was placed on a medium protein plane. It was intended to have her receive the proteins from alfalfa and timothy hay, in a quantity sufficient to furnish about 15 per cent of the energy for growth. Table XVI shows the daily feed given this heifer. During the first 3 periods only alfalfa hay and starch were fed. Bone meal as a supplement to the minerals in the ration was commenced in the third period and continued thruout the experiment. Timothy was added from the fourth period on. During periods 9 and 10 small quantities of 35 per cent cream were added to the ration to observe the effect of an addition of the fat soluble A.

Growth:- As can be gathered from Table XVII and from Chart X, 253 when placed on experiment was a little above normal in weight. Up to period 9 she steadily fell off until she was about 100 pounds below normal. But from this point on she gradually gained until the end of the experiment when she was about 85 per cent of the normal in weight.

As is evidenced by an examination of Chart XI, 253 was considerably below normal in height at withers when placed on experiment. But she gained rapidly and in the 10th period was above normal. At the end of her 26 periods she was 97 per cent of the normal, which may be taken for practical purposes as normal development in this respect. The increase in heart girth and width of hips was quite uniform and as far as could be judged normal. Chart V indicates that in this animal the relative development of the width of thurls and width of hips, as far as could be ascertained, approached the normal. At least we are certain that she did not show that peculiar development noticed with 94 and 250. On the whole then, her skeletal development was normal; her

increase in weight was subnormal.

Observations:- At the beginning of the experiment, in the first two periods heifer 253 was noticed to suffer from a slight swelling of the joints and a stiffness, especially of the hind legs. It was thought to be due to a lack of a sufficient quantity Ca or P in the ration and consequently bone meal was added thereafter. This produced a marked improvement and caused the stiffness and swelling of the joints to disappear. Until the last few periods she appeared in the very best of condition. But in the last few periods she looked a little rough and was not so lively.

Summary on 253:- It is easy to see that on a medium protein plane this animal developed quite satisfactorily with the exception of a small subnormality in weight. It is interesting to inquire if this is the effect of the quantity of protein in the ration.

1. Energy.- The energy value of 253's ration as seen from Table XVIII and Chart XII was

uniformly about 0.5 therms per day below the Armsby standard figured on the basis of weight. On the other hand it was about equal or possibly a little above the Armsby standard on the basis of age. Chart XIII indicates rather definitely that the energy in the ration was not the limiting factor in the increase in weight of 253, for, when it was markedly raised during periods 3, 12, and 19 to 26, there did not occur an increase in the rate of growth.

2. Mineral Matter.-- With probable exception of the first two periods this animal received a rich mineral mixture in her feed as can be seen from Table XI and Charts I and II. It is safe to say then that this nutritional factor was supplied.

3. Quality of Proteins.-- We have no definite data available to show that the proteins from a combination of alfalfa and timothy hay are adequate. From our practical knowledge we know that alfalfa hay produces excellent growth when fed to young stock. To what extent the quality of the proteins is a factor it is still impossible to state.

4. Fat Soluble A.- The vitamin, fat soluble A was well supplied in this ration by the large amount of roughage fed thruout the experiment, and especially by the alfalfa hay. During periods 9 and 10 an addition of this vitamin in the form of 35 per cent cream given with the feed, produced no increased growth.

5. Water Soluble B.- This growth accessory was probably supplied by the ration in sufficient quantities, altho we have no absolute knowledge to prove this point.

6. Toxicity.- As far as we know, there was not a sufficient amount of any one element in the ration to produce toxicity.

7. quantity of Proteins.- Table XVIII and Chart XIV show that the protein fed 253 was at all times considerably below both the Armsby and the Wolf-Lehman standards; on an average about 0.15 pounds per day lower. Chart XV shows quite conclusively that the quantity of protein was the limiting factor in the development of this animal. During periods 5 and 6 when the protein plane was raised the growth

of skeleton and the increase in weight were materially improved. Again during period 11 when the plane of protein intake was high the daily gain in weight was far more rapid than at any time in the experiment.

Conclusions on 253.- In skeletal growth this animal developed normally, in weight she was about 15 per cent below normal. As far as we know we can reasonably conclude that all of the nutritional factors were supplied and did not enter in to produce the limitation in her development. From the fact that 253 responded so markedly by an increased rate of growth when the protein plane was raised is strong evidence that the quantity of protein was the most important if not the only limiting factor of which we know. We can conclude then that on a protein plane where 15 per cent of the energy for growth is supplied by the proteins, Holstein heifers develop normally in skeleton but a little below normal in weight.

TABLE XVI.
FEED CONSUMED DAILY
Average by 30 Day Periods
No. 253

Period	Alfalfa	Timothy	Starch and Sugar	Bone Meal	35 % Cream
	Lbs.	Lbs.	Lbs.	Gms.	Lbs.
1	4.12	-----	3.42	-----	-----
2	4.40	-----	3.89	-----	-----
3	4.88	-----	3.76	50	-----
4	4.80	0.93	3.60	60	-----
5	4.80	1.10	3.38	60	-----
6	4.90	1.00	3.70	60	-----
7	5.00	1.10	3.90	60	-----
8	4.83	0.84	3.25	54	-----
9	4.85	1.39	3.11	55	0.33
10	5.40	1.50	3.59	60	0.50
11	5.58	1.96	4.03	60	-----
12	5.80	2.00	4.37	60	-----
13	4.97	1.42	4.12	54	-----
14	6.10	2.00	4.70	60	-----
15	6.50	2.00	5.00	60	-----
16	6.67	2.06	5.10	60	-----
17	6.90	2.00	5.40	60	-----
18	6.80	2.00	5.40	60	-----
19	6.27	2.00	5.11	58	-----
20	6.70	2.00	5.40	60	-----
21	5.99	2.00	5.00	48	-----
22	5.90	2.00	5.00	60	-----
23	5.80	2.00	5.10	60	-----
24	5.80	2.00	5.10	60	-----
25	5.80	2.00	5.20	62	-----
26	5.80	2.00	5.20	65	-----

TABLE XVII.
WEIGHTS AND MEASUREMENTS AND
AVERAGE DAILY GAINS BY 30 DAY PERIODS
No. 253.

Period	Weight	Height at Withers	Width of Hips	Width of Thurls	Heart Girth	Daily Gain	Lbs. Prot. per Lb. Gain	Therms per Lb. Gain
	Lbs.	Cms.	Cms.	Cms.	Cms.	Lbs.		
1	375	104.3	31.0	-----	123	.367	.930	11.45
2	386	107.3	32.0	-----	120	.233	1.418	20.10
3	393	109.0	33.0	-----	130	.633	.655	7.48
4	412	110.5	33.5	-----	131	.700	.555	6.49
5	435	111.6	35.0	-----	133	.433	.983	11.26
6	448	113.0	34.5	-----	135	1.400	.404	3.66
7	490	115.5	35.8	-----	139	.007	10.410	80.55
8	492	116.5	36.8	-----	137	.003	17.340	133.20
9	493	117.5	38.0	-----	138	1.133	.604	4.22
10	527	118.2	37.8	-----	141	1.000	.764	5.43
11	557	119.8	37.3	-----	143	1.133	.695	5.33
12	591	120.5	40.3	-----	143	2.000	.408	3.21
13	651	121.3	41.0	-----	147	-----	-----	-----
14	647	122.7	42.0	-----	150	1.033	.828	6.57
15	678	123.5	42.3	-----	152	.633	1.435	11.32
16	697	123.8	43.5	43.00	151	1.400	.668	5.25
17	739	125.2	44.3	43.50	155	.967	.995	7.89
18	768	126.5	45.0	44.50	157	1.033	.699	5.56
19	809	127.2	45.8	43.50	161	-----	-----	-----
20	806	127.7	46.5	45.00	155	.733	1.335	10.32
21	828	128.5	46.5	45.00	165	.867	1.013	8.07
22	854	129.2	47.5	45.50	167	.867	1.001	8.04
23	880	130.5	48.0	45.50	169	.733	-----	9.55
24	902	131.0	48.5	46.00	168	.500	-----	14.02
25	917	131.5	48.0	46.00	169	-----	-----	-----
26	917	130.5	48.0	46.50	170	-----	-----	-----

TABLE XVIII.

NUTRIMENTS RECEIVED DAILY BY 253

Average by 30 Day Periods

Period	Age at Be- ginning of Period Days	Average Weight Lbs.	Dig. Prot. Lbs.	Armsby's Dig. Prot. by Age Lbs.	Net Energy Therms	Armsby's Net Energy by Age Therms
1	191	375	.341	.858	4.20	4.150
2	221	381	.331	.875	4.69	4.250
3	251	393	.415	.892	4.74	4.350
4	281	412	.426	.917	4.98	4.517
5	311	435	.426	.950	4.88	4.750
6	341	448	.566	.984	5.13	4.983
7	371	490	.694	1.008	5.37	5.208
8	401	492	.578	1.025	4.44	5.425
9	431	493	.685	1.042	4.79	5.642
10	461	527	.764	1.058	5.43	5.858
11	491	557	.788	1.075	6.05	6.075
12	521	591	.816	1.091	6.42	6.291
13	551	651	.695	1.108	5.68	6.500
14	581	647	.856	1.125	6.79	6.700
15	611	678	.909	1.142	7.17	6.900
16	641	697	.936	1.158	7.35	7.100
17	671	739	.962	1.175	7.63	7.300
18	701	768	.956	1.191	7.60	7.500
19	731	809	.919	1.200	7.18	7.650
20	761	806	.979	1.200	7.57	7.750
21	791	828	.978	1.200	7.00	7.850
22	821	854	.868	1.200	6.97	7.950
23	851	880	----	-----	7.01	8.050
24	881	902	----	-----	7.01	8.150
25	911	917	----	-----	7.09	-----
26	941	917	----	-----	7.09	-----

Periods

Pounds

Therms

Periods

Chart XII

Curves showing therms of energy
in daily ration and Armsby
standard

by weight
by age
Armsby's Standard
No 253

Periods

Pounds

Periods

Heifer No. 103.

Jersey heifer 103 was put on experiment January 1915. It was planned to place her on a little higher plane of protein intake than that of 250 but to feed the same nutriments, timothy hay and skim milk powder. The protein she received was calculated to equal 15 per cent of the energy required for growth, whereas 250 received only 8 per cent. Table XIX shows her daily consumption of feed and indicates that the only difference between the rations of 250 and 103 was the replacement of bone meal by CaCO_3 .

Growth:- When placed on experiment, 103 was a little above normal in weight. During the first 10 periods there occurred a gradual dropping off in weight until she was about 85 pounds below normal. From that time on, as seen from Table XX and Chart XVI, her increase in weight ran parallel with the normal increase. At the finish she was about 12 per cent below normal.

Table XX and Chart XVII indicate that 103 was slightly above normal in height at withers from the very start. This she maintained for the first 7 periods after which she was practically at normal until taken off the experiment. Her heart girth and width of hips developed quite uniformly. Only two measurements were taken on the width of thurls but these show, Chart V, that there was a comparatively excellent development.

Observations on 103:- This animal acted and appeared normal thruout the experiment. She ate well and her coat looked sleek. The only thing out of the ordinary, was that she seemed unable to bear the cold, just as was noticed with 250. When calved she acted very uneasy and wild. Unlike 250, her production was exceedingly poor and she was finally slaughtered. Whether this poor production was the result of her being on the experiment is beyond determination.

Summary on 103:- From the above we must conclude that this animal developed normally in skeleton but a little subnormally in weight.

1. Energy.- Table XXI and Chart XVIII compare the energy furnished in the ration with the Armsby standard. During the first 10 periods the energy in the ration was considerably above the Armsby standard, both on the basis of age and of weight. Between periods 10 and 18, it was intermediate between the two bases in the Armsby standard, whereas after period 18 it dropped a little below both. Chart XIX shows that there was a divergence from the normal in the weight of 103, in spite of the very high energy value in the ration during the first 10 periods. The falling off from the normal in the last two periods may have been due to the lowering of the energy values, but there is nothing to prove this for a slowing up of growth is often noticed in apparently normal heifers, in the last few months of pregnancy. It is safe to say then that thruout the experiment the energy value of the ration was not the limiting factor in the growth of the animal.

2. Mineral Matter.- The mineral matter in this animal's ration was approximately about the same as that furnished 250, Table XI and Charts I and

II. But, being a much smaller animal than 250 it is safe to infer that she received a sufficient quantity of this necessary factor.

3. Quality of Proteins.- What has already been stated in regard to the quality of proteins in 250's ration applies equally as well here. As far as we could determine, the quality of the proteins were adequate.

4. Fat Soluble A.- There is no evidence that this animal did not receive a sufficient amount of fat soluble A.

5. Water Soluble B.- As with 250, the skim milk doubtlessly supplied all of this growth accessory that was necessary.

6. Toxins.- We are reasonably certain that here too, toxins played no part.

7. Quantity of Protein.- Table XXI and Chart XX show that the protein fed was considerably below the Armsby and the Wolf-Lehman standards. Except in periods 2 and 3 the protein was about 0.4 pound per day below the above standards. It is evident from an examination of Chart XXI that there

is a direct relation between the rate of growth and the protein intake. During periods 2 and 3 when the plane of protein intake was the highest the growth was about the most rapid. The slow growth at the end of the experiment has already been partially explained and nothing further can be added.

Conclusions on 103.- From the above discussion we see that 103 developed normally in skeleton but slightly subnormally in weight. With the possible exceptions of energy value in the last two periods, and of fat soluble A, the nutrititional factors were well supplied. Doubtlessly the real limiting factor in the normal development of this animal was the quantity of protein. We can conclude from this that on a protein plane where 15 per cent of the energy for growth is furnished by the protein in the feed, Jersey heifers develop normally in skeleton but a little subnormally in weight.

TABLE XIX.

FEED CONSUMED DAILY

Average by 30 Day Periods

No. 103.

Period	Timothy	Starch and Sugar	Skim- Milk Powder	Bone Meal	CaCO ₃	K. Citrate	Mg. Citrate
	Lbs.	Lbs.	Lbs.	Gms.	Gms.	Gms.	Gms.
1	3.09	2.49	1.29	20	10	----	----
2	1.40	2.82	1.52	37	10	----	----
3	2.78	2.90	2.09	40	10	----	----
4	3.00	3.00	2.44	40	10	10	29
5	3.27	2.89	1.55	40	10	20	55
6	4.09	2.92	1.67	40	10	20	55
7	5.00	2.53	1.62	40	10	20	55
8	5.00	2.30	1.59	40	10	20	55
9	5.00	2.40	1.61	40	10	20	55
10	5.00	2.50	1.65	40	10	20	55
11	5.00	2.50	1.65	40	10	20	55
12	5.50	2.40	1.65	40	10	20	55
13	6.50	2.20	1.61	40	10	20	55
14	6.50	2.30	1.63	40	10	20	55
15	7.30	2.30	1.62	40	10	20	55
16	7.00	2.40	1.65	40	10	20	55
17	7.00	2.50	1.70	40	10	20	55
18	7.00	2.60	1.68	40	10	20	55
19	7.00	2.60	1.69	40	10	20	55
20	7.00	2.60	1.69	40	10	20	55

TABLE XX.

WEIGHTS AND MEASUREMENTS AND
AVERAGE DAILY GAINS BY 30 DAY PERIODS

No. 103.

Period	Weight	Height at Withers	Width of Hips	Width of Thurls	Heart Girth	Daily Gain	Lbs. Prot. per Lb. Gain	Therms per Lb. Gain
	Lbs.	Cms.	Cms.	Cms.	Cms.	Lbs.		
1	272	95.5	27.5	----	115	.300	1.075	10.46
2	281	98.3	28.5	----	116	.500	1.030	9.26
3	296	100.9	30.5	----	121	1.367	.550	4.20
4	337	103.4	33.0	----	130	.667	1.302	9.42
5	357	105.5	33.0	----	132	.900	.635	5.97
6	384	108.0	34.0	----	132	.200	3.180	29.50
7	390	109.3	35.0	----	135	.367	1.753	15.38
8	401	109.5	35.5	----	140	.767	.828	7.40
9	424	110.3	35.0	----	141	.233	2.674	24.81
10	431	112.5	35.0	----	135	.600	1.096	9.85
11	449	112.8	36.75	----	144	.533	1.252	11.08
12	465	114.3	38.00	----	143	.967	.670	6.24
13	494	115.0	39.00	----	149	.967	.684	6.47
14	523	117.2	40.50	----	150	.833	.810	7.63
15	548	117.5	41.00	----	150	1.000	.693	6.70
16	578	118.4	41.50	----	152	.967	.722	7.04
17	607	118.8	42.50	----	153	.600	1.068	11.56
18	625	120.5	43.00	----	155	.467	1.487	15.02
19	639	120.5	43.50	38.5	154	.267	2.632	26.32
20	647	121.5	43.50	39.0	154	-----	-----	-----

TABLE XXI.

NUTRIMENTS RECEIVED DAILY BY 103.

Average by 30 Day Periods

Period	Age at Beginning of Period	Average Weight	Dig. Prot.	Armsby's Dig. Prot. by Age	Net Energy	Armsby's Net Energy
	Days	Lbs.	Lbs.	Lbs.	Therms	Therms
1	192	272	.484	.858	4.71	4.150
2	222	281	.515	.875	4.63	4.250
3	252	296	.752	.892	5.74	4.350
4	282	337	.868	.917	6.28	4.517
5	312	357	.572	.950	5.38	4.750
6	342	384	.636	.984	5.90	4.983
7	372	390	.643	1.008	5.64	5.208
8	402	401	.635	1.025	5.68	5.425
9	432	424	.624	1.042	5.79	5.642
10	462	431	.658	1.058	5.91	5.858
11	492	449	.668	1.075	5.91	6.075
12	522	465	.648	1.091	6.04	6.291
13	552	494	.662	1.108	6.26	6.500
14	582	523	.675	1.125	6.36	6.700
15	612	548	.693	1.142	6.70	6.900
16	642	578	.698	1.158	6.81	7.100
17	672	607	.641	1.175	6.94	7.300
18	702	625	.699	1.191	7.01	7.500
19	732	639	.702	1.200	7.02	7.650
20	762	647	.826	1.200	6.90	7.750

Periods

Pounds

Chart XVII

Curves showing increase in height at withers and normal

— No 103

— Normal

Periods

Centimeters

Therms

Periods

Chart XVIII

Curves showing Therms of energy
in daily ration and Armsby standard

by age — Armsby Standard
by weight —

No 103

Chart XIX

Curves showing the increase in weight and the energy furnished daily in the nation

No 103

- Energy Therms
- Growth lbs.
- Normal growth

Pounds

periods

Heifer No. 115.

Commencing on October, 1916, Jersey heifer No. 115 was placed on a low protein basis. The proteins were to be derived from corn, oats and timothy as seen from Table XXII. Cottonseed meal was added from the eighth period onward. From period 6 to the finish bone meal was supplemented to furnish more minerals and during periods 6 to 10 inclusive magnesium and potassium citrates were also added. It was found necessary to add starch and sugar for energy during periods 6 to 12 inclusive. Commencing with period 8 the protein in this animal's ration was raised to a medium plane to observe the effect it had on the growth. It was noticed that this animal as well as the others on experiment manifested a peculiar craving for something and it was decided in October 1917, to increase the quantity of roughage in the rations without changing the protein plane.

Growth of 115:- In height at withers 115 was above normal at the start but at the finish she was just

normal, Chart XXII. The increase in heart girth was regular and at the finish was practically normal for a Jersey heifer. The relation between width of hips and width of thurls, Table XXIII and Chart XXIII was uniform, altho at the finish there was not a very wide difference in the widths.

In weight 115 was only about 20 pounds below normal at the start. She maintained this relation for the first period when she dropped off rapidly to period 7. From this point on she maintained a constant relation to the normal and at the finish was 83 per cent of the normal, Chart XXIV.

Observations on 115:- From the very start 115 did not do very well. She ate poorly, did not gain rapidly, was narrow in the body, was thin and showed the effects of a low protein ration. When the protein plane was raised to 25 per cent of energy for growth from protein she gained a little better and ate her food more readily but she continued to look poor. When about a year on experiment she seemed to be stiff in the joints and manifested an excessive craving for salt. When her roughage

was increased she picked up somewhat. At present she looks a little narrow in body, and does not appear as thrifty as she should. No. 115 is due to calve in June 1918.

Summary on 115:- This heifer seemed to do poorly. In both skeletal growth and weight she was considerably below normal at the finish, altho when first put on experiment she was slightly below normal in weight and considerably above normal in skeletal growth.

1. Energy.- Chart XXV indicates that the energy furnished in this animal's ration was, after period 9, considerably below the Armsby standard. Nevertheless it is certain from Chart XXVI that energy in her ration was not the limiting factor for after period 9 the growth was considerably better than during the first nine periods.

2. Mineral Content.- It is apparent from Table XI that 115 was not supplied with a very rich mineral mixture. In the first five periods her ration had an abnormally low mineral content

and quite possibly this may have been one of the limiting factors in her growth. After that the bone meal aided considerably in bringing up the quantity of minerals altho, at no time was it very high. As was already noted, this heifer was stiff in her joints and had an unusual craving for salt during a part of the experiment. Undoubtedly this helps to further the conclusion that one of the limiting factors in the ration of 115 was an inadequacy of minerals.

3. Protein Quality. - As seen from Table XXII the proteins were derived from several sources, timothy, corn, oats, during a part of the experiment and later also from cottonseed meal. Timothy together with corn and oats, both known to be very poor proteins probably did not supply an adequate mixture. With the addition of a small quantity of cottonseed meal, after period 7, the protein quality was considerably improved for this feed has been shown to be an adequate protein. It is barely possible, however, that one of the limiting factors in the lack of development during the first part of the experiment and possibly later as well, was the low efficiency of the proteins.

4. Fat Soluble A.- It is reasonable to conclude from Table XXII that the mixture fed 115 contained a sufficient quantity of this growth accessory.

5. Water Soluble B.- The mixture of grains fed this animal doubtlessly supplied a sufficient quantity of this vitamin.

6. Toxicity.- The only feeds that could possibly produce toxic effects, which were given this animal, were oats and cottonseed meal. However, these were not supplied in sufficient quantity to have an appreciable effect on 115.

7. Quantity of Protein.- The protein in 115's ration was during the first 9 periods of a quantity calculated to furnish 8 per cent of the energy for growth or about 50 per cent of the Armsby and Wolf-Lehman standards. After period 9 it was raised to furnish 25 per cent of the energy for growth or about 60 per cent of the before-mentioned standards, Chart XXVII.

It is clear that the quantity of protein was a strong limiting factor in this animal's development. Chart XXVIII indicates that with a rise in the protein supplied by the ration there occurred a more uniform and regular growth.

Conclusions on 115.- From the above discussion it is certain that 115 did not develop normally in skeleton or in body weight. An increase in the quantity of protein in her ration aided materially in her development but nevertheless it continued far below normal. An examination of the data discussed indicates that there is strong proof to sustain the contention that one of the important limiting nutritional factors in her ration was an insufficient supply of minerals. The quality of proteins may also have been poor. As the case now stands, this animal developed very poorly on a supply of protein sufficient to furnish 8 per cent of the energy for growth and subnormally on a supply sufficient to furnish 25 per cent of the energy for growth.

TABLE XXII.

FEED CONSUMED DAILY
Average by 30 Day Periods
No. 115

Periods	Tim- othy Lbs.	Corn Lbs.	Oats Lbs.	C. S. Meal Lbs.	Bone Meal Gms.	Mg.Cit- rate Gms.	K.Cit- rate Gms.	Starch and Sugar Lbs.
1	4.00	2.00	2.00	----	----	----	----	----
2	4.00	2.00	2.00	----	----	----	----	----
3	3.97	1.87	1.87	----	----	----	----	----
4	3.97	1.97	1.97	----	----	----	----	----
5	3.87	2.00	2.00	----	----	----	----	----
6	4.00	2.00	2.00	----	40	40	20	.53
7	4.00	2.00	2.00	----	60	60	30	.60
8	4.32	1.68	1.37	.67	60	60	30	.73
9	5.77	1.60	1.00	.94	60	60	8	.80
10	5.77	1.60	1.00	.94	60	37	----	.48
11	6.50	1.60	1.00	.90	60	----	----	.37
12	6.50	1.60	1.00	.90	60	----	----	.40
13	7.67	1.32	1.00	.90	60	----	----	.27
14	10.00	1.00	1.00	.90	60	----	----	----
15	10.00	1.10	1.00	.90	60	----	----	----
16	10.00	1.17	1.00	.90	60	----	----	----
17	10.00	1.20	1.00	.90	60	----	----	----
18	10.67	1.20	1.00	.90	60	----	----	----

TABLE XXIII.

WEIGHTS AND MEASUREMENTS BY 30 DAY PERIODS
AND NUTRIMENTS RECEIVED DAILY 30 DAY PERIODS.

No. 115

Period	Age	Weight	Height	Width of Hips	Width of Thurls	Heart Girth	Energy Daily Therms	Dig. Prot. Daily Lbs.
	Days	Lbs.	Cms.	Cms.	Cms.	Cms.		
1	246	316	102.7	30.5	31.5	123	4.85	*.383
2	276	340	103.5	31.0	31.5	127	4.85	.396
3	306	344	106.2	31.8	32.0	127	4.63	.395
4	336	345	107.0	32.5	33.0	131	4.78	.393
5	366	361	109.0	32.0	33.5	130	4.79	.400
6	396	371	111.3	33.0	34.0	133	5.29	.404
7	426	365	112.2	34.0	34.5	134	5.34	.402
8	456	395	113.5	35.0	35.0	136	5.49	.602
9	486	409	115.0	36.0	36.0	138	*5.23	.611
10	516	437	115.8	36.0	36.0	139	5.35	.610
11	546	457	116.3	36.5	36.0	140	5.40	.618
12	576	459	116.8	37.0	36.5	144	5.35	.610
13	606	483	118.0	37.5	36.5	147	5.45	.616
14	636	533	119.0	38.5	37.0	150	5.75	.641
15	666	541	118.2	39.0	37.0	150	5.71	.633
16	696	584	119.3	40.0	37.0	149	5.94	.650
17	726	596	120.2	41.5	38.0	152	5.96	.648
18	756	619	120.5	41.5	38.0	155	6.10	.660

*From this point on the values are based on average composition rather than on analysis.

Periods

Chart XXIV

Curves showing increase
in weight and the normal
weight

No. 114

No. 115

Normal

Pounds

Periods

Therms

Periods

Chart XXV

Curves showing therm of energy in daily ration and the Armsby standard
 { by age }
 { by weight }

N 114 } Ration
 N 115 }

Chart XXVI

Curves showing the increase in weight and the energy furnished daily in the ration

No 115 No 119

Energy Therms

Growth lbs.

Normal

Periods

Pounds

Therms

Periods

Periods

Heifer No. 114.

Jersey heifer 114 was placed on experiment August, 1916 on a medium protein plane. Her ration was made up of corn, timothy and alfalfa hay. Commencing with period 8 it was found necessary to add some starch and sugar to increase the energy furnished by the ration. At this time bone meal was also added. Commencing with period 11 the plane of protein intake was raised to note the effect on growth.

Growth of 114:- When first placed on experiment 114 was slightly below normal in skeletal development. During the first period her height at withers remained in a constant relation to the normal. From period 2 to 6 she fell behind considerably and thereafter continued to grow in a line parallel to the normal. At the finish she was 93 per cent of the normal in height at withers, Chart XXII. Table XXV shows that the other skeletal measurements increased but slowly during the first few periods. It is

peculiar as can be seen from Chart XXIII that the relation between the width of hips and thurls was abnormal from the start but practically normal at the end of the experiment.

In body weight 114 was about 20 pounds below normal at the start. In the first 8 periods she dropped off from the normal very rapidly. From the 8th period on she continued to gain until at the finish she was 93 per cent of the normal, Chart XXIV.

Observations on 114:- During the first six months on experiment this animal did not do very well. She often refused her feed, she was thin and rangy and she gained poorly. In the succeeding six months she made somewhat better gains and looked a little better. She made a small gain in the breadth of body. However, she was often off feed. Beginning with period 11 the plane of protein was raised without changing the quality of the proteins and she showed better gains but nevertheless was not in the very best of condition. When the quantity of roughage was increased with this as with the other animals on experiment she

looked a little better and seemed to be in good spirits. Nevertheless this animal was not doing what she should and in December, 1917, the entire ration was increased by 25 per cent without changing the comparative quantities of the feeds. Thereafter she improved greatly in all respects.

Summary on 114.- It is seen that this animal with an unusual consumption of feed finally developed somewhat subnormally in skeleton and body weight.

1. Energy.- Chart XXV and Table XXV shows that the energy in this animal's ration was practically the same as in that of 115. The conclusions reached with 115 therefore hold for this heifer also, Charts XXV and XXVI.

2. Mineral Content.- With the possible exception of the first 7 periods the mineral content in 114's ration was surely sufficient as can be seen from Table XI. We have no evidence that it entered in as a factor to limit the growth of the animal.

3. Quality of Proteins:- A large percentage of the protein in this animal's ration was from corn which has already been shown to be inadequate. However, the fact that timothy and alfalfa hay were also fed makes it highly possible that the quality of the proteins was considerably improved.

4. Fat Soluble A.- The fact that alfalfa hay was present in this animal's ration makes it certain that this vitamin was present in a sufficient quantity.

5. Water Soluble B.- Likewise, because of the presence of corn in the ration this growth accessory was also supplied.

6. Toxicity.- We can conclude safely that toxicity played no part in 114's ration.

7. Quantity of Protein.- In the first 9 periods the protein supplied 114 was of a quantity sufficient to furnish 15 per cent of the energy for growth or about 60 per cent of the Wolf-Lehman and Armsby standards. After period 9 it was increased to furnish 25 per cent of the energy for growth or about 80 per cent of the Wolf-Lehman and Armsby stan-

dards, Chart XXVII.

The quantity of protein in the ration had some effect on the growth for when the protein plane was increased there occurred a slightly more rapid gain. However, the really rapid gain took place when the whole ration was increased by 25 per cent.

Conclusions on 114.- This heifer made a somewhat subnormal gain in both skeleton and body growth. It seems that all of the nutritional factors were supplied and even in the case of protein it is hard to conclude that it was insufficient. If we were certain that the protein mixture was of an adequate quality we would be justified in concluding that heifer 114 was abnormal.

TABLE XXIV.
FEED CONSUMED DAILY
Average by 30 Day Periods
No. 114

Period	Alfalfa	Timothy	Starch and Sugar	Corn	Bone Meal
	Lbs.	Lbs.	Lbs.	Lbs.	Gms.
1	2.00	2.00	----	3.50	----
2	2.00	2.50	----	3.17	----
3	2.00	2.50	----	3.18	----
4	2.00	2.50	----	3.50	----
5	2.00	3.00	----	2.78	----
6	1.90	2.57	----	3.06	----
7	2.00	3.00	----	3.43	----
8	2.00	3.00	.18	3.44	55
9	1.88	2.85	.18	3.26	57
10	2.76	3.00	.30	3.50	60
11	4.40	1.00	.30	3.50	60
12	4.40	2.45	.40	3.02	60
13	4.40	2.50	.50	3.00	60
14	4.40	2.50	.50	3.00	60
15	4.60	4.83	.40	2.33	60
16	4.70	6.00	.50	2.00	60
17	5.72	7.45	.60	2.48	60
18	6.00	7.50	.98	2.50	60
19	6.00	7.50	1.10	2.50	60
20	6.00	7.50	1.10	2.50	60

TABLE XXV.

WEIGHTS AND MEASUREMENTS BY 30 DAY PERIODS
AND NUTRIMENTS RECEIVED DAILY 30 DAY PERIODS

No. 114.

Period	Age	Weight	Height	Width of Hips	Width of Thurls	Heart Girth	Energy Daily	Dig. Prot. Daily
	Days	Lbs.	Cms.	Cms.	Cms.	Cms.	Therms	Lbs.
1	230	287	96.3	30.0	30.0	117	4.66	.544
2	260	299	100.1	30.8	30.5	118	4.58	.526
3	290	315	100.3	31.5	31.0	117	4.59	.556
4	320	317	101.0	32.0	31.0	121	4.88	.579
5	350	330	102.0	33.0	32.3	125	4.45	.538
6	380	353	103.7	34.0	33.0	128	4.48	.535
7	410	342	105.8	34.0	33.0	127	5.03	*.576
8	440	374	106.8	35.0	34.0	130	5.19	.594
9	470	381	108.3	35.5	35.0	132	4.93	.596
10	500	395	109.3	36.5	35.0	137	*5.15	.607
11	530	417	110.5	37.5	36.0	135	5.23	.869
12	560	452	110.8	37.5	36.5	140	5.37	.871
13	590	477	113.5	38.0	36.5	140	5.46	.869
14	620	497	113.0	38.5	36.5	142	5.54	.871
15	650	511	114.5	39.5	36.5	145	5.62	.876
16	680	560	114.5	40.5	37.0	145	5.83	.881
17	710	586	114.5	41.5	37.5	146	5.95	.887
18	740	642	116.0	42.0	39.0	151	6.23	.901
19	770	683	116.3	43.0	39.0	158	6.32	.898
20	800	696	116.8	44.0	39.0	155	6.42	.895

*From this point on the values are based on average composition rather than on analysis.

HEIFER NO. 266.

October, 1916, Holstein heifer No. 266 was placed on a low protein plane. While on this plane her ration consisted of timothy and alfalfa hay and starch and sugar in fairly large quantities. Commencing with period 9 her plane of protein intake was raised by the addition of cottonseed meal and bran.

Growth of 266:- As can be seen from Table XXVI and Chart XXIX this animal was considerably below normal in height at withers when first placed on experiment. This relation she held fairly constantly thruout the experiment for while the height was 96 per cent of the normal at the start, it was also 96 per cent of the normal in period 18. The other skeletal measurements likewise showed a normal development.

Chart XXX shows that the relation between the width of hips and thurls ran as far as we know about normally.

In weight, 266 started on the normal but during the first 8 periods dropped off very rapidly. After period 8 the gain was somewhat more rapid but

not what it should be. In period 18 this heifer was about 89 per cent of the normal weight, Chart XXXI.

Observations on 266:- During the first seven months of the experiment this animal made a very poor showing. She gained poorly, looked poorly and at times refused her feed. When the protein was raised to furnish 15 per cent of the energy for growth she showed considerable improvement. At present she is looking in the best of shape and is about normal.

Summary on 266:- This heifer made a normal skeletal growth but her weight is still a little below normal. As it now appears 266 will probably come up to normal in all respects in a few periods.

1. Energy.- Table XXVII and Chart XXVII indicate that on the whole the energy furnished by this animal's ration was during the first 9 periods about equal to the Armsby standard, and thereafter a little above the standard, if calculated either on the basis of age or weight. It is evident

from Chart XXXIII that the energy was not a limiting factor in this animal's development for an increase in the energy supply was not attended by an increase in the rate of growth.

2. Mineral Content:- As seen from Table XI the minerals in 266's ration probably were of a sufficient quantity to play no part in limiting her growth at any time.

3. Quality of Proteins.- During the first 8 periods when the protein was supplied only from timothy and alfalfa hay, the quality of the protein mixture probably was not very high. It is reasonable to believe, however, that when cottonseed meal and bran were added, the efficiency of the protein was markedly increased.

4. Fat Soluble A.- The fact that alfalfa hay was present in the ration every day, makes it certain that this vitamin was sufficiently abundant in the feed of 266.

5. Water Soluble B.- The alfalfa hay together with the cottonseed meal and bran doubtlessly supplied enough water soluble B.

6. Toxicity.- Toxicity cannot be considered to be present in the ration at any time.

7. Quantity of Protein.- During the first 8 periods 266 received only protein equal to 8 per cent of her energy for growth and on this plane her development was very slow, Charts XXXIV and XXXV. But when the protein was increased to furnish 15 per cent of the energy for growth the increase in weight was very much more rapid.

Conclusions on 266.- This heifer developed normally in skeleton and slightly subnormally in body weight, altho as it now appears she will soon reach the normal in this respect also. All of the nutritional factors with the exception of the quantity of protein were in all probability supplied and did not enter in to limit the growth. When on a plane of protein sufficient to furnish 8 per cent of the energy for growth, the development was very poor. When the plane was raised to furnish 15 per cent of the energy for growth the development approached normal. Consequently we can conclude from 266 that

TABLE XXVI.

FEED CONSUMED DAILY

Average by 30 Day Periods

No. 266

Period	Timothy	Alfalfa	Starch and Sugar	C. S. Meal	Bran
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	3.00	3.00	3.13	----	----
2	3.00	3.00	3.50	----	----
3	3.00	3.00	3.50	----	----
4	2.81	2.81	3.02	----	----
5	2.93	2.03	3.24	----	----
6	3.00	3.22	3.34	----	----
7	2.69	3.29	3.01	----	----
8	3.10	2.52	3.27	.33	.40
9	3.20	2.00	3.53	.57	.60
10	3.71	2.63	3.56	.41	.60
11	4.00	3.00	3.63	.37	.60
12	4.00	3.00	3.67	.46	.60
13	4.00	4.33	3.53	.43	.67
14	4.00	7.00	2.93	.43	.70
15	4.00	7.00	3.19	.50	.76
16	4.13	7.00	3.43	.50	.80
17	4.20	7.00	3.50	.50	.74
18	4.20	7.63	3.37	.44	.70

TABLE XXVII.

WEIGHTS AND MEASUREMENTS BY 30 DAY PERIODS
AND NUTRIMENTS RECEIVED DAILY 30 DAY PERIODS

No. 266

Period	Age	Weight	Height	Width of Hips	Width of Thurls	Heart Girth	Energy Daily	Dig. Prot. Daily
	Days	Lbs.	Cms.	Cms.	Cms.	Cms.	Therms	Lbs.
1	231	386	102.1	32.5	32.5	126	4.88	*.454
2	261	388	103.4	32.5	32.5	134	5.18	.451
3	291	396	105.8	33.0	33.5	128	5.18	.449
4	321	410	107.8	34.5	34.0	130	4.63	.497
5	351	419	109.2	34.0	34.5	132	4.26	.452
6	381	428	110.3	35.5	35.5	131	5.14	.459
7	411	438	112.3	35.5	35.5	135	4.79	.469
8	441	439	112.8	35.5	36.5	136	5.34	.496
9	471	477	114.3	37.0	37.5	139	*6.23	.731
10	501	498	114.5	37.5	37.5	143	6.45	.756
11	531	527	116.7	38.0	37.5	147	6.72	.784
12	561	562	117.5	39.0	39.0	145	7.02	.815
13	591	579	117.7	39.5	39.0	147	7.21	.837
14	621	638	119.8	40.5	39.5	152	7.70	.887
15	651	664	119.7	41.0	40.5	153	7.97	.916
16	681	700	120.5	42.0	40.5	156	8.25	.945
17	711	716	122.0	43.0	41.0	160	8.21	.931
18	741	778	122.7	44.0	41.5	160	8.32	.926

*From this point on the values are based on average composition rather than on analysis.

Holstein heifers develop normally on a protein plane in which 15 per cent of the energy is furnished by the protein.

Heifer No. 267.

Holstein heifer 267 was placed on a high protein plane on October 1916. She was on the same plane of protein intake thruout the whole experiment. During the first 10 periods her ration consisted of timothy and alfalfa hay and skimmilk powder, but after period 10 the skimmilk powder was replaced by bran, cottonseed meal and corn. Thus it was possible to notice the effect of these different protein mixtures. Starch and sugar in fairly large quantities was used thruout the experiment to increase the energy value of the ration, Table XXVIII.

Growth of 267:- As can be seen from Table XXIX and Chart XXIX, this animal was about 95 per cent of the normal in height at withers when started. At the end of the experiment she was 98 per cent of the

normal indicating that she actually made more than a normal gain. Likewise her other skeletal measurements showed a normal or a little better gain, Chart XXX.

In body weight 267 was slightly below normal at the start, Chart XXXI shows it to be about 94 per cent of the normal. Up to period 13 she made about a normal gain and thereafter grew even better for at the end of the experiment she was 106 per cent of the normal in body weight.

Observations on 267:- This animal looked very well at first but seemed to be a little dull after the first few periods. But when, as with the other animals, the roughage was increased she improved greatly. When taken off the experiment she appeared in excellent condition.

Summary on 267:- It is clearly evident that this heifer made a gain in both skeleton and body weight, somewhat better than normal.

1. Energy. - The energy furnished this animal, Chart XXXII and Table XXIX was considerably above the Armsby standard for both weight and age. It was consequently sufficiently supplied for there seems to be no relation between the rate of growth and energy furnished, Chart XXXIV.

2. Mineral Content. - Table XI shows that 267 had an abundance of minerals in her ration.

3. Protein Quality. - The fact that such a mixture of feeds was used, including during a part of the experiment skim milk powder, makes it certain that the protein mixture was adequate and of high quality, Table XXVIII.

4. Fat Soluble A. - The fat soluble A was supplied sufficiently from the alfalfa hay if from no other source.

5. Water Soluble B. - This growth accessory was abundant in the skim milk and later in the grains in 267's ration.

6. Toxicity.— No toxicity was present in the ration, for the only possible toxin bearing substance, cottonseed meal was used in only a part of the experiment and in very small quantities.

7. Protein quantity.— Table XXIX and Chart XXXIV show that 267 was on a plane of protein above both the Wolf-Lehman and Armsby standards. Apparently the plane of protein on which this animal was maintained was sufficient but when the protein intake was slightly raised, period 12 and on, the rate of gain was more rapid. But it is very probable that the change from skim milk powder to bran, cottonseed meal and corn, together with the increase in roughage, was more instrumental in effecting the change than was the quantity of protein.

Conclusions on 267.— This animal made a growth somewhat better than normal on a plane of protein sufficient to furnish 25 per cent of the energy for growth or a little higher than the Wolf-Lehman standard. We can conclude then that such a protein plane is sufficient to produce the very best results with growing Holstein heifers.

TABLE XXVIII.

FEED CONSUMED DAILY

Average by 30 Day Periods

No. 267

Period	Timothy	Alfalfa	Starch and Sugar	Skim Milk Powder	Bran	C. S. Corn Meal	Corn
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	2.92	3.15	2.31	1.46	----	----	----
2	3.00	3.20	2.16	1.50	----	----	----
3	3.00	3.20	2.27	1.50	----	----	----
4	3.00	3.20	2.37	1.50	----	----	----
5	2.93	3.27	2.42	1.50	----	----	----
6	3.00	3.30	2.62	1.56	----	----	----
7	3.00	3.30	2.43	1.62	----	----	----
8	3.00	3.30	2.93	1.74	----	----	----
9	3.00	3.50	3.13	1.80	----	----	----
10	3.00	3.49	3.20	1.49	----	----	----
11	3.00	5.00	1.97	----	1.00	.47	2.00
12	3.00	5.00	2.13	----	1.00	.56	2.00
13	4.00	5.00	2.07	----	1.00	.63	2.00
14	4.00	5.00	1.73	----	1.00	.73	2.00
15	4.00	5.00	1.93	----	1.00	.93	2.00
16	5.45	4.68	1.86	----	.87	.87	1.73
17	6.00	5.20	2.20	----	.94	1.00	2.00
18	6.63	5.20	2.11	----	.90	.94	2.00

TABLE XXIX.

WEIGHTS AND MEASUREMENTS BY 30 DAY PERIODS
AND NUTRIMENTS RECEIVED DAILY 30 DAY PERIODS

No. 267

Period	Age	Weight	Height	Width of Hips	Width of Thurls	Heart Girth	Energy Daily	Dig. Prot. Daily
	Days	Lbs.	Cms.	Cms.	Cms.	Cms.	Therms	Lbs.
1	226	363	101.6	33.5	32.3	120	5.71	*.973
2	256	380	103.8	31.5	34.0	124	5.71	.972
3	286	470	106.8	33.0	34.3	130	5.79	.966
4	316	438	110.2	34.5	35.5	134	5.88	.964
5	346	470	112.8	35.5	36.0	138	5.91	.925
6	376	506	113.4	35.5	37.5	140	6.18	1.000
7	406	527	116.0	37.0	39.0	140	6.36	1.018
8	436	561	117.0	38.0	39.0	143	6.61	1.070
9	466	581	119.2	38.5	39.5	146	6.89	1.109
10	496	599	120.2	39.0	40.0	147	*6.89	1.139
11	526	623	120.0	39.0	40.0	149	7.06	1.174
12	556	652	121.5	41.0	40.5	150	7.29	1.210
13	586	676	122.3	42.5	40.5	155	7.56	1.245
14	616	725	123.0	43.0	41.0	156	7.79	1.304
15	646	767	124.3	42.5	42.0	159	8.22	1.352
16	676	816	124.5	44.5	42.5	161	8.59	1.392
17	706	849	124.3	45.0	43.5	165	8.94	1.372
18	736	892	125.5	47.0	44.5	168	8.99	1.337

*From this point on the values are based on average composition rather than on analysis.

Cms.

Periods

Chart XXIX
Curves showing
increase in height

— No 266 — No 269
- - - No 267 — Normal

Cms.

Cms.

Cms.

Age Months

Pounds

Therms

Therms

Pounds

Therms

Chart XXXIII

Curves showing the increase in weight and the energy furnished daily in the ration

No. 266 No. 267
 --- Energy
 — Growth
 — Normal

Periods

Pounds

Pounds

lbs. Protein

Chart XXXIV

Curves showing the relation between the increase in weight and protein fed daily by 30 day periods

No 266 No 267

Growth lbs.

Protein per day lbs.

Normal growth

Periods

Pounds

lbs. Protein

Periods

Heifer No. 269.

Holstein heifer 269 was placed on experiment November, 1916, on a plane of protein approximately the same as that on which 267 was kept. Her ration, however, was composed of alfalfa, timothy, corn and bran. Only small quantities of starch and sugar for energy were used. Thru accident she died in period 13.

Growth:- In height at withers, 269 made approximately the same rate of growth as 267. The same is true of the rest of her skeletal development, Chart XXXI. It is peculiar as we can notice from Chart XXX that this animal was unlike the other heifers for she was wider at the hips than at the thurls from the start.

In weight, 269 was only 86 per cent of the normal at the start. She gained rapidly and in the period before she became sick she was 97 per cent of the normal in body weight.

Observations on 269:- From the very start this animal was the most thrifty of all in the group, In December, 1917, she began to go off feed and finally refused to eat. It was thought that she had indigestion and she was treated for this ill but to no effect. An operation disclosed the fact that this animal had swallowed a wire which had penetrated the heart cavity and caused an infection. The animal died and only 12 periods of the time she was on experiment are of any value here.

Summary on 269:- As with 267 this animal made excellent gains on a high protein plane.

1. Energy.- What has already been said regarding the energy in the ration of 267 holds equally for this animal as we can see from Charts XXXII and XXXVI.

2. Mineral Content.- Doubtlessly a sufficient supply of minerals was present in the ration of 269, Table XI.

3. Protein quality.- There is no evidence to indicate that the protein mixture of the ration was

adequate but the fact that the protein was supplied from four sources, corn, bran, alfalfa and timothy hay, makes it highly probable that it was at least of a fair quality.

4. Fat Soluble A.- As in 267's ration the presence of alfalfa hay assures the presence of this vitamin.

5. Water Soluble B.- This was supplied by the concentrates, corn and bran.

6. Toxicity.- This factor was doubtlessly eliminated.

7. Quantity of Protein.- The quantity of protein fed 269 was about the same as that fed 267, Chart XXXIV. Chart XXXVI indicates that the relation of protein to growth was about the same as for the other animal.

Conclusions on 269.- A high protein plane, where 25 per cent of the energy for growth is derived from the protein in the ration, is conducive to the best development of Holstein heifers, as evidenced from animal 269.

TABLE XXX.

FEED CONSUMED DAILY
Average by 30 Day Periods
No. 269

Period	Alfalfa	Timothy	Starch and Sugar	Corn	Bran
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	3.35	1.8	----	3.0	1.00
2	3.90	2.0	----	3.0	1.00
3	4.00	2.0	----	3.0	1.00
4	4.00	2.0	.27	3.0	1.00
5	4.00	2.0	.52	3.0	1.00
6	4.00	2.0	.67	3.0	1.00
7	4.25	2.0	.70	3.0	1.00
8	4.40	2.0	.63	3.3	1.00
9	4.46	2.9	.47	3.4	1.00
10	4.50	3.5	.47	3.4	1.27
11	4.50	3.5	.50	3.5	1.40
12	4.67	4.3	.40	3.7	1.37

TABLE XXXI.

WEIGHTS AND MEASUREMENTS BY 30 DAY PERIODS
AND NUTRIMENTS RECEIVED DAILY 30 DAY PERIODS

No. 269.

Period	Age	Weight	Height	Width of Hips	Width of Thurle	Heart Girth	Energy Daily	Dig. Prot. Daily
	Days	Lbs.	Cms.	Cms.	Cms.	Cms.	Therms	Lbs.
1	196	301	99.5	30.0	31.5	117	5.12	.859
2	226	333	101.5	31.5	32.5	121	5.40	.939
3	256	367	105.3	33.0	34.5	127	5.43	.952
4	286	404	107.8	33.5	35.5	130	5.65	*.964
5	316	443	109.5	34.5	37.0	136	5.85	.967
6	346	471	112.3	36.0	38.0	139	5.97	.975
7	376	498	114.5	37.0	39.0	143	6.09	.996
8	406	522	116.5	38.0	40.0	143	*6.29	1.024
9	436	561	117.7	39.0	40.0	149	6.62	1.069
10	466	587	118.2	39.0	40.5	147	6.87	1.109
11	496	618	120.2	40.0	41.5	150	7.17	1.148
12	526	653	120.0	40.5	42.0	154	7.47	1.189

*From this point on the values are based on average composition rather than on analysis.

Heifer No. 129.

Jersey heifer 129 has been on experiment only 5 periods. Her ration consists of timothy, alfalfa and corn, with starch to bring up the energy value. About 15 per cent of the energy for growth is derived from the protein. This ration is approximately the same as that fed 114, which animal 129 is intended to check. So far this heifer has gained rather slowly in both skeletal growth and increase in body weight as can be seen from Charts XXXVII and XXXVIII. It will be necessary to increase the protein in her ration.

Heifer No. 132.

This Jersey heifer was placed on experiment at the same time as 129. Her ration consists of timothy, alfalfa hay, corn, bran and a very small quantity of starch and sugar. The protein yields 20 per cent of the energy for growth. So far, there is not very much difference between her development and that of 129 for while her growth in height dropped off

but slightly from the normal, she made a gain of only 72 pounds in four months. It will probably be necessary to raise the protein in her ration also, to produce normal growth.

Heifer No. 120.

This Jersey heifer was placed on the experiment when 17 months old, on a ration of timothy, corn and bran. She derives 8 per cent of the energy for growth from protein. As was observed with other animals in height she has gained very well but in body weight she gained only 6 pounds while on the experiment for 3 months. It is conclusive then that 120 must have more protein in her ration.

Heifer No. 273.

Holstein heifer 273 was placed on experiment December, 1917, on a ration of timothy, alfalfa, corn, bran and starch and sugar. The protein furnishes 20 per cent of the energy for growth at present.

She does not look very thrifty but her gains have been about normal in both skeleton and body weight.

Heifer No. 277.

Holstein heifer 277 was placed on experiment December, 1917, on a very high plane of protein intake, to note the effect of feeding a large amount of protein. Her ration consists of timothy and alfalfa hay, corn and bran, and contains sufficient proteins to furnish 35 per cent of the energy for growth. So far she is in an excellent condition being thrifty and having gained above normal in both skeleton growth and body weight.

Cms.

Chart XXXVII

Curves showing increase in height at withers and normal

Months Old

Months Old

TABLE XXXII.

SUMMARY OF EXPERIMENTAL ANIMALS TO DATE

8	9	10	11	12	13	14	15	16
Body Weight At Be- ginning	At End	Corrected to Normal Height	at End weight	Actual Growth In Height	Actual Growth in wt.	Lbs. Prot. Per Lb. Gain	T. Energy per Lb. Gain	Av. Gain per Lbs
% of Normal		%	%	% of Normal				
91	73	94	80	85	78	.922	11.95	0.61
86	80	102	93	260	12	7.505	92.05	0.07
100	87	101	87	102	77	.812	10.99	0.67
94	85	94	90	75	77	.892	8.93	0.59
95	93	99	99	93	92	.996	7.40	0.72
100	85	100	89	100	73	.998	9.18	0.66
100	84	99	84	89	44	1.193	10.19	0.50
108	89	99	89	97	89	.863	8.05	0.77
84	93	97	86	88	83	1.000	8.48	0.72
89	75	98	89	80	50	1.181	7.57	0.58
89	91	99	102	89	105	1.224	8.86	0.73
84	93	104	111	106	109	1.243	6.99	0.87
94	106	102	113	111	117	1.088	6.66	1.00
86	97	103	113	117	109	.938	5.66	1.07
89	96	102	108	134	130	1.137	5.38	1.14

COMPARISON OF DIFFERENT PLANES OF PROTEIN FOR THE SAME

ANIMAL.

100	78	99	78	90	39	.994	10.65	0.36
78	89	101	114	110	132	.758	6.55	1.08
94	74	103	79	94	52	1.304	11.04	0.42
74	93	102	126	119	147	.852	5.54	1.02
94	76	96	81	40	89	1.053	13.11	0.38
76	85	98	112	65	112	.835	7.44	0.75

TABLE XXXII.

SUMMARY OF EXPERIMENTAL ANIMALS TO DATE

1 Animal	2 Periods on Exper- iment	3 Energy from Prot. for Growth %	4 Ratio of Prot. to Energy T. 1:	5 Protein From	6 Height at Be- ginning % of Normal	7 at Withers at End
94	22	8	12.96	T.C.	103	97
120	3	8	12.26	T.C.B.	98	100
250	28	8	13.53	A.T.M.	99	100
115	18	8+25	10.01	T.C.O.CS.	106	100
114	20	15+25	7.43	A.F.C.	97	96
103	20	15	9.20	T.M.	101	101
129	4	15	8.79	A.T.C.	97	96
266	18	8+15	9.33	A.T.B.CS.	97	96
253	26	15	8.48	A.T.	103	100
132	4	20	6.41	A.T.C.B.	95	93
273	4	20	7.24	A.T.C.B.	98	97
91	22	25	5.62	A.T.B.C.S.	95	99
267	18	25	6.30	A.T.C.B.MCS	97	98
269	12	25	6.03	A.T.C.B.	95	98
277	4	33	4.73	A.T.C.B.	97	99

COMPARISON OF DIFFERENT PLANES OF PROTEIN FOR THE SAME
ANIMAL.

266	1-8	8	10.72	A.T.	96	95
266	8-48	15	8.64	A.T.B.CS.	95	96
114	1-10	15	8.46	T.C.B.	92	95
114	10-20	25	6.50	T.C.B.CS.	95	97
115	1-8	8	12.45	A.T.C.	106	102
115	8-18	25	8.91	A.T.C.	102	100

e, -Numbers above 200 designate Holsteins, below 200, Jerseys.

Stillon Experiment.

alfa - A; Corn - C; Bran - B; Timothy - T; Cottonseed Meal - C.S;

s - O; Skimmilk Powder-M.

RECAPITULATION.

The discussion here has included fifteen heifers maintained on several planes of protein intake.

All of the animals were pure-bred, seven Holsteins, and eight Jerseys. From the available data it appears advisable to compare the animals on the following bases.

1. The effect of the plane of protein intake on the growth of skeleton.

2. The effect of the plane of protein intake on the increase in body weight.

3. The effect of a change in the plane of protein in the ration on the growth of skeleton and the increase in weight.

4. The effect of the source of the protein on growth.

5. The influence of breed on the utilization of protein for growth.

6. The economy of feeding at the different planes of protein intake.

With a view of presenting clearly these several points, Table XXIX was prepared. In it are presented in brief form the main and most important features of

the whole investigation to date. A word of explanation may be necessary here to clear some of the terms used. Column one represents the number of the animal. Numbers below 200 are Jerseys and above 200 are Holsteins. Column two shows the number of periods the animals have been on experiment. Heifers 91 and 94 were on 28 day periods, the others on 30 day periods. Column three represents the plane of protein intake as measured by the percent of energy for growth from protein. Column four shows the ratio of protein to energy. Column five indicates the source of the protein. Columns six and seven give the height at withers at the beginning and at the end of the experiment respectively, in percent of the normal. Columns eight and nine compare likewise the body weight of the heifers. These last four are not easily comparable because the heifers when placed on experiment are at various distances above or below the normal. For instance, at the finish heifers 120 and 250 are both normal in height, whereas at the start 120 was only 98 per cent of the normal and 250 was 106 per cent of the normal. Consequently, to compare their final

growths either skeletal or body weight, we must start them all at normal, theoretically. Thus columns ten and eleven give the final height at withers and body weight, in percent of the normal and when started on a comparative basis. It can be seen then, with the case of the two animals already referred to as an illustration, that 120 was comparatively, somewhat better in skeletal development than was 250. By far the most comprehensive comparison is made in columns twelve and thirteen. These compare the actual gains with what is expected of a normal animal. Columns twelve and thirteen will consequently be used in making the comparisons already referred to. Columns fourteen and fifteen give the protein and energy respectively, which was necessary to produce a pound of gain. Column sixteen compares the average gain in weight per day on the different protein planes.

1. Growth of Skeleton:- The height at withers corresponds quite uniformly in all of the animals with the other skeletal measurements, as can be seen from the

tables already discussed. Consequently we are safe in taking the height at withers as a criterion of skeletal growth. From column twelve we can see that in general there is not very much difference in the rate of skeletal growth, until we reach the high protein plane. Heifer 120 cannot be considered in the comparison because she has not been on experiment long enough, and as far as she has gone shows abnormalities in growth. It is apparent from the data that the animals maintained on a plane of protein where the protein furnishes from 8 per cent to 20 per cent of the energy for growth, the rate of skeletal growth may or may not be normal, whereas if 25 per cent or more of the energy is derived from the protein, the skeletal growth is above normal. It is significant that heifers 94 and 115 both making a very poor growth, besides being on a low protein plane, were insufficiently supplied with minerals.

2. Increase in Body Weight:- Column thirteen shows the increase in body weight as compared with the normal increase. Excluding 120 for reasons already

explained, it is seen that the rate of gain varies from 44 per cent to 130 per cent of the normal. Comparing columns three and four with thirteen we can see that the rate of gain is in general proportional to the quantity of protein in the ration. There are discrepancies to this generalization, notably 129 and 132 which cannot be explained but which cannot be taken as significant until the animals have been longer on experiment. It is evident, however, that when the ration contains protein sufficient to furnish 20 per cent of the energy for growth, the increase in weight is about normal. A quantity of protein in the ration sufficient to furnish 25 per cent to 35 per cent of the energy produces a growth above normal.

3. Effect of a Change in Protein Plane:- For the purpose of comparison, several animals were raised from a lower to a higher plane of protein intake. Heifer 266 was kept during the first 8 periods on an 8 per cent protein plane after which she was raised to a 15 per cent plane. In consequence there resulted a remarkable increase in the rate of growth. In height at withers

she increased from 90 per cent to 110 per cent of the normal. In body weight she increased from 39 per cent to 132 per cent of the normal. Heifer 114 was maintained on a 15 per cent plane during the first 10 periods and increased to a 25 per cent plane during the last 9 periods. The increase in the rate of skeletal growth was from 94 per cent to 119 per cent of the normal. The growth in body weight increased from 52 per cent to 147 per cent of the normal. Likewise, 115 was kept for 8 periods on an 8 per cent plane and for the last 9 periods on a 25 per cent plane. In height at withers the growth increased from 40 per cent to 65 per cent of the normal. In body weight the rate of growth increased from 89 per cent to 112 per cent of the normal. It is quite conclusive from these three animals that the rate of growth of both skeleton and body weight is greatly accelerated when the plane of protein is raised from a lower to a higher level. This suggests the practical possibility of maintaining growing heifers on a low protein ration during a time of feed shortage and when the feed becomes more plentiful, raising the protein plane and thus securing a fairly satisfactory growth.

4. The Source of Protein:- The only way in which we can satisfactorily compare the effect of the source of protein is to note its effect on animals maintained on the same plane. In the 8 per cent group we cannot make comparisons because with 94 several nutritional factors were probably insufficiently supplied. In the 15 per cent group 103 receiving timothy hay and skim milk powder made the best skeletal growth, whereas 266 receiving alfalfa and timothy hay, bran and cottonseed meal made a growth in skeleton slightly below 103 and a much better growth in body weight. Heifer 253 on alfalfa and timothy hay came second in the rate of growth of body weight, on a ration containing somewhat more protein than that of 266. It would appear then that on the same low plane the proteins from a mixture of alfalfa and timothy hay together with bran and cottonseed meal are more efficient than alfalfa and timothy hay or even after corn has been added. Of the animals on the 25 per cent plane 267 made the best gains in weight on a ration of alfalfa and timothy hay, corn, bran, skim milk powder and cottonseed meal.

Heifer 269 with a ration as above, less the skim milk powder and cottonseed meal, made the best skeletal growth. Altogether it appears that the presence of the skim milk powder had a favorable effect here.

5. The Influence of Breed:- One of the perplexing questions which often arise in feeding cattle is; does the breed influence the efficiency in the use of nutriment? As a result of this investigation, it is possible to offer a view on the matter. Of the animals maintained on the 8 per cent plane Holstein heifer 250 made the best gains in skeletal growth, but this, of course, cannot be taken as due to a difference in breed because 94 had an abnormal ration. On the 15 per cent plane Holsteins 266 and 253 made a considerably better showing on similar rations. On the 20 per cent plane, where the rations were identical, Holstein 273 made by far the best showing. On the 25 per cent plane where approximately the same protein mixtures were supplied, Holsteins 267 and 269 made somewhat better gains in both skeleton and weight. It appears then from what evidence could be gathered from the above discussion that Holsteins are able to make

somewhat better gains on the same protein plane.

6. The Economy of Feeding at Different Planes:- Columns fourteen and fifteen compare the quantities of protein and energy these animals used, to make a pound of gain. With the exception of 120 which we must ignore, the results are fairly comprehensive. In general a raising of the protein plane is attended by an increase in the quantity of protein and a decrease in the therms of energy required to make a pound of gain.

It is highly interesting to note the effect on the economy of utilization of nutriments when the protein in the ration of a heifer is increased from an 8 per cent or a 15 per cent plane to a higher level. In the cases of 266, 114 and 115, the efficiency in the utilization of both protein and energy increased 20 per cent or more when the animals were put on a higher plane. What is more, the total economy of utilization was in every case greater than where an animal was maintained on the same level thruout the experiment. We see from column four that both 103 and 129 received

a ratio of protein to energy very close to that of 266, yet this heifer used much less protein and energy per pound of gain. Likewise 273 received in her ration approximately the same proportion of protein as heifer 114, yet this latter animal used only 80 per cent as much protein and 84 per cent as much energy to produce a pound of gain.

FINAL CONCLUSION.

1. The skeletal development seems to be but slightly affected by the quantity of protein in the ration. It appears that a quantity of protein in the ration sufficient to furnish 20 per cent of the energy for growth is sufficient to produce a normal skeletal development. A protein plane of 8 per cent to 15 per cent produces a slightly subnormal skeletal growth. According to data obtained from two animals (94 and 115) this subnormal skeletal growth is accentuated when the mineral content of the ration is insufficient. A protein plane of 25 per cent or more produces in every case, a skeletal growth above normal.

2. The increase in body weight is influenced by the quantity of protein in the ration, providing all of the other nutritional factors are supplied. It appears that a ration containing protein sufficient to furnish 20 per cent of the energy for growth, will produce a normal increase in weight of growing dairy heifers. A protein plane of from 8 per cent to 15 per cent, in every case produced a subnormal increase in body weight. A protein plane of 25 per cent or better, in every case

produced an increase in weight above the normal.

3. An increase of the protein in the ration of heifers maintained on an 8 per cent or a 15 per cent plane resulted in a remarkable increase in the rate of growth of both skeletal and body weight.

4. No definite conclusion can be reached from the data available in this experiment, regarding the effect of the source of the protein on the growth. It was the aim in every ration to supply as nearly as possible, an adequate protein mixture.

5. From the evidence so far considered, it appears that Holstein heifers are a little more thrifty than Jersey heifers, when kept on the same protein plane.

6. With the fifteen animals already discussed it was found that when the protein plane was raised, there occurred an increase in the quantity of protein and a decrease in the terms of energy used to make a pound of gain.

7. Individual heifers maintained first on a low plane and then on a higher plane of protein, show a marked increase in the economy of the utilization of both protein and energy.

THE END.

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