Approved
C. H. Eckles

PROTEIN REQUIREMENTS FOR DAIRY HEIFERS.

by

George B. Caine, B. S.

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
in the

GRADUATE SCHOOL

of the

UNIVERSITY OF MISSOURI.

1914.

OUTLINE.

PROTEIN REQUIREMENTS FOR DAIRY HEIFERS.

INTRODUCTION.

The last report of the United States Department of Agriculture shows that it costs $61.40 to raise a dairy heifer until two years of age. Most of this cost as shown by them is the feed, and of the feeds used those of a nitrogenous nature are always the most expensive. For the farmer of the middle West where corn and its products are the principle feeds, the protein factor is very essential. With the constant increasing demand for dairy cows thruout the United States and the high priced protein feeds, there seems to be a great need of a definite protein standard. The present standards for dairy cattle have been calculated from experiments with beef steers. The Missouri Experiment Station started an experiment to aid in determining the amount of protein necessary for normal growth of dairy heifers.

In treating this subject, the work has been taken up more from a practical than a scientific standpoint. No attempt has been made to go thoroly into the chemical or physiological study of the problem. What is herein reported is merely a suggestion of what can and will be done later.

DEFINITION OF PROTEIN.

"Proteins are a class of substances, which in the light of our present knowledge, consist in the main of combinations of a-amino-acids or their derivatives. These protein substances form the chief constituents of many of the fluids of the body, constitute the organic basis of animal tissues, and at the same time occupy a decidedly preeminent position among our organic food stuffs."[1] "They are indispensable and cannot be replaced by either the carbohydrates or the fats. They are large factors in cell formation and possess just as important relations to the animal organisms as do carbohydrates to the plants."[2] These protein substances are furthermore essential constituents of all living cells and therefore without them vegetable life as well animal life is impossible.....The proteins, which constitute such an important group of substances differ from the carbohydrates and fats very decidedly in elementary composition. In addition to containing carbon, hydrogen and oxygen, which are present in fats and carbohydrates, the proteins invariably contain nitrogen in their molecule and generally sulphur.[3]"

---

1. Hawks Practical Physiological Chem. 4th Ed. p. 68
2. Abderhalden, Texbook of Physiological Chem, p.119
3. Hawks Practical Physiological Chem. 4th Ed. p. 68

PROTEIN METABOLISM.

"Many hypotheses have been advanced to account for the various changes observed during the course of protein metabolism, but until about five years ago only two were really considered. These two were put forward by Voit in 1867 and by Pfluger in 1893 respectively. Previously the theory advanced by Liebig was almost universally accepted. Liebig considered that the protein of the food was the one essential material, that it entered the organism without having undergone any very serious change during digestion and that it immediately and directly replaced the effete material of the tissues."[1]

"Voit[2] put forward 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. This circulating protein was readily broken down, whereas the tissue protein was resistant. A certain amount of the tissue protein constantly died and was excreted and was replaced by material drawn from the circulating or food protein. No chemical differences existed between the circulating and the tissue protein."

---

1. Cathcart, The Physiology of Protein Metabolism.
2. Zeit, f. Biol. 1907, 49-1, from Cathcart, "The Phys. etc.

"Folin[1] in 1905 advanced an extremely interesting and valuable theory based on the laws which governed the composition of the urine. He carried out a very elaborate series of analyses of normal urine. obtained from subjects on standard diets, (1) rich in nitrogen and (2) poor in nitrogen, both diets being practiaally free from purine, creatine and creatinine. He said that there were two forms of catabolism which were essentially independent and quite different. One kind is extremely variable in quantity, the other tends to remain constant. The one kind yields chiefly urea and inorganic sulphates, no creatinine and probably no neutral sulphur. The other, the constant catabolism, is largely represented by creatinine and neutral sulphur and to a less extent by uric acid and ethereal sulphates. The more the total catabolism is reduced, the more prominent become these representatives of the constant catabolism, the less prominent become the two chief representatives of the variable catabolism. To the constant type he has given the name of tissue or endogenous metabolism and to the variable, intermediate or exogenous metabolism".[2]

---

1. Am. Jour. of Physiology, 1905, 13, 117.
2. Am. Jour. of Phy. 1905, 13 - 170.

"The digestion of protein is essentially a process of cleavage and hydration under the influence of certain enzymes. By this process the complex proteid molecules are partially broken up into simpler ones. By the action of pepsin in acid solution, we obtain albumoses and peptones while the trypsin of the pancreatic juice, at least outside the body carries the cleavage still further, producing crystalline, nitrogenous bodies of comparatively simple constitution.) Opinions are still more or less divided as to how far these processes of cleavage and hydration are carried in the actual process of digestion, where the products of the action are constantly being resolved, but there are not wanting indications that it is both less extensive and less rapid than in artificial digestion. It likewise seems to have been demonstrated that some soluble proteids are capable of direct resorption without change while others are not and some, notably casein, are promptly coagulated by the rennet ferment, apparently expressly in order that they may by subjected to the action of the digestive ferments. In a general way, the statement appears to be justified that the larger share of the protein material of the food is resorbed as albumoses or peptones".[1]

---

1. Ormsby, Prin. of An. Nut. p. 38.

FEEDING EXPERIMENTS WITH ISOLATED FOOD STUFFS.

Altho the proteins have long had attention put upon them, because of their important position in relation to nutrition, it is only in very recent years that the progress of chemical investigation, stimulated by the introduction of new methods of research, has begun to make the conception of these fundamentally important substances more exact.

It will not be the purpose in this work to give a thoro discussion of the various proteins as food stuffs but merely to show in a brief way some of the results obtained experimentally up to this time. The following table[1] gives the per cent of protein utilized in various foods:-

Character of Diet	Per Cent Protein Utilized.
Animal Foods	97
Cereals	85
Legumes, Dried	78
Vegetables	83
Fruits	85
Vegetable Foods	84
Total Food	92

1. Atwater & Bryant, Rpt. Storrs Agr. Exp. Sta. 1899 p. 86.

In experiments on man and dogs, Mendel and Fine[1] showed that Gliadin, Gluten and two characteristic proteins in wheat, Gliadin and Glutenin, are as thoroly utilized as the nitrogenous components of fresh meat. Japanese literature review by Mendel and Fine[2] shows that the protein of barley is from 40 to 76 per cent digestible.

Malfatti[3] found the digestibility of the protein of maize to be 82 per cent. Rockwood[4] working with dogs found the utilization of zein to vary from 78 to 90 per cent. Corn proteins partially purified were somewhat less thoroly utilized than meat proteins. He pointed out, however, that this small difference may in great part be attributed to the cell residues remaining in the corn preparation employed.

It is reported by Mendel[5] that the legume proteins are less well utilized than a number of the other vegetable proteins. He suggests that these results should not be taken as conclusive because of the limited amount of work that has been done on the pure proteins from legumes.

Willcock and Hopkins[6] fed mice on zein to-

---

1. Jour. of Biol. Chem. V. 10, p. 339
2. " " " " " " " "
3. " " " " " " p. 345
4. Amer. Jour. of Physiology, XI, p. 355, 1904.
5. Jour. of Biol. Chem. Vol. 10, p. 457.
6. Willcock & Hopkins, Jour. of Phys. 1906-7, p. 88.

gether with non-nitrogenous foods and compared their length of life with that of mice which had received tryptophane, one of the missing fragments of the imperfect protein. Zein was shown to be quite unable to take the place of a normal protein, like casein in maintaining growth.

Falta and Noeggerath[1] recorded the changes in weight in rats kept on dietaries containing nitrogen in the form of isolated (commercial) proteins; ovalbumin, casein, serum albumin, serum globulin, fibrin, and haemoglobins. They fed no "roughage" in the form of cellulose. Neither these individual proteins nor mixtures of all were adequate to keep the animals alive longer than 94 days under the most favorable conditions. In most cases, a gradual steady decline was noticed thruout the progress of the experiment. Death occured when the animals had been reduced to two-thirds or three-fifths of their initial weights.

McCollum[2] fed both young and full grown rats on complex artificial mixtures, in which edestin, zein and sometimes casein were the sole sources of nitrogen. The chief difficulty encountered was that of amorexia, which the author attempted to overcome by frequent changes in the combination of food stuffs used and by

---

1. Falta & Noeggerath, "Hoffmeister's Beiträge zur chemischen Physiologie, 1905, VII p. 314, from Carnegie Inst. Cir. 156.
2. McCollum, Am. Jour. of Phys. 1909, xxv, p. 120.

addition of flavors. Some of the trials extended over more than 100 days without deaths, but the rats failed to maintain their weights, even with the most persisten coaxing of the appetite.

He also did some work on the growth of young rats. They made considerable gains in weight in experiments with the proteins mentioned, without casein in one series and with it in the other and extending over from 56 to 127 days. McCollum concludes that "the palatability of the ration is the most important factor in animal nutrition and the failure of previous efforts to maintain animals on a mixture of relatively pure proximate constituents of our food stuffs was due to the lack of palatability of such mixtures."

Osborne[1] found that "mature rats supplied with food containing zein as its sole protein declined rapidly in weight. By the addition of tryptophane corresponding to 3 per cent of the protein there is maintenance without growth. Maize Glutenin as the sole protein causes a rapid increase in weight (slightly greater than the average normal rate of growth on natural mixed food). The deficiency observed in the practical feeding of corn meals is probably explained by the peculiar chemical constitution of zein (entire absence of

---

1. Osborne, Science, 37, pp 185 - 191.

tryptophane and lysine) which forms such a large part of the protein in corn."

PROTEIN REQUIREMENTS

Until very recent years and to a certain extent now, the protein problem is, "How much is necessary in the food of various animals to produce normal growth". Later in the paper, this will be discussed in connection with cattle, especially with dairy cattle. A general idea of the amount required by some smaller animals follows:-

Voit[1] in an experiment with laboring men found that for average labor and average sized man required 118 grams proteid, 500 grams carbohydrates and 56 grams of fat per day to keep up the body weight and keep him in good condition.

Rubner[2] in a similar experiment and same class of work gave the requirement for protein as 127 grams. While Atwater[2] under similar conditions gives 125 grams as the protein requirement. This shows some slight difference of results but there is enough similarity to give a good idea of the protein requirements of man.

---

1. Phys. des. Stoff. 1881, p. 519, from Lusk Sci. of Nut.
2. Rubner; Von Leyden's Handbuch Die Ernahrungztherapie," 1903, Ed. I. p. 74., from Lusk, Sci. of Nut. p. 178.

Experiments at the Illinois Station[1] seem to show that pigs which are to be developed for breeding purposes shoulds start with 0.5 pound of digestible protein daily per 100 pounds live weight when about 2 months old. This should be increased to 0.55 pounds during about 7 weeks, then reduced to 0.45 pounds during the next 4 weeks, and then during the following 7 or 8 weeks they should be fed 0.5 pound of digestible crude protein per hundred pounds of live weight daily. Following this there is another 4 weeks reduction from 0.5 pound to 0.35 pound and then another 7 or 8 weeks period of 0.4 pound. Thus the reduction continues until the hog reaches maturity at 2 years of age when only about 0.2 pound of digestible crude protein is necessary as a daily allowance per hundred pounds of live weight.

Influence on Growth of Swine of Amount of Protein Fed -- Numerous practical feeding trials have led animal husbandry workers to hold that growing animals need for the most economical production a relatively narrow ration, i.e., one high in protein. Prof. McCollum[2] has conducted metabolism experiments with pigs to determine the influence of the amount of protein in the ration, other factors remaining constant, on the tendency of young pigs to retain nitrogen for

---

1. Ill. Cir. No. 153.
2. McCollum of Agr. Chem. Dept. of Univ. of Wis. in Wis. Research Bul. No. 19, page 24. Rpt. of Director 1911-12.

growth. All the animals received rations supplying the same amount of energy per pound of body weight, but the protein supply was fixed at 5, 10, 15 or 20 times the amount required for maintenance. When 5 times as much protein was fed as was required for maintenance, making a ration having a nutritive ratio of 1:11, only 10 per cent of the nitrogen fed was retained. When twice as much protein was supplied in the food, 10 times the maintenance requirements being fed or a ration with a nutritive ratio of 1 : 5.5, 23 per cent of the nitrogen in the food was stored up in the tissues. When the amount of protein was increased 15 to 20 times the amount required for maintenance, the same percentage was still stored. In other words, when the very narrow nutritive ration of 1 : 2.7 was fed supplying 20 times the protein required for maintenance, over twice as large a percentage of the protein was stored for growth as on the wide ration which supplied only 5 times the maintenance requirements.

PROTEIN REQUIREMENTS OF GROWING CATTLE.

In discussing the protein requirements of growing cattle, there are several things that must be considered, such as size, age, rate of growth, climate and character of feed.

Size -- It is a generally conceded fact that animals require more feed as they grow both because of the nutrients used in the process of growth and because of greater maintenance requirements. "There is considerable variation in maintenance requirements of different individuals of the same size and species kept under the same conditions due to temperament".[1] For example, restlessness causes greater muscular activity and thereby increases the demand for food fuels. A quiet animal requires less food for maintenance than a nervous, active one. This is well illustrated by the maintenance requirements of different sized cows. Eckles[2] has compared two cows, No. 206, a Holstein weighing 1319 pounds and No. 27, a Jersey weighing 899 pounds in the amount of energy in therms required for sustaining body weight. The smaller cow received but 2120 therms for maintenance while the larger Holstein required 2887 therms energy. While it is probably true

---

1. Henry, Feeds and Feeding, p. 73.
2. Research Bul. No. 7, Mo. Station.

that the maintenance requirement does not vary directly with the weight, of the individual, yet it appears that the two are closely correlated.

Kellner[1] shows that the ox in good condition especially when fat requires a larger ration for maintenance than a lean one of the same body surface.

Maintenance requirements vary with the size and weight of the animal[2]. The loss of heat and energy from the body is not proportional to the size or weight, but rather to the body surface. The protein requirement for maintenance depends not upon the surface of the body of the animal but directly upon its weight.[3]

Age -- Since size and age of animals run in direct correlation with each other, what has just been given in reference to size need not be repeated, and can be applied the same for age.

Rate of Growth -- The rate of growth in animals differs very widely with various breeds and with individuals within the breed. Minot[4] says, "a calf at birth weighs about 77 pounds and the average daily increase during the first 2 years is 1.5 pounds." The

---

1. Landw. Vers. Stat. 50 (1898) from Henry-Feeds & Feeding.
2. Henry, Feeds and Feeding p. 73 (1910)
3. Kellner, Ernähr. Landw. Nutztiere, (1907) p. 410 - from Henry - Feeds and Feeding.
4. Marshall, Physiology of Reproduction.

body of the young growing animal undergoes a rapid increase in protein tissues and bone but that of the mature animal is normally in equilibrium, i.e., the protein out-go equals the protein intake, there being neither increase nor loss of protein tissue. Equilibrium is not possible with young animals. Waters[1] of the Missouri Station experiment with yearling steers, has shown that young animals fed scanty rations increase in height even tho losing weight. With insufficient food, some of the organs or parts may continue to grow at the expense of others, a process which if long continued, results in injury or death. "An abundant supply of protein is essential for the formation of the protein tissues of the body and mineral matter is necessary for the framework of the bone."[2]

Climate -- Dairy cattle properly cared for, the weather conditions in winter would have very little effect on them, but animals exposed to the weather show a noticeable difference in the rate of growth at times from those carefully housed during the winter. Cold, stormy weather invariably checks growth on animals getting restricted rations of any kind. The food is

---

1. Proc. Soc. Prom. Agr. Sci. 1908.
2. Henry, Feeds and Feeding, p. 71.

utilized for heat when it otherwise would be used for growth. Fattening animals being fed all they want of a good palatable ration are not effected seriously by the cold because their appetite is increased and they eat more feed.

Character of Feed -- As has been shown in the paper so far, the character of feed is an important factor influencing growth in animals. The character of proteins as given earlier is of importance but need not be discussed again here. Animals on ordinarily good rations if given plenty will get enough food for normal growth.

There have been several standards published by different men and experiment stations as to the actual protein requirements of growing cattle. Some of these have been estimated from actual experiments with various kinds of animals while others have been calculated from a basis of one class of animals, namely, beef steers.

Haecker[1] of the Minnesota Station after a thoro experiment on "The Food for Maintenance" with dairy cows suggests the following: "It is tentatively suggested that the food of maintenance for a barren dry cow when at rest in the stall be expressed in nutrients of 0.6 of a pound of protein, 6.0 pounds of car-

---

1. Minn. Exp. Sta. Bul. No. 79.

bohydrates and 0.1 pound of ether extract per 1000 pounds live weight and when at work in a dairy with ordinary good care and comfortable quarters 0.7 of a pound of protein, 7.0 pounds of carbohydrates and 0.1 of a pound of ether extract be allowed per 1000 pounds of live weight or one-tenth as much per cwt."

Digestible food nutrients required by Wolff-Lehmann[1] feeding standards for growing dairy cattle are as follows:-

		Digestible Nutrients		
Age, mo.	Wt. Lbs.	Proteins	Carbohydrates	Ether Extract
2 - 3	150	.60	1.97	0.3
3 - 6	300	.90	3.87	0.3
6 - 12	500	1.00	6.25	2.5
12 - 18	700	1.26	8.80	3.3
18 - 24	900	1.35	10.99	4.5

From this table, it is very evident that there is a marked difference in the amount of protein required by growing and mature animals.

The standard used at the Missouri Station to base this experiment on is that calculated by Armsby. The tables as set forth by Armsby can be used to

---

1. Georgia Exp. Sta. Bul. No. 90.

good advantage for most classes of animals.

The following table as calculated by Armsby is self explanatory:

Estimated Requirements Including Maintenance Per Day and Head for Growing Cattle.[1]

Age Months	Lbs. Live Weight	Digestible Protein Lbs.	Energy Value Therms
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	1000	1.65	8.0

The author suggests that in using the above standard the weight of the animal should be considered rather than the age. He further states, "The foregoing data refers to what might be called normal growth in which the animals are kept in a good thrifty condition but do not become fat. If any considerable fattening is desirable somewhat heavier rations must be given in proportion to the amount of gain made, because the increased gain in fattening animals consists

---

1. U. S. Dept. Agr. Farmers' Bul. No. 346.

to a very large extent of fat and therefore means the storing up by the animal of more reserve energy".

From the above table, it is evident there is a gradual increase in the protein requirement until the animal is two years old or past, then it seems to lower slightly. This lowering may not always be possible, however, because all animals do not reach their maximum growth at two years of age and until that stage is reached, there is bound to be a high protein requirement.

Fingerling[1] from experimental studies made on young cattle of modern high grade stock concludes: "First, by feeding 1.5 kg. pure protein per 1000 kg. body weight to young calves the same nitrogen addition was obtained as when a higher protein diet of 3.31 kg. per 1000 kg. body weight was fed in addition to raising the starch ration 12 - 13 kg. second, the protein which was supplied above what was needed did not raise the protein addition in the animal but caused an increase in protein destruction. Third, the diet of 1.5 kg. protein was not the minimum for by it the highest nitrogen addition was obtained. For the maintenance of life, the protein requirement was low".

---

1. Land. Vers. Stat. 76 p. 1 - 74, From Chem. Abs. V. 6, No. 13, p. 176.

Storrs Experiment Station[1] conducted a test to determine the amount of feed required by dairy heifers from birth until 2 years of age. During the second and fourth 6 month periods, the animals were on pasture. The average gain in weight by the Jerseys and the Guernseys for the first 6 months period was 1.15 pounds per day while that of the Holsteins was 1.64 pounds. The average gain for the Jerseys and Guernseys for the third period was .84 pounds per day while by the Holsteins it was .95 pounds per day. During the first 6 months period the Jerseys and Guernseys required .59 pounds of digestible protein and 2.20 therms energy for a pound of growth while the Holsteins required .33 pounds of digestible protein and 1.52 therms energy for one pound of growth. During the third period the Jerseys and Guernseys required .96 pounds of digestible protein and 5.95 therms of energy for one pound of growth. The Holsteins required .87 pounds of digestible protein and 5.76 therms energy per pound of growth.

The results of the data show clearly that as the animals grow older a pound of growth including maintenance requires more nutrients.

Norton[2] of the Michigan Station gives the

---

1. Storrs Agr. Exp. Sta. Bul. No. 63.
2. Michigan Agr. Exp. Sta. Bul. No. 257.

record of the feed required to grow a number of dairy heifers. They were fed on whole milk, skim milk, grain, dried beet pulp, roots, hay and green corn. The nutrients of the total ration for 12 months is calculated in digestible protein and energy value. The animals gained weight at the rate of 1.57 pounds daily during the first year of their life and it required .54 pounds of digestible protein and 2.93 therms energy to produce this daily gain.

In cattle feeding experiments in Britain, H. Ingle[1] found that on an average from .8 to 1.0 pounds of digestible proteids per day for 1000 pounds of live weight was sufficient for the needs of a fattening bullock. Larger amounts involved unnecessary expense.

Jordan[2] of the Maine Station reports an experiment with growing beef steers beginning with calves and feeding to maturity. The object of the test was to determine the influence of a ration high in protein and one relatively low in protein on the rate of growth and character of flesh produced.

Four Shorthorn calves were selected for the test ranging in age from 5 to 7 months. The calves

---

1. Highland and Agr. Soc. Scot. 5 ser. 22 (1910) pp.168-177
2. Rpt. Maine Station 1895, p. 64.

were divided into two lots. The four steers were fed alike at all times on roughages the difference being in the grain received making the low and high protein. The roughage consisted mostly of timothy hay, some fodder corn and corn silage being fed during the first winter only. The concentrates were as follows: lot 1, high protein ration, linseed meal 2 parts, corn meal 1 part, wheat bran 1 part by weight. Lot 2, low protein ration, corn meal 2 parts, wheat bran 1 part by weight.

In this trial, no attempt was made to force the steers to rapid growth, the aim being to keep them steadily gaining. At the end of 17 months, two steers were slaughtered, the other two being carried on until 27 months of age. Up to 17 months of age the steers getting the high protein ration made the better gains weighing 174 pounds more than the lower protein lot. They also looked better and showed more thrift at all times. During the latter 10 months, the growth condition was reversed, the steer receiving the low protein ration made better gains than the one on high ration, weighing 43 pounds more at the end of the experiment.

When the calves were building up flesh and

bone, the high protein ration was much more effective than the other. From the beginning to the end of 15 months feeding, 5.11 pounds of digestible nutrients in the high protein ration proved as effective as 6.16 pounds in the protein poor ration.

During the latter 10 months of feeding with two steers, it required 7.73 pounds of digestible nutrients for the high protein steer against 7.08 pounds for the low animal for one pound of gain. While the high protein ration was more effective during the growing stages, the one with less protein but more carbohydrates proved the most efficient by the end of the 27 months of feeding.

Jordan concludes from this experiment "that rations high in protein were more favorable to rapid growth and finer general appearance of animals when young than rations high in carbohydrates and low in protein. "It appears that when the protein poor ration contains enough nitrogen and ash to supply the actual demands of the body, the animal carefully conserves them, being enabled thereby to fulfill the laws of nature as to growth. No doubt if the steers getting the least protein and ash had been supplied with less protein and ash than nature requires for good body building, they would have plainly shown it by an abnormal

development; but fortunately, such conditions were not laid down in this experiment".

P. N. Flint[1] of Georgia has conducted a very extended experiment on protein requirements for growing dairy animals. The test was divided into three periods and the animals into three groups. During the first period, lot 1 consumed an average of .48 pounds of digestible protein daily, lot 2, 0.60 pounds and lot 3, 0.80 pounds. Lot 1 made an average gain per animal in 88 days of 69.4 pounds, lot 2, 72.4 pounds and lot 3, 98.4 pounds. When calculated per 1000 pounds live weight, the rations of lots 2 and 3 each contained practically 15.7 therms energy value and lot 1, 14.40 therms. During the second period, the average ration of lot 1 contained per 1000 pounds of live weight 0.10 therms more energy value than the average ration of lot 2. In respect to digestible protein on the other hand, the average ration of lot 2 contained per 1000 pounds of live weight 0.77 pounds more than the average ration of lot 1. The average gain per animal of lot 3 was 111.4 pounds while the gains of lots 2 and 1 were 96.4 pounds and 68.9 pounds respectively.

---

1. Georgia Exp. Sta., Bul. No. 90.

Digestible Protein Consumed Daily;
Average Gain per Animal in 88 Days,
Rations Calculated on 1000 pound Basis
By Lot Numbers

Lot No.	Digestible Protein Consumed Daily	Av. gain per Animal 88 days	Energy value per 1000 lbs. live wt.	Av. Gain per Animal 2d Period
	Lbs.	Lbs.	Therms	lbs.
1	.48	69.4	14.40	68.9
2	.60	72.4	15.70	96.4
3	.80	98.4	15.70	111.4

"During each period the ration of lot 3 conformed more nearly to the Wolff-Lehmann feeding standards which were taken as the basis of all work. This lot also made the greatest gains".

From the work reported above, it is very evident that there is wide variation in protein requirements in various sections of the United States and that very few of the experiment stations agree on any one standard.

AMOUNT OF PROTEIN IN RATIONS FOR CATTLE.

Little data is available regarding the amount of protein in rations fed growing animals. Below is given a list[1] of some of the most important feeds with their analysis which shows the varying amounts of protein in different feeding stuffs:

Feed	Digestible Protein per 100 lbs.	Energy Value per 100 lbs.
Hay		
Alfalfa	6.93	34.41
Clover	5.41	34.74
Timothy	2.05	33.56
Corn Stover	1.80	26.53
Cowpea Hay	8.57	42.76
Grains		
Barley	8.37	80.75
Oats	8.36	66.27
Corn	6.79	88.82
By-products		
Cottonseed Meal	35.15	84.20
Roots		
Carrots	0.37	7. 82
Mangels	0.14	4.62
Rutabagas	0.88	8.00

1. Pa. Exp. Sta, Bul. No. 346.

The hays given here are the principle ones grown and used in the United States and represent the feeds containing extreme percentages of digestible protein. It is apparent that when feeds relatively low in percent of protein, as timothy hay or corn stover constitute part of the ration, it is important that feeds high in protein be supplied to make up the necessary amount of protein for the average growing dairy heifer. On the other hand, if feeds high in protein, as leguminous hays, are used in a ration, there is less danger of a shortage in the protein content.

The grains given are nearly equal in their percentage of protein, all being fairly high and able to add considerable to any ration. In feeding a roughage containing a low percent of protein, barley or oats of the grains would be preferred and in addition to this a by-product as cottonseed meal which is extremely high in protein. If alfalfa is fed, less protein in the form of concentrates is necessary and a grain lower in protein, as corn, would be the most satisfactory.

Roots add very little protein to a ration but are helpful in other ways that their analysis does not show. They should be fed with other mixtures mentioned above to get the best results.

The proper protein requirement for normal growth has not been decided experimentally. Therefore, it is difficult to state definitely whether certain rations contain sufficient quantities of protein. The best that can be done in this case is to give rations that have been used by experiment stations and have given satisfactory results. With those it is noticed there is wide variation in the amount of protein described as necessary for normal growth.

A study of the rations suggested by various experiment stations over the United States shows that there is a great variation in the amount of protein actually fed to growing cattle. These experiments do not give the weight of the animals and often not actual age so a direct comparison as to the amount of protein per pound of gain or for animals of a certain age, is hardly possible.

The Purdue[1] Experiment Station gives a ration for calves, yearlings and two-year olds consisting of shelled corn, cottonseed meal and clover hay. The ration for calves contained 0.791 pounds protein and 6.180 therms energy per pound of gain. The yearlings received 0.970 pounds protein and 7.529 therms energy

---

1. Purdue Agr. Exp. Sta. Bul. No. 136.

per pound of gain, while the two year olds consumed 1.204 pounds protein and 9.310 therms energy per pound of gain. The author mentions that the animals made good gains but the weights were not given.

Storrs Experiment Station[1] suggests a ration containing hay, silage and grain; for yearlings, 0.531 pounds protein and 5.94 therms energy per pound of gain. This was found to be deficient for animals past yearlings but they suggest 0.59 pounds protein and 6.95 therms energy as being ample for growing yearlings.

Hoard's Dairyman[2] writes "Young growing animals from 12 to 24 months of age with an average weight of 800 pounds should receive 1.057 pounds digestible protein and 7.72 therms energy per day to stay in good condition".

From material available taken from various experiment stations, it appears that the rations fed to growing animals contains sufficient protein for growth. The place we may find animals low in their protein supply is in those sections where the common feeds are low in protein content, for example, in the corn belt where the ration is made up largely of corn products and such roughages as timothy hay, feeds which are relatively low in their percentage of protein. While animals will eat large amounts of such feeds, the protein nutrients may

---

1. Storrs Con. Exp. Sta. Bul. No. 63.
2. Hoard's Dairyman, Vol. 42.

not be sufficient for growth. On the other hand, sections of the United States where leguminous hays or nitrogenous concentrates are readily accessible rations are more likely to contain ample supplies of protein.

EFFECT OF RATIONS LOW IN PROTEIN CONTENT.

In view of the high cost and relative scarcity of crude protein in feeding stuffs, it is desirable to know the minimum requirement of protein by farm animals. Experimental tests show that the administration of a protein food to an animal that was previously fasting caused a prompt and large increase in the nitrogen cleavage and excretion. While but a very small portion of the protein was supplied for building purposes, the result being that before nitrogen equilibrium is reached, two to three times as much protein must be given as are metabolized during fasting. While the percentage decrease in the protein metabolism is relatively small, nitrogen equilibrium may be reached with a much smaller supply of proteids than is the case in the absence of the non-nitrogenous nutrients. It was noticed that a sufficient supply of carbohydrates or fats in the diet should practically

destroy the stimulative effects of the proteids, in which case we might expect the proteid supply equal to the fasting proteid metabolism to be sufficient to produce nitrogen equilibrium.

Experiments have been conducted on various species of animals to determine the protein minimum. In experiments C. Voit[1] found that non-nitrogenous nutrients largely diminish the protein requirement. He also found that from 1200 to 1500 grams lean meat per day was required to keep a lean dog in nitrogen equilibrium while on an exclusive protein diet. When fat or carbohydrates were added to the ration, it required but 1000 grams and the animal made better gains. In the presence of non-nitrogenous nutrients, nitrogen equilibrium was reached with quantities of proteids from one-third to one-half as great as the amount required when fed alone. In other words, the non-nitrogenous nutrients materially reduce the minimum of crude proteids to maintain the protein tissues of the body.

Munk and Rosenheim[2] both found that when proteid was given to dogs in quantities sufficient to maintain nitrogen equilibrium, they lost strength gradually and became affected with digestive disturbances. The experiments emphasized the benefit derived from diets

---

1. Ztschr. Biol. Vol. V (1869) from Armsby's Prin. of Animal Nutrition.
2. Munk & Archiv. für Physiologie (1891) from Lusk. Sci. of Nut.

containing more proteid than just enough necessary to maintain nitrogen equilibrium.

B. H. Jagervoss[1], in an experiment with dogs in which a diet was fed sufficient for maintenance but poor in protein, found that the animals lived for a number of months on a diet furnishing as low as 0.2 grams nitrogen per kilogram of body weight but finally died from some infectious disease. The dogs had to be coaxed to eat the diet as it became unrelishable, this showing that it was not satisfactory. The author holds that if the diet is palatable, easily digested, composed of fresh materials and of suitable volume, no attention need be paid to the protein content as a sufficient amount will undoubtedly be furnished.

A D. Emmet and E. C. Carroll[2] made a study of the physical constants of the fats of swine. Berkshire pigs of known age ancestery were fed different amounts of blood meal in connection with a basal ration of corn and crude calcium phosphate. Lot 1 were fed on a low protein plane, lot 2 on a medium or balanced plane and lot 3 on a high protein plane. The leaf, back, intestinal and jowl fats were taken and chemical constants determined. If the ancestery, age and type

---

1. Skand. Arch. Phy. 13 (1902) p. 375-418, Armsby's Prin. of Animal Nutrition.
2. Jour. Biol. Chem. 9 (1911) p. 23 - 25.

of the animals were not considered in the data, different amounts of protein fed have not affect on the physical constants of the fats.

Mr. M. Hindhede of Copenhagen[1] studied protein minimum in the diets for men. He found that on diets low in protein consisting largely of potatoes and margerine, individuals were maintained in good health and nitrogen equilibrium was established over long periods. The following figures for protein and calorific minima of the diets were obtained on three individuals; "1st, average work, 3900 cal. and 25 grams of protein; hard work, 5000 cal. and 35 grams of protein; 2d, average work, 3700 cal. and 25 grams of protein; 3d, light work, 2600 cal. and 16 grams protein or reckoned as grams protein per 3000 cal., 19.21 - 20 and 18 grams respectively. In subject 1, nitrogen equilibrium was established if the calorific value of the digestible protein of the diet equalled 1/38 of the total calorific requirement for moderate work and 1/34 of that for heavy work".

The minimum proteid requirement for growing dairy cattle has not been accurately determined. The available material on this subject has been secured almost entirely with tests conducted with beef cattle.

---

1. Skand. Arch. Physiol. 30 pp. 97-182, Chem. Abs. VII, p. 3608.

Armsby[1] in experiments with steers says, "While the data are hardly sufficient to fix absolutely the minimum of proteids for cattle on a maintenance ration, they indicate clearly that from 0.44 to 0.66 pounds of digestible protein per day is at least sufficient for a steer weighing 1000 pounds; and there is a possibility that the amount may be somewhat further reduced. Altho we are unable to compare this with the fasting metabolism, a comparison on the basis of live weight, with some results previously studied shows that the minimum demand for proteids on the part of cattle is relatively less than on the part of carnivera." In all experiments conducted by Armsby, he shows a range of .064 to .098 grams protein per kilogram live weight for maintenance for animals.

Haecker[2] after several years study at the Minnesota Station found that dairy cows with good care and liberal feeding would continue a good flow of milk for a long period on a surprisingly small amount of crude protein. However, after some years of such feeding, their vitality was practically gone and they became physical wrecks years before they would under normal conditions. As previously shown, protein is very essential as a cell

---

1. Pa. Exp. Sta. Bul. No. 42.
2. Henry - Feeds and Feeding, 10th Ed. p. 75.

stimulate and, hence we may conclude that working and growing animals need considerable more digestible crude protein than the minimum on which they may barely subsist.

J. Foster[1] in a paper on minimum protein requirements points out that the commonly accepted protein standards should not be lowered. He believes that proteins in generous amounts is required on account of the mineral matter which is bound up with it and on account of the stimulating and similar specific bodies which are formed from protein by cleavage and are essential to body well-being and resistance to disease.

EXPERIMENT.

Source of Experimental Data.

The material used in this paper has been collected from three sources; first, a special protein experiment with two animals; second, six animals on a short feeding period to determine the relative value of silage and clover hay for wintering growing heifers and, third, fourteen animals from the light and heavy fed experiment conducted at the Missouri Station.

First:- Two pure bred Jersey heifer calves were selected from the herd in August 1913 to be used for the special protein experiment. One of the two heifers, No. 94, was put on as low a protein diet as the poorest of protein feeds would permit and still receive plenty of energy. The other heifer, No. 91, was placed on an ideal ration from the standpoint of protein and mineral and still remain within reasonable energy limits. Complete data, including feed tables is given later in the paper. Since this experiment deals directly with the subject, it will be taken up in detail.

Second:- Two Holsteins, three Jerseys and one Ayrshire heifer of nearly the same age were put on feed in November 1913, primarily to determine the cost of rearing. The heifers were divided in two groups as nearly alike as possible. One group was fed silage as roughage with equal parts of corn and cottonseed meal. The other group was fed clover hay as roughage with corn. The amount of grain fed was constant, being two pounds in the former group and three pounds for the latter. Varying amounts of roughage were fed, the animals receiving what they would eat at all times. These heifers were all on pasture and received some alfalfa at night previous to the time of starting the experiment. Complete tables of feed and growth will be given later.

Third:- The records of fourteen animals, taken from an experiment conducted at the Missouri Station to determine the effect of light and heavy feeding of dairy heifers have been calculated. The animals used were pure bred Jerseys and Holsteins which were divided about equally into two groups. The light feds were given skim milk and leguminous hay. The heavy fed group received whole milk, leguminous hay and grain, the heifers getting as much as they desired at

all times. They were fed in a dry lot thruout the experiment. A little green feed was added occasionally during the summer months. The records herein reported give the feed consumed; weight and gains of all animals from the end of the first six months until first parturition.

Discussion of Heifers Nos. 91 and 94.

Description of Calves -- As mentioned before, the calves used for the special protein experiment were pure bred Jerseys. The dams were about the same size but the birth weight of the calves varied considerable, No. 91 weighing 38 pounds and No. 94 53 pounds. They were treated the same as all other herd calves for the first few months, i.e., sucked cows the first two days, then weaned to whole milk which was gradually replaced by skim milk and grain. After weaning, they were placed in the experiment.

Rations -- The rations fed were very different, No. 91 received a mixture of grain consisting of corn 2 parts by weight, bran 1.5 parts, cottonseed meal 1 part, with alfalfa hay. The proportion of grain and hay maintained was 4.5 parts grain to 5 parts of alfalfa. No. 94 was fed only timothy hay and corn; the

proportion being 4 parts hay to 5 parts of grain.

All calculations of nutrients given are made according to the "Production Value" suggested by Armsby[1]. As shown previously, the feed for No. 91 was very palatable and contained a variety of feeds. The ration also contained the necessary nutrients being especially high in protein. On the contrary, as also shown, No. 94's ration was low in nutrients, especially in protein. The feed is not palatable and the ration has too little variety to help the palatibility to any extent.

Feeds -- Hay and grain were bought in large quantities and enough stored of the same lot to run the calves a year or more. Experience has taught that it is poor policy to run short of feed at some time in the middle of an experiment. New hay has to be purchased and the animals take some time to become accustomed to the change which also requires additional analytical work.

Feeding -- The calves were fed night and morning in the usual manner at regular hours. The feed was weighed each time and a careful account of any waste recorded and the ration raised or lowered at intervals

---

1. U. S. Dept. Agr. Farmers Bul. No. 346.

as the calves developed, receiving all they would eat at all times. Tables will be given with all feed consumed thruout the experiment.

The ration of No. 94 was found to be low in ash and to eliminate as far as possible all but the protein factor, bone meal and calcium carbonate were added to the ration. Twenty grams of calcium carbonate were added to the ration beginning on November 3, 1913. This did not prove sufficient so on December 15, 40 grams of bone meal in addition were added, making a ration with plenty of mineral but as low in protein as ordinary feeds will permit.

Water -- Clear fresh water was supplied in abundance twice daily at feeding time.

Salt -- Salt has been before the calves at all times. A supply was weighed up and kept in jars in the stalls and added whenever necessary. The boxes were cleaned and the salt weighed once a week. Some little trouble was encountered in keeping accurate salt records because of hay mixing with it, affecting the weight.

Stabling -- The calves have been kept practically the full time in small box stalls with board floors. Shaving have been supplied for bedding be-

cause the calves ate the straw. The calves were let out in the yard every few days to exercise. The past month they have had the run of a paddock and have been muzzled to keep them from eating dirt.

Weighing -- Weighings were made every Monday morning after the animals had received their morning feed. Complete data is given in table form.

Measurements -- The following measurements of the heifers were taken monthly:-

1. Height at withers.
2. Height at highest point of croup.
3. Height at hip points.
4. Depth of chest just behind elbow joint.
5. Width of chest just behind elbow joint.
6. Width of hips.
7. Width of loin.
8. Length from pole to point of muzzle.
9. Width of forehead.
10. Circumference of muzzle at opening of mouth.
11. Length from base of horns to withers.
12. From highest point of withers to line between hips.
13. From a line between hips to tail.
14. From point of shoulder to point of hips.

TABLE I.

TOTAL NUTRIENTS RECEIVED.

By Seven Day Periods.

spare out.

NO. 91.

High Protein Ration.

Period	Lbs. Grain	Lbs. Alfalfa	Lbs. Digestible Protein	Therms Energy Value	Lbs. Weight
1	21.0	23.1	4.58	23.52	216
2	21.0	23.1	4.58	23.52	218
3	21.0	23.1	4.58	23.52	225
4	21.0	23.1	4.58	23.52	245
5	21.0	23.1	4.58	23.52	250
6	26.0	28.6	5.67	29.13	242
7	28.0	30.8	6.10	31.37	270
8	28.0	30.8	6.10	31.37	290
9	28.0	30.8	6.10	31.37	287
10	31.0	34.4	6.78	35.75	290
11	34.0	37.5	7.42	38.13	297
12	35.0	38.5	7.63	39.22	315
13	35.0	38.5	7.63	39.22	312
14	35.0	38.5	7.63	39.22	325
15	35.0	38.5	7.63	39.22	338
16	35.0	38.5	7.63	39.22	345
17	35.0	38.5	7.63	39.22	345
18	35.0	38.5	7.63	39.22	350
19	35.0	38.5	7.63	39.22	361
20	35.0	38.5	7.63	39.22	375
21	35.0	38.5	7.63	39.22	380
22	35.0	38.5	7.63	39.22	400
23	35.0	38.5	7.63	39.22	400
24	35.0	38.5	7.63	39.22	397
25	35.0	38.5	7.63	39.22	400
26	35.0	38.5	7.63	39.22	415
27	35.0	38.5	7.63	39.22	420
28	36.2	39.7	7.89	40.52	410
29	37.6	41.1	8.18	42.04	420
30	38.5	42.0	8.37	43.01	430
31	38.0	39.5	8.02	41.27	425
32	35.0	36.7	7.39	38.01	440
33	27.5	35.5	5.81	29.86	442
34	31.5	35.0	6.90	35.41	452
35	31.5	35.0	6.90	35.41	465
36	35.0	38.5	7.63	39.21	475
37	35.0	38.5	7.63	39.21	492

TABLE 2.

TOTAL NUTRIENTS RECEIVED.

By Seven Day Periods.

Leave out.

NO. 94.

Low Protein Ration.

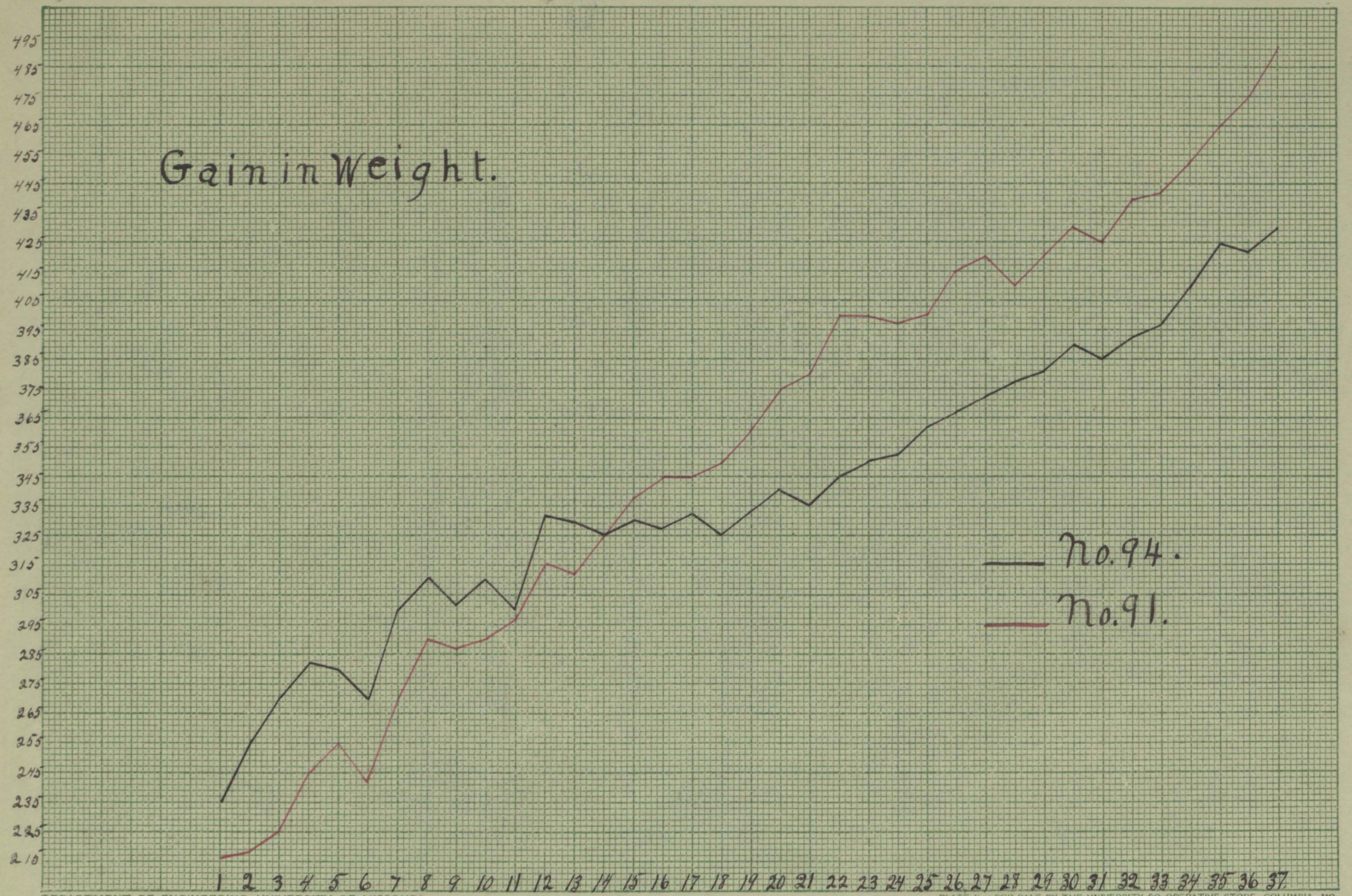
Period	Lbs. Grain	Lbs. Timothy	Lbs. Digestible Protein	Therms Energy Value	Lbs. Weight
1	25.0	19.8	2.09	28.85	235
2	26.6	21.0	2.23	30.67	256
3	26.6	21.0	2.23	30.67	270
4	26.6	21.0	2.23	30.67	282
5	26.6	21.0	2.23	30.67	280
6	31.6	25.0	2.65	30.46	270
7	33.6	26.6	2.82	38.77	300
8	33.6	26.6	2.82	38.77	310
9	33.6	26.6	2.82	38.77	302
10	34.8	27.8	2.92	40.33	310
11	37.5	30.0	3.15	43.37	300
12	35.0	28.0	2.94	40.48	332
13	34.5	22.9	2.80	38.32	330
14	31.5	25.2	2.64	36.43	325
15	31.5	25.2	2.64	36.43	330
16	31.5	25.2	2.64	36.43	327
17	31.5	25.2	2.64	36.43	332
18	31.5	25.2	2.64	36.43	325
19	31.5	25.2	2.64	36.43	333
20	31.5	25.2	2.64	36.43	340
21	34.5	27.2	2.89	39.77	335
22	32.0	25.6	2.69	36.01	345
23	31.5	25.2	2.64	36.43	350
24	31.5	25.2	2.64	36.43	352
25	31.5	25.2	2.64	36.43	362
26	31.5	25.2	2.64	36.43	367
27	31.5	25.2	2.64	36.43	372
28	34.5	27.6	2.90	39.91	377
29	37.0	29.6	3.11	42.80	380
30	38.5	30.8	3.24	45.53	390
31	38.5	30.8	3.24	45.53	385
32	38.5	30.8	3.24	45.53	392
33	35.5	28.4	2.99	41.06	397
34	35.0	28.0	2.94	40.49	410
35	35.0	28.0	2.94	40.49	425
36	38.5	30.8	3.24	44.53	422
37	38.5	30.8	3.24	44.53	430

15. From point of shoulder to ischium.
16. From point of hips to ischium.
17. From point of hips directly forward to last rib.
18. Heart girth just behind elbow joint.
19. Girth of paunch at end of last rib.
20. Smallest circumference of shin bone of fore leg.
21. Smallest circumference of shin bone of hind leg.

Other experiments at the Missouri Station have shown a direct correlation between measurements of height at withers and the others mentioned. For this experiment, data will be given in table form of heart girth and height at withers.

Tables I and 2 show the digestible protein, energy value and weight of heifers No. 91 and 94 by seven day periods from August 1913, when the experiment was started up to May 1, 1914.

From the beginning there is a marked difference in the amount of protein fed. The energy factor is nearly the same with both, No. 94 getting slightly more at the beginning but considerable variation is shown later. The object has been to keep the energy as near constant as possible in order to study the effect of ration lacking in protein only. The weights as given in Table I show that No. 94 was considerable



DEPARTMENT OF ENGINEERING, UNIVERSITY OF MISSOURI

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

larger than No. 91 in the beginning. However, No. 91 continued to make rapid gains until the 22d period when she remained constant for some time. After this time, she fluctuated widely from week to week and failed to make uniform gains. A reverse condition is shown with No. 94, which made very slow gains and fluctuated widely up to the 21st period, after which she made comparatively slow but uniform gains.

The exact cause of the above mentioned results is difficult to definitely determine because of the small number of animals. It is possible that the individuality of the heifers is responsible for some of the results noted. No. 91 seems to have a tendency to be smaller and blockier than No. 94 and never may be as large even with the better feed. Her ration being palatable and containing variety was readily eaten at first causing the rapid early growth. While the ration of No. 94, on the other hand, was not palatable and it took her some time to become accustomed to the new feed. Therefore, she did not eat any more than was necessary for body requirements.

Cold weather seemed to have a marked effect on the growth and appearance of both animals. No. 94 had the better stall of the two but the weather seemed to effect her more than it did No. 91.

TABLE 3.

NUTRIENTS RECEIVED PER DAY.

By Four Period Intervals.

High Protein NO. 91				NO. 94. Low Protein		
Periods	Lbs. Digestible Protein	Therms Energy Value	Lbs. Gain	Lbs. Digestible Protein	Therms Energy Value	Lbs. Gain
1 - 4	.654	3.360	1.035	.313	4.316	1.607
5 - 8	.801	4.121	1.607	.375	5.166	1.000
9 - 12	.997	5.159	0.892	.422	5.819	.785
13 - 16	1.090	5.602	1.071	.382	5.271	No Gain
17 - 20	1.090	5.602	1.071	.377	5.204	.464
21 - 24	1.090	5.602	.785	.387	5.308	.428
25 - 28	1.099	5.649	.464	.386	5.328	.892
29 - 32	1.141	5.868	1.071	.458	6.406	.535
33 - 36	.972	4.996	1.251	.432	5.948	1.071

Dietrich[1] in work with pigs found that "the factor of protein waste when once introduced, apparently becomes such a fixed tendency or habit that it is eliminated or even materially reduced with great difficulty".

There is no doubt that No. 91 was receiving an excess of protein during her early periods of feeding so a condition similar to the above may be the cause of her slow growth at the intervals above mentioned.

Another possible factor influencing growth is the kind as well as the amount of protein in the feed supplied. From the ration of No. 94, it can be seen that most of the protein comes from corn while with No. 91 there is alfalfa and cottonseed meal in addition to the corn, all of which contributes protein in variable quantities. The results of previous work have been reviewed but they do not seem to furnish a definite basis and the work of this experiment is too limited to attempt giving more than an indication of the results to be expected.

Table 3 shows a marked decrease in the growth of No. 91 from the 21st to 28th periods. Most of the

---

1. Illinois Exp. Sta. Cir. No. 126.

TABLE 4.

NUTRIENTS USED PER DAY PER POUND GAIN.

By Four Period Intervals.

	High Protein NO. 91		NO. 94 Low Protein	
Periods	Protein per Lb. Gain Lbs.	Energy per Lb. Gain Therms	Protein Per Lb. Gain Lbs.	Energy per lb. Gain Therms
1 - 4:	.635	3.246	.191	2.685
5 - 8:	.498	2.564	.375	5.166
9 - 12:	1.117	5.782	.537	7.412
13 - 16:	1.017	5.230	No Gain	No.Gain
17 - 20:	1.017	5.230	.812	11.215
21 - 24:	1.388	7.262	.904	12.401
25 - 28:	2.387	12.174	.432	5.973
29 - 32:	1.064	5.478	.856	11.973
33 - 36:	.777	3.996	.403	5.553

cold stormy weather came during these periods and it seemed to have a marked effect on her. She was getting the same amount of feed and the other conditions were similar to the previous periods. Therefore this period of slow growth appears to be due to the extra requirements for maintenance.

No. 94 shows as good gains the first 8 periods as does No. 91. This is possibly due to the fact that she had considerable protein stored in her body from the earlier feeding and utilized it at this time, and because of her low protein feed. From the 13th to the 16th periods there was no gain, which may not be attributed to other than lack of necessary amount of food to foster growth. It is in this period that there seemed to be a complete change as all the excess protein of the body had apparently been utilized and it became necessary for the available protein to be furnished by the feed. After this time she made gradual gains.

Table 4 shows that No. 91 required considerable more protein and energy per pound of gain than No. 94. Another factor that may be mentioned here is the amount of protein necessary for the most enonomical development. From a purely protein standpoint, No. 94's ration was possibly more efficient than that of

No. 91. No. 91 may have received more protein than was economical for the best gains during the early feeding period.

This factor cannot be definitely settled by this experiment since the individuality of the heifers considered may materially affect the results while the number of animals is also small. The present test merely introduces this study which will require for its solution an extended experiment including relatively large numbers of heifers on varying planes of nutrition.

As previously noted above, 20 g. of calcium carbonate were added to the ration beginning on November 3, 1913. This period of low gain is just prior to and at the time the extra mineral was added. Hence it may be concluded that lack of mineral constituents was a strong factor in determining the rate of growth of No. 94 at this particular period.

Weight was kept of the amount of water consumed by each animal for 21 days. It was found that No. 91 consumed an average of 28.11 pounds water per day while No. 94 drank but 20.58 pounds per day. It seems the better ration caused a greater demand for water than the other feed.

TABLE 5.

COMPARISON OF MEASUREMENTS.

High Protein NO. 91				NO. 94 Low Protein		
Date	Height at Withers Cm.	Heart Girth Cm.	Weight Lbs.	Height at Withers Cm.	Heart Girth Cm.	Weight Lbs.
Aug. 19	92.0	106.0	224	97.0	113.0	254
Sept. 15	94.0	111.5	249	98.5	113.5	276
Oct. 8	97.5	119.0	293	99.5	118.0	304
Nov. 17	99.5	123.0	336	101.0	121.0	330
Dec. 15	102.8	125.0	360	103.8	122.0	333
Jan. 16	105.0	131.5	389	105.5	125.0	347
Feb. 16	106.5	132.5	411	106.0	125.0	359
Mar. 16	108.0	135.5	435	107.3	129.0	388
April 16	108.8	138.0	454	109.8	133.0	417

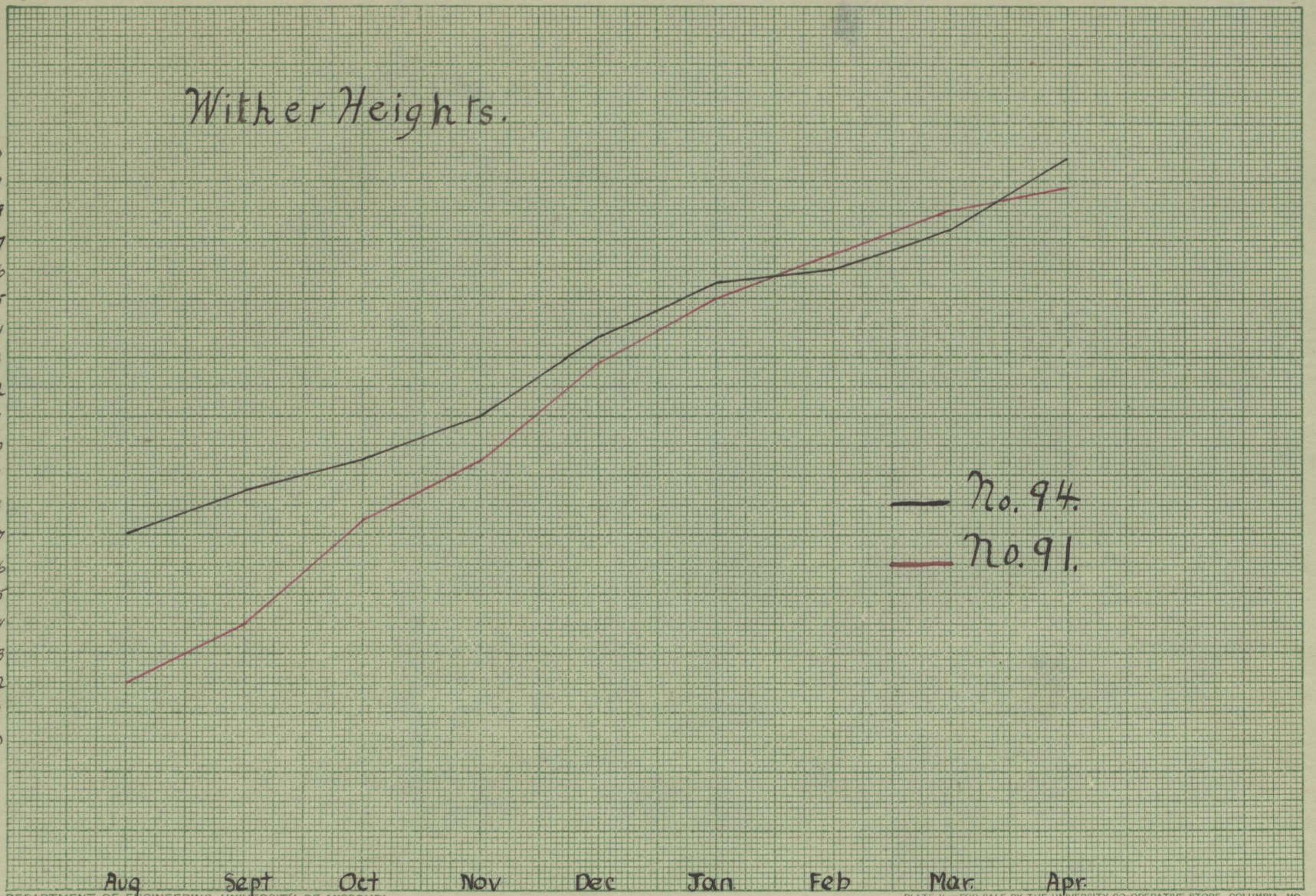
Mattill and Hawk[1] in studies on water drinking with men found that the ingestion of large amounts of water with meals caused the protein constituents of the food to be more completely utilized as shown by a decrease of all forms of nitrogen in the feces. It is possible that a condition similar to the above mentioned prevailed in No. 91, but as no digestion trials were made, this can not be stated definitely.

Records of the amount of salt consumed by the two animals show that No. 91 ate .62 ounces, while No. 94 consumed 1.5 ounces per day. Some difficulty was encountered in keeping accurate salt records because of the dirt that occasionally fell in the salt boxes. The effect of the excessive amount of salt is hard to determine. It possibly had no deleterious effect on the general appearance and may have aided in keeping the digestive tract of No. 94 in good condition. It apparently showed a craving on the part of No. 94 for some thing which was not being supplied in her ration.

The measurements of heifers No. 91 and No. 94 as given in Table 5 were taken monthly from the

---

1. Chemical Abstract Vol. 6, pp 2635.



DEPARTMENT OF ENGINEERING, UNIVERSITY OF MISSOURI

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

time of starting the experiment. They show results of growth similar to the gain in weight discussed earlier in this paper. The differenceo of growth in heart girth was greater than the variation in height at withers. No. 91 gained 32 cm. in heart girth and 16.75 cm. in height while No. 94 gained 20 cm. and 12.75 cm. respectively. This table also indicates that No. 91 made more uniform gains than did No. 94.

Observations -- As mentioned before, the calves were in about the same condition of flesh when the experiment started in August 1913. It, however, did not take long for them to show a change in general appearance. No. 94 made very little gain and development while No. 91 was comparatively fat and sleek all the time. It seemed impossible for No. 94 to lay any flesh on her bones and her muscles were very poorly developed. This was shown especially in the thighs which were exceedingly thin and at time, it looked as if they would not bear the weight of the heifer. No. 94 was very cow hawked and appeared weak on her hind legs most of the time. Her paunch was considerable more distended than that of No. 91 and she generally carried her head down and with drooping ears and compar-

atively dull eyes. The animals were occasionally allowed to run in a dry yard for exercise. No. 91 was always the aggressor in the play and ran much more than No. 94. If the calves were turned out alone, it was often difficult to get No. 94 to run while No. 91 was always very playful and active.

It has been indicated that No. 94 had 20 grams of calcium carbonate added to her ration on November 3, 1913. She was in very poor condition at this time but for several weeks after adding the calcium carbonate she was considerably livelier and looked better. Her eyes brightened up noticeably and when turned in the lot, she was more active and playful. It seemed that the calcium carbonate merely acted as a stimulus for a short time because on December 15 she appeared to be in poor condition again. On December 15, 40 grams of bone meal were added to No. 94's ration to make ample mineral supply. Shortly after this she again showed improvement in that she was brighter eyed and more active when turned in the lot. About January 19 her skin was looser and better and she was licking herself some, which is generally an indication of thrift. It also appeared that she was more steady on her legs but her muscles did not make any appreciable development

From this time, to the end of the data, No. 94 made steady gains in weight.

The animals, when turned into the lot, would eat dirt or straw very ravenously showing a craving for something. No. 94 possibly showed this tendency more than No. 91 but they were both restless when placed in the lot. This may have been merely a desire for some change in feed as they were getting the same feeds and were standing on a board floor. In March 1914, it was thought advisable to turn the heifers in the lot during the day. Muzzles were provided for them to keep them from eating dirt and straw. The first few days, however, they got some dirt thru the muzzles and during this time, they ate practically no salt. When the muzzles were made completely tight, they ate the usual amount of salt. When No. 94 was first turned into the lot, her muscles apparently became thinner than when she remained continuously in the stall. The extra exercise may have affected her in that she expended more energy in walking around.

It was noticed that No. 91 reached sexual maturity much earlier than No. 94 and came in heat regularly.

On March 27, several days after the heifers were turned in the yard during the day, No. 94 went

blind. Blindness came on suddenly altho it had been thought for some time that her eyes were weak. The cause of the blindness was hard to determine. By careful examination, made by the Station veterinarian, it was found that the pupils of both eyes were very much dilated. It was suggested that the blindness may be a paralysis of the contractol muscle of the eye due to nervous disorder. It is hardly possible to attribute the blindness in any way to the feed.

Discussion of Silage and Clover Fed Heifers.

Tables 6, 7, 8, 9, 10 and 11 which give the data on the two groups of heifers receiving silage and clover show some little variation in the amount of nutrients received as well as a difference in the size of the animals. As shown in Tables 12 and 13, the clover group received slightly more protein and energy than the silage group but the gain in growth on the average is but very little better. They apparently did not utilize their feed as well as the silage group. The silage fed heifers seemingly needed some dry roughage because their protein is practically the same as the clover group and is nearly sufficient

TABLE 6.

TOTAL NUTRIENTS RECEIVED.

By 7 Day Periods.

NO. 93
Silage Ration.

Period	Grain Lbs.	Silage Lbs.	Digestible Protein Lbs.	Energy Value Therms	Weight Lbs.
1	14.0	62.0	3.48	22.37	358
2	14.0	81.0	3.64	25.52	
3	14.0	98.0	3.79	28.34	365
4	14.0	100.0	3.81	28.67	373
5	14.0	98.0	3.79	28.34	385
6	14.0	109.0	3.89	30.16	380
7	14.0	112.0	3.92	30.65	392
8	14.0	112.0	3.92	30.65	390
9	14.0	112.0	3.92	30.65	400
10	14.0	121.0	3.99	32.14	410
11	14.0	126.0	4.03	32.97	405
12	14.0	126.0	4.03	32.97	425
13	14.0	127.0	4.04	33.14	420
14	14.0	132.0	4.09	33.96	425
15	14.0	140.0	4.16	35.29	422
16	14.0	145.0	4.20	36.12	415
17	14.0	141.0	4.17	35.45	435
18	14.0	125.2	4.03	32.84	437
19	14.0	126.0	4.04	32.97	440
20	14.0	126.0	4.06	33.30	447
21	14.0	140.0	4.16	35.29	450
22	14.0	142.0	4.18	35.62	445
23*	8.0	82.0	2.40	20.50	468**

* 4 day period.
** Average of 3 days weights.

TABLE 7.

TOTAL NUTRIENTS RECEIVED.

By 7 Day Periods.

NO. 89

Silage Ration.

Period	Grain Lbs.	Silage Lbs.	Digestible Protein Lbs.	Energy Value Therms	Weight Lbs.
1	14.0	112.0	3.85	30.65	493
2	14.0	112.0	3.85	30.65	
3	14.0	112.0	3.85	30.65	517
4	14.0	112.0	3.85	30.65	524
5	14.0	112.0	3.85	30.65	530
6	14.0	123.0	3.95	32.47	530
7	14.0	126.0	3.97	32.97	530
8	14.0	126.0	3.97	32.97	525
9	14.0	126.0	3.97	32.97	535
10	14.0	131.0	4.08	33.80	550
11	14.0	140.0	4.16	35.29	555
12	14.0	140.0	4.16	35.29	557
13	14.0	141.0	4.17	35.45	555
14	14.0	149.0	4.24	36.78	557
15	14.0	171.0	4.43	40.42	554
16	14.0	194.0	4.63	44.23	580
17	14.0	196.0	4.65	44.56	585
18	14.0	188.0	4.58	43.24	580
19	14.0	182.0	4.53	42.25	592.
20	14.0	182.0	4.53	42.25	596
21	14.0	196.0	4.65	44.56	595
22	14.0	203.0	4.72	45.72	590
23*	8.0	105.0	2.60	24.30	596**

* 4 day period.
** Average of 3 weights.

TABLE 8.

TOTAL NUTRIENTS RECEIVED.

By 7 Day Periods.

NO. 238.

Silage Ration.

Period	Grain Lbs.	Silage Lbs.	Digestible Protein Lbs.	Energy Value Therms	Weight
1	14.0	97.0	3.72	28.17	549
2	14.0	65.0	3.44	22.87	
3	14.0	87.0	3.63	26.51	565
4	14.0	91.0	3.67	27.17	574
5	14.0	91.0	3.67	27.17	580
6	14.0	96.0	3.71	28.08	580
7	14.0	103.0	3.77	29.16	592
8	14.0	126.0	3.97	32.97	600
9	14.0	136.0	4.06	34.63	610
10	14.0	147.0	4.22	36.45	610
11	14.0	148.0	4.23	36.61	615
12	14.0	147.0	4.22	36.45	620
13	14.0	149.0	4.24	36.78	652
14	14.0	158.0	4.32	38.27	660
15	14.0	164.0	4.37	39.26	660
16	14.0	159.0	4.32	38.44	660
17	14.0	149.0	4.24	36.78	661
18	14.0	147.0	4.22	35.11	667
19	14.0	143.0	4.19	34.49	667
20	14.0	140.0	4.16	34.02	680
21	14.0	139.0	4.15	35.13	650
22	14.0	134.0	4.11	33.08	680
23	8.0	80.0	2.38	20.16	671

TABLE 9.

TOTAL NUTRIENTS RECEIVED.

By 7 Day Periods.

NO. 90.

Clover Ration.

Period	Grain Lbs.	Clover Lbs.	Digestible Protein Lbs.	Energy Value Therms	Weight Lbs.
1	21.0	49.0	4.07	35.67	450
2	21.0	49.0	4.07	35.67	
3	21.0	45.0	3.85	34.28	465
4	21.0	49.0	4.07	35.67	477
5	21.0	49.0	4.07	35.67	480
6	21.0	55.0	4.30	37.75	490
7	21.0	56.0	4.44	38.11	490
8	21.0	56.0	4.44	38.11	490
9	21.0	56.0	4.44	38.11	497
10	21.0	63.0	4.83	40.54	492
11	21.0	52.0	4.23	36.72	510
12	21.0	63.0	4.83	40.54	515
13	21.0	63.0	4.83	40.54	520
14	21.0	63.0	4.83	40.54	535
15	21.0	63.0	4.83	40.54	537
16	21.0	67.0	4.04	41.93	535
17	21.0	70.0	5.21	42.97	545
18	21.0	65.0	4.84	41.23	550
19	21.0	63.0	4.83	40.54	555
20	21.0	63.0	4.83	40.54	550
21	21.0	63.0	4.83	40.54	560
22	21.0	69.0	5.16	42.62	545
23*	8.0	41.0	2.76	21.35	552**

* 4 day period.
** Average 3 days weights.

TABLE 10.

TOTAL NUTRIENTS RECEIVED.

By 7 Day Periods.

NO. 314.
Clover Ration.

Period	Grain Lbs.	Clover Lbs.	Digestible Protein Lbs.	Energy Value Therms	Weight Lbs.
1	21.0	41.0	3.64	32.89	326
2	21.0	40.0	3.58	32.55	
3	21.0	42.0	3.69	33.24	337
4	21.0	42.0	3.69	33.24	348
5	21.0	42.0	3.69	33.24	355
6	21.0	48.0	4.02	35.33	350
7	21.0	49.0	4.07	35.67	367
8	21.0	49.0	4.07	35.67	370
9	21.0	49.0	4.07	35.67	380
10	21.0	53.0	4.29	37.06	380
11	21.0	56.0	4.54	38.11	382
12	21.0	56.0	4.54	38.11	395
13	21.0	56.0	4.54	38.11	400
14	21.0	56.0	4.54	38.11	405
15	21.0	56.0	4.54	38.11	410
16	21.0	58.0	4.56	38.80	415
17	21.0	63.0	4.83	40.54	420
18	21.0	63.0	4.83	40.54	415
19	21.0	63.0	4.83	40.54	435
20	21.0	63.0	4.83	40.54	432
21	21.0	63.0	4.83	40.54	435
22	21.0	68.0	5.10	42.37	447
23*	12.0	44.0	3.19	25.94	455**

* 4 day period.
** Average of 3 days weights.

TABLE 11.

TOTAL NUTRIENTS RECEIVED.

By 7 Day Periods.

NO. 239

Clover Ration.

Period	Grain Lbs.	Clover Lbs.	Digestible Protein Lbs.	Energy Value Therms	Weight Lbs.
1	21.0	49.0	4.07	35.67	578
2	21.0	48.0	4.02	35.33	
3	21.0	45.0	3.82	34.28	622
4	21.0	42.0	3.69	33.24	600
5	21.0	70.0	4.21	42.97	600
6	21.0	70.0	4.21	42.97	600
7	21.0	70.0	4.21	42.97	620
8	21.0	70.0	4.21	42.97	620
9	21.0	70.0	4.21	42.97	636
10	21.0	77.0	5.59	45.40	635
11	21.0	78.0	5.64	45.75	630
12	21.0	77.0	5.59	45.40	632
13	21.0	77.0	5.59	45.40	645
14	21.0	78.0	5.64	45.75	680
15	21.0	63.0	4.83	40.54	665
16	21.0	88.0	6.17	49.23	665
17	21.0	88.0	6.17	49.23	695
18	21.0	90.0	6.29	49.92	687
19	21.0	65.0	4.84	41.23	707
20	21.0	91.0	6.34	50.26	690
21	21.0	91.0	6.34	50.26	715
22	21.0	97.0	6.67	52.35	700
23*	12.0	60.0	4.06	31.50	751**

* 4 Day Period.

** Average of 3 days weights.

for normal gains but the heifers appeared thin. The gains made by the clover group were much steadier than the silage group. The latter showed wide variation from one period to another and in the 13th and 16th periods, No. 93 failed to gain. The first few months the animals were on the experiment, it was hard to detect any difference in the two groups, but the longer the feeding continued, the more difference became apparent. The animals on silage looked much thinner and did not shed well while the clover group were comparatively fat and sleek. The heifers were all very active and showed very little difference in respect to vigor. It does not appear that the animals on silage were hurt at all and it seems probable that a few months on grass would put them in good condition. These animals when turned on pasture in May 1914, looked better than heifers under average farm conditions.

As also shown in Tables 12 and 13, the amount of protein required per pound of growth was about the same with the two groups. Since No. 89 may be very abnormal in one period, it would make the average of her group high if figured on that basis, but a general con-

sideration excluding that period shows that the groups are very similar.

The clover group required more energy per pound of gain. Had the silage group been able to consume enough to get the same amount of energy as the clover group, the results would undoubtedly have been similar in every respect.

These animals are all apparently low in their protein intake. However, being on a short feeding period and having a surplus of protein stored in the body, the heifers grew fairly well.

Discussion of Light and Heavy Fed Heifers.

Tables 14 and 15 show a gradual increase in feed consumed by the animals as they increase in age. The weight also gradually increases but the gain is much slower during the third, and especially the fourth periods. There is a marked difference in the nutrients fed the two groups and the heavy fed group are much larger but the general results mentioned above are similar.

Tables 14 and 15 also show that the nutrients consumed per day varies widely with different animals. There is a steady increase of the amount of nutrients

TABLE 12.

NUTRIENTS*RECEIVED PER DAY AND PER LB. GAIN.

By Four Period Intervals.

NO. 314

Period	Digestible Protein Lbs.	Energy Value Therms	Gain per Day Lbs.	Protein per lb. Gain Lbs.	Energy per lb. Gain Lbs
1- 4	.521	4.711	.785	.663	6.001
5- 8	.566	4.639	.785	.721	5.909
9-12	.622	5.319	.892	.697	5.963
13-16	.613	5.468	.714	.858	7.658
17-20	.690	5.791	.607	1.136	9.540
**21-23	.728	6.049	1.277	.570	4.736
Average	.623	5.347	.816	.763	6.552

NO. 90

1- 4	.573	5.046	.964	.594	5.234
5- 8	.619	5.344	.464	1.334	11.726
9-12	.654	5.568	.892	.733	6.242
13-16	.661	5.873	.714	.925	8.225
17-20	.703	5.902	.555	1.314	11.033
**21-23	.708	5.806	.111	.637	5.230
Average	.649	5.570	.645	1.006	8.635

NO. 239

1- 4	.558	4.947	.785	.710	6.295
5- 8	.601	6.138	.714	.841	8.596
9-12	7715	6.411	.428	1.670	:14.978
13-16	.793	6.461	1.178	.673	5.484
17-20	.844	6.412	.892	.946	7.188
**21-23	.948	7.450	3.388	.297	2.198
Average	.737	6.301	1.095	.673	5.754

* Clover Ration.
**18 Day Period.

TABLE 13.

*NUTRIENTS RECEIVED PER DAY AND PER LB. GAIN.

By Four Period Intervals

NO. 93

Period	Digestible Protein Lbs.	Energy Value Therms	Gain per Day Lbs.	Protein per lb. Gain Lbs.	Energy per lb. Gain Lbs.
1- 4	.525	3.746	.535	.981	7.001
5- 8	.554	4.278	.607	.912	7.047
9-12	.570	4.668	1.250	.455	3.734
13-16	.588	4.946	-----	----	-----
17-20	.582	4.805	1.142	.509	4.212
**21-23	.596	4.522	1.166	.511	3.878
Average	.568	4.544	.696	.815	6.529

NO. 89

1- 4	.550	4.378	1.107	.497	3.953
5- 8	.562	4.609	.035	----	-----
9-12	.584	4.905	1.142	.511	4.295
13-16	.623	5.602	.821	.758	6.823
17-20	.653	6.153	.571	1.143	10.776
**21-23	.565	6.365			
Average	.603	5.271	.652	.925	8.097

NO. 238

1- 4	.516	3.740	.892	.578	4.192
5- 8	.540	4.189	.928	.585	4.514
9-12	.597	5.147	.714	.836	7.208
13-16	.616	5.455	1.428	.437	3.682
17-20	.600	5.014	.714	.840	7.022
**21-23	.591	4.909			
Average	.576	4.732	.771	.747	6.137

* Silage Ration.
** 18 Day Period.

TABLE 14.

NUTRIENTS RECEIVED PER DAY AND PER LB. GAIN.

By Six Month Periods.

HEAVY FED GROUP.

Period	Digestible Protein Lbs.	Energy Value Therms	Weight Lbs.	Gain per Day Lbs.	Protein per lb. GAin Lbs.	Energy per lb. Gain Therms
No. 216						
1	1.103	8.897	703	1.221	.903	7.286
2	1.122	9.046	898	1.068	1.050	8.470
NO. 223						
1	1.128	8.347	705	1.479	.762	5.643
2	1.607	11.103	960	1.342	1.197	8.273
3	1.613	12.372	1148	1.030	1.517	12.011
4	1.507	11.166	1215	.367	4.106	30.425
NO. 225						
1	1.009	7.376	658	1.265	.797	5.830
2	1.187	9.699	883	1.232	.963	7.872
NO. 220						
1	.843	6.705	636	1.063	.793	6.307
2	1.135	8.233	867	1.265	.895	6.508
3	1.247	9.447	1113	1.347	.925	7.013
4	1.345	10.893	1287	.953	1.411	11.430
NO. 8						
1	.645	5.403	371	1.079	.514	5.100
2	.912	7.768	609	1.247	.731	6.230
3	.920	6.972	737	.701	1.312	9.945
4	1.019	7.586	822	.471	2.163	16.106
NO. 13:						
1	.710	5.670	438	1.054	.673	5.379
2	.921	7.840	619	.991	.929	7.911
3	1.043	8.105	703	.465	2.242	17.430
4	1.081	8.769	828	.684	1.580	11.358
NO. 2						
1	.813	7.328	529	1.347	.603	5.440
2	1.152	8.719	807	1.523	.756	5.724

TABLE 15.

NUTRIENTS RECEIVED PER DAY AND PER LB. GAIN.

By Six Month Periods.

LIGHT FED GROUP.

Period	Digestible Protein Lbs.	Energy Value Therms	Weight Lbs.	Gain per Day Lbs.	Protein per lb. Gain Lbs.	Energy per lb Gain Therms
NO. 222						
1	.749	3.722	401	.663	1.129	5.613
2	1.116	51545	589	1.030	1.083	5.383
3	1.349	6.151	700	.608	2.218	10.116
NO. 224						
1	.722	3.587	397	.723	.998	4.961
2	.970	4.821	530	.728	1.332	6.622
3	1.183	5.877	636	.580	2.039	10.131
NO. 219						
1	1.315	6.719	408	.553	2.377	12.150
2	.912	4.537	612	1.117	.816	4.061
3	1.405	6.978	786	.953	1.474	7.322
4	1.625	8.068	882	.526	3.089	15.338
NO. 3						
1	.591	2.919	333	.515	1.147	5.667
2	.765	3.802	478	.794	.963	4.788
NO. 11						
1	.613	3.047	357	.728	.841	4.185
2	1.024	5.085	502	.794	1.289	6.404
3	1.081	5.370	586	.465	2.324	11.548
NO. 14						
1	.718	3.574	362	.586	1.225	6.098
2	1.011	5.024	490	.701	1.442	7.166
3	1.114	5.589	607	.641	1.737	8.719
4	1.240	6.160	707	.547	2.266	11.261
NO. 39						
1	.510	2.563	338	.619	.823	4.140
2	.862	4.727	473	.739	1.166	6.396

TABLE 16.

NUTRIENTS CONSUMED PER DAY, WEIGHT, AND GAIN DAY OF ANIMALS ON DIFFERENT PLANES OF NUTRITION.

By Six Month Periods.*

No. of Animal	Digestible Protein Lbs.	Energy Value Therms	Weight Lbs.	Gain per day Lbs.
94	.376	5.180	235	.714
3	.591	2.919	333	.515
11	.613	3.047	357	.728
8	.645	5.403	371	1.079
39	.510	2.563	338	.619
14	.718	3.574	362	.586
224	.722	3.587	397	.723
222	.749	3.722	401	.663
91	.953	4.907	216	1.076

* Feed Calculated from first six months after weaning from milk.

TABLE 17.

PROTEIN REQUIRED PER DAY PER LB. GROWTH SECOND AND THIRD SIX MONTHS OF GROWTH.

HOLSTEINS

Light Fed			Heavy Fed		
	First Six Months	Second Six Months		First Six Months	Second Six Months
No. of Animal	Digestible Protein	Digestible Protein Pounds	No. of Animal	Digestible Protein Pounds	Digestible Protein Pounds
222	1.129	1.083	216	.903	1.050
224	.998	1.332	223	.762	1.197
219	2.377	.816	225	.797	.963
			220	.793	.895

JERSEYS

3	1.147	.963	8	.514	.731
11	.841	1.289	13	.673	.929
14	1.225	1.442	2	.603	.756
39	.823	1.166	91	.945	
94	.533				

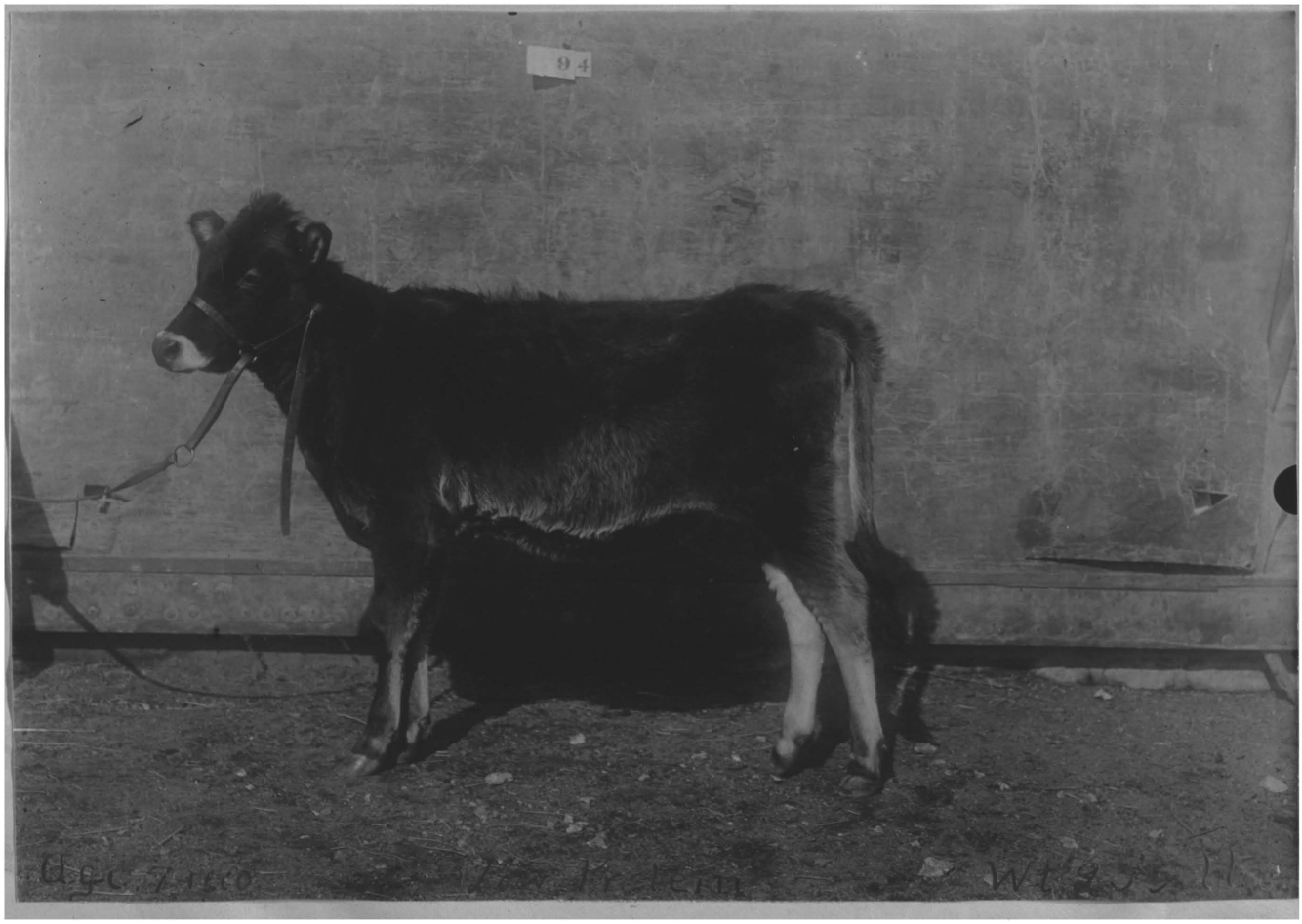
required from the first to the last period with a marked decrease in gain in the last period. The two columns on protein and energy per pound of gain show the same results in a very striking manner. No. 219 of the light fed group shows exceptionally high feed requirements per pound of gain during her first period which may be due to individuality.

Table 15 gives the nutrients with weights and gains comparing No. 94 with other animals of practically the same size and age. It can readily be seen from the table that protein is not the sole source of growth stimulant. No. 94 on an exceedingly low protein intake but relatively high energy made considerable better than average gains. Comparing the nutrients received by No. 94 and No. 14, show results in favor of high energy intake while No. 14 received nearly twice as much protein and about two-thirds as much energy, she make smaller daily gains than did No. 94. Judging from the superior growth made by No. 91, it appears that a combination of high protein and energy are necessary for the most rapid growth in young animals. With so few animals, there is chance for individual variation to effect the results(while the smaller size of No. 94 and No. 91 may also appreciably influence the gains made). The

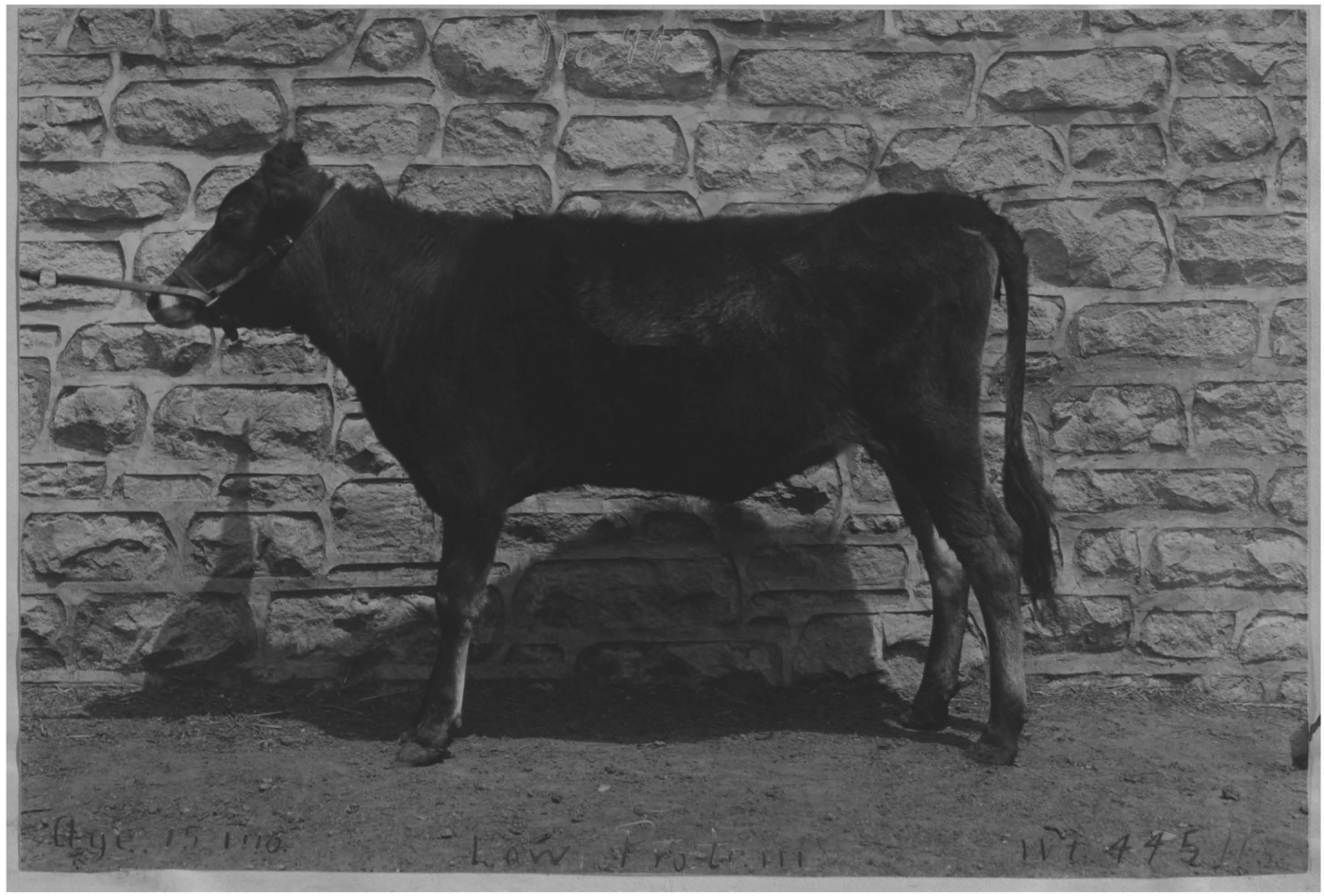
weather conditions as mentioned previously are also possibly influencing factors that have not been considered in discussing this table.

From the results of the work with No. 91 and No. 94 and the 14 animals on the light and heavy fed experiment, tabulated in Table 14, it can be seen that it required 0.941 pounds of protein per pound of gain for heifers during the second six months of their growth. With data from 14 animals shows that it required 1.044 pounds of protein per pound of growth the third six months of feeding. Averaging the results of the requirements as shown above, it shows that 0.992 pounds protein are required per pound of gain during the two periods.

Holsteins required more protein per pound of gain than the Jerseys, which may be attributed to the larger size of the animals. The light fed group required much more protein per pound of growth than the heavy fed group. This may be explained by the fact that the light fed group grew slower than the heavy feds. The energy factor which according to table 13 is very important is not taken into consideration in the discussion of this table. Complete records of all feeds consumed by the fourteen animals can be found in the thesis worked by P. M. Brandt in 1913.



Taken at beginning of experiment.
August 1913.



Taken April 27, 1914.

SUMMARY AND CONCLUSIONS.

The study of the problem of protein requirements for growing dairy animals as reported in this thesis should be considered as a preliminary study of a question too large to be completed within the limits of time available. It is expected that the work will be continued as a part of the regular investigations of the Experiment Station. The data gathered and studied is sufficient however, to justify a few conclusions:-

1. The growth of No. 94 receiving 0.38 pounds of digestible protein daily but abundant energy was considerably retarded, indicating the protein to be the limiting factor.

2. The gain in weight of No. 91 receiving 0.95 pounds of digestible protein daily was 0.37 pounds per day more than No. 94; The indications are that she received protein in excess of requirements.

3. As shown by heifers No. 91 and No. 94, an excessive supply of protein does not cause marked extra growth. A comparatively low amount of protein retards growth but does not check it permanently.

4. The work with the six animals on the short feeding periods show that a ration with silage as roughage while cheaper and adequate to carry heifers thru the winter in thrifty, growing condition is hardly equal, judging from general appearances, to one in which clover furnishes the roughage.

5. Results with the 14 animals show that the requirements per unit growth are increased and the rate of growth decreased as the animals advanced in size and age.

6. The heifers supplying the data, used 0.992 pounds of digestible protein per pound of growth for the second and third six months periods, but the data is not sufficient to indicate that this amount gives the most economical or the best results.

7. With ordinary rations, when plenty of energy is furnished, there is no great danger from lack of protein.

ACKNOWLEDGEMENT.

The writer wishes to express his appreciation to C. H. Eckles, Professor of Dairy Husbandry, University of Missouri, for his helpful suggestions in the preparation of this paper.