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THE ENERGY REQUIREMENTS FOR THE NORMAL GROWTH
OF DAIRY HEIFERS

by

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INTRODUCTION

The nutrient requirements of cattle have been studied by animal husbandmen from the inception of scientific research in agriculture. From the results obtained tentative feeding standards have been formulated to be used as a guide by practical feeders. These standards have been modified, from time to time, as additional information indicated the need of a revision.

The feeding standards as published by the different investigators do not agree as to the amount of nutrients required by cattle. Recent investigations have emphasized the importance of the quality of the proteins and of the character of the mineral matter in relation to the nutrition of animals and have also established the fact that certain growth accessories are necessary for the growth and well being of animals. There is therefore, every reason to believe that further modification of the feeding standards may be needed.

A study of the net energy requirement of animals reveals the fact that, according to our present knowledge, the quantity of the energy supplied seems to be the important thing to consider.

Until quite recently little work has been done to determine the energy requirement of cattle. This was partly due to the fact that animals usually receive an adequate supply of energy, as the rations commonly fed to animals

are as a rule high in net energy value. The study of this phase of animal nutrition has also been delayed because of the fact that it is difficult to determine the energy requirement of animals.

What definite knowledge we have of the energy requirements of cattle has been obtained by a study of mature animals, usually steers. All of the standards that are now available which give the requirements of growing cattle have been calculated from data obtained from mature animals. There is considerable difference of opinion as to the accuracy of these calculations.

There are at least two reasons why more definite knowledge of the energy requirements of growing cattle are desirable. First, the energy requirement of the animal is known to be high and because of the increased cost of feeds with high energy value there is a greater economic demand to know the actual energy requirement of a young animal. Second, if an intelligent study is to be made of the requirement of a growing animal for any other constituent of the ration, it is quite essential that the energy requirement be known.

It was with the hope that we might make a contribution to the knowledge on this subject that the problem of the energy requirement of dairy heifers was undertaken.

REVIEW AND DISCUSSION OF LITERATURE.

A review of the literature on this subject reveals the fact that there is little material that has a direct bearing on the energy requirements of animals for growth. However, one is impressed with the remarkable progress that has been made in adding to our general knowledge of the nutrition of animals. In spite of this progress the leading research workers seem to hesitate to make many dogmatic assertions. Mathews sounds the dominant note when he says that, "nearly all of the really fundamental facts in nutrition remain to be determined."

The nutrient requirements of animals have been expressed, until quite recently, in the terms of digestible protein, carbohydrates and fat. The more recent and probably the most satisfactory method of expressing the value of carbohydrates and fat is in the terms of net energy values.

There seems to be abundant evidence that a certain quantity of nutrients alone will not insure growth or the well being of an animal. The additional requirements for an efficient ration are: First, that the protein is of the proper quality. Second, that the inorganic material contains the necessary mineral matter. Third, that sufficient quantities of certain unknown growth accessories are present.

Since the efficiency of any ration apparently de-

depends upon the presence of these several substances it is evident that to intelligently understand any nutrition problem it is necessary to review the present day knowledge of these more important phases of nutrition.

GROWTH. Growth is hard to define because we do not know definitely what it is or what causes it. Morgan states that growth is, "an increase in the volume of the living material." The fact that an animal has a "growth impulse," and "inherent tendency to grow" or a "capacity for growth" is our most definite knowledge.

Aron³ is sure that abundance of food is not the cause of growth for even with the greatest intake of food, growth will never exceed a certain limit. Morgan^{2a} also says that, "while the rate of growth may easily be accelerated or retarded, the character of the growth is more difficult to modify." This statement is confirmed by the results⁴ obtained by Waters⁵, working with cattle and by Mendel working with rats and mice. The latter secured clear evidence that the growth of rats and mice may be suppressed or held in abeyance for long periods, even beyond the age at which any marked increment of size ordinarily occurs, without loss of the capacity of subsequent growth under appropriate conditions of diet.

⁴Waters after considerable experimental work with cattle growing under normal and adverse conditions believes that the size to which an animal may grow is determined by heredity but that the size to which it will

grow is directly related to the feed furnished during the growing period. He was the first to establish the fact that an immature farm animal may remain at a constant body weight for a long period and at the same time increase in height or in skeleton growth. This increase varied from six to nineteen per cent. His final conclusions are that an animal may advance to normal size by any or all of the following ways:

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

^{2a}
Morgan states that if an individual grows excessively fast for a period there follows a period of slow growth. He also reports that a guinea pig may lose one-third of its size and make it good later.

There seems to be abundant evidence to prove that animals make faster and more economical gains following a period when they have been kept on a low plane of nutrition. Burnett and Smith⁶⁶ found that calves wintered on sorghum hay did not grow as well as those fed alfalfa hay but during the following summer season they made the best gains and by fall the two groups weighed the same.

²⁵
Wylie working with dairy heifers fed one group so that

they would make light gains and another group for heavy gains during the winter. The following summer the light fed cattle gained fast enough to overtake the heavier cattle. Mumford⁶⁷ reports that a steer that had been stunted until it was twelve months old made a gain of 841 pounds in a year. This steer required 5.04 pounds of grain for one pound of gain. A normal steer the same age gained only 499 pounds, on the same ration, and required 9.8 pounds of grain for one pound of gain.

Measurements of growth. It is difficult to measure growth. The most satisfactory method so far suggested is by taking skeletal measurements and body weights. Swett⁶ found that for heifers the height at the withers gave a fair indication of the skeletal growth. The body weight of an animal gives only an approximate measure of the growth of an animal.⁷ In the first place the weight fluctuates from day to day due to the variations in the contents of the digestive tract. In the second place the live weight does not necessarily indicate how much of the growth is real growth and how much is simply a storage of fat or water or both. To accurately measure the character of the growth that has taken place it is necessary either to conduct slaughter tests or to conduct a balance experiment in a respiration calorimeter.

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Normal Growth. The Dairy Department of this station has taken weights and measurements on a group of dairy heifers from birth to maturity in order to determine the normal rate of growth. The average weights and measurements of these heifers from birth to an age of two years give us a standard for comparison.

The influence of the organs of internal secretions on growth. The influence of the organs of internal secretion on growth and the various functions of the body is a mystery that scientists are just beginning to solve. Mathews^{la} describes the organs of internal secretion as, "organs in the body which do not play a part in movement and they either have no ducts for the discharge of their secretions to the exterior or, if they have such ducts, there is abundant evidence that they form a hidden secretion which is passed back to the blood. - - - there are reasons for thinking that the formation of such substances is their main function."

The principal organs of internal secretion are the thyroid, parathyroid, hypophysis, pancreas, ovaries, testes and supra-renals. Of these the hypophysis and the thyroid seem to be the most important.

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The functions of the internal secretions. Cushing removed the anterior lobe of the hypophysis of young dogs. The result was a fatty degeneration throughout the body, very little growth took place except in fat and their

reproductive organs remained in an infantile condition. He concluded from his work that the anterior lobe, "seems primarily associated with the growth of the body, with the metabolism of fat, with sexual activities and to be bound up - - - with the function probably of all the other ductless glands of the body." Mathews^{lb} believes that the secretion of the anterior lobe of the hypophysis is necessary for normal growth and metabolism and to maintain the animal's resistance to disease. Howell⁹ concludes that the hypophysis exerts an important influence upon the general body metabolism; that the secretion of the anterior lobe is necessary for growth, particularly of the skeleton, and that the secretion of the posterior lobe affects the circulation, the secretion of the urine and is connected with the carbohydrate metabolism. The body weight, the development of the sexual organs and the bones are considered secondary characters of the anterior lobe.

The function of the thyroid has been studied more than that of any other organ of internal secretion. Howell^{9a} states that the removal of the thyroid, "is followed by the development of a state of malnutrition." It is a well known fact^{lc} that if the thyroid fails to develop, growth is retarded and a dwarf is produced. This condition may be remedied by feeding sheep's thyroids. On the other hand, if the thyroid is too active the reverse symptoms or giantism result. It is clear that mental and physical development depend in part upon the secretions of the thyroid.

All students of this subject agree that there is an interdependence of all of the organs of internal secretion for their own development and also that the body processes are all more or less controlled by hormones of the internal secretions which act as a stimulant or inhibitor. Thus it is believed that the "growth impulse" is received from the internal secretions and that it is inhibited by the same "chemical messengers". Mathews^{1d} holds that, "the shape and size of the body; the coarseness of the hair; the persistence of the teeth and the tendency toward fatness may easily depend on the hypophysis, on the thyroid and the sexual organs."

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Kellicott emphasizes the fact that the growth of the animal as a whole as measured by skeleton growth or weight is not as important relatively as the growth and development of the more vital organs. Quoting directly, "It seems quite likely that in organisms in general the normal growth of each tissue or even each organ is controlled separately by a specific internal secretion. These substances may regulate growth either through inhibition or acceleration and the effect produced may be due either to the presence or the withdrawal of the specific substance."

In this thesis it is interesting to note that these organs play their part in the transformation of energy.

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Crile after a large amount of clinical and experimental

work explains the conversion of latent into kinetic energy thus, "To become adapted to their environment animals are transformers of energy. This adaptation to environment is made by means of a system of organs evolved for the purpose of converting potential energy into heat and motion. - - - The brain is the great central battery which drives the body; the thyroid governs the conditions favoring tissue oxidization; the supra-renals govern immediate oxidization processes; the liver fabricates and stores glycogen; the muscles are the great converters of latent energy into heat and motion. Each is a vital link, each plays its particular role and one cannot compensate for the other."

REQUIREMENTS FOR ANIMAL GROWTH. The animal is born with an "inherent tendency to grow". It is then the task of the feeder to provide a ration of sufficient quantity and quality to supply all of the physiological requirements of the animal for normal growth. Such a ration should furnish energy to meet all of the needs of the animal, should supply the proper quantity and quality of proteins, enough inorganic constituents and an adequate amount of growth accessories. A bulky and palatable ration is also desirable for a dairy heifer.

PROTEIN REQUIREMENTS. Protein is the most vital nutrient in the ration. It is necessary in the structure of all of the body cells and may be used as a source of energy. Under certain conditions it is used for fat production.

The term crude protein^{7h} is used to designate the nitrogenous part of a feed. All of the nitrogen of feeding stuffs does not exist in the protein form. Many feeding stuffs contain a relatively large amount of nitrogenous compounds such as amino acids and amids which are not protein substances. These are called non-proteins. True protein as the name implies, is that part of the crude protein that remains after the non-protein material has been removed.

The non-proteins are present in considerable amounts in immature plants. There has been considerable difference of opinion as to the value of the non-proteins to the animal. Armsby formerly insisted that they were of little if any value but recently he has stated that^{7a}, "it appears to have been demonstrated by recent experimental results - - that the non-protein of ordinary feeding stuffs is available for the maintenance of ruminants."

Investigations conducted during recent years by Mendel, Osborne, Hart, McCollum and others, have resulted in new and valuable information concerning the proteins of feeds and how they are used by animals. It is now conceded that when digested the proteins yield comparatively simple cleavage products, largely amino acids. The individual amino acids are used for the resynthesis of the various proteins of the body.

The protein used for maintenance may not be so com-

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pletely resynthesized. McCollum¹³ states that, "The repair processes are shown to be of a different character from the processes of growth," and that it is probable that, "the processes of cellular catabolism and repair do not involve the destruction and resynthesis of an entire protein molecule."

Quality of the proteins. There is abundant experimental evidence⁷¹ to establish the fact that the feed given to an animal must not only supply protein as such but that it must contain protein materials whose digestive cleavage products will yield the necessary amounts and proportions of amino acids required for maintenance and growth. Voit²⁰ and Munk discovered that gelatin could not maintain the nitrogen equilibrium of small laboratory animals. This opened up a field of investigation which has called forth the best efforts of some of our greatest scientists. Osborne and Mendel⁶⁸ were the first in this country to enter this field of research. They established the fact that tryptophan was necessary for the maintenance of rats.

During recent years a large amount of investigation has been undertaken for the purpose of determining the value of specific proteins from various sources. In 1911¹⁴ the Wisconsin Station published the results of the first experiments which were undertaken with farm animals to study the efficiency of nutrients derived from restricted sources. Working with cattle it was found that there was

a distinct and physiological value to a ration not measurable by chemical methods or dependent upon available energy. Animals fed on a balanced ration from the wheat plant were not normal as to vigor, size or development, nor did they perform normally the functions of reproduction and the secretion of milk.

Animals fed on a ration derived entirely from the corn plant were normal in every way. Those fed on a ration derived from the oat plant were not normal but were able to perform all of the physiological processes of growth, reproduction and milk secretion with a certain degree of vigor. When animals were fed a ration derived from the wheat, corn and oat plants they responded with less vigor than to corn and oat plant products, but with more vigor than when fed wheat plant feeds. The wheat plant ration was not efficient because of the quality of the proteins, partly because it lacked in the necessary inorganic constituents and also because it contained a toxic substance. 15

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The results obtained by McCollum with pigs shows that the efficiency of the cereal proteins was raised from twenty-five to sixty-five per cent by the use of skim milk and from twenty-five to forty-seven per cent by the use of whey protein, which contributed fifteen per cent of the total nitrogen intake. Over sixty per cent of the protein of skim milk was retained for growth by swine which was over twice as much as was retained of any of the cereal

proteins. It is evident that the protein of milk is efficient itself and also very efficient in supplementing other proteins that are not rich in certain amino acids necessary for growth.

The basic ration used for most of the investigations for the determination of the value of specific proteins was "protein free milk."¹⁷ Practically all of the protein and fat are removed from the milk leaving the whey which contains the inorganic and carbohydrate constituents. The purified food substance to be studied is added to this ration. These tests have been conducted mostly with rats but the results obtained probably hold with the larger animals.¹⁸ However, McCollum¹⁸ feeding pigs on a ration in which the zein of corn was the only source of protein, found that the pig utilized the zein more efficiently than either rats or mice. He concludes that, "The pig appears to be exceptionally efficient in the utilization of food-stuffs."

Classification of proteins. Several of the proteins that have been studied by feeding experiments with laboratory animals have been classed as follows:¹⁹

Proteins that are adequate for growth.

Animal Origin

Casein (milk)	Ovalbumen (hen's egg)
Lactalbumen (milk)	Ovavitellin (hen's egg)

Vegetable Origin

Edestin (hemp seed)	Excelsin (Brazil nut)
Globulin (squash seed)	Glutelin (maize)
Globulin (cottonseed)	Glutenin (wheat)
Glycinin (soy bean)	Cannabin (hemp seed)

Proteins that are not adequate for growth.

Legumelin (soy bean)	Vignin (vetch)
Gliadin (wheat or rye)	Legumin (pea)
Legumin (vetch)	Conglutin (blue or yellow lupin)
Gelatin (horn)	Zein (maize)
Phaseolin (white kidney bean)	Hordein (barley)

In the study of the efficiency of the different proteins it has been possible to learn something of the value of the individual amino acids to the body. It has been found that lysine is necessary for growth and that tryptophane is necessary for maintenance. The experimental evidence of this is interesting. Zein, the protein of corn contains neither of these acids. Willcock and Hopkins²⁰ found that mice lost weight when zein supplied the protein of their diet and that the addition of tryptophane made the diet adequate for maintenance but not for growth. Osborne and Mendel²¹ feeding rats on zein were able to carry them along on maintenance by adding tryptophane and to produce growth or stop it as lysine was added or withdrawn from the ration. McCollum,²³ feeding

pigs, has shown that they will efficiently utilize about eighty per cent of zein to repair losses due to tissue metabolism. No body tissue was formed from zein even when it was fed in excess while feeding casein resulted in an increase of the body protein of from twenty to twenty-five per cent.

The body can synthesize some amino acids such as glycocoll, now usually called glycine, and probably proline and arginine, but the tryptophane and lysine must be furnished in the feed.

An animal fed on a ration from a restricted source may suffer from a lack of the amino acids that it needs. This difficulty is usually overcome in common practice as the deficiencies of the protein of one feed is apt to be supplemented by the protein of another feed. In the case of the dairy animal there is little danger of the protein of a ration not being adequate for growth when ensilage or alfalfa hay are used for roughage.

Protein used for energy. Because of the fact that the protein of the feed is broken down into its constituent amino acids and the animal uses only the acids that it happens to need at the time, when on a normal ration, there will be an excess of some of these acids. These surplus amino acids, according to Armsby,^{7b} are largely deaminized, and their nitrogen excreted mostly as urea. The non-nitrogenous residue is then in a condition to be oxi-

dized as fuel material for energy production or some of it may be converted into glucose and thus to glycogen and be stored as fat.

However, there does not seem to be any advantage of feeding an excess of protein. Both Talbot²⁴ and Wylie²⁵ showed that when heifers received enough protein for normal growth the gains were not materially increased by feeding additional protein. Dietrich²⁷ found that, with pigs, when the factor of protein waste was once introduced it became such a fixed tendency that it was hard to reduce it.

Little work has been done to study the effects of feeding an excess of protein. Forbes²⁶ states that, "the consumption of a needless amount of protein unnecessarily taxes the acid neutralizing capacity of the animal and if carried to a sufficient extreme results either in discouragement of the formation of bone or in malnutrition of the bones."

Armsby^{7b} is of the opinion that when an excess of protein is fed that the animal excretes the nitrogen and retains a large share of the protein for fuel purposes and that the increased nitrogen excretion "does not mean the total destruction of the corresponding amount of protein but simply its transformation into compounds which can serve as a source of energy."

GROWTH ACCESSORIES. Important as are the amino acid requirements of an animal for growth and maintenance they are no more important to the study of nutrition than the discovery of the so called vitamins or growth accessories. These unidentified dietary essentials, like the hormones of the organs of internal secretion, are known by what they do rather than by what they are.

The presence of these substances of an unknown chemical nature were first discovered by Funk³⁴ and others while investigating the cause of beri-beri, a disease common to peoples who have a very restricted diet of which polished rice is the main staple.

Most of the experimental work with these substances³⁵ has been done with rats or chickens. McCollum³⁶ and his co-workers found that young rats fed on purified proteins, carbohydrates, fats and salt mixtures, not only failed to grow but did not live any great length of time because of a "nerve degeneration."³⁶ If a little egg yolk or milk was added to these purified foods the rats began to grow at once.

Further study revealed the fact that there were two growth accessories, one usually soluble in the fats and the other soluble in water and alcohol.³⁷ McCollum has designated these "fat soluble A and water soluble B." He objects to all of the other names used to designate these substances because, "the substances in question are just

as essential for the maintenance of a full grown animal in a state of health as they are for the support of growth in the young" and furthermore because these substances are no more vital nor do they determine the value of a ration for growth more than several other constituents of a ration.

The fat soluble A is abundant in milk, eggs and the leafy portion of plants and water soluble B is found in milk, eggs, seeds and the leafy part of plants.

According to Osborne and Mendel³⁹ it is now known that these growth accessories are found to a greater or less extent in the following food substances:

Fat Soluble A

Butter fat	Maize kernel
Egg yolk fat	Rye
Cod liver oil	Wheat embryo
Beef fat	Wheat kernel
"Oleo-oil" margarines	Cotton seed
Pig kidney fat	Cabbage leaves
Clover	Alfalfa leaves
Oat kernel	Flax seeds
Soy beans	Hemp seed
Sunflower seed	Millet seeds

Fat Soluble B

Milk	Wheat
Eggs	Oat
Rice	Kidney beans

Wheat embryo,

Yeast

Cotton seed

Soy beans

Pancreas

Maize embryo

Maize kernel

Peanut meal

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McCollum and Simmonds found that the seeds of wheat, oat, maize, rice, bean and pea are too low in the unknown dietary essentials to supply the needs of young animals for growth.

The farm animal, except the young animal on a milk ration, obtains its fat soluble A from leafy plants. Alfalfa is especially rich in this accessory. Lard is the only animal fat definitely known not to contain any fat soluble A and it is apparently absent from all vegetable fats.

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42 Osborne and Mendel found that the fat soluble A of

butter fat would resist treatment with steam for two and a half hours and McCollum and Davis state that it is present in boiled eggs, that it withstands hydrolysis and also that heating milk does not destroy the water soluble B, except in the case of milk powder or dry casein. The evidence available at present seems to indicate that these growth accessories may be destroyed by continuous boiling for a long time and by weak alkalies.

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41,42,45,46
Practically all investigators have confirmed the work of McCollum and his associates. Funk, however, states that, "there is no justification - - - to

accept the necessity of two different vitamins one for curing the nervous symptoms and one for the maintenance of body weight." He is inclined to believe that there may be several vitamins each with a separate function.

Some grains like wheat contain toxic substances. When such feeds are fed to an animal it is necessary to supply more growth accessories than when a toxin free ration is fed. Hart and McCollum³⁶ advise that any ration should contain essential factors sufficient to overcome any toxicity that may be present. Alfalfa was found by these men to be especially valuable for this purpose. When 20 per cent of a ration for swine is made up of wheat middlings, an equal amount of alfalfa will overcome the toxic effects.

It is very apparent that the growing heifer would require a supply of fat soluble A and water soluble B. Where milk or skim milk is fed to the calf or older heifer, an adequate amount would be supplied. The older heifer would ordinarily receive an abundant supply in the roughage of her ration. Clover and alfalfa are especially good for this purpose.

INORGANIC MATERIAL. Inorganic material is essential to the growing animal. If an animal is fed a ration free from mineral matter, it will generally die sooner than²⁸ when no feed is given.

The functions of the mineral elements in animal metabolism are:^{7j} To supply the mineral matter necessary for the proper development of the skeleton. To maintain the

osmotic pressure of the blood. To maintain the neutrality of the body fluids.

"As bearers of electricity the elements dominate the whole course of metabolism."⁶⁹

"They conduct nerve stimuli, and play a leading role in the general process of cell stimulation."

"They govern the contraction of the muscles, including the contractions of the heart. They are one of the constituents of every living cell."

"They assist in the coordination of the digestive processes."

"Through their control of the inhibition of water by the colloids they govern absorption and secretion."

"Through their control of the affinity of the blood for gases, they govern respiration."

"They control the state of solution, precipitation, mechanical aggregation, chemical association and ionization of the colloids which compose living tissue."

Individual ash constituents have minor but vital functions such as supplying the iron of the blood or the iodine of the thyroid gland.

It is commonly accepted that calcium, magnesium, potassium, sodium, phosphorus, sulphur, iron, and chlorine are required in varying proportions by all animals.

It has also been shown^{29a} that grains are deficient in calcium and rich in phosphorus, and that roughages are

deficient in phosphorus and that their calcium content varies. Straw and timothy hay are low in calcium while legume hay has a high calcium content. All of the other essential mineral elements for growth, except sodium and chlorine, are furnished in ample amounts in any normal ration, but these elements are easily supplied as common salt.

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Forbes has shown that it is practically impossible to maintain the mineral equilibrium of cows in milk during the period of high production. This condition is made worse by overstocked pastures and by feeding timothy hay or forage grown on infertile or sandy soils. Hart and McCollum

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found that pigs fed on corn meal and gluten feed, which are deficient in ash, made very little if any growth even when the ration was supplemented with plenty of protein. When salts were added to make the ash content of the ration equivalent to that of milk, practically normal growth resulted.

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McCollum reports that cows grew and were in a good state of nutrition on a ration of corn grain and wheat straw to which was added a suitable salt mixture. They produced normal, vigorous calves. These cows were then put on the same ration minus the salt mixture. The result was that the cows were maintained but they produced dead calves.

It is important to consider the calcium and phosphorus content of a ration for growing heifers so as to avoid feeding a restricted ration, yet there is little danger of a practical farm ration not supplying enough ash to an animal not giving milk. To quote our two leading author-

ities on this subject - Hart ^{29b} says that, "Ruminants - - consuming the usual roughage will ordinarily receive calcium ³³ enough for growth", and Forbes states that, "It is generally true that animals that receive a considerable part of their ration as leafy forage, receive plenty of mineral nutriment."

THE NUTRIENT VALUE OF FEEDS. The Value of a Ration as Determined by Digestion Trials. The most common method of determining the use that an animal makes of feed is by ^{7d} conducting a digestion trial. When conducting a digestion experiment the feed is analyzed to determine the amount of crude protein, carbohydrates and fat that it contains. It is then fed to an animal and the solid excrement is collected and analyzed. The amount of nutrients retained in the body of the animal are expressed as digestible protein, carbohydrates and fat.

The Determination of Energy Values. The carbohydrates and fat of a feed serve as a source of heat and energy to the body, or if fed in excess, for the formation of fat. For this reason the value of feeds is expressed quite commonly in the terms of net energy values.

The respiration calorimeter. To determine the energy value of a feed requires considerably more equipment than the conducting of a digestion trial. Not only must all of the material voided by the animal be collected, but all of the heat given off must also be accounted for. The respiration calorimeter is the apparatus that has been developed

for this work.

The modern respiration calorimeter according to ⁴⁷Jordan may be briefly described as an air tight chamber, arranged in such a manner and with such devices that all that enters and comes from the body of the animal placed within it can be accurately measured and studied. Everything that passes into the animal, air, food, and water, is carefully measured and analyzed so that the exact intake of the body is known. The air is in turn drawn from the chamber and analyzed. All of the waste products given off by the body in any way are carefully weighed and analyzed. If the intake is larger than the outgo, the animal has increased in body weight. If the intake is less the animal has lost.

Computation of results. The conclusions drawn from experiments conducted with the respiration apparatus, as far as energy values are concerned, are based largely upon what is termed the respiratory quotient. The respiratory quotient as defined by Armsby ^{7k} is, "the ratio of the volume of carbon dioxide excreted by an animal to the volume of oxygen taken up during the same time." When an animal uses body fat for energy the quotient approximates 0.7 ⁷⁰ When an animal is supplied with just enough carbohydrate food for the energy requirement of the body, the oxidization value is approximately 1.0. If the respiratory quotient is found to lie between 0.7 and 1.0 it is usually an indication that the body is oxidizing both carbohydrate food and fat. The

respiratory quotient of protein is approximately 0.8 but ordinarily the proportion of the gaseous exchange of the body due to the katabolism of protein is comparatively small. If the animal is fed a large excess of carbohydrate food the determination of the respiratory quotient gives a value greater than 1.0. This has been found to indicate clearly that carbohydrates are being converted into fat.

The energy expenditures of animals. There are three methods which may be used for estimating the energy expenditure of an animal on a given ration. The easiest method is by the use of average digestive coefficients to calculate the approximate amount of digestible nutrients in a ration.

The second method, which is more accurate, is to determine, by the use of a bomb calorimeter,⁴⁸ the heat units of the ration fed and then of the urine and feces. The difference between the heat units of the feed and those found in the excreta represent approximately the energy value of the nutrients used by the animal. This method gives an estimation of the energy equivalent of the food used but furnishes no definite information as to what the body uses it for.

The third and most accurate method of determining energy expenditures is with a respiration calorimeter. With this apparatus the two methods used to determine the extent to which food is burned by any living organism, are to measure the products of combustion and to measure the

amount of oxygen used. By determining the amount of oxygen that is taken up by combining with the carbon and hydrogen of the food the amount of actual energy consumed can be calculated. One of these methods of measurement checks the other, and thus it is possible to know the oxygen consumption of an animal when at rest, when masticating food or when working. In this way it has been possible to determine the differences in the net energy values of different feeds due to the different amounts of energy used in masticating and digesting them.

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Chaveau, working with dogs, found that when they were fed sugar, or fat or meat, either at work or at rest that the utilization of the nutrients caused an increased consumption of oxygen, indicating an increase in the energy expenditure of the organism for digestion and assimilation. The increase was found to be slight in the case of the carbohydrates, somewhat greater in the case of the fat, and very decidedly larger in the case of the proteins.

The net energy value of feeding stuffs. The gross energy of a feed is the total energy that it contains or would produce if it was completely oxidized. The metabolizable, or available, energy^{7e} of a feed is that part of the gross energy which is not carried off in the excreta but is capable of being used by the animal. A certain part of the metabolizable energy is used in the mastication and digestion of the feed. That part of the metabolizable energy that is not used in the processes incident to the

7b

consumption of the feed is the net energy. It is obvious that the amount of energy required to masticate and digest one feed, such as straw, would be greater than that required to masticate and digest more digestible feed.

FEED REQUIREMENTS FOR GROWTH. Feeding Standards. The
 28a
 Wolff-Lehman standard is the leading type of feeding standard now in general use which is based on the digestible protein, carbohydrates and fat contained in the feeds the the requirements of the different animals for these nutrients. The great objection to this standard is that it does not take account of the varying value of digestible matter in different feeding stuffs due to the losses of energy in the processes of digestion and assimilation. Rations composed of feeds that supply similar amounts of digestible matter might differ greatly in the amount of net available energy that they supply and would therefore
 50
 have a different feeding value. Kellner's standard gives the value of the carbohydrates in the terms of starch equivalent. This standard has never been used much in this country. It is possible to convert the starch equivalent and the fat into their approximate net energy value as one pound of starch will produce 1071 calories of energy.

The first feeding standard that was based on the energy value of feeds and the energy requirements of an-
 51
 imals was published by Armsby in 1909. This standard gave the protein in the terms of true protein and the en-

ergy value in therms. A therm is 1000 calories. ⁸¹ Later
^{55b} Armsby revised this standard for growing cattle and
gave us a standard for growing dairy cattle. A revision
^{7m} of the latter has just been published.

The standards for growing dairy cattle are given in the following tables.

TABLE I

WOLFF-LEHMAN STANDARD FOR GROWING DAIRY CATTLE.28a

Age in Months	Average live weight per head Lbs.	Per Day Per 1000 Pounds Live Weight			
		Digestible Nutrients			
		Dry Matter	Crude Protein	Carbo- hydrates	Fats
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2-3	150	23	4.0	13.0	2.0
3-6	300	24	3.0	12.8	1.0
6-12	500	27	2.0	12.5	0.5
12-18	700	26	1.8	12.5	0.4
18-24	900	26	1.5	12.0	0.3

TABLE II

THE KELLNER STANDARD FOR GROWING DAIRY CATTLE.50

Age in Months	Live wt. per head Lbs.	Per Day Per 1000 Pounds Live Weight					
		Digestible nutrients					Net energy value
		Dry Matter	Protein	Crude Protein	Starch equiva- lent	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs. (estimated)	
2-3	150	23	3.4	3.7	18.5	2.0	19.81
3-6	300	24	2.8	3.1	14.7	1.0	15.74
6-12	500	26	2.3	2.6	12.5	0.6	13.39
12-18	700	26	1.8	2.2	10.5	0.4	11.25
18-24	900	26	1.3	1.6	9.2	0.3	9.85

TABLE II cont.

Age in Months	Live wt. per head	Per Day For Weight Given.					
		Digestible nutrients					
		Dry Matter	Protein	Crude Protein equiva-	Starch	Fat	Net Energy value
	Lbs.	Lbs.	Lbs.	Lbs. lent		Lbs. (estimated)	
Per Day for Weight Given							
2-3	150	3.45	.51	.56	2.78	.30	2.97
3-6	300	7.20	.84	.93	4.41	.30	4.72
6-12	500	13.00	1.15	1.30	6.25	.30	6.70
12-18	700	18.20	1.26	1.54	7.35	.28	7.88
18-24	900	23.40	1.17	1.44	8.28	.27	8.87

TABLE III

ARMSBY STANDARDS FOR GROWING DAIRY CATTLE. 55b-7m.

Age Mo.	Live Weight Lbs.	1916 Standard			:	1917 Standard		
		Digestible true	protein	Net Energy		Digestible true	protein	Net Energy
		Lbs.	Lbs.	Therms		Lbs.	Lbs.	Therms
1	100					.40		3.1
2	135					.45		3.4
3	165	.65		3.6		.55		3.6
6	275	.85		4.1		.70		4.1
9	325	.90		4.4		.75		4.4
12	400	1.00		5.1		.80		5.1
18	550	1.10		6.4		.85		6.4
24	700	1.20		7.6		.85		7.6
30	800	1.20		8.2		.85		8.2

ENERGY REQUIREMENTS FOR MAINTENANCE. When considering the feed requirements of animals, it is necessary to learn as near as possible what the maintenance requirements are. Practically all of the maintenance trials have been conducted on mature animals of the beef type. Thus when an attempt is made to determine the energy requirement of growing animals one of the chief difficulties met with is the fact that no definite maintenance requirements have been determined for young animals. The principal reason for this is that it is almost impossible to keep a growing animal on maintenance for any length of time and get normal results.

⁴
Waters after considerable experimental work with growing beef cattle on maintenance ration, says that, "The term maintenance has been used somewhat loosely, but in general we have been in the habit of regarding the animal in maintenance when its live weight was constant. A more correct definition of the term would perhaps be to say that the animal was in maintenance when its body was in energy balance, but the live weight has been the conventional measure of our maintenance values. - - - In a number of experiments at the Missouri Station it has been found that an ungrown animal may remain at a constant body weight for a long period of time and yet increase in height and apparently decrease its store of fat." It is now generally recognized that an animal has an inherent tendency to grow even when it is receiving just enough

feed for maintenance.

As the energy requirement for the maintenance of growing animals has not been determined, their requirement has been estimated from the requirement of mature animals. The basis for this estimation has been the partly substantiated theory that the energy requirement of animals varies with their surface area rather than with the weight of the animal. The explanation given for this hypothesis is that the small animal exposes relatively more surface to radiation and thus loses heat more rapidly.

The surface area can be approximately calculated by applying the rule that the surfaces of solids of the same shape are proportional to the two-thirds powers of their volumes.^{7g} If W equals the weight in grams, S the surface area in square centimeters, and K the factor which is constant for all animals of the same shape, then $S = KW^{\frac{2}{3}}$ or $\frac{S}{W^{\frac{2}{3}}} = K$.

Experimental work at the Missouri Station^{79b} indicates that, "If the weight increases faster than the surface area we will find a decrease in the value of $\frac{S}{W^{\frac{2}{3}}}$ as the animal gets heavier" and that, "The proportion of the surface area to the two-thirds power of the live weight is shown to vary with the condition of the animal but to be fairly constant for a given condition."

The majority of authorities on the nutrition of farm animals seem to agree that the relative surface area of

an animal is the chief factor which determines the energy requirements of an animal. Kellner,^{50a} Armsby^{7g} and Trowbridge⁷⁹ have obtained considerable experimental data which substantiates this hypothesis. McCrudden and Lusk⁵³ also emphasize the relation of metabolism to the body surface rather than between the metabolism and the body weight.

There are those, however, who do not agree with these findings. Murline and Hoobler⁵⁴ concluded that the metabolism in different children is much more nearly proportional to the weight than to the surface area and when the weight is first multiplied by the specific gravity, the agreement is even better. Benedict and Talbot⁷¹ after having conducted an extensive study of infants found that the basal metabolism cannot in any wise be considered a direct function of the body weight and the body surface, and has no relationship with body surface on the basis of the law of cooling bodies. They believe that, "the active mass of protoplasmic tissue" which cannot as yet be measured directly determines the fundamental metabolism. Hopkins⁷² states that, "experience leads me to believe that at least in the case of young rats the demand for maintenance is more nearly determined by the live weight than by the surface area." It is evident however, that the total maintenance requirements increase with the age and weight of the animal.

Muscular activity influences the maintenance requirements of an animal more than any other single factor.⁷¹

⁷³
Zuntz and Hagemann report a respiration experiment upon a horse in which the uneasiness caused by the presence of a few flies resulted in an increase of 10 per cent in the metabolism. ⁷⁴ Armsby and Fries, conducting experiments with steers in the respiration calorimeter, found that a steer possessing the active, nervous temperament of the dairy type, required considerably more energy for maintenance than a beef steer with a quiet disposition.

^{4a}
Waters expressed the opinion that the feed necessary for maintenance varies directly with the plane of nutrition on which the animal is kept because animals that had been highly fed for some time require more feed for maintenance than similar animals that had been sparsely fed. ^{79a} This idea was later confirmed by Trowbridge.

⁸⁰
Experimental trials conducted by Armsby and Fries, ⁷⁵ ⁷⁶ ⁷⁷ ⁷⁹ Armsby, Haecker, Evvard, Trowbridge and others, seem to indicate that fat or heavy animals require more feed for maintenance per unit of surface area, than thin or heavy animals. ^{79b} Moulton explains this as follows: "first, the energy necessary to support the body is proportional to the weight sustained and not to the surface area; and second, the weight increases faster than the surface area, causing an increase in energy per unit of surface area."

⁷⁹
Results obtained by Trowbridge, Moulton and Haigh which have not been previously noted are as follows:

79a
 "Fat steers lost considerable in fatness while on maintenance, thus getting an additional supply of energy, and consequently showing a saving in feed." "The maintenance requirement is higher for a young steer and decreases with the age of the steer." 79c
 "Greater activity causes a higher maintenance." Poor thrift and high maintenance requirements seem to go together.

19a
Standards for Maintenance. Mendel is of the opinion that, "a precise formulation of the energy requirements of the growing organism expressed in general terms must abide further investigation."

The following standards by Armsby are the only ones available which give the maintenance requirements for growing cattle. The first standard given was published in 1916 55 and the second standard was published in 1917. 7n The important difference between the two standards is the marked change of the protein requirements in the latter.

TABLE IV

MAINTENANCE REQUIREMENTS OF CATTLE PER DAY AND HEAD.

ARMSBY STANDARD

Live Weight Lbs.	1916 Standard		1917 Standard	
	Digestible true protein Lbs.	Net Energy Therms	Digestible true protein Lbs.	Net Energy Therms
150	.15	1.70	.08	1.69
250	.20	2.40	.13	2.38
500	.30	3.80	.25	3.78
750	.40	4.95	.38	4.95
1,000	.50	6.00	.50	6.00
1,250	.60	7.00	.63	6.96
1,500	.65	7.90	.75	7.86

56

Armsby would have us remember that, "the great law of the conservation of energy rules in the animal mechanism - - - just as in the engine. The body neither manufactures nor destroys energy. All that it gives out it gets from its food and all that is supplied in its food is sooner or later recovered in some form.

55a

ENERGY REQUIREMENTS FOR GROWTH. To quote Armsby again, "no very extensive determinations of the composition and energy of the increase of live weight in growing animals have yet been reported. The following estimates - - - can not lay claim to any high degree of accuracy."

TABLE V.

ENERGY VALUE OF ONE POUND OF GAIN IN WEIGHT BY GROWING CATTLE.

Age Months	Net Energy Value (Therms)
3	1.50
6	1.75
12	2.00
18	2.50
24	2.75
30	3.00

It is evident that the energy requirement for a pound of gain increase as the animal matures. A young animal gains in weight faster than an older animal but a pound of increase in a young animal contains less dry matter and more water than a like increase in an older animal. Furthermore, the young animal gains more in protein and less in fat than a more mature animal and thus stores up a smaller proportion of energy.

Energy Requirements for Maintenance and Growth. The Kellner and Armsby standards for growing dairy cattle have been given in Tables III and IV. These are the only guides that have been published.

⁵⁷
Brandt's data on sixteen dairy heifers show that it required 5.56 therms of energy for every pound of growth up to two years of age, including maintenance, and that the nutrients required for a pound of growth increased with the age of the animal. He also found that breed has practically no effect on the nutrients required for growth and that heavy fed as compared to light fed heifers required practically the same amount of energy for a pound of growth, provided they receive the same proportion of protein in one ration as they do in the other.

⁵⁸ Wing, ⁵⁹ Dawson, ⁶⁰ Maughan, ²⁴ Talbot and ²⁵ Wylie all working with dairy heifers that on the average made practically normal gains, obtained the following averages:

TABLE VI.

ENERGY REQUIREMENTS FOR GROWING DAIRY HEIFERS.

Author	No. of animals	Av. Wt. Lbs.	Av. energy per day therms	Energy for maintenance per day (Armsby)	Energy for growth therms	Gain per day	Energy for 1 lb. gain therms
Wing	9	152.8	2.86	1.70	1.16	.94	1.23
Dawson	18	497.7	5.09	3.80	1.29	1.05	1.23
Maughan	12	503.7	6.39	3.82	2.57	.96	2.68
Talbot	12	556.5	5.79	4.05	1.74	.78	2.23
Wylie	12	567.2	6.18	4.10	2.08	.95	2.19

61

Norton found with calves that gained 1.57 pounds per day for the first twelve months, that they required 2.93 therms for each pound gained. This included maintenance.

62

At the Indiana Station, growing steers required nutrients for one pound of growth and maintenance as follows:

Age of Animal	Weight at beginning Lbs.	Nutrients for 1 pound growth, including maintenance	
		Energy therms	Digestible proteins (lb)
Calves	474	6.16	.78
Yearlings	684	7.52	.96
Two year olds	966	9.30	1.19

7c

Armsby states that more net energy will be required for a pound of gain when an animal is fat than when it is thin, due to the fact that the thin animal will include more water and body protein in the gain than a fat animal will.

63

This statement is substantiated by work done by Georgeson and also by Mumford.

64

65

Gouin and Andouard found that growing cattle used 67.6 per cent of the energy of the assimilated matter for growth.

OBJECT OF THE INVESTIGATION

The object of this investigation was to study the energy requirements of dairy heifers for normal growth. The purpose was to study the influence of several factors on energy requirements. This problem, of a necessity, included a consideration of the energy requirement for maintenance.

It is a well known fact that a respiration calorimeter is essential for the exact determination of energy requirements. However, there is every reason to believe that at least approximate results may be obtained from accurate records of feed consumed and gains made by a large number of growing animals kept under normal conditions.

The author realizes that the character of the data at hand, altho large in volume is not sufficiently complete in certain respects to justify definite conclusions concerning the energy requirement of dairy heifers for normal growth. However, the hope was that it would be possible to contribute some additional knowledge on this subject and to at least begin an investigation of the problem.

EXPERIMENTAL DATA

Source of Experimental Data

The Dairy Department of the University of Missouri has conducted several experiments with dairy heifers. The heifers used in these experiments were carefully weighed and measured and a record kept of the feed consumed. In this way the department has accumulated a large amount of experimental data relating to this subject.

From this data it was possible to select for our study a considerable number of records of heifers of different ages that had made practically normal growth while receiving different rations.

In addition to the material obtained from this available data, maintenance trials were conducted on two young heifers.

METHOD OF STUDYING EXPERIMENTAL DATA

The records of the individual heifers used in this study and given in the various tables of experimental data, were carefully selected from the standpoint of supplying data on the particular point under consideration. In the light of our present knowledge of the factors which may limit growth, this was obviously necessary. All of the records used in our data, unless otherwise designated, are of heifers that were receiving rations which, according to our present knowledge of nutrition, were adequate for growth.

The standard used for determining whether a heifer had made normal growth was one compiled by Eckles and Swett of the Dairy Department. This data was obtained by weighing and measuring a group of dairy heifers. The average weights and measurements of these heifers from birth to the age of two years are given in Table VII.

From the standpoint of energy requirement the striking fact brought out in this table is that the growth of the different breeds for the first two years is almost exactly the same in proportion to their size when two years of age. On the average, the Jersey, during the first year, makes sixty-three per cent of the weight and eighty-nine per cent of the height that it attains when it is two years old. The Ayrshire makes sixty per cent of

TABLE VII

NORMAL GROWTH OF DAIRY HEIFERS

Age in Months	Ayrshires		Jerseys		Holsteins	
	Withers cm.	Weight lbs.	Withers cm.	Weight lbs.	Withers cm.	Weight lbs.
1	70.0	90	70.3	76	76.8	121
2	75.0	128	74.7	105	82.0	157
3	79.3	170	79.3	140	86.8	200
4	84.2	218	83.9	174	92.0	249
5	89.2	254	89.3	222	96.5	302
6	92.6	286	93.7	260	100.9	349
7	94.8	304	96.8	302	104.0	389
8	97.8	336	99.8	340	107.1	425
9	99.1	366	102.8	376	109.1	466
10	100.8	406	105.0	407	111.2	501
11	101.0	427	106.5	432	112.6	529
12	103.5	456	108.3	456	114.0	558
13	105.0	486	110.1	480	115.7	574
14	106.8	533	111.4	503	117.4	596
15	107.8	547	112.7	520	118.8	612
16	108.5	560	113.4	533	120.3	643
17	109.5	579	114.6	553	121.3	660
18	111.2	604	115.6	572	121.8	686
19	112.3	627	116.8	598	122.7	715
20	113.4	651	117.5	621	123.8	746
21	114.1	679	118.1	649	124.3	774
22	115.3	707	118.9	668	124.9	796
23	115.9	733	119.8	689	125.7	824
24	116.5	759	120.4	716	126.5	841

the weight and eighty-nine per cent of the height, while the Holstein makes sixty-six per cent of the weight and ninety per cent of the height reached at the age of two years.

The energy requirement for maintenance, as given by Armsby⁵⁵ in his 1916 standard was used throughout our calculations of the amount of energy available for growth.

Our conclusions are based on the total net energy that the animal received for a day, or for each hundredweight a day, and the net energy required for one pound of gain in weight.

To determine the energy required for one pound of gain, the energy required for maintenance, according to Armsby, was subtracted from the energy received for a day. The energy remaining after that required for maintenance was deducted, was considered to be the amount available for growth. This figure divided by the daily gain in pounds gave the energy used for one pound of gain.

DISCUSSION OF EXPERIMENTAL DATA

THE ENERGY REQUIREMENT FOR THE MAINTENANCE OF DAIRY HEIFERS

Plan of Trial. In order to determine the energy requirement for the growth of dairy heifers it is fundamental to know the amount of the energy of the ration that is used for maintenance.

55

Armsby's feeding standard is the only one that gives the energy requirement of heifers for maintenance. "Strict accuracy" is not claimed for this standard as it was formulated from the requirements of older animals.

The object of this trial was to determine the result of feeding to heifers, the amount of energy that is specified by Armsby as being sufficient to maintain them.

There are obviously many difficulties to be overcome in determining the maintenance requirement of a growing animal. The accuracy of a short trial may be questioned but it is apparent that, admitting the danger of drawing wrong conclusions from a short feeding period, the errors introduced by the demand of an animal for growth make a trial of long duration out of the question.

Heifers Used. The heifers used were two thrifty Holstein-Friesian heifers, 180 days old, that were practically normal in weight and skeleton growth.

Ration Fed. The ration used was made up of alfalfa hay, timothy hay and ground corn. It is believed that this ration meets the nutritional requirements as now understood and was therefore adequate for the wellbeing of the heifers.

The amount of feed consumed by the heifers and the composition of the ration, together with the energy requirements as given by Armsby, are contained in Table VIII.

The calculations of the composition of the feeds used are based on Armsby's most recent tables.⁷

Records. Accurate records were kept of all feeds consumed. The quantity of each feed given was carefully weighed and recorded on feed sheets kept in the barn for that purpose.

Stabling. The heifers were kept in stalls built especially for trials of this nature. They were bedded with shavings.

Weights and Measurements. Weights were taken at the time that the heifers were put on a preliminary feeding period, ten days previous to the beginning of the trial. Weights were taken on three successive days at the beginning of the trial and at ten day intervals. An average was made of these three successive weights and this figure used as the basis for calculations.

The height at withers was the only measurement made of the growth in skeleton of the heifers used in this trial, and was taken at the end of each ten day period.

TABLE VIII
 FEED AND NUTRIENTS CONSUMED
 HEIGHT AND WEIGHT OF TWO HEIFERS IN MAINTENANCE TRIAL

10 Day Period	Corn	Alfalfa	Timothy	Digestible crude protein	Net Energy	Weight	Height
	Lbs.	Lbs.	Lbs.	Lbs.	T.	Lbs.	Lbs.
Holstein Heifers H-1							
Prelim.	10	15	40	3.54	30.9	355	99.83
Beginning						365	
1	10	15	40	3.54	30.9	355	101.16
2	10	15	40	3.54	30.9	365.7	101.66
3	10	15	40	3.54	30.9	367.6	102.83
4	10	15	40	3.54	30.9	381.3	103.08
Total	40	60	160	14.16	123.6		
Ave. per day	1.0	1.5	4.0	.354	3.09		
Armsby's Standard				.295	3.04		

Holstein Heifers H-2							
Prelim.	10	15	35			328	100.5
Beginning						329	100.66
1	10	15	35	3.39	28.5	335.3	101.16
2	10	15	35	3.39	28.5	330	101.33
3	10	15	35	3.39	28.5	338.3	101.66
Total	30	45	105	10.17	85.5		
Ave. per day	1.0	1.5	3.5	.339	2.85		
Armsby's Standard				.279	2.85		

Results Obtained. The data by ten day periods of each of the animals used is given in Table VIII. The data includes the kind and amount of food consumed, the digestible crude protein, net energy value, together with the weight and height at withers at the beginning of the trial and the end of each period.

Discussion of Data. A comparison of the digestible crude protein and net energy contained in the ration of our heifers, with the requirements, according to Armsby,⁵⁵ for heifers of their weight, shows that these heifers were receiving an adequate supply of protein and almost exactly the amount of energy given as the requirement for heifers of their weight by Armsby.

The normal daily gain in weight for a heifer six months of age is 1.33 pounds and the normal increase in height at withers is .123 centimeters in a day. The normal weight and height of these heifers at the end of the trial should have been 404.6 pounds and 105.4 centimeters for H 1 and 397.4 pounds and 104.7 centimeters for H 2.

The weights of these heifers were more constant during the trial than one could hope for, because of the fact that the weight of cattle varies from day to day. So far as can be judged by weight these heifers were in maintenance. Altho the number of animals is too limited and the time too short to be of great significance, the data show the energy requirement for the maintenance of these animals nearly check the figures as given by Armsby.

Whether the increase in weight by H 1, at the end of the last period, has any significance is a question. The weight of both animals show somewhat of an upward tendency and it may be that this indicates, as has been observed by others, that after becoming accustomed to a maintenance ration, a vigorous animal will be able to make some gain in weight.

The skeleton growth of heifers is very slow and it is difficult to take accurate measurements of this growth. The wide limit of error and the short period covered will not admit of any definite conclusions but the data show that skeleton growth took place at a retarded rate. H 1 made 30.6 per cent of the normal growth, as indicated by the height at the withers, and H 2 made 32.2 per cent of the normal growth.

A review of our data emphasizes the fact that several trials should be conducted with heifers of various ages before we can arrive at any definite conclusions.

INFLUENCE OF AGE ON THE ENERGY REQUIREMENT FOR GROWTH

The data on the influence of age on the energy requirement for the growth of dairy heifers are contained in Tables IX and X. Table IX contains the records of heifers for ninety-six periods of thirty days each, for ages varying from three to twenty months. Table X gives a summary of the data contained in Table IX, arranged according to the age of the heifers in each group.

The outstanding fact that seems apparent from the data contained in Tables IX and X is that the energy requirement for a hundredweight is higher for a young heifer than an older one and that it decreases with the age of the heifer. There are two probable reasons for this. First, we have already observed that the maintenance requirement is higher for young animals than for older ones.^{79c} Second, the growth impulse is much stronger in the young animal which results in a much greater gain in proportion to their size than is the case with older animals. The calves three months of age would add 35.4 pounds, in a month, to their weight, which is a gain of 21.7 per cent of their total weight. The heifers fifteen to eighteen months of age, gaining 1.03 pounds a day would gain 30.9 pounds a month, which represents only 5.2 per cent of their total weight. The energy received for a hundredweight by the older heifers is to that received by the younger heifers as 1 is to 2.8. The

TABLE IX
INFLUENCE OF AGE ON ENERGY REQUIREMENT
30 DAY PERIODS

Heifer	Age	Ave. Wt.	Net Energy per Day			Gain Energy		
			Ave. Total re-ceived	Mainten-ance Armsby	For Growth	per day	for 1 lb.	Energy per day per cwt
No.	Mo.	Lbs.	T.	T.	T	Lbs.	T.	T.
Three Months Old Group								
200	3	156	3.23	1.74	1.54	1.00	.88	
235	3	149	3.25	1.70	1.55	1.17	1.32	
105	3	150	3.76	1.70	2.06	1.57	1.31	
201	3	198	3.40	2.05	1.35	1.00	1.35	
Ave.	3	163	3.42	1.81	1.61	1.18	1.36	2.98
Four Months Old Group								
326	4	173	3.91	1.88	2.03	1.70	1.19	
235	4	185	4.33	1.95	2.38	1.17	2.03	
105	4	171	4.86	1.84	3.02	1.70	1.78	
301	4	146	3.67	1.70	1.97	1.17	1.69	
200	4	180	3.53	1.91	1.62	.93	1.72	
201	4	232	3.16	2.26	.90	1.40	.64	
87	4	159	3.29	1.77	1.52	1.17	1.30	
Ave.	4	178	3.82	1.91	1.91	1.32	1.45	2.14
Five Months Old Group								
326	5	204	4.60	2.09	2.51	1.50	1.67	
235	5	250	5.08	2.40	2.68	1.73	1.55	
105	5	239	5.62	2.33	3.29	1.83	1.80	
301	5	175	3.30	1.88	1.42	1.03	1.38	
200	5	210	4.03	2.12	1.91	1.20	1.69	
1	5	147	3.46	1.70	1.76	1.17	1.50	
325	5	155	3.54	1.74	1.80	1.00	1.80	
201	5	257	4.33	2.46	1.87	1.10	1.70	
87	5	198	3.97	2.05	1.92	1.27	1.51	
Ave.	5	204	4.22	2.09	2.13	1.54	1.38	2.07

TABLE IX continued
 INFLUENCE OF AGE ON ENERGY REQUIREMENT

30 DAY PERIODS

Heifer	Age	Ave. Wt.	Net Energy per Day			Gain per day	Energy for 1 lb.	Energy per day per cwt
			Total re- ceived	Mainten- ance Armsby	For Growth			
No.	Mo.	Lbs.	T.	T.	T.	Lbs.	T.	T.
Six Months Old Group								
301	6	199	3.95	2.05	1.90	1.33	1.43	
200	6	240	4.45	2.33	2.12	1.11	1.91	
1	6	179	3.41	1.91	1.50	1.53	.98	
325	6	177	4.07	1.91	2.16	1.23	1.75	
201	6	304	4.65	2.71	1.94	1.76	1.10	
87	6	258	4.00	2.46	1.54	1.60	.96	
130	6	282	5.17	2.57	2.60	1.06	2.46	
Ave.	6	234	4.24	2.30	1.94	1.37	1.42	1.81
Eight to Ten Months Old Group								
2	9.5	441	7.54	3.46	4.08	1.46	2.79	
13	9.0	348	5.28	2.96	2.32	1.08	2.15	
216	9.0	597	9.01	4.24	4.77	1.17	4.07	
220	9.0	552	6.85	4.03	2.86	1.17	2.44	
223	9.0	538	8.42	3.98	4.44	1.46	3.04	
225	9.0	542	7.50	3.98	3.52	1.28	2.90	
130	8.5	324	5.17	2.82	2.35	.89	2.64	
280	9.5	400	5.14	3.24	1.90	1.29	1.47	
Ave.	9.1	458	6.86	3.63	3.23	1.23	2.63	1.47
Ten to Twelve Months Old Group								
279	10.5	485	5.11	3.72	1.39	1.28	1.08	
278	11.5	378	3.88	3.13	.75	1.00	.75	
274	11.5	486	4.46	3.72	.74	.96	.77	
128	11.5	378	4.03	3.13	.90	1.00	.90	
275	11.5	487	4.61	3.72	.89	1.30	.69	
276	11.5	513	5.04	3.87	1.17	1.26	.93	
102	10.5	381	4.94	3.13	1.81	.81	2.23	
249	11.5	457	5.49	3.55	1.94	.76	2.55	
108	12.0	389	4.98	3.18	1.80	.80	2.25	
255	11.0	444	4.99	2.43	2.56	.91	2.81	
Ave.	11.3	440	4.75	3.46	1.29	1.01	1.28	1.08

TABLE IX continued
 INFLUENCE OF AGE ON ENERGY REQUIREMENT
 30 DAY PERIODS

Heifer	Age	Ave. Wt.	Net Energy per Day			Gain per day	Energy	
			Total re- ceived	Mainten- ance Armsby	For Growth		for 1 lb.	per day per cwt
No.	Mo.	Lbs.	T.	T.	T.	Lbs.	T.	T.
Twelve to Fifteen Months Old Group								
98	15.0	555	4.81	4.05	.76	.34	2.23	
100	13.0	440	5.42	3.46	1.96	.87	2.48	
101	12.5	486	5.74	3.72	2.52	.95	2.65	
245	15.0	632	6.25	4.40	1.85	.83	2.23	
246	13.0	649	7.61	4.49	3.12	1.13	2.76	
248	13.5	583	5.56	4.19	1.37	.64	2.14	
249	12.0	457	5.49	3.58	1.91	.76	2.77	
254	13.5	625	7.41	4.38	3.03	1.10	2.76	
105	14.5	490	5.92	3.74	2.18	.81	2.69	
317	15.0	577	6.41	4.17	2.24	1.29	1.74	
263	13.0	606	7.13	4.28	2.85	1.48	1.92	
262	15.0	592	6.26	4.21	2.05	1.17	1.75	
113	13.0	451	5.37	3.52	1.85	.51	3.62	
264	13.0	650	9.99	4.49	5.50	1.61	3.41	
11	15.0	425	4.84	3.38	1.46	.81	1.80	
39	15.0	405	4.78	3.27	1.51	.77	1.96	
14	15.0	426	5.07	3.38	1.69	.68	2.48	
215	15.0	539	5.41	3.98	1.43	.54	2.65	
219	15.0	510	4.50	3.85	.65	.99	.67	
222	15.0	495	5.59	3.77	1.82	1.09	1.67	
224	15.0	463	4.86	3.60	1.26	.74	1.70	
2	15.0	712	8.81	4.76	4.05	1.56	2.59	
8	15.0	525	7.38	3.92	3.46	1.34	2.58	
127	12.5	385	3.93	3.16	.77	.77	1.00	
278	11.5	378	3.88	3.13	.75	1.00	.75	
274	11.5	486	4.46	3.72	.74	.96	.77	
275	11.5	487	4.61	3.72	.89	1.30	.68	
Ave.	13.8	519	5.83	3.89	1.94	.97	2.00	1.12

TABLE IX continued
 INFLUENCE OF AGE ON ENERGY REQUIREMENT
 30 DAY PERIODS

Heifer	Age	Ave. Wt.	Net Energy per Day			Gain per day	Energy for 1 lb.	Energy per day per cwt
			Total re- ceived	Mainten- ance Armsby	For Growth			
No.	Mo.	Lbs.	T.	T.	T.	Lbs.	T.	T.
Fifteen to Eighteen Months Old Group								
243	18.0	724	7.16	4.84	2.32	.99	2.34	
244	16.5	581	5.61	4.17	1.44	.95	1.52	
104	16.5	542	5.90	3.98	1.92	.82	2.34	
316	17.0	534	5.52	3.96	1.56	1.08	1.44	
258	17.5	701	10.84	4.76	6.12	1.62	3.78	
318	17.5	612	7.02	4.31	2.71	1.23	2.23	
125	16.5	505	5.70	3.82	1.87	.79	2.37	
271	17.5	677	7.11	4.61	2.50	1.16	2.15	
324	16.5	610	5.68	4.31	1.37	.62	2.21	
272	16.5	624	5.75	4.38	1.37	.99	1.38	
325	15.5	435	4.53	3.44	1.09	1.07	1.02	
Ave.	16.9	595	6.44	4.24	2.20	1.03	2.14	1.08
Eighteen to Twenty-One Months Old Group								
96	18.0	551	5.63	4.03	1.60	.82	1.99	
251	19.5	786	7.96	5.10	2.86	.75	3.81	
252	18.5	691	6.50	4.67	1.83	.63	2.90	
11	21.0	544	5.42	4.01	1.41	.46	3.06	
14	21.0	548	5.58	4.03	1.55	.60	2.58	
215	21.0	656	5.78	4.51	1.27	.76	1.67	
219	21.0	699	6.97	4.72	2.25	1.09	2.06	
222	21.0	644	6.76	4.47	2.29	.65	3.52	
224	21.0	583	5.93	4.19	1.74	.60	2.90	
8	21.0	699	6.40	4.72	1.68	.59	2.84	
220	21.0	1019	9.61	6.00	3.61	1.43	2.52	
121	18.5	561	5.08	4.08	1.00	.90	1.11	
270	20.5	834	6.56	5.31	1.25	1.53	.82	
Ave.	20.3	678	6.47	4.63	1.84	.83	2.22	.95

TABLE X

INFLUENCE OF AGE ON ENERGY REQUIREMENT

SUMMARY

Age	Weight	Weight Armsby	Net Energy Per Day				Energy for 1 lb. gain	Gain per day
			Armsby Standard	Total Received	Per cwt.	For Growth for cwt		
Mo.	Lbs.	Lbs.	T.	T.	T.	T.	T.	Lbs.
3	163	165	3.60	3.42	2.98	.99	1.36	1.18
4	178	202	3.77	3.82	2.14	1.07	1.45	1.32
5	204	238	3.93	4.22	2.07	1.04	1.38	1.54
6	234	275	4.10	4.24	1.81	.83	1.42	1.37
9	468	325	4.40	6.86	1.47	.69	2.63	1.23
11	440	375	4.87	4.75	1.08	.29	1.28	1.01
14	519	450	5.53	5.83	1.12	.37	2.00	.97
17	595	525	6.18	6.44	1.08	.37	2.14	1.03
20	678	600	6.80	6.47	.95	.27	2.22	.83

per cent of gain made by the older animals is to that made by the younger as 1 is to 4.2. This is in accord with the well known fact that has been repeatedly brought out in nutrition studies that a young animal uses a larger proportion of the nutrients of its ration for growth than an older animal.

The average amount of energy available for growth for a hundredweight, as summarized in Table X, indicates clearly that the young animal has much more energy available for growth for a hundredweight than an older animal and that the amount available decreases as the animal matures. The heifers three and four months of age use forty-nine per cent of the energy of the feed for growth. Those twelve to eighteen months of age use for growth only thirty-four per cent of the energy received.

According to the data in Table X the energy requirement for a pound of gain is less for a young heifer than an older one and it increases with the age of the heifer. There may be other factors which influence this condition but the only satisfactory explanation that has been advanced is that the gain in weight of the young heifer is made up of more water and protein and less fat than the gain made by a more mature animal. The reason for this is that the animal stores up 1.67 times as much energy in a pound of fat as in a pound of protein. It is thus evident that a gain of live weight in a young animal represents the stor-

ing up of less energy than a similar gain in an older animal in which the gain contains a higher percentage of fat.

The above explanation does not seem sufficient to account for the difference between the energy requirement for a pound of gain in young and older heifers as practical observation does not lead us to believe that the gains made by an older heifer, receiving a large proportion of roughage, consist of more fat than the gains made by a younger heifer, that is usually fed either milk or a liberal allowance of grain. While no definite conclusions can be arrived at from the data at hand, it is not improbable that a young heifer may utilize the energy of its ration more efficiently than an older animal.

Comparing the energy requirement for one pound of gain as set forth by Armsby^{55a} to the requirement of the heifers whose records we are considering, we find that our heifers required about ten per cent less net energy for a pound of gain than the amounts specified by Armsby.

There is such a variation between the average weights of the heifers in the several groups and the weights as given by Armsby for heifers of the same age, that no satisfactory comparison can be made to the energy requirement as set forth in Armsby's standard. The groups of heifers six months of age and younger average below the weights as given by Armsby and all of the groups nine

months of age and older average heavier than the weights as given by Armsby for the age specified. The first six heifers in the group nine months of age are known to have been on a high plane of nutrition. However, it is interesting to note that in six groups out of the nine, the average figures show that these heifers received more energy than Armsby's standard would allow.

THE INFLUENCE OF WEIGHT ON THE ENERGY REQUIREMENT FOR GROWTH

The data on the influence of weight on the energy requirement for the growth of dairy heifers are contained in Table XI and XII. Table XI contains the records of heifers for thirty days each, with weights varying from 150 to 700 pounds. Table XII gives a summary of the data contained in Table XI, arranged according to the weight of the heifers in each group.

Weight apparently has a decided influence on the energy requirements for the growth of heifers. Because of the fact that the weight increases with the age it is rather difficult to determine whether the variation in energy requirement apparently resulting from weight is due primarily to the weight or to the age of the animal. Our rather limited knowledge of the effect of age on the "growth impulse" would lead us to believe that age has the greater influence. On the other hand because of the fact that animals vary so in weight, at the same age, it is evident that the weight of the animal after all is the most practical basis on which to formulate a standard of energy requirement.

The data in Table XII shows very decidedly that in order to make normal growth a light animal requires more energy to the hundredweight than a heavier animal and that the energy requirement decreases with the increase in

TABLE XI
INFLUENCE OF WEIGHT ON ENERGY REQUIREMENTS
30 DAY PERIODS

Heifer	Average Weight	Net Energy per Day			Gain per day	Energy per 1 lb. gain	Energy per cwt
		Total Received	For Maintenance (Armsby)	For Growth			
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>150 Pound Group</u>							
326	155	3.05	1.74	1.31	1.27	1.03	
235	152	3.52	1.70	1.82	1.17	1.56	
105	152	3.61	1.70	1.91	1.28	1.49	
1	145	4.02	1.70	2.32	1.17	2.00	
325	145	3.79	1.70	2.09	.77	2.71	
201	150.5	3.03	1.70	1.33	1.47	.96	
Ave.	149.9	3.50	1.70	1.80	1.19	1.51	2.33
<u>200 Pound Group</u>							
105	200	4.87	2.05	2.82	1.70	1.66	
301	198	3.74	2.05	1.69	1.33	1.27	
200	202	3.31	2.05	1.26	1.43	.88	
201	201	3.40	2.05	1.35	.93	1.45	
87	197	3.96	2.05	1.95	1.17	1.65	
Ave.	200	3.86	2.05	1.81	1.31	1.38	1.93
<u>250 Pound Group</u>							
235	247	5.05	2.40	2.6	1.73	1.50	
105	255	2.85	2.43	.42	1.83	.23	
200	255	4.59	2.43	2.16	1.77	1.22	
87	245	4.37	2.37	2.00	1.33	1.50	
201	250	3.58	2.40	1.18	1.10	1.07	
Ave.	250	4.09	2.40	1.69	1.55	1.09	1.64

TABLE XI continued
 INFLUENCE OF WEIGHT ON ENERGY REQUIREMENTS
 30 DAY PERIODS

Heifer	Average Weight	Net Energy per Day			Gain per day	Energy per lb. gain	Energy per cwt.
		Total Received	For Mainten- ance (Armsby)	For Growth			
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>400 Pound Group</u>							
102	400	5.08	3.24	1.84	1.03	1.79	
100	401	5.47	3.24	2.24	1.33	1.69	
249	400	4.99	3.24	1.75	1.00	1.75	
93	400	5.60	3.24	2.36	1.07	2.21	
314	400	3.81	3.24	1.30	.89	1.46	
Ave.	400	4.99	3.24	1.75	1.02	1.72	1.25
<u>500 Pound Group</u>							
90	497	5.44	3.80	1.64	.71	2.31	
101	481	5.77	3.69	2.08	1.03	2.02	
100	500	5.38	3.80	1.58	.90	1.76	
244	510	5.38	3.85	1.53	1.20	1.28	
98	522	5.05	3.89	1.16	.83	1.40	
249	483	5.47	3.72	1.45	1.00	1.45	
Ave.	499	5.42	3.80	1.62	.95	1.71	1.08
<u>600 Pound Group</u>							
239	600	6.19	4.26	1.93	.73	2.64	
246	607	7.15	4.28	2.87	1.83	1.57	
95	615	5.05	4.33	.72	1.00	.72	
98	585	4.93	4.19	.74	.67	1.10	
245	601	6.73	4.26	2.47	1.50	1.65	
Ave.	601	6.01	4.26	1.75	1.15	1.52	1.00

TABLE XI continued
 INFLUENCE OF WEIGHT ON ENERGY REQUIREMENTS
 30 DAY PERIODS

Heifer	Average Weight	Total Received	For Maintenance (Armsby)	For Growth	Gain per day	Energy per 1 lb. gain	Energy per cwt.
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>700 Pound Group</u>							
239	715	7.18	4.79	2.39	.83	2.84	
246	703	7.63	4.74	2.89	1.33	2.17	
245	700	6.73	4.72	2.01	1.40	1.45	
9	670	5.05	4.58	.47	.50	.94	
Ave.	697	6.65	4.72	1.93	1.02	1.89	.95

TABLE XII
 INFLUENCE OF WEIGHT ON ENERGY REQUIREMENTS
 SUMMARY

Weight	Net Energy Per Day			Energy		Gain per day	Per cent difference Armsby vs. thesis.
	Armsby's Standard	Total Received	Per cwt.	For Growth per cwt	for 1 lb. gain		
Lbs.	T.	T.	T.	T.	T.	Lbs.	
150	3.50	3.50	2.33	1.20	1.51	1.19	.0%
200	3.76	3.86	1.93	.91	1.38	1.31	-2.6
250	3.99	4.09	1.64	.67	1.09	1.55	2.5
400	5.10	4.99	1.25	.44	1.72	1.02	2.1
500	5.97	5.42	1.08	.32	1.71	.95	9.2
600	6.80	6.01	1.00	.29	1.52	1.15	11.6
700	7.60	6.65	.95	.28	1.89	1.02	12.5

weight. This is probably due, as noted under the influence of age on energy requirements, to the high maintenance requirements of young animals and to the fact that the younger an animal is the larger gains does it make in proportion to the size of its body.

A light animal has available for growth considerably more energy to the hundredweight than a heavier animal and the amount available for growth decreases as the weight increases. Comparing the 150 pound and 200 pound groups of heifers to the 600 pound and 700 pound heifers in Table XIII we find that the former groups used on the average forty-nine per cent of the total energy received for growth while the latter groups used only twenty-nine per cent of the energy received for growth. This again emphasizes the fact that the young animal has a greater "growth impulse" and utilizes a larger proportion of its ration for growth.

The energy required by a light animal for a pound of gain seems to be somewhat less than the amount that a heavier animal requires. This is somewhat of a contrast to the results noted under the effect of age on the energy requirement for a pound of gain in that the energy requirement for a pound of gain does not increase as much with the weight of an animal as it does with the age of the animal.

The daily energy requirement of these heifers show a gradual increase, altho not in proportion to the weights. The data as compiled in Table XII show that the heifers

weighing from 150 to 400 pounds received, on the average, practically the same amount of energy that is given in Armsby's standard for heifers of that weight. The heifers weighing from 500 to 700 pounds received from 9 to 12.5 per cent less energy than Armsby gives for heifers of that weight. In this connection it should be noted that the animals of each group averaged twenty per cent better than normal gains according to Armsby^{55b} or Eckles.¹²

THE INFLUENCE OF THE RATE OF GAIN
ON ENERGY REQUIREMENT FOR GROWTH

The data on the effect of the rate of gain on energy requirement for growth are contained in Tables XIII and XIV. Table XIII contains the records of forty heifers each for a period of 150 days. The rate of gain of these heifers varied from less than five-tenths of a pound to over a pound a day. Table XIV gives a summary of the data contained in Table XIII, arranged according to the rate of gain of the heifers in each group.

A consideration of the effect of the rate of gain on the energy requirement of the heifers whose records were studied seems to indicate that the rate of gain and the amount of energy available for growth vary almost directly with the amount of energy supplied in the ration. The group that made small gains received twenty-five per cent less energy than the amount specified in Armsby's standard. The groups making from .5 to .75 pound and .75 to 1 pound of gain in a day, received thirteen per cent and seven per cent respectively less energy and the large gain group received nine per cent more energy than would be allowed by Armsby's standard.

The heifers in the group making small gains were not receiving a ration adequate for growth. Their ration was deficient in protein. However, this group was evidently not receiving energy enough for normal growth and the en-

TABLE XIII.
INFLUENCE OF RATE OF GAIN ON ENERGY REQUIREMENTS
150 DAY PERIODS

Heifer	Net Energy per Day				Gain per day	Energy for 1 lb. gain	Energy per day per cwt
	Average	Total	For Maintenance (Armsby)	For Growth			
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>Group Gaining Less Than .5 Lb. per Day</u>							
265	500	4.59	3.80	.79	.24	3.29	
116	286	2.87	2.60	.27	.27	1.00	
322	313	3.43	2.76	.67	.21	3.19	
95	634	5.19	4.42	.77	.25	3.08	
Ave.	433	4.02	3.44	.58	.24	2.42	.93
<u>Group Gaining .51 to .75 Lb. per Day</u>							
324	610	5.68	4.31	1.37	.62	2.21	
252	691	6.50	4.67	1.83	.63	2.90	
109	332	4.48	2.85	1.63	.67	2.43	
113	451	5.37	3.52	1.85	.51	3.63	
260	587	5.42	4.19	1.23	.68	1.81	
248	583	5.56	4.19	1.37	.64	2.11	
Ave.	542	5.50	3.98	1.52	.65	2.41	1.01
<u>Group Gaining 1 or more Lbs. per Day</u>							
246	649	7.61	4.49	2.12	1.13	1.88	
249	741	7.29	4.86	2.43	1.06	2.25	
102	667	6.95	4.56	2.39	1.08	2.29	
317	577	6.41	4.15	2.26	1.29	1.75	
316	534	5.52	3.96	1.56	1.08	1.44	
254	625	7.41	4.38	3.03	1.10	2.75	
263	606	7.13	4.79	2.34	1.48	1.55	
262	592	6.26	4.38	1.88	1.17	1.61	
264	650	9.99	4.49	5.50	1.61	3.42	
258	701	10.84	4.72	6.12	1.62	3.78	
320	600	9.42	4.26	5.16	1.67	3.09	
318	612	7.02	4.31	2.71	1.23	2.23	
Ave.	630	7.65	4.40	3.25	1.29	2.52	1.21

TABLE XIII continued
 INFLUENCE OF RATE OF GAIN ON ENERGY REQUIREMENTS
 150 DAY PERIODS

Heifer No.	Weight Lbs.	Net Energy per Day			Gain per day	Energy	
		Average Received	Total For Maintenance (Armsby)	For Growth		for 1 lb. gain	per day per cwt
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>Group Gaining .75 to 1.0 Lb. per Day</u>							
130	324	5.17	2.82	2.35	.89	2.64	
125	505	5.70	3.83	1.87	.79	2.37	
127	385	3.93	3.16	.77	.77	1.00	
121	561	5.08	4.08	1.00	.90	1.11	
326	450	4.39	3.52	.87	.82	1.06	
251	786	7.96	5.10	2.86	.75	3.81	
108	389	4.98	3.18	1.80	.80	2.25	
105	490	5.92	3.74	2.18	.81	2.69	
255	444	4.99	3.49	1.50	.91	1.64	
104	542	5.90	3.98	1.92	.82	2.34	
101	486	5.74	3.72	2.02	.95	2.13	
102	381	4.94	3.13	1.81	.81	2.23	
243	724	7.16	4.84	2.32	.99	2.34	
245	632	6.25	4.40	1.85	.83	2.23	
249	457	5.49	3.35	1.94	.75	2.41	
96	551	5.63	4.03	1.60	.82	1.99	
100	440	5.42	3.46	1.96	.87	2.25	
244	581	5.61	4.17	1.44	.95	1.52	
Ave.	507	5.57	3.82	1.75	.85	2.06	1.09

TABLE XIV
INFLUENCE OF RATE OF GAIN ON ENERGY REQUIREMENT
SUMMARY

Group Gain	Weight	Net Energy per Day				Energy for 1 lb. gain	Gain per day
		Armsby's Standard	Total Received	Per Cwt.	For Growth per Cwt.		
Lbs.	Lbs.	T.	T.	T.	T.	T.	Lbs.
-.5	433	5.39	4.02	.93	.12	2.42	.24
.5-.75	542	6.32	5.50	1.01	.28	2.41	.63
.75-1.0	507	6.02	5.57	1.09	.34	2.06	.85
1.0 +	630	7.04	7.65	1.21	.52	2.52	1.29

ergy used for a pound of gain was high.

The group making subnormal gains of from .5 to .75 pounds per day, received almost the normal supply of energy and the energy required for one pound of gain was high. The energy requirement of the group making normal gains of from .75 to 1.0 pound of gain was normal in every respect while the requirement of the group that made heavy gains was high throughout.

The important lesson to be learned here seems to be that the growing heifer will utilize the energy of her ration to the best advantage if she is fed so as to make about normal gains.

THE INFLUENCE OF WEIGHT IN RELATION TO THE NORMAL
ON ENERGY REQUIREMENT

The data on the effect of the weight of the animal in relation to the normal weight on energy requirement for growth are contained in Table XV. This table contains the records of eighteen heifers, each for a period of 150 days.

The light weight heifers averaged ten per cent below normal weight while the heavy weight heifers averaged nineteen per cent above normal at the beginning of the period.

Comparing the records of the group of heifers that were below normal weight at the beginning of the feeding period to the records of the group that were above normal weight, we find that in proportion to weight the heavy weight group received twenty-seven per cent more energy than the light weight heifers. If we deduct the amount of energy that normal heifers require for maintenance we find that the heavy weight group received eighty-one per cent more energy for growth than the light weight group.

The light weight group apparently required 2.24 therms of energy and the heavy weight group required 3.27 therms for a pound of gain. The latter made the best gains, averaging thirty-three per cent better gains on forty-six per cent more energy for a pound of gain than the former.

It is obviously impossible to get dependable data on this phase of the problem without the use of a respiration calorimeter. For this reason no definite conclusions can

TABLE XV
INFLUENCE OF WEIGHT AT BEGINNING OF PERIOD
ON ENERGY REQUIREMENT
150 DAY PERIODS

Heifer	Weight		Net Energy per day			Lb. Energy		
	at beginning	Normal Weight	Total received	For Maintenance	For Growth	Gain per day	for 1 lb. gain	Energy per cwt.
				(Armsby)				
No.	Lbs.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>Light Weight at Beginning of Period</u>								
249	661	832	7.29	4.90	2.39	1.06	2.25	
102	586	636	6.95	4.56	2.39	1.08	2.29	
317	480	516	6.41	4.15	2.26	1.29	1.75	
254	513	531	7.41	4.38	3.03	1.10	2.75	
108	329	391	4.98	3.18	1.80	.80	2.25	
105	430	463	5.92	3.74	2.18	.81	2.69	
252	644	648	6.50	4.67	1.83	.63	2.90	
262	487	548	6.26	4.38	1.88	1.17	1.61	
Ave.	516	571	6.47	4.25	2.22	.99	2.24	1.25
<u>Heavy Weight at Beginning of Period</u>								
2	572	456	8.81	3.46	4.35	1.56	2.79	
216	492	349	9.01	4.24	4.77	1.17	4.08	
220	447	349	6.85	4.03	2.82	1.17	2.41	
220	657	558	8.31	5.06	3.25	1.29	2.52	
223	407	349	8.42	3.98	4.44	1.46	3.04	
223	670	558	11.61	5.16	6.45	1.43	4.51	
225	427	349	7.50	3.98	3.52	1.28	2.75	
225	658	558	9.87	5.03	4.84	1.25	3.87	
264	505	480	9.99	4.49	5.50	1.61	3.42	
243	650	612	7.16	4.84	2.32	.99	2.34	
Ave.	549	462	8.75	4.43	4.32	1.32	3.27	1.59

be drawn from our data.

The results obtained were also complicated by the fact that the animals of the two groups varied considerably in their rate of gain and that would favor the group making nearly normal gains. However, it would seem that the heifers that were light weight at the beginning of the period had a lower energy requirement than the heavy weight group. This would be expected as we have observed^{4, 25, 66, 67} that animals usually make larger and more economical gains following a period when they are under weight. As far as is known this is due to the fact that an animal that has been on a high plane of nutrition^{4a, 79a} has a high maintenance requirement and also that a heavy animal requires more energy^{79a} for a unit of surface area than a lighter animal. We know that the heavy weight group had been on a high plane of nutrition.

THE INFLUENCE OF CHARACTER OF RATION ON ENERGY REQUIREMENT

The data on the influence of the character of the ration on the energy requirement for growth of heifers are contained in Tables XVI and XVII. Table XVI contains the records of forty-three heifers each for a period of 150 days. These heifers were receiving rations that differed considerably in the amount of roughage and concentrates contained. Table XVII gives a summary of the data contained in Table XVI, arranged according to the ration that the heifers received.

There are available only a limited amount of data of heifers which have received rations adequate for growth, made up of varying proportions of roughage and concentrates, when the heifers were on the same plane of nutrition. For this reason no definite conclusions can be drawn as to the effect of the relative amounts of concentrates and roughage in the ration.

However, a study of the data at hand in Tables XVI and XVII seems to indicate that the energy requirement of the heifers receiving a ration made up entirely or largely of roughage was lower than where a more concentrated ration was fed.

The heifers fed on alfalfa alone received less than a normal energy supply, but because of their small gains the energy requirement for a pound of gain was about normal.

TABLE XVI.

INFLUENCE OF CHARACTER OF RATION ON ENERGY REQUIREMENT
150 DAY PERIODS

Heifer	Average Weight	Net Energy per Day			Energy		
		Total re- ceived	For Mainte- nance (Armsby)	For Growth	Gain per day	for 1 lb. gain	Energy per day per cwt
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>Alfalfa Group</u>							
11	425	4.84	3.38	1.46	.81	1.80	
11	544	5.42	4.01	1.41	.46	3.06	
39	405	4.78	3.27	1.51	.77	1.96	
14	426	5.07	3.38	1.69	.68	2.46	
14	548	5.58	4.03	1.55	.60	2.58	
215	539	5.41	3.98	1.43	.54	2.65	
219	510	4.50	3.85	.65	.99	.65	
222	495	5.59	3.77	1.82	1.09	1.67	
224	463	4.86	3.60	1.26	.74	1.70	
224	583	5.93	4.19	1.74	.60	2.90	
Ave.	494	5.20	3.77	1.43	.73	1.96	1.05
<u>Alfalfa and Silage Group</u>							
98	555	4.81	4.05	.76	.34	2.24	
245	632	6.25	4.40	1.85	.83	2.23	
249	457	5.49	3.55	1.94	.76	2.41	
121	561	5.08	4.08	1.00	.90	1.11	
274	486	4.46	3.72	.74	.96	.77	
272	624	5.75	4.38	1.37	.99	1.38	
275	487	4.61	3.72	.89	1.30	.68	
276	513	5.04	3.87	1.17	1.26	.93	
326	450	4.39	3.52	.87	.82	1.06	
Ave.	529	5.10	3.94	1.16	.91	1.27	.96

TABLE XVI continued
 INFLUENCE OF CHARACTER OF RATION ON ENERGY REQUIREMENT
 150 DAY PERIODS

Heifer	Average Weight	Net Energy per Day			Gain per day	Energy	
		Total re- ceived	For Mainte- nance (Armsby)	For Growth		for 1 lb. gain	per day per cwt
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>Alfalfa Silage and Corn Group</u>							
317	577	6.41	4.15	2.26	1.29	1.75	
316	534	5.52	3.96	1.56	1.08	1.44	
263	606	7.13	4.79	2.34	1.48	1.55	
262	592	6.26	4.38	1.88	1.17	1.61	
113	451	5.37	3.52	1.85	.51	3.63	
264	650	9.99	4.49	5.50	1.61	3.42	
320	600	9.42	4.26	5.16	1.67	3.09	
125	505	5.70	3.83	1.87	.79	2.37	
279	485	5.11	3.72	1.39	1.28	1.09	
324	610	5.68	4.31	1.37	.62	2.21	
Ave.	561	6.66	4.08	2.58	1.15	2.24	1.19
<u>Timothy Hay, Silage and Grain Group</u>							
96	551	5.63	4.03	1.60	.82	1.99	
100	440	5.42	3.46	1.96	.87	2.25	
244	581	5.61	4.17	1.44	.95	1.52	
248	583	5.56	4.19	1.37	.64	2.11	
252	691	6.50	4.67	1.83	.63	2.90	
255	444	4.99	3.49	1.50	.91	1.64	
104	542	5.90	3.98	1.92	.82	2.34	
260	587	5.42	4.19	1.23	.68	1.81	
Ave.	552	5.63	4.03	1.61	.79	2.04	1.02

TABLE XVI continued

INFLUENCE OF CHARACTER OF RATION ON ENERGY REQUIREMENT

150 DAY PERIODS

Heifer Weight	Average	Net Energy per Day			Gain per day	Energy	
		Total re- ceived	For Mainte- nance (Armsby)	For Growth		for 1 lb. gain	per day per cwt
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>Heavy Fed Group (Alfalfa, Corn and Oats)</u>							
227	737	9.86	4.88	4.98	1.21	4.12	
225	542	7.50	3.98	3.52	1.28	2.75	
216	597	9.01	4.24	4.77	1.17	4.09	
216	800	9.20	5.16	4.04	1.08	3.74	
220	552	6.85	4.03	2.82	1.17	2.41	
220	773	8.31	5.06	3.70	1.29	2.87	
Ave.	667	8.36	4.60	3.76	1.20	3.30	1.25

TABLE XVII

INFLUENCE OF CHARACTER OF RATION ON ENERGY REQUIREMENT

SUMMARY

Average Weight	Armsby's Standard	Net Energy per Day			Energy for 1 lb. gain	Gain per day
		Total re- ceived	Per cwt.	For Growth per cwt.		
Lbs.	T.	T.	T.	T.	T.	Lbs.
<u>Alfalfa Group</u>						
494	5.92	5.20	1.05	.29	1.96	.73
<u>Alfalfa and Silage Group</u>						
529	6.23	5.10	.96	.22	1.27	.91
<u>Alfalfa, Silage and Corn Group</u>						
561	5.62	6.66	1.19	.46	2.24	1.15
<u>Timothy, Silage and Grain Group</u>						
552	6.40	5.63	1.02	.29	2.04	.79
<u>Heavy Fed Group (Alfalfa, Corn and Oats)</u>						
667	7.35	8.36	1.23	.56	3.30	1.20

The heifers fed on alfalfa and corn ensilage made practically normal gains. They used less energy for the hundredweight and appear to have had less energy available for growth than any other group, but they made better than normal gains on thirty-five per cent less energy for a pound of gain than any other group, and on thirty-nine per cent less than the requirement as given by Armsby. Our data clearly indicate that, from the standpoint of energy requirement, the alfalfa and corn silage ration was the most economical ration fed.

The group of heifers fed on the alfalfa, silage and corn ration were on a higher plane of nutrition than the two groups just described. For this reason their rate of gain was high with the characteristic high energy requirement for a pound of gain.

The heifers receiving the timothy, silage and grain ration were on the same plane of nutrition as the alfalfa and silage group, as they received about the same supply of energy, but they made comparatively small gains and thus had a much higher energy requirement for a pound of gain.

The energy requirement of the heavy fed group was very high in every respect. This was undoubtedly due to the high plane of nutrition, the high rate of gain and the heavy weight for the age of the animals in this group.

There are several possible reasons for the apparent efficiency of a ration composed largely of roughage. First, it is not improbable that the net energy values for roughage, that are commonly used, are too low. Second, the rate of gain of heifers receiving a ration of good roughage is normal and therefore the energy requirement for growth would probably be normal or low. Third, heifers on a roughage ration would not be apt to be heavy for their age at the beginning of the feeding period, and for this reason they would make good use of the energy received.

THE INFLUENCE OF PROTEIN ON THE ENERGY REQUIREMENT

The data on the influence of protein on the energy requirement for the growth of dairy heifers are contained in Tables XVIII, XIX and XX. Table XVIII contains the records of seven heifers for fifty-seven, sixty day periods. These heifers were receiving a high or medium supply of protein. The per cent of protein in their ration refers to the per cent of energy available for growth that was derived from protein. Table XIX gives a summary of the data contained in Table XVIII.

The data of three heifers that evidently were not receiving sufficient protein for normal growth are contained in Table XX, together with the record of these heifers after their protein supply had been increased.

A study of the data contained in Tables XVIII and XIX leads to the conclusion that the protein of the ration does not influence the energy requirement, if the protein is supplied in sufficient quantities for the normal growth of the heifers. The only high energy requirement noted in this data is that of one of the medium protein heifers and this is probably due to the low daily gain.

The records of the three animals whose data are contained in Table XX indicate that when the animal is not receiving an amount of protein adequate for normal growth, that the energy requirement for a pound of gain is exceedingly high. The daily energy supply of these heifers was,

TABLE XVIII
INFLUENCE OF PROTEIN ON ENERGY REQUIREMENT
60 DAY PERIODS

Heifer	Average Weight	Net Energy per Day			Gain Per Day	Energy	
		Total re- ceived	For Mainte- nance (Armsby)	For Growth		for 1 lb. gain	Energy per cwt
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>High Protein Heifer (28%)</u>							
91	240	4.14	2.33	1.81	.90	2.11	
	308	5.52	2.71	2.81	1.13	2.49	
	372	5.78	3.07	2.71	1.00	2.71	
	417	5.77	3.32	2.45	.66	3.71	
	469	5.67	3.63	2.04	1.00	2.04	
	514	5.94	3.87	2.07	.96	2.15	
	562	5.92	4.08	1.84	.52	3.54	
	590	6.17	4.21	1.96	.68	2.88	
	617	7.00	4.33	2.67	.89	3.00	
	677	6.89	4.61	2.28	.61	3.74	
	722	5.94	4.81	1.13	.41	2.76	
Ave.	499	5.89	3.08	2.09	.80	2.61	1.17
<u>High Protein Heifer (20 to 35%)</u>							
273	543	6.56	3.96	2.60	.68	3.82	
	557	6.72	4.05	2.67	.75	3.56	
	604	7.13	4.28	2.85	.83	3.43	
	676	7.67	4.61	3.06	1.22	2.51	
	733	8.23	4.88	3.35	1.63	2.05	
Ave.	621	7.26	4.35	2.91	1.02	2.85	1.17
<u>High Protein Heifer (25%)</u>							
269	333	5.32	2.88	2.44	1.10	2.22	
	367	5.49	3.04	2.45	1.18	2.07	
	443	5.82	3.49	2.33	1.12	2.08	
	498	6.13	3.80	2.33	.85	2.74	
	561	6.73	4.08	2.65	1.08	2.45	
	618	7.43	4.33	3.10	1.10	2.82	
Ave.	470	6.15	3.63	2.52	1.07	2.36	1.31

TABLE XVIII continued

INFLUENCE OF PROTEIN ON ENERGY REQUIREMENT

60 DAY PERIODS

Heifer	Average Weight	Net Energy per Day			Gain per day	Energy	
		Total re- ceived	For Mainte- nance (Armsby)	For Growth		for 1 lb. gain	Energy per cwt.
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>High Protein Heifer (25%)</u>							
267	380	5.75	3.13	2.62	.73	3.59	
	407	5.79	3.27	2.52	.97	2.61	
	470	5.99	3.63	2.36	1.13	2.09	
	527	6.19	3.92	2.27	.92	2.46	
	587	6.83	4.19	2.64	.63	4.19	
	623	7.30	4.38	2.92	.88	3.32	
	676	7.82	4.61	3.21	1.21	2.65	
	767	7.60	5.01	2.59	1.52	1.70	
	849	7.27	5.37	1.90	1.27	1.50	
Ave.	587	6.93	4.19	2.74	1.03	2.66	1.18
<u>High to Medium Protein Heifer (20 to 35%)</u>							
277	496	6.25	3.77	2.48	1.02	2.43	
	524	6.48	3.92	2.56	1.05	2.44	
	583	5.61	4.19	1.42	.35	4.05	
	605	6.17	4.28	1.89	.83	2.27	
	648	7.39	4.49	2.90	.95	3.05	
Ave.	571	6.38	4.12	2.26	.84	2.69	1.11
<u>Medium Protein Heifer (15%)</u>							
253	386	4.54	3.16	1.38	.30	4.60	
	412	4.87	3.30	1.57	.70	2.24	
	448	5.13	3.52	1.61	.92	1.75	
	492	4.86	3.74	1.12	.32	3.50	
	527	5.42	3.92	1.50	1.07	1.40	
	591	6.28	4.21	2.07	1.53	1.35	
	647	6.51	4.47	2.04	.45	4.53	
	697	7.28	4.68	2.60	1.02	2.55	
	768	7.47	5.03	2.44	1.17	2.08	
	806	7.25	5.18	2.07	.32	6.47	
	854	6.99	5.39	1.60	.87	1.84	
	902	7.04	5.58	1.46	.62	2.35	
Ave.	628	6.14	4.40	1.74	.77	2.26	.97

TABLE XVIII continued
 INFLUENCE OF PROTEIN ON ENERGY REQUIREMENT
 60 DAY PERIODS

Heifer	Average Weight	Total re- ceived	For Mainte- nance (Armsby)	For Growth	Gain per day	Energy for 1 lb. gain	Energy per cwt.
No.	Lbs.	T.	T.	T.	Lbs.	T.	T.
Medium Protein Heifer (15%)							
103	281	5.03	2.57	2.46	.48	5.12	
	337	5.80	2.88	2.92	1.02	2.86	
	384	5.64	3.16	1.48	.55	2.69	
	401	5.70	3.24	2.92	.57	2.86	
	431	5.87	3.41	2.46	.42	5.86	
	465	6.07	3.60	2.47	.75	3.29	
	523	6.44	3.92	2.52	.90	2.80	
	578	6.81	4.15	2.66	.91	2.92	
	625	6.99	4.38	2.61	.53	4.92	
Ave.	447	6.04	3.49	2.55	.68	3.75	1.35

TABLE XIX
 INFLUENCE OF PROTEIN ON ENERGY REQUIREMENT
 SUMMARY

Weight	Protein plane	Armsby's Standard	Net Energy per Day Total re- ceived	Per cwt.	For Growth per cwt.	Energy for 1 lb. gain	Gain per Day
Lbs.		T.	T.	T.	T.	T.	Lbs.
499	High	5.97	5.89	1.17	.42	2.61	.80
621	High	6.96	7.26	1.17	.47	2.85	1.02
470	High	5.71	6.15	1.31	.53	2.36	1.07
587	High	6.68	6.93	1.18	.47	2.66	1.03
571	High to Medium	6.56	6.38	1.11	.39	2.69	.84
628	Medium	7.04	6.14	.97	.28	2.26	.77
447	Medium	5.53	6.04	1.35	.57	3.75	.68

TABLE XX

INFLUENCE OF PROTEIN ON ENERGY REQUIREMENT

Weight	Total Energy	Energy Armsby for main-tenance	Energy for Growth	Lb. Gain per day	Energy for 1 lb. gain	Energy per cwt.
Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>No. 114 on Medium Protein (15%)</u>						
299	4.61	2.68	1.93	.47	4.11	
315	4.68	2.76	1.92	.30	6.40	
330	4.60	2.85	1.75	.60	2.92	
342	4.90	2.90	2.00	.35	5.69	
381	5.23	3.13	2.10	.35	6.00	
333	4.80	2.87	2.13	.41	5.27	1.51
<u>No. 114 on High Protein (25%)</u>						
417	5.38	3.32	2.06	.95	2.17	
477	5.63	3.66	1.97	1.00	1.97	
511	5.16	3.85	1.31	1.05	1.25	
586	7.54	4.19	3.35	1.37	2.44	
683	8.43	4.65	3.78	.90	4.20	
535	6.43	3.96	2.47	1.05	2.35	1.20
<u>No. 115 on Low Protein (8%)</u>						
316	4.78	2.76	2.02	.47	4.30	
344	4.75	2.93	1.82	.28	6.50	
361	4.95	3.02	1.93	.43	4.48	
365	5.37	3.04	2.33	.40	5.42	
346	4.96	2.93	2.03	.40	5.07	1.43
<u>No. 115 on Medium Protein (15%)</u>						
409	5.82	3.30	2.32	.70	3.31	
457	5.99	3.55	2.44	.37	6.59	
483	6.33	3.72	2.61	1.23	2.12	
548	6.79	4.03	2.76	.85	3.24	
596	6.98	4.24	2.74	.58	4.72	
499	6.38	3.80	2.58	.75	3.44	1.28

TABLE XX continued

INFLUENCE OF PROTEIN ON ENERGY REQUIREMENT

Weight	Total Energy	Energy Armsby for main-tenance	Energy for Growth	Lb. Gain per day	Energy for 1 lb. gain	Energy per cwt.
Lbs.	T.	T.	T.	Lbs.	T.	T.
<u>No. 266 on Low Protein (8%)</u>						
388	5.08	3.18	1.90	.17	11.17	
396	4.99	3.21	1.78	.37	4.81	
419	4.68	3.35	1.33	.30	4.43	
438	5.09	3.46	1.63	.18	9.06	
410	4.95	3.30	1.66	.25	6.64	1.21
<u>No. 266 on Medium Protein (15%)</u>						
477	5.67	3.66	2.01	.98	2.05	
527	6.27	3.92	2.35	1.07	2.19	
579	6.99	4.17	2.82	.98	2.87	
664	7.83	4.56	3.27	1.03	3.17	
716	8.18	4.79	3.39	1.30	2.61	
593	6.99	4.24	2.75	1.07	2.57	1.17

at all times, more than the normal supply for heifers of their size. There was also a liberal energy supply available for growth.

The reason for the high energy requirement for a pound of gain, just noted, probably is that a low gain usually causes a high energy requirement for a pound of gain and normal gains require only a normal amount of energy.

It is therefore necessary that animals be supplied with sufficient protein for normal growth if they are to make economical use of the energy of their ration.

THE INFLUENCE OF BREED ON ENERGY REQUIREMENT

The data on the influence of the breed on the energy requirement for growth are contained in Tables XXI and XXII. Table XXI contains the records of thirty Ayrshire, Jersey and Holstein heifers, each for a period of 150 days, and twenty-seven heifers for periods of from 30 to 150 days in length. Table XXII gives a summary of the data contained in Table XI, arranged according to the breed of the heifers in each group.

The breed of the animal does not seem to have any noticeable effect on the energy requirement of heifers. Any differences that may exist between the averages of the breeds are easily within the bounds of experimental error. It is also true that there is more difference between the energy requirement of individuals of the same breed than there is between the different breeds.

TABLE XXI

THE INFLUENCE OF BREED ON ENERGY REQUIREMENTS

150 DAY PERIODS

Heifer No.	Average Weight Lbs.	Net Energy per Day			Energy	
		Total re- ceived	For Mainte- nance (Armsby)	For Growth	Gain per day	for 1 lb. gain per day per cwt.
No.	Lbs.	T.	T.	T.	Lbs.	T.
<u>Ayrshires</u>						
326	450	4.39	3.52	.87	.82	1.06
317	577	6.41	4.15	2.26	1.29	1.75
316	534	5.52	3.96	1.56	1.08	1.44
320	600	9.42	4.26	5.16	1.67	3.09
324	610	5.68	4.31	1.37	.62	2.21
318	612	7.02	4.31	2.71	1.23	2.20
Ave.	564	6.41	4.10	2.21	1.12	1.97
<u>Jerseys</u>						
105	490	5.92	3.74	2.18	.81	2.69
101	486	5.74	3.72	2.02	.95	2.23
98	555	4.81	4.05	.76	.34	2.24
121	561	5.08	4.08	1.00	.90	1.11
113	451	5.37	3.52	1.85	.51	3.63
125	505	5.70	3.83	1.87	.79	2.37
96	551	5.63	4.03	1.60	.82	1.99
100	440	5.42	3.46	1.96	.87	2.25
104	542	5.90	3.98	1.92	.82	2.34
Ave.	509	5.51	3.85	1.66	.76	2.16
						1.08

TABLE XXI continued

THE INFLUENCE OF BREED ON ENERGY REQUIREMENTS

150 DAY PERIODS

Heifer	Average Weight	Net Energy per Day			Gain per day	Energy	
		Total received	For Maintenance (Armsby)	For Growth		for 1 lb. gain	Energy per day per cwt.
.No.	Lbs.	T.	T.	T.	Lbs	T.	
<u>Holsteins</u>							
245	632	6.25	4.40	1.85	.83	2.23	
249	457	5.49	3.55	1.94	.76	2.41	
274	486	4.46	3.72	.74	.96	.77	
272	624	5.75	4.38	1.37	.99	1.38	
275	487	4.61	3.72	.89	1.30	.68	
276	513	5.04	3.87	1.17	1.26	.93	
263	606	7.13	4.79	2.34	1.48	1.55	
262	592	6.26	4.38	1.88	1.17	1.61	
264	650	9.99	4.49	5.50	1.61	3.42	
279	485	5.11	3.72	1.39	1.28	1.09	
244	581	5.61	4.17	1.44	.95	1.52	
248	583	5.56	4.19	1.37	.64	2.11	
252	691	6.50	4.67	1.83	.63	2.90	
255	444	4.99	3.49	1.50	.91	1.64	
260	587	5.42	4.19	1.23	.68	1.81	
Ave.	561	5.91	4.09	1.82	1.03	1.77	1.05

TABLE XXI continued

INFLUENCE OF BREED ON ENERGY REQUIREMENT

Heifer	Length of Period	Ave. Wt.	Net Energy per Day			Gain per day	Energy	
			Total	For Mainten- ance (Armsby)	For Growth		for 1 lb. gain	Energy per day per cwt
No.	Days	Lbs.	T.	T.	T.	Lbs.	T.	
<u>Ayrshires</u>								
318	100	572	6.44	4.12	2.32	1.22	1.01	
320	80	551	8.78	4.03	4.75	1.87	2.54	
316	150	651	5.52	4.49	1.56	1.08	1.44	
317	100	561	6.27	4.08	2.19	1.24	1.76	
325	30	491	4.43	3.74	.69	1.60	.43	
326	60	486	4.55	3.72	.83	.68	1.22	
Ave.	87	552	6.00	4.03	2.06	1.27	1.62	1.09
<u>Jerseys</u>								
101	50	525	5.81	3.92	1.89	1.52	1.24	
98	150	561	4.81	4.08	.73	.34	2.15	
96	150	551	5.63	4.03	1.60	.82	1.99	
100	60	498	5.39	3.80	1.59	.72	2.21	
105	120	518	5.89	3.89	2.00	.58	3.44	
104	150	565	5.90	3.98	1.92	.82	2.34	
125	150	527	5.70	3.92	1.78	.79	2.25	
126	30	469	4.84	3.63	1.21	.90	1.44	
121	150	583	5.08	4.19	.89	.90	.99	
Ave.	112	533	5.45	3.94	1.51	.82	1.84	1.02

TABLE XXI continued

INFLUENCE OF BREED ON ENERGY REQUIREMENT

Heifer	Length of Period	Ave. Wt.	Net Energy per day			Energy	
			Total received	For main- tenance (Armsby)	For Growth	Gain per day	Energy 1 lb. per day per cwt
No.	Days	Lbs.	T.	T.	T.	Lbs.	T.
<u>Holsteins</u>							
246	30	593	7.36	4.24	3.12	1.83	1.59
244	150	581	5.61	4.17	1.44	.95	1.52
248	150	583	5.56	4.19	1.37	.64	2.11
245	90	610	6.08	4.31	1.77	.92	1.92
260	150	587	5.42	4.19	1.23	.68	1.81
263	90	572	6.83	4.12	2.71	1.45	1.87
262	110	578	6.60	4.17	2.43	1.19	2.04
264	80	577	8.59	4.15	4.44	1.70	2.61
258	40	607	9.30	4.28	5.02	2.05	2.45
254	30	593	7.12	4.15	2.60	1.43	1.82
279	30	518	5.51	3.89	1.62	1.30	1.26
276	90	562	5.13	4.08	1.05	1.08	.97
Ave.	87	580	6.59	4.17	2.42	1.27	1.90
							1.14

TABLE XXII

INFLUENCE OF BREED ON ENERGY REQUIREMENT
SUMMARY

Weight	Net Energy per Day			Energy for 1 lb. gain	Gain per day
	Total Received	Per cwt.	For Growth per cwt.		
Lbs.	T.	T.	T.	T.	Lbs.
<u>Ayrshires</u>					
564	6.41	1.14	.39	1.97	1.12
552	6.00	1.09	.37	1.62	1.27
558	6.20	1.12	.38	1.79	1.19
<u>Jerseys</u>					
509	5.51	1.08	.33	2.16	.76
533	5.45	1.02	.28	1.84	.82
521	5.48	1.06	.31	2.00	.79
<u>Holsteins</u>					
561	5.91	1.05	.32	1.77	1.03
580	6.59	1.14	.40	1.90	1.27
570	6.25	1.09	.36	1.83	1.15

SUMMARY AND CONCLUSIONS

1. From a study of the subject under consideration it is apparent that an accurate knowledge of the energy requirements for the growth of dairy animals is exceedingly limited. What information there is available has been derived from rather incomplete investigations of the requirements of beef animals. The beef animal because of a greater daily gain and also because of the difference in the character of the gain, due to a larger proportion of fat, offers a somewhat different problem from a dairy animal.

2. As far as may be determined from a short trial with two young animals, the energy required for the maintenance of these heifers is practically the same as the requirements as given in Armsby's standard.

3. The energy requirement of young heifers for maintenance and growth is higher, to the hundredweight, than for an older animal and the requirement decreases with the age of the heifer.

4. The energy requirement, in excess of maintenance, for a pound of gain is less for a young heifer than for an older animal and the requirement increases with the age of the heifer.

5. The young heifer makes much better gains for the energy received than an older animal and seems to use

the energy of her ration more efficiently. The common explanation given for this is that the gains made by young animals contain more water and protein and less fat than those made by a more mature animal. However, practical observation leads us to believe that an older heifer subsisting principally on roughage is not putting on any more fat than the younger animal.

6. The total energy requirement of heifers increases with the weight of the animal.

7. The energy requirement of heifers for a pound of gain increases with the size of the animal.

8. The energy requirements for the growth, including maintenance, of heifers as given by Armsby appear to be high, especially for the more mature animals.

9. The energy requirement for one pound of gain as given by Armsby is high as compared to the requirement of normal heifers whose records were studied. This is especially true of the heavier animals, probably due to the fact that Armsby's figures evidently apply to animals of the beef type.

10. Our data indicate that heifers making normal gains require less energy for a pound of gain than when making gains below or above normal.

11. Heifers below normal in weight at the beginning of the period probably require less energy for gains made on normal rations than those that were over weight at the beginning.

12. Calculating the net energy values of the feed according to Armsby's table, the heifers seem to make better use of the energy supplied in a ration made up principally but not entirely of roughage than from a more concentrated ration.

13. Heifers on a high plane of nutrition had uniformly high energy requirements in every respect.

14. The energy requirement of heifers is not affected by the amount of protein in the ration, provided sufficient protein is furnished for normal growth. If the heifers are not fed sufficient protein for normal growth, and make low gains, the result is a high energy requirement for a pound of gain.

15. Breed has no apparent effect on the energy requirement of heifers.

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DEPARTMENT OF AGRICULTURAL CHEMISTRY

April 11th 1919.

Dean Walter Miller,
Graduate School,
211 Academic Hall.

My dear Dean Miller:

I have read the thesis submitted by
J. R. Dice and it is my opinion that it
meets the general standard that has been
established in the University for the Master's
dissertation.

Yours sincerely,

A handwritten signature in cursive script, reading "Robert Moulton". The signature is written in dark ink and is positioned above the typed name.

Professor Agricultural Chemistry.

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Scanning system software	Omni scan v. 12.8 SR2 (2675)
Optical resolution	600 dpi
Color settings	grayscale, 8 bit
File types	tiff

Source information

Format	Book
Content type	Text
Source ID	010-100702884
Notes	Pages typed and single-sided. Title page has signature and perforated property stamp. Some pages have handwritten marginalia and corrections. Approval letter follows thesis.

Derivatives - Access copy

Compression	Tiff compressed with LZW before conversion to pdf
Editing software	Adobe Photoshop CS5
Resolution	600 dpi
Color	Grayscale
File types	pdf
Notes	Grayscale pages cropped, canvassed, and images brightened. Blank pages removed. Canvas size: 8 x 11