SIMPLE VERSUS COMPLEX RATION FOR LACTATING DAIRY COWS

THESIS FOR THE DEGREE OF M. S.

Russell E. Horwood

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THESIS

Feeding & feeding stuffs

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Thesis

Respectfully submitted to the Graduate School of Michigan State College in partial fulfillment of the requirements for the degree of Master of Science.

By

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INTRODUCTION

Variety in the ration of lactating dairy cows is usually considered necessary in order to insure the presence of all the dietary factors, especially the essential amino acids.

The ordinary home grown feeds for dairy cattle in Michigan are alfalfa, clover and timothy hays; corn silage, sunflower silage and roots for succulence; and barley, oats and corn for grain. A home grown ration usually consists of a hay, silage or roots, and one or more of the cereals. Such a ration even when a protein concentrate is added to furnish a sufficient quantity of protein is considered by most investigators to be lacking in the quality of protein necessary to maintain good health, reproduction, and a high level of milk production.

Consequently many dairymen purchase a variety of protein feeds to supplement home grown rations. Milk could be produced more economically if the cheapest protein supplement supplied the essential amino acids.

It is the purpose of this investigation to compare a simple ration consisting of home grown feeds supplemented with cottonseed meal, with a complex ration consisting of the same home grown feeds supplemented with wheat bran, cottonseed meal, linseed oil meal and gluten feed, for milk production.

REVIEW AND DISCUSSION OF LITERATURE

The importance of variety in the ration of dairy cows has long been emphasized. The opinion prevails that a variety of feeds is more likely to contain all the dietary factors than a simple ration. However, simple rations composed largely of home-grown feeds are usually less expensive. The prevailing low prices of dairy products and the prospect that they will continue makes it highly desirable that a cheaper ration consisting largely of home-grown feeds, that will be suitable for high milk production and satisfactory reproduction be worked out. Such rations have been considered to lack in some of the essential amino acids, especially when non-legume hays were used in the ration.

REQUIREMENT OF PROTEIN IN RATION OF DAIRY COW

Quality as well as quantity of protein is essential in the dairy cow's ration for satisfactory production and reproduction. In 1911 Hart, McCollum, Steenbock and Humphrey (1) fed dairy cows on restricted rations from the wheat, corn and oat plants. They found that rations from different plant sources balanced in regard to supply of digestible organic nutrients and production therms were not alike in respect to general vigor, size, and strength of offspring and capacity for milk secretion.

Hart and McCollum (2) secured results that are not in harmony with the theory that the failure of swine to grow on corn alone is due entirely to the incomplete nature of its protein content.

Hart and Humphrey (3) in 1919 showed that it is impossible to furnish dairy cows of high milk producing capacity with a protein level of sufficient magnitude or quality to maintain that capacity from a clover, corn silage, cereal grain mixture, the latter being made up of corn, barley, oats or a mixture of the three. Cows of low mammary capacity and large food capacity were kept in nitrogen equilibrium. One animal produced 22.24 pounds of milk daily for 16 weeks and maintained nitrogen equilibrium on such a ration. They concluded that with the present knowledge a safe procedure for maintenance of high milk production is through the use of a high plane of protein intake which although of low relative efficiency should be drawn from the plant protein concentrates rather than those of animal origin. These same investigators (4) after feeding dairy cows on rations in which the protein was furnished with milk were able to maintain a nitrogen balance with production as high as 35 pounds of milk daily. However, negative balances resulted when the protein was derived from either corn or wheat grain. The milk protein had an efficiency for milk production and tissue restoration of about 60 per cent; corn

40 per cent, and wheat 36 per cent. These investigators concluded "That the quality of the protein is an important factor in maintenance and production and that the synthetic powers of the mammary gland will not compensate for deficiencies in protein structure". They suggest that the efficiency of a protein depends upon its structure.

From experiments with rats and monkeys McCollum, Simmonds and Pitz (5) concluded that "Failure to maintain a normal state of nutrition on a diet of corn is due to a poor relationship among the inorganic constituents and to its lack of quantity and quality of protein". From other feeding trials these investigators stated that "Complete success in nutrition of rats with strictly vegetarian diets of but three natural food stuffs and the failure attending a wider variety in the food mixture emphasizes the fallacy of the assumption that the safest plan to insure perfect nutrition is to include a wide variety in the selection of the constituents of the diet. Until definite knowledge is obtained, variety will unquestionably make for safety but will not by any means assure safety and can scarcely secure the optimum results in any considerable per cent of the cases."

In a study of simple home-grown rations for dairy cows Bowling (6) found ground oats, alfalfa leaf meal, alfalfa hay and corn silage as efficient in maintaining three high producing cows on a positive nitrogen balance as a more com-

plex ration made up of alfalfa hay, corn silage, corn, oats, wheat bran, linseed oil meal and cottonseed meal.

Following carefully conducted investigations Nevens (7) showed that there is little if any foundation for the claim that protein of a variety of feeds will be used more efficiently than the proteins in simple mixtures made up of one or two farm grains and a single protein supplement, when good quality roughages and properly balanced grain mixtures are used. He suggests, however, that rations be made up of at least four different kinds of feeds.

Protein

Amino Acids

The ability of proteins to maintain body weight, milk production, and satisfactory reproduction depends upon their amino acid content.

Osborn and Mendel (8) stated that new tissue involves the synthesis of new protein. Growth will be limited, therefore, by any factor which prevents this synthesis. The lack of any component amino acid which cannot be manufactured directly in suitable amounts in the body represents such limiting factors. This explains why adequate growth has never been obtained with rations which fail to furnish sufficient proportions of certain amino acids such as tryptophane, lysine, or cystine. These investigators stated further (13) that "Obviously the relative value of the different proteins in nutrition is based upon their content of those special amino acids which cannot be synthesized in the animal body and which are indispensable for certain distinct, as yet not clearly defined processes, which are expressed as maintenance or repair."

From experiments with rats Hawk and Bergeim (9) found that at least four amino acids are absolutely essential for normal development. They are lysine, tryptophane, cystine and tyrosine. Life without these amino acids is impossible. They stated that histidine has been added to this list and proline may be required. Synthesis of unessential amino acids probably takes place in the animal's body.

From a survey of experimental work Mathews (10) stated that "It appears that rats and mice at any rate cannot make sufficient lysine, tryptophane, cystine and tyrosine to supply their needs and that these amino acids must be present in the diet."

Following the feeding of different isolated proteins to rats Osborn and Mendel (11) stated that proteins are called incomplete because they lack one or more of the essential amino acids.

Hart, Nelson and Pitz (12) in reporting upon experiments with rats stated "The evidence makes it very probable that the mammary gland has not the capacity to synthesize the amino acid, lysine. The evidence also supports the view that as far as the proteins are concerned milk secretion, like growth, is ultimately dependent upon the quality and quantity of amino acids ingested in the food."

Lysine Osborn and Mendel (13) succeeded in promoting growth in rats at a normal rate when a maintenance ration containing glaidin as the sole protein was supplemented with lysine. They stated "These feeding trials in conjunction with our demonstration of the almost complete cessation of growth on a diet containing only lysine free proteins furnished the first and only conclusive demonstration that lysine is indispensable for the function of growth". Other work reported by these investigators (8) (14) demonstrated that zein of maize as the sole protein can be made adequate for maintenance and even slight growth by additions of both lysine and tryptophane. Failure of animals to grow or even be maintained when zein is the sole form of nitrogenous food intake for any considerable period has been widely recognized.

Gliadin protein of wheat, hordein of barley and zein of maize were called incomplete proteins by Osborn and Mendel (11) because they lack one or more essential amino acids. None of them furnish glycocoll or lysine. In experimental work with chickens these investigators (15) found that corn gluten permitted only a very slight growth. This was due to the fact that it contains some maize glutenin, a protein which yields tryptophane as well as a little lysine. They conclude that chickens as well as rats require a sufficient amount of lysine in order to make normal growth and that this

will doubtless be found true for other species. In further experimental work with rats these investigators (16) found that to maintain normal growth 15 per cent of casein was the least that could be fed. Normal growth could be maintained on 12 per cent casein plus lysine equal to two per cent of the casein. When less than 12 per cent casein was included in the diet the lysine caused some improvement in growth.

Using rats Hawk and Bergeim (9) found lysine to be one of the amino acids absolutely essential for normal development. Life without this amino acid is impossible.

Mathews (10) concluded that rats and mice at any rate cannot synthesize sufficient lysine to supply their needs but that it must be present in the diet.

In a feeding trial with two lots of chickens on a high and low lysine ration Buckner, Nollan and Kastle (17) found that the high lysine ration gave normal growth while the low lysine ration materially stunted their growth.

Geiling (18) following an experiment with mice concluded that "Lysine does not appear to be necessary for the maintenance of adult mice."

Lewis and Root (19) found that gliadin comprising 18 per cent of the diet was inadequate for normal growth of the white rat. It did, however, permit maintenance or slow growth. When lysine was added in amounts equivalent to three per cent of the protein in the diet without further altera-

tions it renders the diet adequate for normal growth. These results agree with the work of Osborn and Mendel. Neither dl-nor d-nor-leucine is able to supply the deficiency of a gliadin diet as does lysine. Nor-leucine replaced by lysine insures normal growth. No evidence was found that the white rat can substitute nor-leucine for lysine in the synthesis of its body protein for growth.

Hart, Nelson, and Pitz (12) stated that "The evidence presented in this paper makes it very probable that the mammary gland has not the capacity to synthesize the amino acid lysine". On a lysine free diet young rats were born but were not successfully nursed.

Tryptophane Ackroyd and Hopkins (20) found that when tryptophane was removed from the complete amino acid diet of rats they not only discontinued growth but lost in weight.

Wheeler (21) discovered that mice fed zein lost on the average one-third of their weight in 25 days while two mice which had an addition of tryptophane equal to three per cent of zein fed lost only about one-fifth of their original weight by the fifteenth day, thus showing the effect of the small amount of tryptophane on body maintenance.

Willcock and Hopkins (22) observed that zein is the only nitrogenous constituent unable to maintain growth in young mice. The addition of tryptophane, an amino acid absent from the decomposition products of zein to this dietary did not

make it capable of maintaining growth. It did, however, greatly prolong the survival period and materially aided the well being of the animals.

Hawk and Bergeim (9) using rats found that tryptophane was absolutely essential for normal development. Without it life was impossible.

Mathews (10) concluded that rats and mice at any rate cannot synthesize sufficient tryptophane to supply their needs but that this amino acid must be present in the diet.

Osborn and Mendel (8) (13) found that tryptophane can <u>not</u> be synthesized in the animal's body. They stated "The need for tryptophane and lysine is governed by the 'Law of Minimum'." The rate of growth increases with increased amounts of these amino acids furnished by the food until the normal rate is attained. A certain minimum amount of tryptophane is essential for maintenance without growth. Zein can be made adequate for maintenance and even slight growth by additions of both lysine and tryptophane. Zein failed to promote growth satisfactorily even with the addition of plenty of tryptophane, unless two per cent or more lysine was furnished with the protein. This emphasizes the indispensability of tryptophane for maintenance and lysine for growth.

Berg and Rose (23) found that tryptophane when administered to tryptophane deficient basal diets exerted a marked influence upon the rate of increase in body weight thus supporting growth as well as maintenance. Feeding half daily allowances each 12 hours induced better growth than when the total daily allowance was administered at one time. More frequent feeding appeared to exert little if any influence. These same investigators (24) later found that acetyltryptophane and tryptophane ethyl ester hydrochlorde were utilized for growth just as satisfactorily as free tryptophane. Thus these tryptophane derivatives are used for growth in place of tryptophane. Also 3-indolepyruvic acid added to tryptophane deficient diets leads to an immediate resumption of growth in rats at a rate quite comparable to that induced by the equivalent quantity of tryptophane. This synthetic product is probably substituted for tryptophane by being transformed into the amino acid. This they stated "Is proof of replacement of an indispensable amino acid by a synthetic compound."

Cystine Osborn and Mendel (8) stated that adequate growth has never been obtained with rations which failed to furnish sufficient proportions of the amino acid cystine. They also found (16) that the minimum amount of casein which the food must contain in order to promote normal growth was 15 per cent. Twelve per cent casein failed to support normal growth until cystine equal to three per cent of the casein was added. These same investigators (27) following work with rats stated "The addition of cystine equivalent to three per cent of the casein used effected considerable economy in the availability

of this protein." By replacing cystine with alanine they failed to bring about any nutritive advantages.

Hawk and Bergeim (9) found with rats that cystine was absolutely essential for normal development. In fact life without this amino acid was impossible.

Mathews (10) stated "It appears from these experiments that rats and mice at any rate cannot make sufficient cystine to supply their needs but that this amino acid must be present in the diet."

Lewis (25) concluded that the addition of small amounts of cystine to the diet of dogs on a low protein diet diminished the loss of nitrogen from the body and favorably influenced the nitrogen balance. This result was interpreted to be a specific demand for cystine for metabolic purposes since tyrosine and glycocoll added to the diet under like conditions of experimentation did not diminish the nitrogen loss or influence the condition of nitrogen equilibrium.

Muldoon, Shiple and Sherwin (26) found after several trials that the dog was unable to synthesize cystine.

Beadles, Braman and Mitchell (28) were able, by adding cystine to a ration whose protein was so low as to be a limiting factor in growth and deficient in this amino acid to increase its value for the promotion of hair growth in the albino rat.

Lightbody and Lewis (29) found that the amount of hair was related to the protein content of the diet but under their experimental conditions the demand for protein (and cystine) for the growth of hair appeared to be secondary in importance to the demand for growth of the body with its more essential tissue.

Woods (30) found that rats stunted for eight weeks by the absence of cystine were able upon returning cystine to the ration to resume growth at a rate fully normal for their size and make normal records in reproduction and the rearing of young. The basal ration was whole milk over diluted with starch, minerals and vitamins.

Westerman and Rose (31) secured results which they stated showed conclusively that "Neither synthetic dithiodglycollic acid or B-dithiodproipionic acid when fed to rats are capable of serving in the place of cystine and producing growth despite the close similarity in chemical structure. This evidence also shows that dithiodglycollic acid in the presence of cystine leads to a subnormal growth apparently due to either toxic or in some other manner exerts an inhibitory influence upon the growth process. B-dithiodiproipionic acid produces little if any effect or influence providing an adequate amount of cystine is present."

Lewis and Lewis (32) conducted experiments in which taurine and cystinic acid were fed to young white rats on two types of diet in which cystine was the limiting factor. They obtained no evidence showing that either taurine or cystinic acid could replace cystine entirely or in part for the purpose of growth in the absence of an adequate amount of cystine in the diet.

Sherman and Merrill (33) found that cystine is the first limiting amino acid of the protein of cow's milk for the growth of young rats.

Cystine was found in experiments with rats by Sure (34) to be the primary growth limiting factor of the protein, lactalbumin. The results suggested that protein free milk contains either cystine or organically bound sulphur which the animal organism can transform into cystine.

Sherman and Wood (35) were able to make determinations of cystine by means of feeding a diet in which cystine was the growth limiting factor. When this ration was fed to carefully standardised young rats with or without graded additions of cystine it was found possible to determine a direct linear or arithmetical relationship between the added cystine fed and the added growth thereby induced up to an added gain of 10 grams in an experimental period of six weeks. This induced growth was brought about by graded additions of cystine from 0.025 to 0.04 per cent with added gains obtained up to 17 grams.

Parallel experiments with graded additions of casein to the same basal diet gave correspondingly graded responses in growth. With these results an arithmetical proportion was worked out to interpret the amount of cystine furnished by casein. Results indicate casein contains 1.3 to 2.5 per

cent cystine or that three-eighths to three-fourths total sulphur in casein is cystine or cystine plus other sulphur containing radicals which are interchangeable with cystine in nutrition. This lower limit was higher than the amount obtained by analytical methods.

A diet of cooked lima bean meal supplemented with 0.3 per cent of cystine together with other necessary non-protein dietary ingredients according to Flinks and Johns (36) furnished adequate protein for the normal growth of albino rats. A similar diet to which no cystine was added, merely maintained the weight of the experimental animals. Growth did not occur if the diet consisting of either raw or cooked lima bean meal was not supplemented with cystine although the other non-protein dietary factors were added.

Following experiments with rats Haag (37) stated that "There can be no reasonable doubt concerning the effectiveness of cystine in improving the nutritive value of rations in which protein is supplied by alfalfa leaves. These experiments are interpreted as demonstrating a deficiency of cystine in the mixed crude protein of alfalfa".

In feeding experiments with young rats Rose and Huddlestun (38) showed that taurine is totally incapable of replacing cystine in the diet for the purpose of growth.

It is stated by Mitchell (39) that cystine added to a cystine deficient diet will improve its growth promoting

value in animal nutrition. It is convertible into cystine in anabolism. No evidence was obtained indicating that taurine possesses this property.

Geiling (18) stated, following experimental work with mice, that cystine appeared to be necessary for the maintenance of adult mice.

Tyrosine Diets containing zein as the only nitrogenous constituent were found by Willcock and Hopkins (22) to be unable to maintain growth in young mice. The addition of tyrosine, which is already present in zein, had no effect in maintaining growth or adding to the well being of the animal.

It was found by Totani (40) that rats may exhibit almost normal growth when the supply of tyrosine is diminished to an extremely small amount. These results differ from those of Abderhalden who fed a dog a preparation of the digestive products of caseinogen freed from tyrosine as completely as possible, that lost weight to the extent of 750 grams in nine days. Loss of weight was almost entirely regained when tyrosine was again added to the diet.

In feeding experiments conducted by Abderhalden (41) in which a diet low in tyrosine was fed to rats, it was found that for a period of 12 weeks growth was independent of the tyrosine content of the food.

Lewis (25) found in feeding trials with dogs that the addition of small amounts of tyrosine added to the low protein diet did not diminish the nitrogen loss or influence the condition of the nitrogenous equilibrium.

Tyrosine was found to be the secondary growth limiting factor in the protein lactalbumin by Sure (34). He also found that protein free milk gave qualitative tests for tyrosine.

Mathews (10) stated that it appeared from experiments with rats and mice that these animals at any rate cannot make sufficient tyrosine to supply their needs but that these amino acids must be present in the diet.

Using rats Hawk and Bergeim (9) found that tyrosine was one of at least four of the amino acids absolutely essential for normal development. In fact, life without it is impossible.

Histidine The importance of histidine in the diet of a young rat was demonstrated by Harrow and Sherwin (41a). They found imidazol pipwic acid able to replace histidine to some extent in the diet. However, imidazol lactic acid was much more efficient in this capacity, while imidazol acrylic acid was less so. They found imidazol alone to have no value when used with a histidine free diet.

Cox and Rose (42) found upon adding non-amino acids to a ration from which most of the histidine had been removed that some rats failed to inhibit the loss in weight occasioned by deficiency of histidine. The addition, however, of dl-B-4 imidazole lactic acid to this diet caused an immediate resumption of growth at a rate slightly slower than that induced by the equivalent quantities of histidine. This synthetic product is capable of serving in place of histidine, probably through being transformed by the cell into the amino acid. This they stated "Is the first successful attempt by growth experiments, to replace an indispensable amino-acid of the diet by a non-amino-acid." These investigators (43) concluded from later work that growing animals receiving diets deficient in histidine but adequate in every other respect to meet the nutritive requirements of the organism that neither adenine, guanine, creatinine, creatine, nor a combination of these compounds is capable of functioning in place of the missing amino acid. These results are interpreted as indicating that the reaction of purine synthesis from histidine is an irreversible one in the animal organism.

Berg, Rose and Marvel (24) reported that 4-imidazole lactic acid induces the growth of rats upon a histidine deficient diet.

<u>Histidine and Arginine</u> Rats upon arginine-histidine free amino acid mixtures were found by Rose and Coy (44) to be neither able to grow or maintain weight but promptly and continually lost weight. The addition of histidine to such a ration resulted invariably in an immediate resumption of

growth at a normal rate. Histidine was thus shown to be an indispensable component of the diet. In contrast to histidine the addition of arginine to the deficient diet exerted no influence upon growth even when the quantity added was more than equivalent to the sum of the arginine and histidine present in the native casein which was used in this diet to furnish the nitrogen and which allowed rats to grow to maturity providing the arginine and histidine were not removed, although at a rate somewhat slower than normal. It is evident therefore, that arginine and histidine are not mutually interchangeable in metabolism. These same investigators (45) stated that further experiments with three rats showed the total inability of arginine to assume the functions of histidine.

In studies made by Ross and Cook (46) of creatine and purine metabolism in growing rats upon diets in which the nitrogen was supplied respectively in the form of casein, completely hydrolized casein from which histidine and arginine had been precipitated by the Kossel-Kutscher procedure, the diets of whole casein and completely hydrolized casein led to excretion of progressively increasing quantities of total creatinine, allantain and uric acid, which were roughly proportioned to the increments of the body weight of the animal. On diets of hydrolized casein from which histidine and arginine had been precipitated the output of allantain

decreased 40 to 50 per cent. Uric acid excretion also decreased but the variation from normal values was not quite so great as for allantoin. Total creatinine manifested an increase followed by a decline but did not fall below the level seen on an adequate ration.

The effect upon purine metabolism was not attributed solely to loss in weight of rats on deficient diets as indicated by experiments in which a deficiency of tryptophane was induced. On rations adequate in every respect except tryptophane content the animal steadily declined in weight but the output of the allantoin and uric acid remained quite constant.

The adding of histidine to diets which component hydrolized casein had been subjected to silver-precipitation, lead to increase in excretion of total creatinine, uric acid, and allantoin until the same as animals on whole casein. On the contrary the addition of arginine to deficient rations failed to effect the output entirely. Thus, this evidence pointed out that arginine and histidine are not interchangeable in purine metabolism.

There was no relationship observed between the arginine content of the diet and total creatinine elimination of urine. This may be due to the fact that none of the diet is completely devoid of arginine.

Ackroyd and Hopkins (20) using rats found the removal of arginine and histidine from a diet otherwise made up to meet the amino acid requirement resulted in a sharp decline in weight. The decline in weight after a time became less rapid than in the case of tryptophane deficiency. There seems to be some adjustment to the lack of arginine and histidine. When one of these two amino-acids was present, however, there was no loss in weight such as follows when both are absent, in fact there was maintenance and even slight growth. It appears that the body with some efficiency can utilize one amino acid vicariously for another.

Geiling (18) stated that "Arginine and histidine seem to be interchangeable in nutrition. Full grown mice are able to hold their weight when either one of them together with cystine is present in the ration. In the absence of both, loss of weight results."

Zein can be made ideal for growth by adding arginine and histidine in addition to lysine and tryptophane according to Osborn and Mendel (8).

Other Amino Acids A response to proline was secured by Sure (47) on a six per cent edestin level, in the presence of cystine and lysine in some animals and in the presence of cystine, lysine and arginine in others in feeding trials with rats. The author thus concluded that "Proline is an essential amino acid for growth."

Hawk and Bergeim (9) found that glycocoll can be synthesized in the animal's body. They stated that "Synthesis of unessential amino acids probably takes place in the animal's body".

Mathews (10) stated that "Experiments show that at least glycocoll can be synthesized in large amounts in the animal body."

Lewis (25) in adding small amounts of tyrosine and glycocoll to the diet of dogs on a low protein diet did not diminish the nitrogen loss or influence the condition of nitrogen equilibrium.

From the evidence presented in the review of literature it appears that the amino acids, tryptophane, cystine, tyrosine and histidine, are essential for growth and maintenance and that lysine is essential for growth. There is some evidence that arginine and proline are essential for maintenance and growth and that arginine may be interchangeable with histidine.

Protein Level

Following three experiments on the food of maintenance Haecker (148) drew the conclusion that with cows at rest in comfortable stalls a ration containing 0.06 pounds digestible protein per hundredweight of cow would be ample for maintenance.

Ellett, Holdaway and Harris (155) used 24 cows in an experiment to determine the feeding standard for milk production. They found that each pound of milk required 0.053 pounds of digestible protein and 0.315 therms net energy for its production on a basal ration. The addition of more protein to the basal ration slightly increased the digestibility and cows gained in weight but the efficiency of the protein utilization was slightly lower. Using actual digestibility co-efficients and deducting body gains of protein the selected basal ration and basal protein cows produced results closely in accord, being 0.042 pounds and 0.046 pounds of digestible protein per pound of milk. This standard would allow 0.5 pounds of digestible crude protein and 6.0 therms for maintenance per 1000 pounds of live weight.

A ration containing one pound of digestible protein per 1000 pounds live weight was found by Hill, Beach, Borland, Washburn and Story (156) to serve the purpose for not overly heavy milking cows. When one and one-half pounds were used there was a certainty of serving the purpose. Two pounds of

protein allowed a slight increase in milk and two and one-half pounds were quite unnecessary.

Hill (157) stated that the protein and maintenance requirement for 1,000 pound dry-non-pregnant dairy cow was 0.5 pounds true protein or 0.6 pounds digestible crude protein and six therms of energy or its equivalent of 0.5 pounds total digestible nutrients. For fetal construction no additional non-nitrogenous nutrients were needed. However, the protein intake requirement was 0.05 to 0.1 pounds in addition to requirements for maintenance and milk production. One and one-half pounds of protein per 1,000 pounds live weight were sufficient for reasonable good milk yield, body maintenance and a healthy full sized calf. The author concluded that during the first two-thirds of the gestation period the ration should contain nutrients for maintenance and milk production. This would also serve the purpose of fetal construction during this period. The last one-third of the gestation period, when little if any milk is being produced, a maintenance ration plus a ration needed for the milk being produced plus twice the total digestible nutrient content of the new born calf would meet the requirements.

Forbes and Swift (158) using a group of 45 balanced periods, averaging 18 days, with farrow Holstein Friesian cows in the first half of a lactating period producing an average of 42.6 pounds of milk per day on a plane of feed

intake sufficient on the average to maintain slight nitrogen storage and live weight equilibrium found the average utilization of feed nitrogen for milk production and body gain was 31.6 per cent ± 0.4 per cent and utilization of utilizable nitrogen (feed minus maintenance) was 38 per cent ± 0.5 per cent.

Forbes, Fries and Kriss (159) in studying the maintenance requirement of cattle for protein as indicated by the fasting katabolism of dry cows found the daily nitrogen excreted in urine during the last four days of a nine day fasting period was 46.5 grams for one cow and 43.6 grams for a second cow per 1000 pounds of live weight. These nitrogen values are equivalent to 0.62 and 0.58 pounds of body weight respectively or 0.6 pounds as an average per 1000 pounds live weight, which figure is identical with Armsby's published estimate of the crude digestible protein maintenance requirement of cattle. It is 0.1 pound less than Morrison's Standard (0.7 pounds) which may be considered as providing more liberally for reproduction and other exigencies of practice. This may not represent the minimum protein requirement during feeding in which case an abundant supply of non-nitrogenous nutrients may reduce katabolism of protein to an amount less than that during fasting. The figures for protein katabolism of fasting, therefore, when

used as a measure of protein maintenance requirement during feeding must be considered as providing a certain margin of safety.

Perkins and Monroe (160) found no marked difference in digestibility of a very low protein ration observed between cows long accustomed to a ration and others recently transferred from a ration containing a liberal supply of protein.

From an extensive experiment with 40 cows over a year's time Savage (161) in 1930 found a 16 per cent protein grain mixture as efficient for milk and butterfat production as a 20 per cent and a 24 per cent mixture when fed with mixed hay and corn silage.

The review of literature indicates that 0.6 pounds of digestible protein per 1,000 pounds of live weight is ample for maintenance and 0.05 pounds of digestible protein in addition for each pound of 3.5 per cent milk produced.

Energy

Haecker (147) found that a standard ration should contain 25 pounds of dry matter, 2.5 pounds of digestible protein, 12.5 pounds of carbohydrates and 0.4 pounds ether extract of fat for cows weighing 1,000 pounds in ordinary working condition. From feeding trials carried on later (148) he concluded that with cows at rest in comfortable stalls a ration containing 11.5 pounds of dry matter containing 0.06

pounds of digestible protein, 0.6 pounds carbohydrates and 0.01 pounds ether extract per hundredweight of cow would be ample for maintenance.

Ellett, Holdaway and Harris (155) found that each pound of milk requires 0.053 pounds of digestible protein and 0.315 therms of net energy for its production on a basal ration equivalent to 0.053 pounds of digestible protein, 0.12 pounds digestible carbohydrates and 0.019 pounds of digestible fat or 0.053 pounds of digestible protein and 0.3 pounds of total digestible nutrients. These amounts gave the most economical results from the standpoint of efficient use of protein, although the cows lost live weight slightly. The addition of more carbohydrates to the basal ration reduced the digestibility though the cows gained in body weight. Therefore, the above amounts of carbohydrates and fat are the maximum to use. Additional protein added to the basal ration slightly increased the digestibility and cows gained in weight but the efficiency of the protein was slightly lower. These results indicated that 0.5 pounds of digestible crude protein and 6.0 therms of energy are necessary for maintenance of a 1,000 pounds of live weight.

The maintenance for dry-non-pregnant cows was found by Hill (157) to be 0.5 pounds of true protein or 0.6 pounds of digestible crude protein and six therms of energy or its equivalent, 6.48 pounds total digestible nutrients per 1,000 pounds of live weight.

The net energy requirement for cattle was found by Armsby (162) to be 6.00 therms per 1000 pounds of live weight and 0.238 therms per pound of 3.5 per cent milk produced.

The review of literature indicates that approximately 6.00 therms of energy are required for maintenance and 0.23 therms for each pound of 3.5 per cent milk.

Vitamin

The importance which vitamins play and the problem of supplying them differs with different animals and the types of foods they ordinarily consume. A review of the literature will indicate the possibility of a simple ration furnishing vitamins for dairy cows.

Vitamins - General

It was concluded by McCollum and Davis (48) after feeding a ration containing protein, carbohydrates, fats and salt that there are certain other unidentified substances indispensable for growth and prolonged maintenance. They found that growth could not take place when highly purified casein, dextrin, salt mixture, liberal amounts of water and alcohol soluble accessory were fed. Both water soluble and fat soluble accessories must be present before growth can take place. Growth during a period of a few weeks on diets of isolated food stuffs is an indication that both classes of

accessories are retained in the lactose and casein as impurities. A high degree of purity must be attained in order to eliminate these substances.

It was stated by Nevens (7) in 1931 that dairy cattle receiving rations containing well cured legume hay in liberal amounts with well balanced grain rations are not likely to suffer from deficiencies of vitamins. Pastures and legumes are the best source of vitamins. Farm grains and seeds and most milk by-products contain at least moderate amounts of vitamins. There is no known advantage in adding vitamin rich substances to rations for milk production.

Studies were made by St. Julian and Heller (49) on the effect of vitamin deficiency upon the co-efficient of digestibility of proteins, fat and carbohydrates. This was done by comparing metabolism of animals on a diet deficient in a given vitamin with metabolism of animals on the same diet plus the vitamin. Vitamins A, B, B_2, D and C were studied. in case of each of these vitamins the co-efficient of digestion of protein, carbohydrates and fat were the same in the animals on deficient rations as in those which received a complete diet. It would appear unlikely, therefore, that the digestive process is effected by the vitamins studied.

<u>Vitamin A</u> Lindquist (136) stated that vitamin A is necessary for growth and prevents xeropthalmia.

Studies were made by Jones, Eckles and Palmer (136) using nine calves, which show that vitamin A is an indispensable factor in the diet of calves. The characteristic symptoms of vitamin A deficiency in other species of animals including failure to grow, xerophthalmia, respiratory troubles, diarrhea and death, occur in herbivora as represented by calves. When cod liver oil was added to the vitamin A deficient ration a resumption of growth and a disappearance of symptoms took place. It required less than one per cent of cod liver oil in a ration otherwise practically free of vitamin A to allow calves to grow normally. It was found that vitamin A was present in large amounts in the liver of calves fed normal rations but is absent from the liver of calves fed vitamin A deficient rations.

In feeding a ration devoid of roughage consisting of whole milk, to calves from birth to six months of age, plus a concentrate mixture fed ad libitum and made up of 400 pounds rolled barley, 300 pounds rolled oats, 300 pounds wheat bran, 100 pounds linseed meal and 8 pounds salt, with the roughage replaced by an amount of alfalfa ash equal to that supplied by a normal alfalfa hay ration Mead and Regan (52) found that calves can be reared to 19 months of age and normal growth secured providing cod liver oil is added to supply vitamin A.

<u>Vitamin B</u> Vitamin B, according to Lindquist (51) protects against neuritis and beri-beri.

Eckles, Williams, Wilbur and Palmer (53) found upon adding vitamin B in the form of dried yeast to the ration ordinarily fed on dairy farms that it did not increase the rate of growth of calves from 20 to 180 days of age. No definite effect was observed on the health of these calves.

When a dried yeast preparation was added at the rate of 25 grams per pound of milk produced to a ration commonly fed in good dairy herds, Eckles and Williams (54) found it did not increase the milk or fat yield. Further, no effect could be observed in the condition of the animal or on the appetite.

Bechdel, Eckles and Palmer (55) found that calves will grow to maturity and produce normal offspring on a ration that carries insufficient amounts of vitamin B to support growth and general well being in rats. They stated that if calves possess a physiological requirement for vitamin B similar to other animals, the deportment of experimental calves described can be explained only on the basis of vitamin B synthesis by bacteria and other microorganisms in the digestive tract unless further investigation should prove that various species of animals differ materially in vitamin B requirement. It was found further that milk produced by cows fed on rations deficient in vitamin B is apparently, but not markedly, reduced in its vitamin B content.

Investigations by Bechdel, Honeywell, Dutcher and Knutsen (56) showed that vitamin B complex was produced in the rumen of their experimental cow by bacteria fermentation. These results offer a satisfactory explanation as to why cattle, unlike any other species of animal yet studied, have the ability to grow to maturity, to reproduce normally and to produce milk of normal dietary composition on a ration that carries an insufficient amount of vitamin B complex to support growth and well being in rats.

Vitamin C   Lindquist (51) stated that water soluble C vitamin prevents scurvy, bone disease, and partial paralysis.

It was found by Thurston, Eckles and Palmer (57) that calves do not require vitamin C in quantities that can be measured by the present methods of testing food materials for their antiscorbutic potency by feeding them to guinea pigs. They stated that "Under practical conditions even where very poor feeding practices are followed there is little if any reason to believe the well being of the calf will be affected by a shortage of vitamin C. These same investigators (58) later found vitamin C in the liver of calves fed for one year on a ration capable of producing scurvy in guinea pigs within 30 days. They found that heifers fed from birth on a scorbutic diet secreted appreciable quantities of vitamin C in the milk. The absence of vitamin C apparently does not in-

interfere with reproduction. It is probably that vitamin C is synthesized within the body of the bovine. Evidence is supplied to indicate that the digestive tract is not concerned in this synthesis.

Vitamin D It was shown experimentally in 1922 by McCollum Simmonds and Becker (59) that cod liver oil oxidized 12 to 20 hours does not cure xerophthalmia in rats. It does, however, cause deposition of calcium in the bones of young rats which are suffering from rickets. They concluded that oxidation destroys fat-soluble A without destroying another substance which plays an important role in bone growth. This evidence demonstrates that the power of fats to imitate the healing of rickets depends on the presence in them of a substance which is distinct from fat soluble A. Thus these experiments clearly demonstrate the existence of a fourth vitamin whose specific property as far as we can tell at present is to regulate the metabolism of the bones.

In 1929 Sheehy and Senior (60) added six to eight ounces of cod liver oil daily to the ration of three milking cows which were fed on a winter ration of hay, roots and meal and had reached the 14th, 11th and 19th weeks respectively of their lactation periods. They found that it did not alter the calcium or phosphorus content of the milk produced.

Hart, Steenbock, Tuet, and Humphrey (61) found alfalfa hay cured inside no more potent in antirachitic properties than alfalfa cured under the best sunning conditions in Wisconsin. "All the hays studied possessed measurable antirachitic properties, however, none of these hays fed in our ration at a level of about 10 pounds per day were able to maintain calcium equilibrium in a liberally milking cow." These same investigators found from another experiment (62) that the feeding of one-half pound daily of cod liver oil, potent in vitamin D, showed no favorable influence upon the calcium assimilation of liberally milking cows. The vitamin D in cod liver oil was poorly absorbed, if at all, from the intestinal tract.

In 1930 Hart, Steenbock, Kline and Humphrey (63) conducted an experiment in which irradiated yeast, potent in vitamin D, showed no positive influence in improving the lime assimilation of liberally milking cows receiving alfalfa hay, corn silage, grain and grain by-products although vitamin D was absorbed into the blood as evidenced by the enrichment of the milk in this factor. The composition of the blood in respect to calcium and inorganic phosphorus was not changed during this irradiated yeast feeding period, nor was the per cent of calcium and phosphorus changed in the milk. The milk production was well sustained during eight months of irradiated yeast feeding and there was no indication of disturbance of physiological functions during this period.

Steenbock, Hart, Hanning and Humphrey (64) increased the antirachitic potency of milk by feeding 50 grams of irradiated yeast to lactating dairy cows. Two hundred grams did not lower the milk production or butter fat content altho 10 grams showed some effect on the antirachitic potency of butter fat. They found 180 grams of cod liver produced similar results to 10 grams of the yeast.

In an experiment in which cows were exposed daily to sunlight or artificially generated ultra violet radiation, Steenbock, Hart, Rising, Hoppert, Basherov and Humphrey (65) found little if any effect on the antirachitic potency of milk. No improvement in milk or butter fat secretion was observed. They concluded that, "The superiority of summer produced milk and butter fat must therefore have origin in other factors than sunlight acting directly on the cow."

These investigators also found that direct exposure of goats to the radiation of a quartz mercury vapor lamp increased the antirachitic value of its milk very decidedly. Ultimately the goat showed a very decidedly negative calcium balance although at first there was a slight improvement in calcium retention.

Gulickson and Eckles (66) stated that "So far as could be measured by general observations, weights and rate of skeletal growth, the absence of sunlight was without effect upon calves kept in darkness from the age of one week to two years. Normal reproduction also occurred.

Results secured by Huffman (67) indicate that calves require vitamin D. Calves fed a basal ration low in this vitamin and kept from sunlight developed rickets, while calves fed the same ration and turned into an open lot where they were exposed to the sun were normal. Calves fed the same ration plus cod liver oil and kept out of the sunlight did not manifest symptoms of rickets, thus indicating that calves are able to use vitamin D in cod liver oil. The addition of two pounds of sun cured timothy hay per day prevented the onset of rickets in calves fed this basal rachitic ration and kept away from sunshine.

"It is likely", the author concluded, "that such hay is the principle source of vitamin D for dairy cattle during the winter months. These results also explain why calves under ordinary farm conditions fail to show rickets during winter. Calves eat hay at an early age which probably furnishes sufficient vitamin D for normal growth and for prevention of rickets."

Vitamin E The vitamin E requirement of cattle is not known altho several investigators have demonstrated that this vitamin is necessary for normal reproduction in rats.

Vitamin G Hussemann and Hetler (69) found that to produce successful lactations in rats both vitamins B and G must be present in the diet. It may be that there is a definite quantitative relationship which exists between these two vitamins. They found that either vitamin B or G in quantities above and added to the maintenance level of the vitamin B complex yields more successful lactation. In view of the fact that as successful results followed the use of autoclaved yeast, a source of vitamin B free from vitamin G, as were obtained when tikitiki a source of vitamin B also containing vitamin G was used in addition to the maintenance level of yeast,it seems possible that the added vitamin G is the more important for successful lactation.

The review of literature on the vitamin requirement for the dairy cow indicates that vitamin A and D are necessary for satisfactory growth; that vitamin B is synthesized in the rumen and C in the body. Little is known regarding the requirement of vitamins E and G by the dairy cow.

Mineral

A large number of experiments have been conducted in recent years on the mineral requirement of dairy cattle and the factors which influence mineral retention. The review of literature will cover only calcium and phosphorus although it is known that there are other minerals which are needed. However, they are provided in most cases in the normal ration by adding salt. Iodine is also needed where goiter is prevalent.

Calcium and Phosphorus

It was found by McCollum and Davis (70) that with other factors adequate, young rats can grow normally and remain in apparently good health on diets whose base content varies widely in amount. The growth and well-being was not markedly interfered with on highly acid rations. However, no reproduction took place which shows that the ration was not sufficiently adequate.

Meigs and Woodward (71) concluded that ordinary rations are more likely to be deficient in one or both of the principal bone building elements than any other constituents. Cows fed for several years on ordinary rations with little or no additional pasture may result in milk yields being reduced below optimum. This may be corrected by feeding legume hay plus grain with a high phosphorus content and three to four times the protein and two to three times the total nutrients needed for maintenance during two months' dry period.

Becker and Eckles (73) found that milk remained normal in calcium and phosphorus even under conditions of osteomalacia so severe as to show marked symptoms in the animal resulting from an extreme and long continued shortage of phosphorus.

From an experiment to determine the value of a mineral supplement of 80 per cent dicalcium phosphate plus 20 per cent carbonate for dairy cows fed on a ration supposedly de-

ficient in lime, Lindsey and Archibald (73a)(74) found that the cows with one exception maintained their general condition. The cows on the mineral supplement, however, remained in slightly better condition and made considerable gain in weight while those not on the mineral showed little change. The mineral supplement showed little effect on the growth of young cows and heifers. There was no effect on quality or quantity of milk. From the standpoint of reproduction neither group had serious troubles. The mineral supplement group was slightly nearer normal and had somewhat better calves. None of these differences were sufficiently striking to warrant a general recommendation of this mineral. They stated, "With cows producing 5000 to 8000 pounds of milk, fed normally good quality roughage, the need of mineral supplement was not indicated. The average cow has a considerable margin of safety." "For heavy producers, 10000 pounds, it is probably good insurance to supply lime and phosphorus, but the efficiency of such a practice is by no means well established." The same cows used in this experiment produced 12000 pounds of milk on a low ash ration. Four and one-half years of previous work indicated that the benefits derived from adding steamed bone meal to the ration of dairy cows was very slight.

It was found by Turner and Hartman (75) that two cows receiving an excellent dry ration consisting of well cured

alfalfa hay, mangel beets, and a good grain mixture (calcium and phosphorus ratio 1.09/1.19) and yielding 27 and 22 kilograms of milk daily remained in prevailingly negative calcium and phosphorus balance throughout a period of seven weeks.

Huffman, Robinson and Winter (76) found in a series of calcium and phosphorus balances on cows when in heavy, medium and low milk production and when dry that a ration of timothy hay, corn silage, and grain furnished sufficient calcium and phosphorus for the production of at least 10,000 pounds of milk per year. During the height of production the animals were frequently in negative balance but subsequently positive balances made up the loss. A positive calcium and phosphorus balance was obtained in heavy milking cows when this ration was supplemented with bone flour. A cow milking 80 pounds of milk a day showed positive calcium and phosphorus balances. There was a tendency for cows to utilize both calcium and phosphorus more efficiently when in high production than when in low production or when dry. The total intake of calcium and phosphorus was considered to have a greater significance in the utilization than the calcium phosphorus ratio.

Ellenberger, Newlander and Jones (77) fed a ration consisting of timothy hay, corn silage and a good grain mixture during the barn feeding period with fresh pasture clippings

being substituted for silage and most of the hay during the usual pasture season to which was added in three trials both steamed bone meal and ground limestone as mineral supplements. They found that all cows ended their trials with positive balances. When the mineral supplements were fed the negative periods were noticeably shortened. The negative balances appeared to be normal during the early part of the lactation period and to be compensated by rapid storage as lactation and gestation periods progressed. The cows in this experiment produced from approximately 10,000 to 18,000 pounds of milk yearly.

<u>Calcium</u> On a ration of alfalfa, silage and grain Huffman, Robinson and Winter (76) obtained positive calcium balance in heavy milking cows. They found the low calcium ration was utilized more efficiently than the high.

Meigs (72) stated following his experimental work on the mineral requirement of dairy cows that, "There is every reason to believe that stall fed cows can be kept in calcium equilibrium only by feeding large quantities of roughage high in calcium as alfalfa." There is no doubt that mineral deficiencies play an important practical part in the feeding of dairy cows as practiced in many parts of the country when fed dry feed and silage. He stated further that "Deficiencies of phosphorus are less common than calcium." Less apt to have a deficiency of calcium if cows are on pasture. He further questioned the value of mineral supplements.

The adding of a mineral supplement furnishing lime to the ration of cows, sheep and horses when the forage fed is grown in acid soils and of a non-legume type was recommended by Hart, Steenbock and Morrison (78).

Salmon and Eaton (81) secured data which showed that two ounces of steamed bone meal per animal per day did not have a decided effect on the growth in weight or height of three Jerseys and one Holstein. The character of the growth was very similar to that of comparable heifers that did not receive any mineral supplement except common salt. The ration used was low in calcium.

Monroe and Perkins (82) conducted eight balances of phosphorus, calcium, magnesium and nitrogen on four cows that had always been restricted to dry feed and on four cows from the regular herd pastured the previous summer. The rations used were identical. A 30 pound level of daily milk production was secured. The calcium balance formed the chief difference between the dry feed and the regular herd group. Taking 36 days as a unit all these balances were negative. The negative balances of the regular dairy herd amounting to approximately 8.5 grams daily, which were more than double the losses sustained by the dry fed cows.

Reed and Huffman (83) stated "Cows producing less than 10,000 pounds of milk a year, receiving rations containing a high quality hay do not need additional calcium."

It was found by Miller (84) in balanced experiments of calcium and phosphorus with liberally milking dairy cows that there was a better assimilation of calcium when clover hay instead of timothy was fed as a part of the ration which included corn silage and a grain mixture. There was, however, little variation in the calcium and phosphorus content of the milk.

It is stated by Scott (85) that "Many Montana forage crops while plentifully supplied with calcium are deficient in phosphorus."

Following experimental work on the assimilation of calcium fed as calcium gluconate, Turner, Kane, Hale and Wiseman (86) stated "A supplement of calcium gluconate was of little value in improving the calcium and phosphorus balance of cows giving 19 to 21 kilograms of milk daily. A supplement of limestone also gave inconclusive results."

Four cows were maintained under herd conditions on a ration of timothy hay, a grain mixture of corn meal 30 pounds, wheat bran 20 pounds, cottonseed meal 25 pounds, linseed oil meal 25 pounds and salt one pound, and corn silage for a period of 14 to 32 months by Hartman and Meigs (87). They found that the relative amount of ash, calcium, phosphorus, nitrogen and organic matter in cows' bones were little if at all altered by long periods on rations low in calcium even when a considerable amount of milk is given in such periods. This treatment reduced from 10 to 20 per cent the total weight

of the bones and therefore the amount of calcium and phosphorus in the body. The results indicate that even on a mediocre roughage the calcium assimilation tends to be somewhat higher in long periods under natural conditions than shown by most balanced experiments. These results also indicate that in case of good cows it may be much higher than shown by most balanced experiments.

No consistent and favorable influence on calcium assimilation in dairy cows was found by Hart, Steenbock and Kline (88) through the daily addition of three pounds of cirelose glucose to a standard ration of hay, silage, cereal grains and cereal grain concentrates. The daily ingestion of 115 to 230 cc. of 40 per cent hydrochloric acid increased the calcium excretion in urine with a greater net loss of calcium to the animal than when no acid was fed. The calcium absorption from the intestine was slightly improved through the use of mineral acids. What factors in green plant tissue operate in securing for the cow a better utilization of the calcium in the green plant tissue or added calcium salts was not solved by the technique used in the above experiment.

The causes of rickets or disease of the bone according to Huffman (67) are low calcium, low phosphorus, improper relation of calcium and phosphorus, and deficiency of vitamin D in the ration, or insufficient amounts of ultra violet light.

Calcium content of feeds by Forbes, Boyle and Mensching (163) expressed in parts per 100 of dry matter.

Barley	0.043*
Oats	0.112
Wheat bran	0.139
Cottonseed meal	0.291
Linseed oil meal	0.403
Corn gluten meal	
Mixed hay (timothy)	0.192
Sunflower silage	

*Expressed by Sherman (164) in percentage of edible portion.

The review of literature indicates that cattle require a certain amount of calcium for satisfactory growth, reproduction and milk production.

Phosphorus   Theiler, Green and Du Toit (165) found that in certain areas phosphorus is a limiting factor in the growth of young stock, in the condition of older cattle and in the milk yield of cows. The demands for phosphorus are least for mere maintenance, intermediate for growth, and highest for milk production. Bran is useful for dairy stock or high grade animals receiving supplementary rations in the ordinary course of events. These authors concluded, "In all areas where soil and pasture are known to be deficient in phosphorus it is profitable to feed bone meal to practically

all stock for the sake of improving conditions and facilitating rapid growth. For cattle it is particularly advisable since two important diseases, lamsiekte and styfsiekte, can be prevented by liberal bone meal feeding. When insurance against disease, increased beef production, increased milk yield and more rapid growth of young cattle are all taken into consideration, it will be found that any expenditure on bone meal is repaid many times over."

Meigs (72) stated in 1923 that "Deficiencies of phosphorus are less common than a calcium deficiency".

Following experimental work conducted by Hart, Steenbock and Morrison (78) they stated "Phosphorus added as sodium phosphate to the ration of a dairy cow during her dry period has been found to increase her milk flow the following lactation period."

Eckles, Becker and Palmer (79) stated "If the dry matter of food contains less than 0.2 per cent phosphorus it is classed as phosphorus deficient and more than 0.5 per cent is classed as phosphorus rich. On grass pastures with the presence of vitamin D and sunlight, cows may get along on less than this amount although it is not possible to demonstrate the effect of sunlight in the case of cattle." He found that poor roughage and grain containing only moderate amounts of phosphorus will not furnish sufficient amounts for dairy cattle. There is some relationship between the

phosphorus and calcium. Rations deficient in calcium may result in phosphorus starvation even when there is enough phosphorus in the ration.

Experiments conducted in 1922 by Monroe (80) showed that the narrow ration would permit a greater phosphorus retention than a wide ration.

In a calcium and phosphorus experiment with regular herd cows pastured the previous year and dry fed cows, Monroe and Perkins (82) found the regular herd cows retained only 0.9 grams and 1.4 grams phosphorus daily while dry fed cows retained 3.9 and 4.5 grams daily. The type of water used had no apparent effect.

Reed and Huffman (83) stated, "Phosphorus is the mineral element most likely to be deficient in the ration of dairy cattle."

Miller (84) found that a better assimilation of phosphorus occurred when more ample provision was made for the element in the grain mixture. The percentage of phosphorus in the milk seemed to increase slightly in response to an increase in the supply in the feed.

Hart, Beach, Delwiche and Bailey (89a) reported Pica, (depraved appetite), which they stated is probably due to low phosphorus roughage and to grazing on pasture low in phosphorus. Six cows suffering from this disease were fed the following two rations with and without cod liver oil: alfalfa hay, corn silage, 35 pounds yellow corn, 25

pounds wheat bran, 5 pounds of oil meal and salt; mixed hay, corn silage and a grain mixture of 45 pounds ground oats, 50 pounds yellow corn, and 5 pounds steamed bone meal plus salt. It was found that the rations were equally effective in correcting the phosphorus deficiency and that the cod liver oil did not appear to improve the ration.

Becker and Eckles (73) stated that "Data indicate that a shortage of phosphorus in the ration over a long period of time may become the limiting factor in milk production."

It was found by Scott (85) that many Montana forage crops while plentifully supplied with calcium are deficient in phosphorus. This phosphorus deficiency results in calcium excess when forages are fed to animals and this is physiologically detrimental to cattle, giving rise to various mineral-deficiency disorders.

Phosphorus content of feeds by Forbes, Beegle and Mensching (163) expressed in parts per 100 of dry matter.

Barley	0.400*
Oats	0.434
Wheat bran	1.233
Cottonseed meal	1.479
Linseed oil meal	0.786
Corn gluten meal	
Mixed hay (timothy)	0.123
Sunflower silage	

*Expressed by Sherman (164) in percentage of edible portion.

The review of literature indicates that cattle require a certain amount of phosphorus for satisfactory growth, reproduction and milk production.

SOURCES OF REQUIREMENTS

Protein

The discussion of the literature of protein requirements brought out the fact that certain proteins are essential for maintenance, growth and milk production in animals. Some of the sources of these proteins for dairy cattle are cited.

Proteins of Roughage

It is stated by Krauss (89) that dairy rations made up of hay, silage and grain contain relatively large amounts of non-protein nitrogen. This nitrogen is apparently useful in meeting a part of the protein requirement of a cow in milk.

Larsen, Wright, Jones, Hoover and Johnson (90) stated in 1920 that there is a possibility of one protein undergoing changes to supply entirely or in part the substances ordinarily furnished by another form of protein although it is doubtful if one protein can replace another entirely.

Hay It was found by Hart, Humphrey and Morrison (61a) that on total nitrogen ingested the utilization of nitrogen for growth was as efficient from alfalfa hay as from the

corn kernel and the storage of nitrogen was essentially alike on the two rations. The sudden change from one feed to another did not change the nitrogen content of the urine or the feces. This is evidence that the amid nitrogen was being used as the true protein nitrogen. The data shows full value for growth can be given to the total nitrogen of the alfalfa hay. Two years later Hart and Humphrey (62a) stated that experimental data shows that on the plane of intake used the nitrogen of the alfalfa is as effective for milk protein building as that of the corn kernel. In addition the amount of nitrogen absorbed from the digestive tract on the two rations was very closely alike, approximately 60 to 65 per cent of the total nitrogen ingested. The acid amid nitrogen of alfalfa is very low in amount being about one per cent of the total nitrogen and amino acid nitrogen 10 per cent. It is well established that amino nitrogen has a nutritive value and that of alfalfa probably is not an exception. Alfalfa was found to have a specific diuretic property and its ingestion was generally followed by a marked rise in the output of urine. This caused a decrease in milk flow which rose again as the alfalfa was withdrawn from the ration. This was as much as five to six pounds a day on a 25 pound daily flow.

Steenbock (91) stated that it is difficult to interpret results sometimes with alfalfa hay due to diuresis alone if urea diuresis can be taken as a type.

In 1916 Grindley (92) published the determinations of the basic amino acids of certain feeds and food materials according to the method of Van Slyke. The following table gives his results on roughage.

Percentage Total Nitrogen in Form of

	Arginine	Histidine	Lysine	Cystine	Non-protein
Alfalfa	8.0	3.9	4.4	1.0	19.1
Red Clover	6.9	5.0	2.6	0.9	13.5

Hart, Miller and McCollum (93) found that alfalfa was an excellent supplementary material to grain even in the presence of toxic material of wheat. Alfalfa undoubtedly introduces an abundance of fat-soluble A and a better salt mixture. Its richness in calcium may be important.

These results with alfalfa make it clear how successful growth even with omnivora can be obtained on a strictly vegetable diet and what an important part the leaf and stem portions of plants play in the life of the herbivora. When alfalfa constituted 20 to 25 per cent of a ration and middlings 20 per cent the toxicity of middlings was overcome, inadequacy of the grains disappeared and the animals remained sound and vigorous. Undoubtedly other roughages, as the leaves and stems of plants would serve similar purposes.

Investigations by McCollum, Simmonds and Pitz (94) indicate that the leaf is distinctly different from the seed in its dietary properties in two respects; its total inorganic content is very high and it is especially rich in both sodium and calcium, both of which are deficient in the seeds generally used. Mixtures of seeds failed to support growth (corn, wheat, oats, hempseed and millet). Rats on 20 per cent alfalfa plus 80 per cent maize grew noticeably better than those receiving higher planes of alfalfa leaf. Later McCollum and Simmonds (95) stated that the protein of alfalfa leaves when compared with seed protein as the sole source of protein showed no superiority.

Miller (96) in reporting on the nitrogen compounds of alfalfa hay stated that certain non-protein nitrogen composing 28 per cent of the total nitrogen easily extracted with water regardless of degree of fineness of hay. Alkali extracted more protein from finely grown material than from coarse. The protein extracted from alfalfa by dilute alkali had a nitrogenous content of 13 per cent and contained the basic amino acids arginine, histidine, lysine and cystine.

In the quantitative determinations of amino acids of feeds reported in 1921 by Hamilton, Nevens and Grindley (97) the average analysis of four alfalfa samples showed it to contain 2.628 per cent nitrogen and 19.09 per cent non-protein nitrogen.

Expressed as Per Cent of Total Nitrogen

	Total Non-protein N	Arginine	Cystine	Histidine	Lysine	Nitrogen
Alfalfa	19.090	7.996	0.991	3.931	4.434	2.628

Expressed as Per Cent of Feed

Alfalfa	0.5017	0.2101	0.0269	0.1033	0.1165	2.628

Roughages were found to have a higher non-protein nitrogen content and concentrates a lower content than cereals. Alfalfa found to be low in arginine, cystine and histidine and high in lysine as compared to oats, corn, and cottonseed meal. The total basic nitrogen as per cent of total nitrogen was 1.1735 per cent. In this report Hamilton, Nevens and Grindley gave their analysis of amino acids in alfalfa and expressed them in per cent of total nitrogen.

	Arginine	Cystine	Histidine	Lysine
Hamilton, Nevens & Grindley	8.00	0.99	3.93	4.43
Grindley & Associates	7.68	0.88	7.44	4.10

Mitchell and Villegas (98) found the content of digestible protein in alfalfa to be 10.6 per cent, the biological value of digestible protein to be 62 per cent and the content of net protein 6.6 per cent. As worked out with rats the calculations assume that no considerable supplemental effect of one protein upon another occurs and that biological values of digestible protein obtained with rats have a wide applicability to other species of animals and to other physiological functions than growth and maintenance. No data on other species of animals were sufficiently complete to permit of comparison with their data on rats.

Chibnall and Nolan (99) obtained samples of alfalfa when the plant stood two feet high and the flower buds were about to form by taking the top, six to eight inches with a scythe. The leaflets were found to contain 64 per cent of the total solids and 78 per cent of the total nitrogen of the plant cuttings. The fresh alfalfa contained 18.25 per cent dry solids and 1.08 per cent nitrogen.

The following table shows the distribution of nitrogen in the cytoplasmic and vacuole proteins from the leaves of alfalfa after hydrolysis with 20 per cent HCl for 16 hours.

	Cytoplasmic Protein		Vacuole Protein	
	Nitrogen	Protein	Nitrogen	Protein
Amid N	5.62%	0.90%	9.97%	1.32%
Humin N	2.85	0.45	2.11	0.28
Basic N	25.20	3.97	21.75	2.86
Other N (difference)	66.33	10.43	66.17	8.76
Total N	100.00	15.75	100.00	13.22

The following table gives Van Slyke's Analysis of the cytoplasmic protein after hydrolysis with 20 per cent HCl for 27 hours*.

	Nitrogen +	Nitrogen
Amid N	0.0271 gm.	5.51 gm.
Humin N in acid	0.0060 "	1.22 "
Humin N in lime	0.0072 "	1.46 "
Humin N in amyl alcohol	0.0002 "	0.04 "
Cystine	0.0041 "	0.84 "
Arginine	0.0753 "	15.32 "
Histidine	0.0152 "	3.09 "
Lysine	0.0490 "	9.97 "
Amino N in filtrate	0.2878 "	58.56 "
Non Amino N in filtrate	0.0157 "	3.19 "
Total N recovered	0.4876 "	99.20

Protein

Arginine	7.49%	(containing N 2.41%)
Histidine	1.79%	(containing N 0.48%)
Lysine	8.17%	(containing N 1.57%)
Total		4.46

Total nitrogen in aliquots used for analysis was 0.4915 grams *Nitrogen figures corrected for solubility of base + means of two determinations.

Later work indicated that cytoplasmic nitrogen is equivalent to about 14 per cent of the total leaf nitrogen.

The tryptophane and cystine content of alfalfa crude protein was found to be 2.86 and 0.93 per cent respectively by Jones, Gersdorff and Moeller (100).

It was reported by Vickery (101) that free amino acids make up a relatively small portion of the nitrogen of the alfalfa filtrate since only 13.6 per cent of the total nitrogen of alfalfa occurs as amino acid nitrogen in the fraction in which the simple amino acids are concentrated. Tyrosine was isolated in very small amounts. Indirect evidence of small proportions of polypeptide was found in the juices of the alfalfa plant.

Appreciable amounts of adenine, arginine, lysine, stachydrine, aspartic acid and tyrosine have been isolated by Vickery and Vinson (102) from the precipitate obtained by adding an excess of basic lead acetate to the concentrated protein-free juice of the alfalfa plant which was decomposed by hydrogen sulphide and the solution hydrolized with sulphuric acid.

It was found by Krauss (69) that non-protein nitrogen in hay and silage varies greatly in different samples, presumably due to different methods of curing, stages of maturity, and other factors. This large variation suggests that figures for true protein based on average analysis are of limited usefulness. Dairy rations made up of hay, silage and grain contain relatively large amounts of non-protein nitrogen. This nitrogen is apparently useful in meeting a part of the protein requirement of a cow in milk. There was no difference in protein metabolism when timothy or clover hay was fed as indicated by urine analysis.

In their report on "The Physiological Effects of Rations Restricted Principally or Solely to the Alfalfa Plant" Haag and Jones (103) stated that it is difficult to determine the extent to which dairy cattle restricted largely to alfalfa hay are merely suffering from underfeeding due to bulky nature of rations and to what extent specific nutritive factors are involved.

<u>Silage</u> Setola (104) made a determination of the biological values of the proteins of hay, corn silage and sunflower silage and found them to be 56, 94, and 67 respectively. A combination of one part alfalfa and three parts corn silage had a value of 81 while the mathematical mean calculated on this basis of the nitrogen that each contributed to the mixture was 64. This shows a difference of 17 due to favorable supplementary effects of the two proteins. Similarly a value of 62 was obtained from a mixture of proteins of one part alfalfa and three parts sunflower silage. The mathematical mean of 58 in comparison shows only a negligible supplementary effect.

Jones and Csonka (105) found corn (zea Mays) contained two glutelins, A and B. Analysis of the a-glutelin by the Van Slyke method showed the following percentages of amino acids.

Amid N	7.73%
Cystine N	2.04
Arginine N	15.11

Histidine N	2.81%
Lysine N	7.99

The Amid N in filtrate from bases was 59.64 per cent.

The leaves of Zea mays (ensilage corn) when three to four feet long and obtained about a week before tasseling were found to contain the following protein by Chibnall and Nolan (106). The Van Slyke analysis of the cytoplasmic protein was made after hydrolysis with 20 per cent hydrochloric acid for 28 hours.

	Nitrogen	Nitrogen
Amid N	0.0397 gms.	7.44 gms.
Humin N in acid	0.0102 "	1.91 "
Humin N in lime	0.0132 "	2.74 "
Humin N in amyl alcohol	0.0010 "	0.19 "
Cystine	0.0041 "	0.77 "
Arginine	0.0784 "	14.69 "
Histidine	0.0254 "	8.78 "
Lysine	0.0468 "	55.81 "
Amino N	0.2978 "	2.04 "
Non-amino N	0.0109 "	98.80 "
Total recovered	0.5275 "	

Means of two determinations.

Proteins of Cereals

From experiments conducted with pigs McCollum (107) concluded that while there was some variation among his experiments, the data showed that there is very little dif-

ference in the value for growth of the protein mixtures contained in the three cereal grains, wheat, oats and corn. A maximum of 23 to 24 per cent of the ingested nitrogen from one of these sources can be retained for growth. In one experiment in which the three grains were fed together in equivalent amounts they did not appear to give a very appreciable favorable influence on the nitrogen retention due to supplementary action of the protein from one source on those of another. No conclusion can be drawn from one experiment, however. It is conceivable that a mixture of two or more cereal grains in certain proportions may supply the amino acids necessary for growth in a very favorable fashion. The data is convincing that the protein mixture in each of these grains is singly, adequate chemically for the complete formation of the specific proteins of the pig body although quantitatively the possibility for this conversion is relatively low.

There was always a significant rise in the amount of nitrogen eliminated as creatinine in all cases where a fairly large amount of nitrogen was retained for growth. This would appear to strengthen the evidence that all the necessary cleavage products of protein necessary for the construction of metabolizing tissue in the animal were supplied by the proteins of each of the cereal grains employed.

The author stated that this throws no light on the value of the single grain ration for long continued growth and well being. He observed in pen feeding experiments after two or three months signs of inadequate nutrition.

McCollum and Simmonds (95) found that when seeds are improved from the standpoint of minerals and vitamins the limiting factor in determining their biological values is the protein.

It was found difficult if not impossible to obtain even a moderate amount of growth over an extended period on a diet restricted to the seeds of plants.

Seed protein yielded larger quantities of arginine and amid nitrogen than the leaf protein which may account for the difference in the total nitrogen of the two proteins.

Mitchell and Hamilton (110) stated that prolomines from cereal seeds are generally low in basic amino acids, particularly lysine and tryptophane. Prolomines differ from other proteins of its class by its relative high content of arginine and histidine nitrogen.

Albumins and globulins as a class appear to be better balanced with respect to the six amino acids, namely, arginine, histidine, lysine, tyrosine, tryptophane and cystine than prolomins although it makes up only a small per cent of the nitrogen of the cereal seeds. Cereal glutelins and prolamins account for most of protein in cereal seeds although it is difficult to characterize them relative to

their amino acid content. In general the lysine content is only moderately high and arginine less than that of the albumin and globulins. The tryptophane content is also only moderate, thus these proteins cannot be considered effective supplements to prolamins insofar as these amino acids are concerned.

The prolamins as a class are low in tryptophane and high in cystine according to Jones, Gersdorff and Moeller (100).

Corn Willcock and Hopkins (22) found that tryptophane was absent from the decomposition products of zein although tyrosine was present in this protein.

Zein was spoken of as an incomplete protein by Osborn and Mendell (108) because it lacks certain amino acids, namely, glycocoll or lysine and tryptophane.

It was found by Wheeler (109) that zein cannot replace more than half the protein in the food of mice if there is to be repair as well as maintenance.

Hart and Humphrey (62a) secured data which indicated that on the plane of intake used the nitrogen of the corn kernel is as effective for milk protein building as that of alfalfa hay.

Experimental work by Osborn and Mendel (14) showed that zein was the first most abundant protein of corn and maize glutelin was second. These two make up about 75 per cent of the corn protein. There is not much known about the rest.

Maize glutein has been shown to yield all the amino acids that zein lacks and it is also probable that the remaining proteins yield them. The amino acid deficiencies of zein therefore are thus more or less supplemented when the entire seed is fed.

Zein of maize was found by Osborn and Mendel (13) to be devoid of lysine, glycocoll, and the presence of tryptophane was questionable.

Grindley (92) made basic determinations of the basic amino acids of certain feeds according to the method of Van Slyke. He found in two different samples of corn the following amino acids as a percentage of total nitrogen.

	Arginine	Histidine	Lysine	Cystine	Non-protein
corn	8.7	4.8	2.2	1.1	9.8
corn	7.7	2.5	2.1	1.6	-

The proteins of the maize kernel were found by McCollum, Simmonds and Pitz (68) to contain all the amino acids essential for growth but their proportions were such that they cannot be utilized to a high degree as the sole source of protein. With other factors affecting nutrition properly adjusted growth was produced at about two-thirds normal over a six or seven months' period on a diet in which all protein was derived from 91 per cent ground maize. The authors stated they had seen pigs grow during several months when

the diet was restricted to the maize kernel fortified with additional maize protein (gluten feed and inorganic salt additions.) However, normal reproduction never occurred. The young were born but the mother failed to rear them.

Hogan (9a) found that tryptophane was the first and lysine was the second limiting factor in the protein of corn.

Mitchell and Hamilton (110) stated that zein is notably low in cystine. The per cent of total nitrogen in the form of amino acids given by these authors is as follows:

Prolamins	Character of Protein	Argi- nine	Histi- dine	Lysine	Tyro- sine	Trypto- phane	Cys- tine
corn	zein	3.6	1.3		2.8		0.5
glutein			2.1		2.7	0.14	0.6
corn	zeanin	9.4	3.9	4.5		1.0	1.0

Corn glutein was found by Osborn and Mendel (15) to permit a very slight growth with chickens, as well as of rats, because it contains some glutelin, a protein which yields tryptophane as well as a little lysine.

McCollum and Simmonds (95) found that lysine cannot be the limiting factor in maize kernel.

Nitrogen determinations made by Brewster and Alsberg (111) showed that corn contains 0.2220 grams of total nitrogen in a 12 gram sample. There was 7.75 per cent arginine and 2.06 per cent lysine, 2.46 per cent histidine and 1.60 per cent cystine of the total nitrogen.

The average of six analyses of corn by Hamilton, Nevens and Grindley (97) showed 1.4074 per cent nitrogen and 9.83 per cent non-protein nitrogen.

	Total non protein N	Argi-nine	Cys-tine	Histi-dine	Lysine	Nitro-gen
	Expressed as per cent total nitrogen					
corn contained	9.829	8.725	1.072	4.832	2.200	1.4074
	Expressed as per cent of feed					
corn contained	0.1383	0.0151	0.0680	0.0310	0.6573	1.4074

Total basic nitrogen as per cent of total nitrogen 16.83 per cent. These authors also gave the results for different investigators expressed in per cent of total nitrogen.

	Hamilton, Nevens & Grindley	Grindley & Associates	Nollan
Arginine	8.73	8.49	16.19
Cystine	1.07	2.68	4.06
Histidine	4.83	3.50	4.45
Lysine	2.20	1.17	8.53

In work with rats Mitchell and Villegas (98) found corn to have 7.5 per cent digestible protein, a biological value of 58 per cent digestible protein and 4.3 per cent content of net protein.

Berg (112) stated that many investigators working with many animals had shown that corn protein was inadequate. He also stated that zein is almost entirely lacking in lysine and trytophane. He also stated that when an animal is fed upon an inadequate protein, retention of the nitro-

gen may occur despite the decline in body weight.

The tryptophane and cystine content of corn as given by Jones, Gersdorff and Moeller (100) are as follows: zein protein, tryptophane none, and cystine 0.85 per cent. Zein from corn is entirely lacking in tryptophane.

Mitchell (113) fed corn protein at a five and at a 10 per cent level and found the average biological value to be 72.0 per cent and 59.6 per cent respectively. An increase in protein level lowered the biological value.

The mean values of histidine and tyrosine in zein (corn) were found by Hanke (114) to be 1.25 per cent and 3.66 per cent respectively.

Cystine was found in zein protein to the extent of 1.03 per cent by Folin and Marenzi (115).

Barley Hordein of barley was commonly spoken of as an incomplete protein according to Osborn and Mendell (108) because it lacked glycocoll and lysine. In later work (120) they found that rats failed to make more than slight growth on hordein from barley. Hordein was found to be very much like gliadin in physical properties and amino acids make up, and appears to have a similar value in nutrition. Although maintenance and reproduction occurred, the young left with the mother began to fail after about 30 days. In 1914 these same authors (13) stated that hordein of barley contained no lysine.

The determination of the basic amino acids in barley was made by Grindley (92) following the Van Slyke method. He found it to contain 9.5 per cent arginine, 3.6 per cent histidine, 2.2 per cent lysine and 1.3 per cent cystine and no non-protein nitrogen in the form of percentage of total nitrogen.

In experimental work conducted by Berg (112) it was found that barley as the sole protein was incapable of maintaining growth in chickens and rats. Hordein, the main protein of barley, contains lysine. Normal growth on 16 to 17 per cent protein ration was secured. Rye and barley are the only cereals capable of keeping up the nitrogen balance.

The tryptophane and cystine content of two samples of hordein protein of barley were found by Jones, Gersdorff and Moeller (100) to be 1.05 and 1.55 per cent respectively for the first sample and .44 and 1.47 per cent for the second.

Hanke (114) found hordein protein of barley to contain 1.25 per cent histidine and 3.66 per cent tyrosine.

The amino acid content of hordein and leucosine protein of barley was found by Mitchell and Hamilton (110) to be as follows:

Expressed in per cent of total nitrogen

Source	Character of protein	Arginine	Histidine	Lysine	Tyrosine	Tryptophane	Cystine
Prolamin Barley	Hordein	5.4%	(3.6%) (1.6%)	1.0%		(0.6%) (0.6%)	1.0%
Albumins Barley	Leucosine	11.6%	4.5%	8.4%		1.2%	1.5%
Glutelins Barley	Hordein	11.1%	2.0%	5.3%		1.1%	1.8%

Csonka and Jones (116) found as determined by the Van Slyke method a-glutelin of barley to contain 3.24 per cent cystine, 11.13 per cent arginine, 1.84 per cent histidine and 3.41 per cent lysine nitrogen.

Oats The amino acid content of oats was found by Grindley and cited by Mitchell and Hamilton (92), expressed in the form of total nitrogen, to be 11.6 per cent arginine, 5.8 per cent histidine, 2.8 per cent lysine, 0.9 per cent cystine and 12.9 per cent non-protein.

Oats in the dry state or subjected to germination were found by Funk (116a) to be an inadequate diet for young rats.

McCollum, Simmonds and Pitz (117) stated that "The oat kernel seems to contain protein of a poorer quality than either the maize or wheat kernel." Nine per cent of oat protein served, when all other dietary factors were properly adjusted to induce a small amount of growth at the beginning of the experiment, but cessation of growth always followed after about a month and thereafter the animals remained stationary in weight or declined.

The addition of a single dietary component as protein, inorganic salts, or fat soluble A did not supplement the oat kernel so as to induce appreciable growth. Supplementing the oat protein with casein or gelatin in the diet of rats improved the results, but did not, however, cause normal growth and reproduction.

According to McCollum and Simmonds (95) 26 per cent of ingested oats were retained for growth by rats. Four per cent of oat protein was found to maintain animals in better condition than six per cent wheat or maize protein. These authors stated that lysine cannot be the limiting factor in the oat kernel.

The average of six analyses of oats by Hamilton, Nevens and Grindley (97) showed 1.68 per cent nitrogen and 12.93 per cent non-protein nitrogen. The amino acid content of oats expressed as per cent of total nitrogen was found as follows:

Arginine	Cystine	Histidine	Lysine
11.647	0.944	5.786	2.841

Expressed as percent of feed:

0.0158	0.0973	0.0473	0.7079

These authors gave the amino acid content of oats as found by several investigators as follows:

	Hamilton, Nevens & Grindley	Grindley & Associates	Nollan
Arginine	11.65	11.42	11.42
Cystine	0.94	1.16	4.48
Histidine	5.80	4.32	9.58
Lysine	2.84	3.49	0.00

Oat protein was found incompetent to maintain normal growth in rats by Berg (112).

The average biological value of oats at a five per cent and a ten per cent level was found by Mitchell (113) to be 78.6 per cent and 64.9 per cent respectively. Increasing the protein level lowered the biological value.

The investigations of Jones, Gersdorff and Moeller (100) gave the following results as to tryptophane and cystine content of oat proteins.

	Per cent tryptophane	Per cent Cystine
Oat gliadin	none	3.48
Sorguim Prolamin	none	0.86
Emhirn "	0.47	1.85
Spelts "	1.08	1.79
Teosimite "	none	1.02
Emmer "	0.80	1.98

The prolamins of oats were found to be entirely lacking in tryptophane although they are high in cystine exceeding that of all other proteins.

In studies with rats Hartwell (118) found that oatmeal as the sole protein in the diet provided for growth in rats, however, at a slower rate than when given a mixed diet as kitchen scraps and bread and milk. Probably quantity rather than quality of protein was responsible for failure. The author concluded that the protein of oatmeal is of good value as regards growth in rats.

Csonka (119) found, using the Van Slyke method of analysis, oats to contain 13.46 per cent amid nitrogen, 1.99 per cent cystine, 15.30 per cent arginine, 3.49 per cent histidine and 5.45 per cent lysine.

Mitchell and Hamilton (110) pointed out that the low lysine content of oat globulin in conjunction with that of prolamin is worthy of note. The per cent of amino acids in the total nitrogen discovered by the authors in the different proteins of oats is as follows:

Source	Character of Protein	Arginine	Histidine	Lysine	Tyrosine	Tryptophane	Cystine
Prolamin Oats		6.4%	2.3%	0.2%			2.4%
Globulins Oats	Avenalin	15.0	8.3	3.5		0.9	1.0
Glutelins Oats	Avenin	14.4	7.2	4.4			1.5
Oats	Avenin	15.5	3.2	4.6			1.1
Oats	Avenin	15.3	3.5	5.4		1.0	2.0

Wheat It was found by Osborn and Mendel (120) that rats failed to make more than slight growth on gliadin from rye or wheat.

Wheeler (109) kept mice in health for five months in which the source of protein was that of either of the chief proteins of wheat.

Large quantities of wheat, in the swine ration, were found to be toxic by Hart, Miller and McCollum (93) even in the presence of all recognized factors for growth. Only with liberal quantities of all of these factors could the toxicity be overcome. They stated that it appears possible to produce similar pathological conditions in swine in the absence of all known toxic material and in the presence of a fair quality of protein, plentiful supply of fat soluble A and water soluble B, but a poor salt mixture, namely, that natural to the grain used.

Grindley (92) found wheat to contain 8.0 per cent arginine, 1.7 per cent histidine, 2.5 per cent lysine, and 1.3 per cent cystine, expressed in percentage of total nitrogen.

Investigations with swine by McCollum and Simmonds (92) showed them capable of retaining 20 per cent of protein ingested for growth. To secure normal growth it is necessary to double the protein over maintenance.

The following distribution of nitrogen in wheat was found by Brewster and Alsberg (111). The total nitrogen was 0.3333 grams in a 12 gram sample. There was 8.96 per cent arginine, 1.73 histidine, 0.87 per cent cystine and 2.65 per cent lysine expressed in per cent total nitrogen.

Berg (112) found glutein protein of wheat to be sufficient to maintain the body weight. On the other hand gliadin was quite inadequate largely due to lack of lysine and possibly tryptophane.

The tryptophane and cystine content of the proteins of wheat as reported by Jones, Gersdorff and Moeller (100) are:

	Per cent tryptophane	Per cent cystine
Wheat Gliadin	1.09	1.42
I "	0.70	1.68
II "	1.09	1.76

Hanke (114) found that gliadin contains 2.1 per cent histidine and 2.35 per cent tyrosine.

Protein Concentrates

Larsen, Wright, Jones, Hoover and Johnson (121) found that the proper interpretation of results obtained from substituting one protein feed for another in the ration of the dairy cow producing milk is a difficult one. Because of other factors effecting the results as energy supply and variation of milk production, it cannot be said that the most valuable protein is always the one which with the least quantity establishes and maintains approximate nitrogen equilibrium. Unless the energy content of the ration is abundant part of the protein will probably go to satisfy the energy requirement rather than the nitrogen requirement.

<u>Cottonseed Meal</u> The protein of cottonseed meal was found by Nollan (122) to contain 2.74 per cent cystine, 12.77 per cent arginine, 7.57 per cent histidine, 1.94 per cent lysine, and proline-oxy proline and tryptophane 7.49 per cent.

Grindley (92) found cottonseed meal to contain 18.7 per cent arginine, 7.2 per cent histidine, 4.2 per cent lysine, 0.9 per cent cystine and 6.2 per cent non-protein expressed in percentage of total nitrogen.

It was found by McCollum and Simmonds (95) that cotton seed proteins are of relatively good quality as indicated by the maintenance of body weight in all rats fed a ration where six per cent protein content was derived from this source.

Brewster's (111) analysis of a four gram sample of cottonseed flour showed 19.73 per cent arginine, 3.8 per cent histidine, 1.11 per cent cystine and 6.69 per cent lysine expressed in per cent of total nitrogen.

The amino acid content of cottonseed meal found by Hamilton, Nevens and Grindley (97) is as follows:

	Arginine	Cystine	Histidine	Lysine
Expressed as total N	18.705%	0.943%	7.171%	4.209%
Expressed as per cent of feed	1.2712%	0.0641%	0.4873%	0.286%

These investigators also expressed the findings of three groups of investigators.

	Hamilton, Nevens & Grindley	Grindley & Associates	Nollan
Arginine	18.71	19.52	12.77
Cystine	0.94	0.65	2.74
Histidine	7.17	5.47	7.57
Lysine	4.21	4.78	1.94

Nevens (123) found that when cottonseed meal furnishes the sole source of protein in a ration as 10 per cent crude protein the utilization of protein for growth of albino rats was 66 per cent. There was no clear cut supplementary effect of proteins of one feed upon another except when cottonseed meal and alfalfa were fed together and then only slight. No symptoms of toxicity were noted as a result of feeding cottonseed meal in rations over periods of seven months duration. It was (124) also found that cottonseed meal is remarkably high in arginine and histidine content. It is higher than any other feeding stuff examined up to 1921 with the exception of peanuts. It is reasonable to assume that the proteins of cottonseed meal have a high nutritive value. Lysine cannot be said to be exceptional in any particular. It seems apparent that combined proteins of cottonseed meal contain a sufficient amount of both cystine and lysine to render them adequate for nutrition.

Cottonseed meal (124) was found to contain twice as much arginine nitrogen and nearly twice as much histidine nitrogen as alfalfa, while alfalfa contains nearly three times the non-protein nitrogen. The difference in utilization of proteins of alfalfa and cottonseed meal was only four per cent. This difference is probably due to a difference in the quality of nitrogen. It may be due to the arrangement of the amino acids in the protein molecule or to the possible interchangeable ability of different forms of nitrogen in nutrition as histidine and arginine. It is questionable as to what extent non-protein nitrogen of alfalfa is utilized in maintenance. It is reasonable to assume that the higher content of basic amino acid of cottonseed meal is the reason for superiority over the protein of alfalfa and corn with corn also low in lysine content.

Mitchell and Villegas (98) found by working with rats that cottonseed meal containing 37 per cent digestible protein, had a net protein content of 24.4 per cent and a biological value of digestible protein of 66 per cent.

The tryptophane and cystine content of cottonseed globulin as given by Jones, Gersdorff and Moeller (100) was 2.58 and 1.07 per cent respectively. There is a high regard held for the proteins of cottonseed because of the tryptophane content.

The average analysis of four samples of cottonseed globulin by Folin and Marenzi (126) for tyrosine and tryptophane gave 3.64 and 1.34 per cent respectively.

Cottonseed meal injury in dairy cattle was found by Reed, Huffman and Addington (125) to be similar, if not identical to the injury produced when too much concentrates in proportion to roughage was fed. At least two pounds of cottonseed meal daily can be fed to calves five months of age or older which receive all the silage and hay of good quality they will eat. No appreciable difference was found in the sleekness of coats and pliability of the hide between heifers receiving cottonseed meal and linseed oil meal. Also there was no appreciable difference in the rate of food passage and the consistency of the feces.

Huffman and Moore (127) concluded, following experimental work with dairy cattle that cottonseed meal injury in dairy cattle is due to a lack of a factor or factors carried by good quality hay. Liberal feeding of cottonseed meal to dairy cattle from three months to four years of age along with ample hay of high quality and corn silage had no apparent effect on health, reproduction or lactation. The liberal

feeding of cottonseed to lactating dairy cows did not increase the susceptibility to udder infection.

Linseed Oil Meal In 1916 Grindley (92) found by analysis that linseed oil meal contained 15.9 per cent arginine, 6.1 per cent histidine, 3.7 per cent lysine, and 1.1 per cent cystine expressed in percentage of total nitrogen.

McCollum and Simmonds (95) found that 16 to 17 per cent of the nitrogen ingested as flaxseed protein can be retained for growth. Eight per cent of the flaxseed protein was required in the food mixture to maintain grown rats.

The average per cent availability of linseed oil meal was found by Larsen, Wright, Jones, Hoover and Johnson (121) to be 52.4 per cent to establish nitrogen equilibrium.

The tryptophane and cystine content of flax seed globulin was found by Jones, Gersdorff and Moeller (100) to be 3.98 and 1.20 per cent.

Soybean Oil Meal The amino acid content of soy beans was found upon analysis in 1915 by Nollan (122) to be 1.52 per cent cystine, 15.52 per cent arginine, 2.6 per cent histidine, and 7.06 per cent lysine.

It is stated by McCollum and Simmonds (95) that chemical methods show that the proteins of beans and peas contain all known amino acids necessary for nutrition and in no unsymetrical distribution as in case of wheat and maize protein. Eleven per cent of protein from either of these two seeds is required for maintenance.

Mitchell and Villegas (98) in working with rats found that soy beans have 30.7 per cent digestible protein, a 64 per cent biological value for digestible protein and a 19.6 per cent content of protein nitrogen.

The tryptophane and cystine content of glycine of soy beans was found to contain 1.66 and 1.12 per cent respectively by Jones, Gersdorff and Moeller (100).

Corn Gluten Feed   Larsen, Wright, Jones, Hoover and Johnson (121) found that the average per cent availability of gluten feed was 76.4 per cent. In all but two instances gluten feed protein seemed to show a higher relative value than linseed oil meal protein. The higher value may be due, not necessarily to the source of protein, but possibly in part to the increasing percentage of therms of net energy in the hay and silage.

Wheat Bran   Nollan (122) found that wheat bran contains the amino acids, cystine, arginine, histidine and lysine to the extent of 5.96, 12.53, 3.84 and 4.04 per cent respectively.

Jones, Gersdorff and Moeller (100) gave the tryptophane and cystine content of wheat as follows:

	Tryptophane	Cystine
Wheat Bran		
Prolamin	1.37%	2.29%
Globulin	2.85	1.52
Albumin	4.76	3.29

Wheat bran contains a protein, globulin, which is 25.2 per cent arginine, 4.1 per cent histidine, 12.6 per cent lysine, 1.6 per cent tyrosine, 2.2 per cent tryptophane and 1.0 per cent cystine.

The review of literature indicates that roughages as a whole are high in the amino acid, lysine, and low in arginine, histidine, cystine, tyrosine and tryptophane. The cereals are very low in lysine, tryptophane and tyrosine and high in arginine and histidine. The proteins of the concentrates, especially cottonseed meal, are very high in arginine and histidine. They contain sufficient amounts of cystine, tyrosine, and lysine and are given high regard especially because of the tryptophane content. Thus, a ration of roughage, cereal grains and concentrates furnishes all the necessary amino acids for dairy cattle.

Protein Content of Feeds Used in this Experiment

The digestible crude protein content of the feeds used in this experiment according to Henry and Morrison (128) are:

	Pounds Digestible Crude Protein per 100 lbs. Feed
Barley	9.0
Oats	9.7
Wheat Bran	12.5
Cottonseed Meal	37.0
Linseed Oil Meal	30.2
Corn Gluten Feed	21.6
Mixed Hay	4.7
Sunflower Silage	1.0

These feeds will furnish sufficient protein to meet the protein level for lactating dairy cows if fed in correct proportions and amounts.

Energy

The energy content of the feeds used in this experiment according to Henry and Morrison (128) is as follows:

	Total Digestible Nutrients per 100 lbs. of Feed
Barley	79.4
Oats	70.4
Wheat Bran	60.9
Cottonseed Meal	78.2
Linseed Oil Meal	77.9
Corn Gluten Feed	80.7
Mixed Hay	47.5
Sunflower Silage	12.6

These feeds will furnish sufficient energy to meet the requirements of lactating dairy cows if fed in correct proportions and amounts.

Vitamin

Nevens (7) stated that "Dairy cattle receiving rations containing well cured legume hay in liberal amount with well balanced grain mixtures are not likely to suffer from deficiencies of vitamins." Pastures and legumes are the best sources. Farm grains and seeds and most mill by-products contain at least moderate amounts of certain vitamins. There

is no known advantage in adding vitamin rich substances to rations for milk production.

Results secured by Hiller and St. Julian (143) indicated that after green leaves have become a potent source of vitamins through exposure to sunlight the potency is not destroyed with the destruction of the color in blanching. Since the vitamin formed seemed to be stored in the portion of the plant most exposed to sunlight and was not transferred to other portions of the plant, the most actively growing portion etiolated may be devoid of potency. A number of interrelated factors are active in the synthesis in light. Neither wave length nor heat are considered solely responsible.

Vitamin A

Hart and co-workers (93) using swine found that alfalfa undoubtedly introduces an abundance of vitamin A into a ration.

McCollum, Simmonds and Pitz (129) showed that vitamin A is not found in fats and oils of plant origin. In an experiment where vitamin A of the diet was supplied wholly by vegetable products it was found that alfalfa leaves are excellent as a source of this dietary factor. The superiority of the forage portion of the plant over seed with respect to its content of vitamin A is of considerable interest when viewed in the light of the dietary habits of lower animals. Those which consumed the forage grew successfully from generation to generation on a strictly vegetarian diet. The seed eating animals normally vary their diet to a considerable degree by the addition of green leaves, worms, insects, etc. Certain combinations of seed may, however, suffice for normal nutrition. These workers found cottonseed oil, soy bean oil, linseed oil unable to supply vitamin A and support growth. Ether extracted ground maize kernel produced slow growth while ether extracted wheat embryo produced rapid growth for a short time. These authors (130) also found that the wheat embryo contains qualitatively all the factors essential for the promotion of growth and well being in an animal but these factors are not so proportioned that wheat may serve as a satisfactory diet without several modifications. In still later work they (5) stated that vitamin A is furnished by alfalfa.

In 1916-17 Hart and his co-workers (68) reported that the maize kernel contained vitamin A, although in too small amounts for maintenance and growth in rats over a long period of time.

McCollum and Simmonds (95) stated that most seeds are deficient in vitamin A.

Fat-soluble A is present in the oat kernel in very small amounts according to McCollum, Simmonds and Pitz (117).

Millet seed and flax seed, according to McCollum and Simmonds (131), are a distinctly better source of fat-soluble

A than the cereal grains, wheat, corn and oats.

Data secured by Crist and Dye (132) supported the conclusion that the vitamin A content of plant tissue is associated with its greenness.

Hange (133) working with hybrid red corn found vitamin A associated with yellow endosperm and lacking in corn grains with pure white endosperm even when grown on the same ear. The color of the pericaps appeared to have an effect on the vitamin A content of corn.

According to Quinn, Hartley and Derow (134) vitamin A of dry plant tissue appeared to be susceptible to destruction during periods of storage. A loss occurred in the vitamin A content of dry spinach amounting to approximately 70 per cent upon storage over a period of 12 to 15 months.

Alfalfa leaves artificially dried (Mason process) were found by Russell (135) to contain seven times the amount of vitamin A as field cured leaves with a greater part of the green color lost. The samples containing a large amount of vitamin A were green compared with a brownish green color of the field sample.

Lindquist (51) stated that fat-soluble A is found most abundantly in milk, eggs, cod liver oil and green leaves. The following chart lists the dairy feeds with an estimate of their relative vitamin A content.

Wheat bran	0	Wheat	x
Mangels	xx	Soy beans	x
Rutabagas	0	Cottonseed	xx
Potatoes	0	Flax seed	xx
Beet root	x	Peas (dry)	x?
Barley	x	Alfalfa	xxx
Maize yellow	x	Timothy	xx
Maize white	0	Clover	xxx
Oats	x	Cod liver oil	xxxx
Rye	x	Yeast	0

xxxx very abundant; xxx abundant; xx relatively large amounts; x small quantities; 0 absent, (?) not definitely proven.

Jones, Eckles and Palmer (136) found wheat straw a good source of vitamin A for ruminants. White corn (Rustler white variety) and dried beet pulp were practically free of vitamin A.

Whole yellow corn was found rich in vitamin A by Meyers and Hetler (137).

Russell (138) found yellow corn 50 per cent more potent with reference to vitamin A than a white capped yellow dent variety. The more highly pigmented varieties contain a greater amount of vitamin A.

Mead and Regan (52) found that a concentrate mixture fed ad libitum to calves which was moderately made up of

400 pounds rolled barley, 300 pounds rolled oats, 300 pounds wheat bran, 100 pounds linseed meal along with alfalfa ash equal to that supplied by a normal alfalfa hay ration was inadequate in vitamin A as evidenced by the fact that all calves developed marked symptoms of this deficiency which disappeared upon the administration of cod liver oil.

Vitamin B

McCollum, Simmonds and Pitz (5) (68) (117) found that water soluble B is furnished by alfalfa, the maize kernel also furnishing an abundance of vitamin B, and oats a liberal supply.

Lindquist (51) stated that vitamin B is found in grains and cereals. The following chart gives the relative differences of feeds in this vitamin.

Potatoes	xxx	Soy beans	xxx
Rutabagas	xxx	Cottonseed	xxx
Mangels	xx	Flax seed	xxx
Barley	xxx	Peas (dry)	xx
Maize yellow	xxx	Alfalfa	xxx
Maize white	xxx	Timothy	xxx
Oats	xxx	Clover	xxxx
Wheat bran	x	Cod liver oil	0
Wheat	xxx	Yeast	xxxx

xxxx very abundant; xxx abundant; xx relatively large amounts; x small quantities; 0 absent; (?) not definitely proven.

According to Aykroyd and Roscoe (144) the vitamin G value of wheat and corn is poor, that of corn being on the whole lower in the sample examined. In wheat the germ and bran are better sources than the endosperm and about equal to each other. In maize the germ is not so rich a source but the whole maize is better than maize endosperm. Dried peas have a low vitamin G content while dried ox liver, yeast and fresh whole milk are excellent sources of this vitamin.

Hunt (139) stated that vitamin B complex is composed of two vitamins, one which prevents polyneuritis in rats (vitamin F) and vitamin G which prevents experimental pellagra and together with vitamin F produces fair growth in rats.

Vitamin C

Lindquist (51) gave the following table showing the vitamin C in common food stuffs.

Potatoes	xx	Soy beans	0
Rutabagas	-	Cottonseed	-
Mangels	(?)	Flax seed	-
Beet root	xx	Peas (dry)	0
Corn embryo	-	Alfalfa	(?)
Barley	(?)	Timothy	0
Maize yellow	(?)	Clover	(?)
Maize white	(?)	Cod liver oil	0
Oats	0	Yeast	0
Rye	0	Wheat bran	0
		Wheat	0

xxxx very abundant; xxx abundant; xx relatively large amounts; x small amounts; 0 absent; (?) not definitely proven.

Thurston, Eckles and Palmer (57) stated that under practical conditions even where very poor feeding practices are followed there is little if any reason to believe the well being of the calf will be affected by a shortage of vitamin C.

Vitamin D

McCandlish (50) found that roughage as good pea green alfalfa may provide some of the antirachitic vitamin.

Hart, Steenbock, Tuet and Humphrey (61) found that alfalfa hay cured in Colorado was no more potent in antirachitic properties than alfalfa cured under the best sunning conditions in Wisconsin. All hays studied possessed measureable antirachitic properties.

It was found by Russell (135) that when alfalfa was dried in the sun without exposure to dew or rain there was an increase in antirachitic potency of leaves, but was accompanied by a decrease in vitamin A.

Irradiated yeast potent in vitamin D was found by Hart, Steenbock, Kline and Humphrey (63) to show no positive influence in improving the lime assimilated by liberal milking cows receiving alfalfa hay, corn silage, grain and grain byproducts although it was absorbed into the blood stream as evidenced by the enrichment of the milk in this factor.

Steenbock, Black and Thomas (140) found in general regardless of calcium and phosphorus additions, the cereals ran high in antirachitic potency in descending order of wheat, rolled oats and corn.

Vitamin F

Wheat and corn according to Hunt (139) contain approximately the same amounts of vitamins F and G, but that they are richer in vitamin F than G.

Hunts' (141) experiments indicated that autoclaved yeast is rich in the antipettagra vitamin, vitamin G, and wheat is rich in antineuritic vitamin F.

Vitamin G

Hunt (139) secured information to support the view that the limiting factor for growth in rats on wheat and corn is vitamin G. They do contain a small amount of this vitamin.

Tests with white rats conducted by Munsell (142) showed that 30 per cent of white corn in Sherman and Spohn's vitamin B free diet did not supply an amount of vitamin G sufficient to promote growth or to prevent symptoms of pellagra. Normal growth did occur when 30 per cent white corn was fed as the only source of vitamin B plus autoclaved yeast to supply vitamin G.

The review of literature indicates that the normal dairy rations provide sufficient quantities of the various vitamins to meet the requirements of a lactating dairy cow.

Minerals

McCollum and Davis (70) found that wheat was low in mineral content for successful growth with rats.

According to Meigs and Woodward (71) ordinary rations for dairy cows are more likely to be deficient in one or both of the principal bone building elements than any other constituent. This can be corrected by feeding legume hay plus grain with a high phosphorus content and three to four times the protein for maintenance and two to three times the nutrients during two months' dry period.

Eckles, Becker and Palmer (79) found that the pasture season is the best for feeding calcium and phosphorus supplements to build up the mineral reserve because of sunlight and vitamins received at that time.

In 1931 Ellenberger, Newlander and Jones (77) stated that when high producing cows were fed timothy hay, corn silage and a good grain mixture during the barn feeding period with fresh pasture clippings substituted for the silage and most of the hay in summer, all cows ended the trials with positive balances. This indicated that there was sufficient mineral in these feeds to meet the dairy cows requirements.

Calcium   Following an experiment with swine, Hart, Miller and McCollum (93) stated that the richness of alfalfa in calcium may be an important factor in nutrition.

McCollum, Simmonds and Pitz (94) found the leaf to be distinctly different from the seed in its dietary properties. Its total inorganic content is very high and it is especially rich in both sodium and calcium both of which are deficient in the seeds generally.

McCollum and Simmonds (95) also stated that all seeds are deficient in calcium.

Meigs (72) stated that there is every reason to believe that stall fed cows can be kept in calcium equilibrium only by feeding large quantities of roughage high in calcium as alfalfa.

Monroe (80) found that cows on a high protein ration stored calcium while those on a low protein ration lost calcium. He explained this difference as being due to a large amount of clover hay in the high protein ration which was fresh and not subjected to excess bleaching.

Miller (84) found that there was a better assimilation of calcium when clover hay instead of timothy hay was fed as a part of the ration which included corn silage and a grain mixture.

Scott reported (85) that many Montana forage crops are plentifully supplied with calcium.

Greaves and Hirst (145) found the average calcium content of oats, barley, wheat and corn to vary under varying conditions such as irrigation, types of soil and variety of

grain. They gave the calcium content of oats as 0.117 per cent, barley 0.086 per cent, wheat 0.090 per cent and corn 0.150 per cent.

Two cows receiving an excellent dry ration of well cured alfalfa hay, mangel beets and a good grain mixture, according to Turner and Hartman (75), failed to keep in positive balance during seven weeks when producing 27 and 22 kilograms of milk daily.

Alfalfa was found by Haag and Jones (103) to keep cows in a calcium balance usually in the early part of the lactation.

The work of Huffman, Robinson and Winter (76) who fed a ration made up of timothy hay,corn silage and grain to cows indicated that such a ration furnished sufficient calcium for at least 10,000 pounds of milk per year. Positive calcium balances were obtained in heavy milking cows on a ration of alfalfa, silage and grain.

Hartman and Meigs (87) found that a ration of timothy hay U. S. No. 2, corn silage and a grain mixture of 30 pounds corn meal, 20 pounds wheat bran, 25 pounds cottonseed meal and 25 pounds linseed oil meal and 1 pound salt fed to four cows for a period of 14 to 32 months supplied a sufficient amount of calcium to meet their requirements.

<u>Phosphorus</u> Hart and co-workers (78) stated that grains carry an abundant supply of phosphorus and wheat bran and middlings are especially rich in this element.

Eckles, Becker and Palmer (79) found that poor roughage and grain containing only moderate amounts of phosphorus would not furnish a sufficient amount of this mineral for dairy cattle. In general a ration containing enough protein and energy giving nutrients to support milk flow of which the animal is capable will also contain an ample supply of phosphorus unless it is composed largely of foods grown in phosphorus poor soil.

Information secured by Monroe (80) indicated that a narrow ration permitted greater phosphorus retention than a wide ration.

Reed and Huffman (83) stated that roughages and cereals are low in phosphorus while wheat bran, cottonseed meal, and linseed oil meal are high in this mineral element.

Hart, Beach, Deliwiche and Bailey (89a) found that a ration of corn silage and alfalfa hay along with a grain mixture of 35 pounds yellow corn, 25 pounds wheat bran and 5 pounds of linseed oil meal furnished sufficient phosphorus to cure cattle of "Pica", a phosphorus deficiency disease.

Greaves and Hirst (145) gave the phosphorus content of oats as 0.364 per cent, barley 0.351 per cent, wheat 0.331 per cent and corn 0.334 per cent.

Two cows producing 27 and 22 kilograms of milk daily were found by Turner and Hartman (75) to remain in a negative phosphorus balance throughout a period of seven weeks when receiving an excellent dry ration of well cured alfalfa hay, mangel beets and a good grain mixture.

Scott (85) found many Montana forage crops deficient in phosphorus.

Haag and Jones (103) found that dairy cows were always in a phosphorus balance when only alfalfa hay was fed.

According to Huffman, Robinson and Winter (76) a ration consisting of timothy hay, corn silage and grain provided sufficient phosphorus for 10,000 pounds of milk per year.

Nevens (7) stated that phosphorus may be deficient when the ration is made up largely of roughage. Protein supplements and steamed bone meal are a good source of phosphorus.

The review of literature points out that roughages, especially legumes, are an excellent source of calcium, while protein supplements are good sources of phosphorus. Under most conditions the normal dairy ration which meets the protein and total digestible nutrient requirements of dairy cattle will supply sufficient amounts of these two minerals. However, in regions where depraved appetite occurs, rations consisting of legume roughage and cereal grains should be supplemented by a protein supplement.

LIMITATIONS OF RATION

The protein reguirement of the Haecker Feeding Standard was based on numerous experiments with simple rations. Haecker (146) in a feeding trial to determine the cost of butterfat fed a simple ration made up of hay, roots, silage and a grain mixture of one part linseed meal, two parts barley, two parts corn meal and three parts wheat bran, or when corn or barley was omitted the other grains were increased. He secured an average production on this ration of 6407 pounds of milk and 300 pounds of butterfat. The high producing cow on this ration gave 10,287 pounds of milk and 407 pounds of butterfat.

In a second experiment prairie hay was compared with timothy. The basal grain mixture fed with these two legumes was 98 pounds of bran, 44 pounds of ground barley, 44 pounds ground corn and 26 pounds of linseed meal plus ensilage. Sixteen cows used in this trial. Prairie hay was found equal to timothy for milk and butterfat production.

Haecker (147) stated "The kind of feed has little if anything to do with the yield as long as they get the required amount of nutrients in the right proportions and in palatable form. We get as much out of fodder as out of ensilage and as much out of a pound of protein in bran as from a pound of protein in any other concentrate." A standard ration should contain 25 pounds dry matter, 2.5 pounds digestible protein, 12.5 pounds carbohydrates and 0.4 pounds of ether extract for cows weighing 1000 pounds in ordinary working condition. A ration made up of 14 pounds timothy and 14 pounds bran furnished nutrients needed for light dairy work. Haecker considered the following rations capable of meeting the requirements of a lactating dairy cow.

1. Timothy hay, 12 pounds; oat straw, 4 pounds; corn, 4 pounds; bran, 5 pounds; linseed oil meal, 2 pounds, and cottonseed meal, 1 pound.

2. Clover hay, 15 pounds; barley, 4 pounds; corn, 4 pounds; oats, 4 pounds; cottonseed meal, 1/2 pound.

3. Alsike hay, 14 pounds; barley,4 pounds; corn, 4 pounds; oats, 4 pounds.

4. Alfalfa hay, 15 pounds, and corn meal, 10 pounds.

5. Prairie hay, 15 pounds; either corn or barley, 5 pounds; bran, 5 pounds; linseed oil meal, 2 pounds; cottonseed meal, 1 pound.

6. Fodder corn, 20 pounds; corn, 4 pounds; bran, 5 pounds; gluten meal, 3 pounds.

Haecker (148) used simple rations in feeding trials to determine the maintenance requirement. In 1894 he found that 10 pounds of timothy hay plus 10 pounds of barley meal when fed for 81 days gave an average daily gain of 0.36 pounds, while in 1896-97 14 pounds of timothy hay plus 18 pounds of corn fodder maintained the dairy cow's weight for 100 days although they did not appear in good health. The following

year a ration of fodder corn, beets and oil meal showed gain in weight and good health.

The rations used to determine the protein requirement were five times as much corn silage as grain and one-half as much hay as grain by weight plus first, a grain mixture of equal parts corn, wheat bran, and gluten meal; second, corn 4 pounds, wheat bran 4 pounds and gluten meal 1 pound; and third, equal parts corn, barley and oats except that one cow got wheat bran in place of oats. Poor quality prairie hay was used. Some beet pulp of very poor quality was also used. The cows were fed continuously for about 100 days. They yielded 20 to 30 pounds of milk daily and even up 37.77 pounds daily.

Doane (149) found alfalfa plus corn meal superior to silage and a mixed grain made up of malt sprouts, linseed oil meal, gluten meal and corn chop, as a food for dairy cows by a safe margin in total milk production. In a second feeding trial alfalfa and silage gave less production than silage plus grain. No ill effects from these rations were noted.

A ration of 13 pounds of alfalfa and 30 pounds of corn silage was found by Lane (150) to be practical and economical when fed in comparison to two-thirds protein derived from wheat bran and dried brewers grains. A ration of 16.4 pounds crimson clover plus 30 pounds of corn silage proved practical from a feeding standpoint when fed in comparison to a ration in which the protein was largely purchased. A third ration of 10 pounds of crimson clover hay plus 36 pounds of cow pea silage and 6 pounds of corn and cob meal produced as much milk as a ration in which two-thirds of the protein was purchased in the form of dried brewers grains and cottonseed meal. The results show that rations of home grown crops may be fully equal for milk production to a ration in which the protein is largely supplied by purchased feed. This investigator (167) also found that a ration of 36 pounds of soybean silage, 8 pounds of alfalfa hay and 6 pounds of corn meal produced more milk at less cost per hundredweight than a ration in which the protein was largely supplied by wheat bran, dried grains and cottonseed meal.

In a number of experiments on home grown protein versus purchased proteins Billings (151) found that crimson clover hay wholly replaced purchased proteins. Cow pea silage, crimson clover hay and corn and cob meal proved four per cent more efficient than mixed hay, corn silage and dried brewers grains. Cow pea hay was a good substitute for purchased proteins resulting in a saving of 32 per cent in efficiency. Soy bean silage, alfalfa hay and corn meal proved 11.7 per cent more efficient than a ration of corn silage, corn stalks, wheat bran, dried brewers grain and cottonseed meal. When alfalfa replaced 60 per cent of the purchased protein there was a 4.5 per cent loss in yield of milk and a gain of 18

per cent in cost of production. A repetition of the last trial resulted in a loss of 3.7 per cent in yield of milk and 33.7 per cent in cost of production. Alfalfa hay wholly replaced purchased feed resulting in a loss of 4.15 per cent in yield of milk.

New Mexico (168) report an experiment in which alfalfa hay was compared with alfalfa hay plus wheat bran. Eight cows were divided into two lots of four cows each and fed these rations for two six weeks' periods. The alfalfa group consumed 11,378 pounds of alfalfa and produced 4,628 pounds of milk. The alfalfa plus wheat bran group consumed 11,207 pounds of alfalfa, 2,700 pounds of wheat bran and produced 5,543 pounds of milk.

Frazier and Hayden (169) in comparing alfalfa and timothy, used 16 cows divided into two lots, over a 25 weeks' period. A basal ration of 2.5 pounds of corn meal, 1 pound of wheat bran and corn stover was used. The cows fed the alfalfa were in much better condition and produced more milk than those fed timothy. The timothy, although of good quality was not palatable and the cows receiving it lost in flesh, their hair was rough and they were in poor condition generally. A number of them were off feed at different times. This was not the case with the same cows while being fed alfalfa.

The same investigators compared alfalfa hay with wheat bran. Six cows were used in this test. They were divided into two lots of three each. The time was divided into two periods of 9.5 weeks. The basal ration was 6 pounds of clover hay, 30 pounds corn silage and 6 pounds corn meal. The animals in Lot I were given in addition to the basal ration all the choice alfalfa hay they would clean up. Lot II was given an equal amount of wheat bran by weight. The groups were reversed in the second period. Each cow consumed eight pounds of alfalfa hay or wheat bran daily. Alfalfa was found equal to or a little better than wheat bran for milk production. The cows receiving the alfalfa were in better physical condition at the end of each period than those receiving wheat bran. "These two demonstrations indicate that alfalfa will not only supply a palatable roughage and a large amount of protein but also that alfalfa keeps animals in better physical condition than such rations as timothy hay with grains high in proteins."

Caldwell conducted two feeding trials (170). The first trial compared corn meal, corn silage and alfalfa hay with corn meal, wheat bran, cottonseed meal, corn silage and corn stover. In a second trial he compared corn silage, soy bean hay and a grain mixture of six parts by weight of corn meal, and one part soy bean meal with corn silage, corn stover and a grain mixture made up of equal parts by weight of corn meal, wheat bran and cottonseed meal. The nutritive value of the rations used in each trial were practically the same. All the animals made about the same gain in body weight. Thus he concluded that alfalfa as well as soy bean hay can replace much of the high priced protein concentrates in the ration of dairy cows. Other legumes answer the same purpose to a lesser degree. The extensive use of milling by-products or other commercial feeds is not necessary in milk production where legumes can be grown successfully. It often proves profitable, however, to use such feeds unless the home grown feeds will yield as great a profit.

Hart, McCollum, Steenbock and Humphrey (1) found that animals restricted to the wheat and oat plants were abnormal in growth, milk production and reproduction. The corn plant, however, keeps animals strong and vigorous at all times. Animals on a mixture of the three cereals responded with less vigor than those on the oat or corn ration.

Hart and Humphrey (3) showed that it was impossible to furnish dairy cows of high producing capacity with a protein level of sufficient magnitude or quality to maintain that capacity from a clover, corn silage, cereal grain mixture containing corn, barley or oats separately or a mixture of the three. These authors (152) found it possible to furnish dairy cows with high milk producing capacity with a protein level of sufficient magnitude to maintain that capacity for 16 weeks from a ration the same as quoted above except the clover was replaced by alfalfa. Four cows were

used in this test. One cow produced 40 to 45 pounds of (11.4 per cent solids) milk daily over this period and maintained a nitrogen equilibrium as well as a sustained milk flow. The other three cows were not as high milk producers. However, they maintained a positive nitrogen balance and sustained milk with less of the ration.

In still a later experiment Hart and Humphrey (153) showed that it was entirely possible when feeding equal but limited amounts of protein, to maintain nitrogen equilibrium and high milk production in dairy cows with a ration composed of either barley or corn supplemented with corn silage and alfalfa hay, but not when the whole oat grain was used.

Larsen, Wright, Jones, Hoover and Johnson (90) found that rations made up of hay, silage, and oil meal or gluten feed supported satisfactory milk production of 20 to 30 pounds daily.

McCandlish (171) found soy beans a valuable protein supplement for dairy cows.

An experiment was conducted at the Ohio Agricultural Experiment Station (172) in which two Holstein cows were fed only alfalfa hay and ground corn. The first cow was started on this ration five months after calving. Eight months later this cow gave birth to a 105 pound calf and in five months produced an average of 1,264 pounds of milk per month. In

the 13 months she produced 11,040 pounds of milk and 382 pounds of butterfat. The second cow after being on this ration for four months freshened and produced in 12 months 11,276 pounds of milk and 351 pounds of butterfat. A few days later she gave birth to a 90 pounds calf. These records indicate the value of alfalfa hay for milk production.

Dice and Jensen (173) found in studying home grown feeds that cows receiving alfalfa hay as a roughage produced five per cent more milk and fat than when receiving prairie hay. This indicates the significant advantage of feeding alfalfa hay, but also indicates that good prairie hay is a good feed for cows.

With an interval of seven days between the periods for changing of rations, Cunningham (174) compared ground hegari and rolled barley. Two lots of five cows each were used throughout four periods of 14 days each. Lot I received hay and silage plus ground hegari and wheat bran two to one. Lot II received the same except rolled barley was substituted for ground hegari. The ground hegari produced 7,931 pounds of milk and 318 pounds of butterfat while the rolled barley produced 7,865 pounds of milk and 320 pounds of butterfat. The amount of feed consumed was about the same.

The same investigator made a comparison of ground yellow corn and rolled barley. Two groups of six cows each were fed for two periods of 28 days each with a seven day interval between the periods. The grain mixture consisted of two parts yellow corn and one part wheat bran. Both groups were fed 20 pounds of alfalfa daily and an equal amount of silage. The combined production from the corn ration was 9,084 pounds milk and 307 pounds of butterfat, while the barley ration produced 8,966 pounds of milk and 330 pounds of fat. The cows gained more weight on the corn than on the barley ration. Ground yellow corn and rolled barley were approximately equal for dairy cows.

The Wyoming Agricultural Experiment Station (175) reported that the addition of sunflower silage to the ration added variety and palatability so that greater quantities of roughage were consumed and the milk production increased.

Headly (176) conducted feeding experiments with three groups of five dairy cows each over a period of four years. The first group was fed alfalfa hay alone, the second, alfalfa hay plus grain, and the third, alfalfa hay plus grain during each alternate feeding period. He found that adding grain increased the milk and butterfat production and enabled the cows to maintain their average weight at a higher level. The amount of hay consumed was reduced when grain was added to the ration. The total digestible nutrients in alfalfa hay and in the grain ration were equally efficient for producing butterfat.

Haag and Jones (103) fed cows producing 9 to 18 kilograms of milk daily solely on the alfalfa plant. They stated that the milk production on alfalfa hay was not as high as expected on the regular herd rations.

Bowling (6) using 10 cows comparing a simple home grown ration composed of ground oats, alfalfa leaf meal, alfalfa hay and corn silage, found it to be practically as efficient for milk and butterfat production to 65 pounds milk daily as a complex ration containing purchased proteins, during four 30-day feeding periods. The simple ration maintained the cows as satisfactorily as the complex ration although it did not seem as palatable. The simple ration maintained three cows on a positive nitrogen balance equally as efficiently as the complex ration and seemed to produce no abnormal physiological effects.

Hart and Humphrey (154) concluded that "Dairymen who have an abundance of alfalfa hay and cereal grains including corn, barley or oats, may provide rations which meet all needs for maintenance and milk production up to 50 or more pounds a day without the expense of buying other concentrates."

The review of literature indicates that a simple ration made up of hay, silage and cereal grains meets the requirements of the dairy cow for high milk production if sufficient protein is provided.

DISCUSSION OF REVIEW OF LITERATURE

A review of the literature indicates that the amino acids, tryptophane, cystine, lysine and histidine are essential for maintenance and growth and lysine for growth. Arginine and proline may be essential and arginine may be interchangeable with histidine.

Roughages in the form of hays are high in the amino acid, lysine, and non-protein nitrogen. They contain all of the rest of the essential amino acids, however, in limited quantities. Little is known about the quantities of the essential amino acids contained in silage, however, all of them have been shown to be present.

Cereal grains contain all of the essential amino acids. They are as a whole, however, very low in lysine and tryptophane.

Protein concentrates, especially cottonseed meal, are high in arginine and histidine. Cottonseed meal contains moderate amounts of cystine and lysine and is especially valued for its tryptophane.

Vitamin C is apparently synthesized by cattle while vitamin B may be produced by germ life in the rumen. Vitamins A and D are required by cattle. Vitamin A is amply supplied by hays, cereal grains and protein concentrates.

Vitamin D is furnished in hays in sufficient quantities to meet the requirement of the lactating dairy cow. Cattle can probably utilize ultra violet rays from the sun for vitamin D formation.

The chief minerals required by lactating dairy cows are calcium and phosphorus. Of these two minerals phosphorus is most likely to be deficient in the ration. Roughages are high in calcium while cereals and protein concentrates are low in this mineral element. Phosphorus is found in very small quantities in roughages and cereals while concentrates contain considerable phosphorus.

A limited amount of experimental work indicates that simple rations made up largely of home grown feeds from limited sources meet the requirements of high producing dairy cows when a sufficient quantity of protein is provided. However, a review of the literature shows the need of further research work to determine the relative value of simple and complex rations for growth, reproduction and milk production.

EXPERIMENTAL WORK

Object

It is the object of this experiment to determine the value of variety in the ration of lactating dairy cows.

The use of simple rations containing as much home grown feeds as possible with a minimum amount of purchased supplementary feeds is highly desirable, providing such rations meet the dietary requirements of the dairy cow. However, the belief is common that such a ration lacks variety, more especially of protein sources.

PLAN OF EXPERIMENT

Animals

It is the plan to use 10 cows selected from the experiment station dairy herd in pairs as equally matched as possible from the standpoint of time of freshening, previous production of milk, butterfat and per cent butterfat, consistency of production, size and breeding dates.

Management

Rations and Methods of Feeding

All the animals are to be fed the same amount of mixed hay and sunflower silage. The grain will be fed by the double reversal system. Five animals will be started on the simple grain mixture and five on the complex mixture and continued for 40 days. The grain mixtures will then be switched for 30 days after which time it will be switched back and fed a third period of 30 days. The extra 10 days in the first period will be allowed to get the animals accustomed to the grain and determine the amount of hay and silage they will consume. The grain is to be fed at the rate of one pound to each three and one-half pounds of milk. The animals will be continued on the grain mixture fed the third period until after freshening. The simple and complex grain mixtures are as follows:

Simple grain mixture

300 pounds ground barley
108 pounds cottonseed meal

Complex grain mixture

400 pounds ground barley
200 pounds ground oats
100 pounds wheat bran
125 pounds linseed oil meal
125 pounds cottonseed meal
100 pounds gluten feed

Salt will be added to both grain mixtures at the rate of one per cent. Additional salt will be given as needed.

Milking

The cows will be milked three times daily.

Bedding

The cows will be bedded with shavings.

Collection of Data

Health notes will be taken daily by the herdsman of any abnormalities which appear. Such things as appetite, breeding dates, consistency of feces, etc. will be noted.

Weight The cows will be weighed the three consecutive days before each 30 day feeding period and at the close of of the last period.

Feed Consumed All hay, grain and silage will be weighed and recorded and the daily amounts for each animal recorded. Any feed not consumed will be weighed back and deducted from the original amount of feed fed. Samples will be taken for analysis.

Samples Samples of grain are to be taken at the time of mixing for analysis. Samples of hay and silage will be taken on the fifth, fifteenth and twenty-fifth of each 30 day feeding period.

Production Daily milk weights will be kept, composite samples of milk will be taken and tested on the fifth, fifteenth and twenty-fifth of each 30 day feeding period to determine the butterfat produced.

Reproduction Records will be kept on the breeding and freshening dates. Any irregularities will be handled by a competent veterinarian.

PROCEDURE

Animals

The animals used in this experiment were pure bred Holstein-Friesian cows selected from the Michigan State College Experiment Station herd located at Chatham, Michigan. Two groups of five animals each were used. The groups were balanced as equally as possible in regard to age, weight, time since freshening, days in pregnancy, milk production, percentage of butterfat in milk, and persistency of production where previous lactation records existed. This information is summarized in Table I.

Season of Year

Six of the animals, three from each group, were started on the experiment November 18, 1930 and concluded February 25, 1931. The remaining four were started February 18 and were concluded May 3, 1931.

Management

Shelter

The animals were sheltered in the main dairy barn.

Exercise

The animals were allowed to exercise for thirty minutes each day in a dry lot.

Milking

The cows were milked three times each twenty-four hours. The milking hours were 5:oo A.M., 1:00 P.M. and 8:00 P.M. The cows were milked with a De Laval milking machine and stripped by hand. The total milk was weighed and recorded after each milking.

Bedding

The cows were bedded with shavings.

Weight

The cows were weighed at 2:30 P. M., after milking and before feeding, for three consecutive days prior to each 30 day feeding period and for three consecutive days at the end of the last period.

Length of Feeding Period

The feeding periods were thirty days in length. The animals were placed in stanchions with special mangers and given the feed they were to receive during the first period, ten days before the starting of the first period. They were continued for three periods. Lot I was placed on the complex ration during the first and third periods and on the simple ration during the second period. Lot II was on the simple ration during the first and third periods and on the complex ration during the second period.

Watering

The cows had free access to water from watering cups in the stanchions.

Feeds and Feeding

The complex grain mixture consisted of ground barley 400 pounds, ground oats 200 pounds, wheat bran 100 pounds,

old process linseed oil meal 125 pounds, cottonseed meal (43 per cent) 125 pounds, gluten feed 100 pounds, and one per cent common salt.

The simple grain mixture consisted of ground barley 300 pounds, cottonseed meal (43 per cent protein) 108 pounds and one per cent common salt.

The complex ration according to Henry and Morrison (128) contained 16.39 per cent digestible crude protein and 74.94 per cent total digestible nutrients. The digestible crude protein content of the simple grain mixture was 16.25 per cent and the total digestible nutrient content was 78.32 per cent. The grain was fed on the basis of one pound to each three and one-half pounds of milk. A check was made on the milk production of each cow every ten days and the grain changed if necessary. Grain was fed three times each day at 5:00 A. M., 1:00 P. M. and 7:30 P. M.

An equal amount of mixed hay and sunflower silage was fed to each cow in each lot. The mixed hay was made up largely of timothy. The animals were fed hay three times daily at 6:00 A. M., 2:00 P. M. and 7:30 P. M. The silage was fed twice daily at 5:00 A. M. and 7:30 P. M. The silage ran out seven days before the last period on the four animals. Roots were then fed five days. No succulence was added the last two days of the period.

The animals were fed in special mangers to assure individual feeding, and any feed not consumed was placed in individual sacks, air dried in a boiler room and weighed back. A daily record was kept of the amount of hay, silage and grain consumed by each cow during the experiment.

A summary of the grain mixtures is given in Table II. The grain was mixed by spreading on a floor in layers and carefully shoveled over three times. It was then shoveled into baskets and dumped into a bin.

Samples

A composite sample of milk was taken for a butterfat test each fifth, fifteenth and twenty-fifth day of each period.

EXPERIMENTAL RESULTS

Butterfat Production

Table III shows the butterfat production of each cow during each period and the total butterfat production per lot for each period.

Table IV shows the butterfat produced by each cow and by each lot while on the complex ration.

Table V shows the butterfat produced by each cow and by each lot while on the simple ration.

The complex ration produced a total of 565.44 pounds of butterfat and the simple ration produced a total of 571.32 pounds of butterfat. The simple ration thus produced 5.88 pounds more butterfat during the three periods.

Milk Production

The milk production of each cow for the three periods is given in Tables VI, VII and VIII. Table VI shows the total production of animals in Lot I and Lot II and the total amount of four per cent corrected milk by periods. Table VII shows the milk production during each period by the cows of each lot during the three periods while they were on the complex ration. Table VIII shows the milk production of each cow during the three periods while they were on the simple ration. These tables also show the total production made on each ration.

The milk production of each cow, except No. 179, gradually declined with each succeeding period. Cow No. 179 went off feed during the first period on the simple ration. However, this animal came back to full feed quickly. Her production was higher during the second period on the complex ration and still higher in the third period on the simple ration.

During the three periods the complex ration produced 20,522.1 pounds of milk with a daily average of 45.60 pounds, and the simple ration produced 20,303.3 pounds of milk with a daily average of 45.11 pounds. The complex ration thus produced 218.8 pounds more milk than the simple ration.

Fat Corrected Milk

The total milk production on each ration and the total milk production for each cow for the three periods was corrected to a four per cent butterfat basis by the following formula which was developed by Gaines and Davidson (166): 0.4 M plus 15 F equals Fat Corrected Milk; in which M is the quantity of milk produced and F is the quantity of fat in the normal milk. Table IX summarizes the milk production on the four per cent fat corrected basis.

Production on the complex ration was 16,690.44 pounds of fat corrected milk.

Production on the simple ration was 16,591.12 pounds of fat corrected milk.

The complex ration thus produced 99.32 pounds more of four per cent milk during three 30 day feeding periods. This difference in production is very small.

Feed Consumption

Table X shows the feed consumption of each animal for each period during the experiment.

Table XI shows the feed consumption while the cows were on the complex ration.

Table XII shows the feed consumption while the cows were on the simple ration.

Table XIII shows a summary of the hay, silage and grain consumed while the cows were on the complex ration.

Table XIV gives a summary of the hay, silage and grain consumed while the cows were on the simple ration.

Comparison of Total Feed Consumed by Cows on each Ration

	Hay lbs.	Silage lbs.	Roots lbs.	Grain lbs.
Complex ration	7580.0	11330.0	364.0	5838.8
Simple ration	7602.9	11226.0	364.0	5844.5
Difference in favor of complex ration	22.9			5.7
Difference in favor of simple ration		104.0		

Cow No. 196 while on the complex ration in period I did not consume as much hay as the other animals. In the second period on the simple ration this animal consumed only 3.3 pounds less hay than the other animals. In period III on the complex ration she consumed the same amount of hay as the other animals on the experiment. Cow No. 179 was off feed four days during the first period on the simple ration, which reduced its feed consumption.

Palatability of the Rations

The two rations appeared equally palatable.

Health of Animals

During the first period on December 19, while on the simple ration, animal 179 went off feed although it appeared normal in every other respect. Its feed was decreased to eight and one-half pounds of silage and it was given two pounds of Epsom salts. On December 20 this animal consumed one-half of the grain mixture and eight and one-half pounds of silage. This feed was continued until December 23 at which time it was given full feed. The milk production dropped to 10.3 pounds on December 21 and then quickly rose again.

All the other cows used appeared normal throughout the experiment.

Weight of Animals

Table XV shows the three day average weight of each animal at the beginning of the experiment, the average weight of each lot at the beginning of the experiment, and the average weight of each lot at the end of each of the three periods. It also shows the gain or loss of each animal when on the complex and on the simple ration and the total gain or loss due to these rations.

The complex ration shows a total gain during the entire experiment of 186 pounds. The simple ration shows a gain of 68 pounds, a difference of 118 pounds gain in body weight in favor of the complex ration.

Discussion of Experimental Results

A simple ration consisting of mixed hay, sunflower silage, ground barley and cottonseed meal was compared with a complex ration for milk production. Ten Holstein cows were used in this investigation. The double reversal system of

comparing the relative value of feeds for milk production was used. The periods were of 30 days duration.

Cows on the simple ration produced 20,303.3 pounds of milk and 20,522.1 pounds of milk while on the complex ration. There was a difference of 218.8 pounds of milk in favor of the complex ration, and 5.88 pounds fat in favor of the simple ration. The milk computed to a four per cent fat corrected basis showed an advantage of only 99.3 pounds of milk in favor of the complex ration. This difference is not significant.

While on the complex ration the cows consumed 104 pounds more silage, 22.9 pounds less hay and 5.7 pounds less grain than on the simple ration.

The cows gained 186 pounds body weight on the complex ration and 68 pounds on the simple ration.

The results of this feeding trial are in line with McCollum's (177) conclusion that the leaf supplements the deficiencies of the seed.

The results of this experiment are in agreement with those of Bowling (6) in which a simple home grown ration composed of ground oats, alfalfa leaf meal, alfalfa hay and corn silage was compared with a complex ration containing purchased proteins.

The experiments conducted by Hart and Humphrey (152)(153) (154) (3) in which they found that home grown feeds maintained

a high level of milk production only when alfalfa of the best quality in contrast to other kinds of hay was fed indicated the lack of either quality or quantity of protein or both. Interpreting these results in the light of the present experiment it appears that the limiting factor in the home grown ration is quantity of protein when plenty of good quality of hay is provided. When this is provided the simple ration made up largely of home grown feeds meets the requirement of lactating dairy cows producing up to 45 pounds of milk daily.

SUMMARY

1. A simple grain mixture composed of ground barley and cottonseed meal was as efficient for milk and butterfat production as a complex grain mixture consisting of ground barley, ground oats, wheat bran, cottonseed meal, linseed meal and gluten feed when fed with mixed hay and sunflower silage during three 30 day feeding periods.
2. The simple ration maintained the body weight of the animals during the experiment as satisfactorily as did the complex ration.
3. The simple ration was as palatable as the complex ration.

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Table I. Showing Animals Used Throughout Experiment.

Animal No.	Breed	Age	Weight	Days in Milk	Days in Pregnancy	Daily Milk Yield	Per cent Butterfat in Milk
		Years	lbs.			lbs.	
Lot I							
196	Pb.Hol.	2	1150	119	46	47.7	2.40
177	" "	3	1200	135	52	38.1	2.65
153	" "	6	1250	52	0	54.8	3.05
181	" "	3	1105	90	0	68.2	2.80
254	" "	2	1155	33	0	44.6	3.60
Lot II							
189	" "	2	1100	101	42	37.4	3.20
179	" "	3	1050	86	0	41.6	3.29
176	" "	3	1170	66	0	62.1	3.15
185	" "	3	1140	21	0	58.7	3.20
255	" "	2	1020	19	0	46.9	3.00

Table II. Showing Grain Mixture Fed.

Grain Mixture (Complex Ration)

	Pounds	Digestible Crude Protein Pounds	Total Digestible Nutrients Pounds
Ground Barley	400	36.00	317.60
Ground Oats	200	19.40	140.80
Wheat Bran	100	12.50	60.90
Linseed Oil Meal	125	37.75	93.37
Cottonseed Meal	125	46.25	97.75
Gluten Feed	100	21.60	80.70
Common Salt	11		
Average Percentage		16.35	74.94

Grain Mixture (Simple Ration)

Ground Barley	300	27.00	238.20
Cottonseed Meal	108	39.96	84.46
Common Salt	4		
Average Percentage		16.25	78.32

Table III. Showing Butterfat Production During Each 30-day Feeding Period.

Lot I

Period	Cow 196	Cow 177	Cow 153	Cow 181	Cow 254	Total
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
I (Complex Ration)	32.07	28.36	42.52	53.82	33.16	189.93
II (Simple Ration)	32.18	27.27	42.45	46.63	34.91	183.44
III (Complex Ration)	29.66	27.11	39.27	44.34	34.86	175.24

Lot II

Period	Cow 189	Cow 179	Cow 176	Cow 185	Cow 255	Total
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
I (Simple Ration)	37.56	27.60	47.61	60.35	40.11	213.23
II (Complex Ration)	33.91	29.65	40.69	54.89	41.13	200.27
III (Simple Ration)	32.04	27.23	35.11	46.10	34.17	174.65

Table IV. Showing Butterfat Production During Each 30-day Feeding Period on Complex Ration.

Lot I

Period	Cow 196	Cow 177	Cow 153	Cow 181	Cow 254
	lbs.	lbs.	lbs.	lbs.	lbs.
I	32.07	28.36	42.52	53.82	33.16
II					
III	29.66	27.11	39.27	44.34	34.86

Lot II

Period	Cow 189	Cow 179	Cow 176	Cow 185	Cow 255
	lbs.	lbs.	lbs.	lbs.	lbs.
I					
II	33.91	29.65	40.69	54.89	41.13
III					
Total					565.44

Table V. Showing Butterfat Production During Each 30-day Feeding Period on Simple Ration.

Lot I

Period	Cow 196	Cow 177	Cow 153	Cow 181	Cow 254
	lbs.	lbs.	lbs.	lbs.	lbs.
I					
II	32.18	27.27	42.45	46.63	34.91
III					

Lot II

Period	Cow 189	Cow 179	Cow 176	Cow 185	Cow 255
	LBS.	lbs.	lbs.	lbs.	lbs.
I	37.56	27.60	47.61	60.35	40.11
II					
III	32.04	27.23	35.11	46.10	34.17
Total					571.32

Table VI. Showing Milk Production During Each 30-day Feeding Period

Lot I

Period	Cow 196	Cow 177	Cow 153	Cow 181	Cow 254	Total	4% Corrected Milk
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
I (Complex Ration)	1369.5	1251.1	1535.5	1922.9	1276.7	7355.7	5791.23
II (Simple Ration)	1322.5	1223.3	1465.5	1611.1	1150.3	6772.7	5460.68
III (Complex Ration)	1202.6	1101.8	1338.2	1604.2	1089.5	6336.3	5163.12

Period	Cow 189	Cow 179	Cow 176	Cow 185	Cow 255	Total	4% Corrected Milk
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
I (Simple Ration)	1137.2	998.2	1738.5	1992.9	1451.2	7318.0	6125.65
II (Complex Ration)	1081.4	1055.2	1544.6	1793.3	1355.6	6830.1	5736.09
III (Simple Ration)	1000.4	1088.7	1350.3	1538.2	1235.0	6212.6	5104.79

Table VII. Showing Milk Production During Each 30-day Feeding Period on the Complex Ration.

Lot I

Period	Cow 196	Cow 177	Cow 153	Cow 181	Cow 254
	lbs.	lbs.	lbs.	lbs.	lbs.
I	1369.3	1251.1	1335.5	1922.9	1276.7
II					
III	1202.6	1101.8	1338.2	1604.2	1089.5

Lot II

Period	Cow 189	Cow 179	Cow 176	Cow 185	Cow 255
	lbs.	lbs.	lbs.	lbs.	lbs.
I					
II	1081.4	1055.2	1544.6	1793.3	1355.6
III					

Total	20,522.1

Table VIII. Showing Milk Production During Each 30-day Feeding Period on Simple Ration.

Lot I

Period	Cow 196	Cow 177	Cow 153	Cow 181	Cow 254
	lbs.	lbs.	lbs.	lbs.	lbs.
I					
II	1322.5	1223.3	1465.5	1611.1	1150.3
III					

Lot II

Period	Cow 189	Cow 179	Cow 176	Cow 185	Cow 255
	lbs.	lbs.	lbs.	lbs.	lbs.
I	1137.2	998.2	1738.5	1992.9	1451.2
II					
III	1000.4	1088.7	1350.3	1538.2	1235.0
Total					20,303.3

Table IX. Showing Summary of Milk Production on Four Per Cent Fat Corrected Basis.

Cow No.	Simple Ration lbs.	Complex Ration lbs.	Simple Ration lbs.	Complex Ration lbs.	Total Per Cow lbs.
196		1028.85	1011.70	925.94	2966.49
177		925.84	898.37	847.37	2671.58
153		1252.00	1222.95	1124.33	3599.28
181		1576.46	1343.89	1306.78	4227.13
254		1008.08	983.77	958.70	2950.55
189	1018.28	941.21	880.76		2840.25
179	813.28	866.83	843.93		2524.04
176	1409.55	1228.19	1066.77		3704.51
185	1702.41	1540.67	1306.78		4549.86
255	1182.13	1159.19	1066.55		3347.87
Total	6125.65	11527.32	10565.47	5163.12	33381.56
Ave.per cow	1205.13	1152.73	1056.547	1032.624	3338.156

Total production on Complex Ration 16,690.44 pounds

Total production on Simple Ration 16,591.12 pounds

Total difference 99.32 pounds

Table X. Showing Feed Consumption During Each 30-day Feeding Period.

Cow No.	Kind of Feed	Period I lbs.	Period II lbs.	Period III lbs.
		Lot I		
		Complex	Simple	Complex
196	Hay	447.5	506.7	510.0
	Silage	778.0	780.0	780.0
	Grain	387.8	382.5	351.0
177	Hay	510.0	510.0	510.0
	Silage	778.0	780.0	780.0
	Grain	360.0	360.0	328.0
153	Hay	502.5	510.0	510.0
	Silage	778.0	780.0	780.0
	Grain	360.0	445.5	389.0
181	Hay	510.0	510.0	510.0
	Silage	780.0	780.0	598.0
	Roots	none	none	182.0
	Grain	564.0	494.0	433.0
254	Hay	510.0	510.0	510.0
	Silage	780.0	780.0	598.0
	Roots	none	none	182.0
	Grain	360.0	333.0	300.0
		Lot II		
		Simple	Complex	Simple
189	Hay	503.0	510.0	510.0
	Silage	778.0	780.0	780.0
	Grain	315.0	315.0	296.0
179	Hay	476.0	510.0	510.0
	Silage	674.0	780.0	780.0
	Grain	314.5	325.5	272.0
176	Hay	507.2	510.0	510.0
	Silage	778.0	780.0	780.0
	Grain	492.0	452.5	402.0
185	Hay	510.0	510.0	510.0
	Silage	780.0	780.0	598.0
	Roots	none	none	182.0
	Grain	528.0	529.0	454.0
255	Hay	510.0	510.0	510.0
	Silage	780.0	780.0	598.0
	Roots	none	none	182.0
	Grain	386.0	384.0	360.0

Table XI. Showing Feed Consumed on Complex Ration.

Lot I

Cow No.	Kind of Feed	Period I	Period II	Period III	Total
		lbs.	lbs.	lbs.	lbs.
196	Hay	447.5		510.0	957.5
	Silage	778.0		780.0	1558.0
	Grain	387.8		351.0	739.8
177	Hay	510.0		510.0	1020.0
	Silage	778.0		780.0	1558.0
	Grain	360.0		328.0	688.0
153	Hay	502.5		510.0	1012.5
	Silage	778.0		780.0	1558.0
	Grain	360.0		389.0	749.0
181	Hay	510.0		510.0	1020.0
	Silage	780.0		598.0	1378.0
	Roots	none		182.0	182.0
	Grain	564.0		433.0	997.0
254	Hay	510.0		510.0	1020.0
	Silage	780.0		598.0	1378.0
	Roots	none		182.0	182.0
	Grain	360.0		300.0	660.0

Lot II

Cow No.	Kind of Feed	Period I	Period II	Period III	Total
189	Hay		510.0		510.0
	Silage		780.0		780.0
	Grain		315.0		315.0
179	Hay		510.0		510.0
	Silage		780.0		780.0
	Grain		325.0		325.0
176	Hay		510.0		510.0
	Silage		780.0		780.0
	Grain		452.5		452.5
185	Hay		510.0		510.0
	Silage		780.0		780.0
	Roots		none		none
	Grain		529.0		529.0
255	Hay		510.0		510.0
	Silage		780.0		780.0
	Roots		none		none
	Grain		384.0		384.0

Table XII. Showing Feed Consumed on Simple Ration.

Cow No.	Kind of Feed	Period I	Period II	Period III	Total
		lbs.	lbs.	lbs.	lbs.
			Lot I		
196	Hay		506.7		506.7
	Silage		780.0		780.0
	Grain		382.5		382.5
177	Hay		510.0		510.0
	Silage		780.0		780.0
	Grain		360.0		360.0
153	Hay		510.0		510.0
	Silage		780.0		780.0
	Grain		445.5		445.5
181	Hay		510.0		510.0
	Silage		780.0		780.0
	Roots		none		none
	Grain		494.0		494.0
254	Hay		510		510.0
	Silage		780.0		780.0
	Roots		none		none
	Grain		333		333
			Lot II		
189	Hay	503.0		510.0	1013.0
	Silage	778.0		780.0	1558.0
	Grain	315.0		296.0	611.0
179	Hay	476.0		510.0	986.0
	Silage	674.0		780.0	1454.0
	Grain	314.5		282.0	596.5
176	Hay	507.2		510.0	1017.2
	Silage	778.0		780.0	1558.0
	Grain	492.0		402.0	894.0
185	Hay	510.0		510.0	1020.0
	Silage	780.0		598.0	1378.0
	Roots	none		182.0	182.0
	Grain	528.0		454.0	982.0
255	Hay	510.0		510.0	1020.0
	Silage	780.0		598.0	1378.0
	Roots	none		182.0	182.0
	Grain	386.0		360.0	746.0

Table XIII. Showing Summary of Hay, Silage, Grain and Roots Consumed While on the Complex Ration.

Cow No.	Hay lbs.	Silage lbs.	Roots lbs.	Grain lbs.
196	957.5	1538.0		738.8
177	1020.0	1558.0		688.0
153	1012.5	1558.0		749.0
189	510.0	780.0		315.0
179	510.0	780.0		325.5
176	510.0	780.0		452.5
181	1020.0	1378.0	182.0	997.0
254	1020.0	1378.0	182.0	660.0
185	510.0	780.0		529.0
255	510.0	780.0		384.0
Total	7580.0	11,330.0	364.0	5838.8

Table XIV. Showing Summary of Hay, Silage, Grain and Roots Consumed While on the Simple Ration.

Cow No.	Hay lbs.	Silage lbs.	Roots lbs.	Grain lbs.
196	506.7	780.0		382.5
177	510.0	780.0		360.0
153	510.0	780.0		445.5
189	1013.0	1558.0		611.0
179	986.0	1454.0		596.5
176	1017.2	1558.0		894.0
181	510.0	780.0		494.0
254	510.0	780.0		333.0
185	1020.0	1378.0	182.0	982.0
255	1020.0	1378.0	182.0	746.0
Total	7602.9	11,226.0	364.0	5844.5

Table XV. Showing Weights of Animals by 30-day Periods.

Cow No.	Initial Weight	Weight at End of 1st Period	Weight at End of 2nd Period	Weight at End of 3rd Period	Complex * Loss	Complex * Gain	Simple ** Loss	Simple ** Gain
Lot I.		Complex	Simple	Complex				
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
196	1122	1127	1138	1156		22		11
177	1183	1243	1223	1240		79	22	
153	1248	1297	1287	1293		55	10	
181	1075	1103	1100	1097		25	3	
254	1112	1158	1208	1187		25		50
Average	1145	1186	1192	1194				
Lot II.		Simple	Complex	Simple				
189	1095	1110	1103	1110	7			22
179	1077	1110	1085	1082	25			30
176	1193	1248	1238	1245	10			62
185	1107	1140	1155	1098		15	24	
255	1048	1020	1027	1007		7	48	
Total					42	228	107	175
Average	1104	1126	1126	1108				

* Total gain in body weight on complex ration 186 pounds

** Total gain in body weight on simple ration 68 pounds