NUTRIENTS REQUIRED FOR MILK PRODUCTION

by

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TABLE OF CONTENTS

INTRODUCTION

According to the latest census (43) the dairy cows in the United States number 22,443,000. The value of the feed required each year by these animals represents approximately $1,391,466,000, based on Dairy Herd Improvement Association estimates. With the increasing competition in dairying, the decreasing unit value of dairy products, and the prevailing prices of feeds, it is recognized that proper methods of feeding are necessary in order that this large amount of feed be used to the best advantage.

Undoubtedly the dairyman's greatest problem is to make his cows return him the most for the feed they consume. Marketing the greater part of his farm products through the cows, and buying extra feed at direct cash outlay, he is vitally concerned with the efficiency with which the feed is converted into milk. If the cows pay a good return for the feed they consume, he can usually make a good income; if they do not, successful dairying is impossible.

The relation of the feed consumed to milk produced may therefore be taken as the most vital problem in milk production. Other problems deserve consideration, but the effectiveness with which the cows convert feed into milk is the most fundamental one and the one which must be given first consideration.

The problem of economical feeding has received the attention of numerous investigators for the past seventy years, however, even to-day we connot refer to the results of any individual or group of investigators and feel that the same are entirely accurate. It is true scientific investigation has given us the foundation on which to base our general conclusions concerning such problems as the nutrients required for milk production, but we must look to the future for information which will permit us to solve such problems in an authenic manner. Many variables influence the solving of such a problem. To supply figures which will apply to such a great variety of conditions is a very difficult task. However, from the available information supplied by such well known investigators as Armsby, Haecker, Savage, Eckles and Morrison, we can draw conclusions which are highly practical for making determinations concerning such problems as the amount of nutrients required for milk production.

The present work was undertaken to determine the nutrient requirements for milk production in the dairy herd of the Kansas State College.

REVIEW OF LITERATURE

Feeding Standards. Since about 1860 numerous investigators have interested themselves in trying to calculate, for certain groups of animals, the definite food requirements for such purposes as labor, meat, wool and milk production. These food requirements, presented in a tabulated form, have been designated "feeding standards."

Thaer, of Germany, made the first attempt to express the relative value of different feeding stuffs in a systematic manner. The value of various feeds for feeding purposes is shown in the so-called hay equivalents or hay values determined by this investigator and quite commonly advocated in Europe prior to 1860. One hundred pounds of good meadow hay was taken as the unit, and the relative values of other feeds were compared to this. While these values were based upon the results of practical experiments, they were found to vary greatly due to the variation in the quality of the meadow hay used and the quality of other feeds used for comparison by different workers under varying conditions.

Grouven in 1859 compounded the first feeding standard for farm animals showing the required amounts of crude protein, carbohydrates and ether extract in the ration. These standards were based entirely on live weight, the components not being varied at all for production. Grouven's standard was also imperfect since it was based on the total instead of the digestible nutrients.

Some writers (9) (33) credit two German scientists, Henneberg and Stohmann, for starting what may be called the science of animal nutrition. These investigators proved Grouven's work to be in error by showing that the various constituents were not digested in the same proportions for all feeds, so they suggested that only the digestible nutrients be used in the calculation of rations. These two scientists published the results of their work between 1860 and 1870. This work supplies the real foundation for the study of feeding standards.

As a result of Henneberg and Stohmann's work, Emil von Wolff, another German scientist, in 1864 presented the first feeding standard based upon the amounts of digestible nutrients contained in feeding stuffs. Kuhn (24) criticizes Wolff's standard for not being applicable to all cases, and proposed to vary the amount of feed for an animal depending upon her production. Kuhn was the first scientist of prominence to question the advisability of feeding all cows the same, irrespective of production or kind or quality of feed. Wolff's standard did, however, seem to meet the requirements of a good average dairy cow fairly well, but did not make any allowance for a very heavy or a light producer.

In 1897 Dr. Lehmann of Berlin, published a new standard which was a modification of the Wolff standard. This is known as the Wolff-Lehmann standard. In formulating this standard Lehmann gave due consideration to Kuhn's criticisms of the Wolff standard, and modified the latter to meet the supposed requirements of cows giving different quantities of milk. It was based on 1000 pounds live weight. The Wolff-Lehmann standard received wide recognition and serves to-day as the foundation for some of our most popular standards -- Savage's, Haecker's and Morrison's modified Wolff-Lehmann standard. The chief criticism of the Wolff-Lehmann standard is the fact that considerably less protein is needed than is recommended. Protein-rich feeds usually are the highest in price, therefore, following this standard is decidedly uneconomical.

By 1894 American investigators were suggesting feeding standards. Most of these, however, were based on the work of earlier German scientists. For example, in this year, Woll (40) of Wisconsin published a standard which was quite similar to the Wolff-Lehmann standard but recommending less protein.

Haecker (19)(20)(21) of Minnesota, started a very thorough study of the nutrients required for milk production in 1892. His work was not reported in detail until about 1903. This worker made a very complete study of the Wolff-Lehmann factors and definitely proved them to be too high in the protein requirements. He was the first to show that the nutrients required for the nourishment of a dairy cow should vary not only with the quantity of milk yielded, but also with the quality of the product. Haecker expressed his requirements in terms of digestible crude protein, digestible carbohydrates and digestible fat.

Haecker's work, from an experimental standpoint, was practically duplicated by Savage (33) at the New York (Cornell) Station in 1912. Savage proposes a modification of Haecker's standard by increasing the protein requirement per pound of milk from 18 to 20%, and increasing the total nutrient by 10%. He expresses the requirements in his standard in terms of dry matter, digestible crude protein, and total digestible nutrients.

Morrison (22) has formulated another standard. His recommended standard for dairy cows is based largely upon the findings of Haecker and Savage, which in turn are based upon the old Wolff-Lehmann requirements. Consequently, Morrison's standard is also known as the modified Wolff-Lehmann standard. Morrison states his requirements in terms of total dry matter, digestible crude protein and total digestible nutrients, and, realizing that feeding standards are but approximations in most cases he gives both minimum and maximum figures for the different values. The Morrison standard is undoubtedly more widely used than any other to-day.

Another interpretation of the feeding standard may be obtained by reviewing the work of Kellner, Armsby and Eckles. Kellner really paved the way for the other two investigators who have published considerable data on net energy values. His standard, however, has never been extensively employed in this country. Kellner's work was reported in terms of starch values which were in reality net energy values.

Armsby (1)(2)(3) considered the reported work of other investigators on the basis of digestible nutrients highly inaccurate, so proceeded to make determinations concerning the value of feeds similar to the method of Kellner. He employed the respiration calorimeter at the Pennsylvania Station and sought to place the relative value of feeding-stuffs on the production values of the different feeds. By "production value" of a food Armsby refers to that part which can really go toward growth or the production of milk. He expressed his recommendations in terms of digestible true protein and therms of net energy. Armsby states that where the value of feeds is stated in terms of digestible nutrients, no allowance is made for the energy required for digestion and assimilation. Consequently, those feeds which are difficult to digest, ordinarily classed as roughages, when compared with concentrates show a greater efficiency than they really possess. Armsby found that timothy hay with 57% as much digestible material as corn meal, was worth for flesh or fat production, only 37% as much as corn meal.

While the theory here is undoubtedly correct, Armsby's results have been shown to be in error. His determinations for dairy cows were based on work with only a few animals and these being small beef steers. He also based some of his conclusions on work which Kellner had done with one cow. His work was first reported in 1909 and revised in 1917.

Eckles (9) in 1912 carried out an investigation at the Missouri Station to determine the nutrients required for milk production in terms of digestible protein and therms of net energy per pound of milk. From these investigations and from the work of Savage and Armsby, Eckles formulated a tentative standard according to the Armsby system. Eckles concluded that the methods Armsby used were in error and were too low when applied to milk production.

The modes of expression of the nutrient requirements for milk production of dairy cows are as varied as the feeding standards of which they are representative. Thus, we have the so-called modified Wolff-Lehmann table of requirements stated in terms of digestible nutrients; Kellner and his standard of starch values; and the standard of net energy values evolved and amplified to include the leading classes of livestock by Armsby. These have been the guides in formulating rations for farm animals in the past and will likely continue to be for some time in the future. It is with the former that this thesis is concerned.

Criticism of Feeding Standards Commonly Used To-day

In the light of recent investigations and practical application of the principles outlined in the standards mentioned, several present day writers have advanced opinions relative to the value and weaknesses of the feeding standards commonly used to-day.

Converse (7) questions the adequacy of nutrients prescribed in the Savage standard. This investigator, working at the Beltsville Station, has shown in two experiments that a 16% increase in milk yield could be secured by feeding cows well along in lactation 12% more than is advocated by this standard. In another experiment, working with whole lactation period comparisons, this writer has shown from a 14% to 16% increase in production as the result of feeding 17% more than the requirements.

The net energy requirements as outlined in the Armsby standard have been questioned by Meigs and Converse (29) on the ground that Armsby based his conclusions on the results of a single experiment which Kellner conducted with a milking cow for a period of two weeks. It is stated that this standard is not based on any experiments carried out under conditions approaching those which are obtained in practice.

Meigs (28) in a later paper further attacks Armsby's net energy values and states that they are inapplicable under almost all practical conditions. Meigs also shows that in order to suppose that Armsby's figures would be applicable, one must make a number of questionable assumptions. This author further states that experiments carried out with dairy cows indicate that the existing figures for the total digestible nutrients of dairy feeds furnish a very good measure of the relative values of these feeds as sources of nutritive energy under practical conditions.

Such contraversies amplify the statement made by many nutrition authorities that any feeding standard should be looked upon only as a guide. No feeding standard is applicable in all cases. Several may serve as a very good guide, but must be modified to meet specific conditions by a thoroughly trained and experienced feeder to give the best results.

Nutrients Requirements for Maintenance

The amount of the various nutrients required for maintenance is a highly variable factor with various animals not only of different species but also of the same species. Such factors as the temperament of the animal, plane of nutrition on which the animal is kept, condition and age cause considerable variation in the nutrients required for maintenance. Consequently, we find considerable variation in the factors reported by different workers on this subject.

Savage (33) advocates 0.07 of a pound of protein and 0.7925 of a pound of total nutriment per 100 pounds live weight for maintenance of the dairy cow. Haecker (20) recommends the same amount of protein as Savage but lists the balance as 0.7 of a pound of carbohydrate and 0.01 of a pound of fat for each 100 pounds live weight. These two standards are stated differently yet demand exactly the same amount of nutrients.

Armsby (3) sets his requirements for maintenance at 0.5 of a pound of protein and 6 therms of net energy for each 1000 pounds body weight. Cochrane, Fries and Braman (6) determined the net energy required for maintenance by three dry cows in a series of respiration calorimeter experiments to be 4.15, 5.42 and 5.566 therms, respectively, per 1000 pounds live weight. The lowest value was for a cow with an unusually quiet disposition. The other two values are for two quite normal cows, thus proving Armsby's figure of 6 therms to be too high.

Forbes, Fries and Kriss (13) have determined the maintenance requirements of cattle for protein as indicated by the fasting katabolism of dry cows. Working with two cows these investigators have set the requirement at 0.6 of a pound per 1000 pounds live weight. This is 0.1 of a pound more than Armsby's published estimate and 0.1 of a pound less than Morrison's stated requirement. This factor may be considered as providing more liberally for reproduction and other necessities of practice.

Morrison (11) has compiled his tables for maintenance requirements from a large number of investigations and after duly considering all previously published tables. He advocates 0.7 of a pound of protein and 7.925 pounds of total digestible nutrients for a 1000 pound cow. It will be noted that throughout Morrison closely agrees with Haecker and Savage on this subject. Morrison's tables are, however, somewhat more extended to cover a wider range of body weights. It is from Morrison's tables that the maintenance requirements have been determined for the cows referred to in this thesis.

Nutrient Requirements for Production of Milk

Practically the same statements could be made concerning the variability of published tables on this subject as have been written concerning the requirements for maintenance of dairy cows. However, here we encounter a wide variation in the quality of product produced and investigators have made due allowance for this.

Savage's tables (33) give the nutriment requirement for one pound of 4% milk as 0.0648 of a pound of protein and 0.3497 of a pound of total digestible nutrients. Haecker

(20) has set figures of 0.048 of a pound of protein, 0.233 of a pound of carbohydrate and 0.0164 of a pound of fat as the requirements to produce one pound of 4% milk. Haecker's standard has a lower requirement than Savage's when considered on the same basis.

Armsby (3) advocates 0.055 of a pound of protein and 0.3 of a therm of net energy for each pound of 4% milk.

Morrison (22), whose figures have been used in determining the requirements for production in this problem, sets his values as from 0.311 to 0.345 of a pound of total digestible nutriemts and from 0.054 to 0.065 of a pound of protein for each pound of 4% milk. It will be noted that Morrison's requirements fall approximately midway between Savage's and Haecker's.

Factors Affecting the Efficiency of Milk and Fat Production

Weight and Age of Cow. Brody, Ragsdale and Turner (5) have shown that increasing body weight contributes only about 20% to increasing milk secretion with age. The fact that milk secretion and body weight follow the same course, even though they are largely independent of each other, indicates that increase in body weight is a good measure of growth of the dairy cow. This fact also shows that the increase of milk secretion with age may be used as a measure of growth.

In a study of Jersey Register of Merit records where the weight records were available, comparing the body weight and yearly fat production of these cows, Turner, Ragsdale and Brody (38) found when all records were grouped together that after the Jersey cow reached the body weight of 470 pounds there was an increase of 104 pounds in fat production per year for an increase of 100 pounds of body weight with age. However, when the age was made constant an increase of approximately 20 pounds of fat for each 100 pounds of body weight was noted. It was concluded that an increase of body weight contributes about 20% to the total increased fat yield with age, while the other 80% of increased fat yield with age is due to other factors accompanying increased maturity.

After a study of 2700 Guernsey Advanced Register records where body weight was available, Turner (35) confirmed the conclusions of Turner, Ragsdale and Brody mentioned above. It was found in the case of the Guernseys under consideration that for an increase of 100 pounds in live weight accompanying age there was an increase of 77 pounds of fat per year. However, when age was held constant there was an increase of only 20 pounds of fat for an increase of 100 pounds in weight. It was concluded that about 25% of the total increase of fat secretion with age was due to the live weight of the animals concerned, whereas the other 75% of the increase in fat secretion with age would be ascribed to the development of the udder by recurring pregnancies.

From a study of 29,799 cow testing associations records, McDowell (26) concluded that the big cows win on the average in production of milk and butter fat and in income over cost of feed per cow. From the data presented by McDowell, the author has computed the average increase in yearly fat production to be 14 pounds for each 100 pounds increase in body weight. Only mature cows were included in McDowell's paper, thus eliminating the factors of age. The average increase in income over cost of feed per cow for each 100 pounds increase in body weight amounts to $6.14 according to McDowell's data.

To further determine the rate of growth of lactating cows, a study was made by Turner, Ragsdale and Brody (37) of the body weights of over 15,000 Register of Merit Jersey cows. It was found that these animals continue to increase in live weight at a constantly decreasing rate until approximately eight years old.

After carefully studying a large number of Jersey records, Turner (36) presents evidence which indicates that the greater production of large cows at best only slightly exceeds the cost of obtaining the additional product.

Gaines (16) has made a careful study of McDowell's extensive data to determine the efficiency of milk production as affected by the size of the cow. This writer is of the opinion that energy yield increases with the size of the cow in a linear manner and at the rate of about 250 pounds of 4% milk per year for each 100 pounds increase in weight. Since this is about half the corresponding figure found in advanced registry records, and the average yield also about half, it appears that the weight-yield relation is similar in the two classes of records if level of yield is used as a base. Gaines calculates that the recorded feed cost per hundred weight of 4% milk decreases with live weight of the cow in the range 600 to 800 pounds; and is practically constant in the range 800 to 1600 pounds.

Herd and Test Conditions Compared. Woodward (42) has made a study at the Beltsville Station comparing cows kept under test conditions with those under herd conditions to determine the economy of production. Twenty-two cows included in this study have conpleted records under both conditions making a total of 52 records; 27 being made under test conditions and 25 under herd conditions. The average length of lactation period is reported as 365 days for test cows, and 346.5 days for those not on test. This investigation shows that cows kept under the test conditions which prevail at the Beltsville Station yield approximately 50% more milk and butter fat than cows kept under herd conditions. This is an important point to remember in buying stock on the basis of records. A 400 pound record under herd conditions is equal to 600 pounds under test conditions. This writer states that with cows such as were used in this work it is obvious that test-cow care and feeding will not pay if the product is to be disposed of for butter making even if both feed and labor are cheap.

Reed (31) has reported on a similar experiment covering 18 lactations - 8 cows were milked twice daily and 10 under three time milking. The length of the lactation periods varied from 217 to 365 days. The only variable condition in this experiment being the number of times per day which cows were milked. Cows milked three times gave 21.2% more milk and 22.4% more butter fat. Much of this increase is due to the fact that cows milked three times a day held up better in their milk flow. The decline in production from the first to the last 30 days of the lactation period was only about one-half as great with the cows milked three times as with those milked twice. Although this writer apparently questions the advisability of milking more than twice a day under average conditions, he states that this is dependent upon so many variable factors that each individual must carefully determine this for himself after considering all local factors.

Quantity of Milk and Fat Produced. Cows require a certain amount of feed for maintenance, above which the feed cost for each 100 pounds of butter fat produced annually will be practically the same whether a cow is a light or heavy producer. The high producing cow is generally considered more profitable because the cost of maintenance is spread over a larger quantity of product rather than because of a more efficient use of the feed she consumes. These facts have been verified by McIntyre (27) after making a study including 3844 individual yearly cow records. McIntyre also shows that a positive correlation exists between the annual fat production and annual feed costs of dairy cows under farm conditions; and that the feed cost of one pound of butter fat is lower when the annual production of a cow is greater. This proportionate increase in feed cost is greater when the production of good cows is doubled than when the production of poor cows is doubled.

After a study of 1605 records of Holstein cows, 3 year old or over, Ross, Hall and Rhode (22) concluded that the annual production of milk and fat per cow and the nutrient consumption per unit of product are negatively correlated. As production is increased by increasing the potential production ability of a herd, the amount of nutrients consumed per unit of product decreases at an ever-decreasing rate. Ezekiel, McNall and Morrison (12) give practically the same conclusions after having considered 5087 records of Wisconsin dairy cows. These latter workers report that their results indicated that slightly more additional feed was required to produce milk of high butter fat content as compared with milk of lower fat content than is called for by current feeding standards.

<u>Other Factors.</u> Perhaps the three most important factors to be considered when comparing the ability of certain cows as producers could be listed as length of record, frequency of milking and pregnancy. Two of these have been discussed herein, and pregnancy will be considered along with some other factors.

Copeland (8) states that during the first 5 or 6 months of pregnancy the lactation curve is not appreciably affected. If a calf is carried longer than six months there are certain inhibiting factors which become noticeable. Undoubtedly the fetus, after 5 or 6 months growth, is in part responsible for this decline, due to its demands for nutrients to support its life processes. However, Eckles (10) believes that the nutrients required for the development of the fetus constitute only a very minor drain on the dam. In fact, on the dry matter basis, a Jersey calf at birth is equivalent to only 125 to 175 pounds of Jersey milk. Another explanation offered by Hooper (23) and Gaines and Davidson (18) is that the growing fetus after 5 months produces a material (Hormone) that tends to check the milk flow and dries off the cow preparatory to the duties of feeding another calf. Copeland also presents data which indicates that pregnancy appears to exert little if any influence on the butter fat percentage.

McCandlish (25) concludes after considering 868 cases that there is a wide variation not only between cows but also between different heat periods of the same cow as influencing their milk production. There is a decrease in milk production on the day of breeding and the day following, with an apparently compensating increase taking place two days after breeding. This would seem to prove that the period of heat has but little if any influence on the milk production.

Persistency of lactation has been quite generally looked upon as an inherited factor. Becker and McGilliard (4) have studied 53 lactations of 34 cows, both scrubs and registered animals, and conclude that although common cows attained maximum milk yield earlier in the lactation period and declined in milk flow less rapidly (pounds per day), their lactation periods were not as long as those of the registered cows studied. Woll (41) after working with 395 yearly records, 347 of which were for purebred cows and 48 grades, concludes that cows decrease in production about 5% each month for the first 7 months. If cows are bred to freshen within a year they will have fallen off about 98% in their production by the twelfth month on the average.

Much has been written concerning the possibility of changing the percentage composition of milk by varying the diet. A recent piece of work by Taylor and Husband (34) shows that diet has no direct influence on the percentage composition of the milk. However, it does appear that a high protein diet would stimulate the rate of secretion of the milk.

Composition of Milk and Its Effect on the Energy Required for Production

It is entirely unsatisfactory to compare the production of cows merely on the basis of pounds of milk produced. The composition of milk is so highly variable that a consideration of the solid material contained in milk from different cows is absolutely necessary. One cow may produce less in so far as pounds of milk are concerned, yet she may be producing a product which contains much more energy and real food value than another cow which is producing a great many more pounds of milk.

Gaines (17) after making an analysis of 23,302 records to study the relation between percentage of fat content and yield of milk, has derived a formula to equate the milk yield at varying fat percentages to the standard of a milk having a fat content of 4%. This is referred to as determining the milk yield on the basis of "4% milk" or "fat-corrected milk". The suggested formula takes the following form:

$$F.C.M. = 0.4M + 15F$$

F.C.M. is pounds of "fat-corrected milk", M represents pounds of milk actually produced and F represents pounds of fat in milk actually produced.

The fat content of the milk is a factor affecting milk yield. No other single constituent of milk varies with the milk yield as does the percentage of fat. Overman and Sanmann (30) and White and Judkins (39) have carried out similar investigations to determine the relation between the composition of milk and its energy value. The former workers suggest a method for computing the heat of combustion of a quart of milk. The latter two investigators have presented several conclusions relative to factors which are responsible for the variation in composition of milk from individual cows. Maturity, condition at calving and seasonal changes being the more important factors given.

Gaines, previously mentioned, suggests that energy yield, that is, the gross energy value of the milk, is a better measure of yield than either the milk or the fat. Again Gaines (14)(15) in referring to the relation between the composition of the milk and the nutrients required for lactation under comparable conditions of feeding, makes the following statement: "The nutrients required for lactation are directly proportional to the energy value of the milk solids."

In enlarging upon the merits of measuring milk yield on the energy basis, Gaines says that energy yields are directly comparable in so far as the fat percentage of the milk is concerned. Energy yields may be regarded as the primary measure of yield, showing the amount of work done in milk secretion. This work may be done in different directions, that is, to variable degrees in the elaboration of fat, protein and lactose. Fat percentage may be regarded as a secondary measure of yield, showing the direction in which the work is done. From a biological point of view, the essential measures of performance of the cow are the energy yield and fat percentages.

The author has used the Gaines formula to determine the milk production of the cows used in this study as an attempt to put the cows on a more comparable basis.

EXPERIMENTAL DATA

Purpose of the Investigation. The purpose of this investigation is to make a study of the nutrients required for milk production under conditions which exist in the dairy herd of this station. These requirements are expressed in terms of digestible crude protein and total digestible nutrients per 100 pounds of milk and per pound of butter fat.

Source of Data for the Problem. Feed records have been kept on cows in the dairy herd at this station since January 1, 1920. Therefore, considerable data have been accumulating in regard to the feeding of dairy cows. While not as comprehensive as might be desired, the data were still thought to be of sufficient compass to warrant a close study.

The regular plan followed at this station has been to get feed weights on each of the cows in the herd for two successive days each month, this serving as the information from which the regular monthly feed consumption of each cow is determined. Silage weights are usually taken for one day since considerable variation in the amount of this bulky feed allowed would have but little affect on the nutrients a cow would get. The concentrates are weighed twice each month to reduce the possibility of errors. Hay is usually fed in racks for the entire herd, consequently it became necessary to estimate the amount of hay which each cow consumed. No attempt has been made to estimate the amount of nutrients derived from pasture.

These data represent work with purebred cows of the four leading dairy breeds and have been compiled from the the records of animals fed under both herd and test conditions. Test conditions involve both three and four time milking. Cows kept under herd conditions are milked twice daily and cared for about as would be expected on the average dairy farm.

In all there are 29 different cows with a total of 143 different lactation periods included in this study. The distribution is as follows: 12 Ayrshires with 64 lactation periods, 7 Holsteins with 31 lactation periods, 5 Guernseys with 26 lactation periods and 5 Jerseys with 22 lactation periods.

In the station herd cows are weighed at the time of calving and on the first day of January and July, therefore, sufficient weights are available to estimate the average body weight of each cow concerned for any lactation period considered during the period in which feed weights are available. Complete individual milk records are kept on the cows at this station.

Procedure in Studying Data. From the feed records available, the number of pounds of each of the various feeds consumed during a lactation period were determined. Henry and Morrison's tables for the average digestible nutrients in American feeding stuffs were used to determine the pounds of digestible crude protein and total digestible nutrients contained in the feed. Feeds which the cows received at various times may be listed as follows: A test mixture which was made up of 200 pounds corn chop, 150 pounds oats chop, 100 pounds bran, 60 pounds cottonseed meal and 40 pounds linseed oil meal; a herd mixture consisting of 400 pounds corn chop, 200 pounds bran and 100 pounds cottonseed meal; alfalfa hay of at least average composition; silage which for the most part was about 90% sorghum and 10% corn; and beet pulp. The amount of digestible crude protein and total nutrients in 100 pounds of each of the various feeds is listed below:

Feed	Lbs. Digestible Crude Protein	Lbs. Total Digestible Nutrients
Test Mixture	13.8	74.1
Herd Mixture	12.3	74.5
Alfalfa Hay	10.6	51.6
Silage	0.6	13.7
Beet Pulp (dry)	4.6	71.6

Knowing the total pounds of each feed consumed and the pounds of digestible crude protein and total digestible nutrients in such feeds it was a simple matter to determine the total pounds of digestible crude protein and total digestible nutrients consumed by each cow during a single lactation period.

From the body weight figures which were available, the average weight of each cow for a certain lactation period was determined. This was used as the basis for estimating the amount of hay which a cow consumed. The hay consumption was figured as one pound per day for each 100 pounds body weight. Since it was not practicable in this study to determine the amount of nutrients derived from pasture, the hay consumption was figured the same during summer as for the winter months, and pasture was eliminated. Furthermore, cows at this station have access to good pasture only a comparatively short time each year.

To determine the pounds of digestible crude protein and total digestible nutrients which were allowed for maintenance the author has used Morrison's figures (11) for maintenance requirements in so far as possible, and interpolated to get other needed values not included in this table.

After the average body weight of a cow was calculated, the daily maintenance requirements could readily be determined, then multiplied by the number of days in the cow's lactation period to calculate the pounds of digestible crude protein and total digestible nutrients allowed for maintenance during a certain lactation period.

The pounds of digestible crude protein and total digestible nutrients available for production were determined for each cow by substracting the maintenance allowance from the total amount of nutrients derived from the feed which was consumed during the lactation period in question.

At this point the pounds of digestible crude protein and total digestible nutrients required to produce one pound of butter fat was calculated. This figure was on the basis of the actual number of pounds of butter fat produced. In making similar determinations per 100 pounds of milk, the author has converted all milk records to "fat-corrected milk" on the 4% fat basis, as suggested by Gaines (15). It was thought that this would place the cows of different breeds on a more comparable production basis.

DISCUSSION OF DATA

Individual Variation in Nutrients Required for Milk Production. The data showing the nutrients required by each cow in this study for the production of 100 pounds of milk and one pound of fat, are presented in Tables I to IV inclusive.

An analysis of the figures presented in these tables discloses the fact that there are extremely wide variations in the requirements for production among different cows. a quite pronounced variation is noticeable in different lactation periods for the same cow. Several factors may enter into this problem and account for this fluctuation. Age, length of lactation period, whether a cow is carried under herd or test conditions, body weight and plane of lactation are factors which tend to influence the economy of production.

While the data presented in Tables I to IV inclusive, are for individual cows, and are too variable to be of any considerable value as recorded, the summaries which follow furnish evidence for some definite conclusions.

Listed below are the cows which have been included in this study. The index number for each cow corresponds to the index numbers for cows given in Tables I to IV inclusive.

Index to Cows Used in This Study -
29 Cows Representing the Four Major Dairy Breeds

Ayrshires (12 considered)

Index Number	Name	Registration Number
1	Bangora's Melrose	37839
2	B. M's Bangift	74838
3	B. M's Bangora Melrose	60018
4	B. M's Johannah	67446
5	B. M's Melcroft	73687
6	Cavalier's Croft Melrose	44693
7	Henderson's Canary Bell	74339
8	Melrose Canary Bell	37838
9	Melrose Canary Bell 2nd	52315
10	Melrose Cavalier's Croft	71177
11	Melrose Croft Maud, 3rd	56838
12	Melrose Johannah	55311

Guernseys (5 considered)

Index Number	Name	Registration Number
13	Benefactor's College Frances	108644
14	Benefactor's Happy Girl	81268
15	Imp. Golden Chance of Ashburton	66993
16	Stars and Stripes Golden Cherry	127088
17	Stars and Stripes Rose	126326

Holsteins (7 considered)

Index Number	Name	Registration Number
18	Canary Paul Walker	518925
19	Carlotta Empress Fobes	330881
20	Inka Hijlaard Walker	360354
21	Juliana Walker	270081
22	K.S.A.C. Korndyke Canary	592608
23	K.S.A.C. Korndyke Ina	792575
24	K.S.A.C. Korndyke Inka	792576

Jerseys (5 considered)

Index Number	Name	Registration Number
25	Oakland's Double Tipsy	491586
26	Oakland's Jolly Tipsy	307645
27	Sultana's College Princess	417612
28	Sultana's Jolly Tipsy	361499
29	Winnie's Tipsy	426830

TABLE I

Data on Ayrshire Cows

Index Number of Cow	Test (No or Yes)	Age at Beginning of Record		Length of Lactation Period	Milk Produced during Period	Total Butter Fat for Period	Fat Corrected Milk	Dig. Prot. in Feed Consumed	T.D.N's. in Feed Consumed	Average Weight of Cow	Dig. Prot. for Maintenance	T.D.N's. for Maintenance	Dig. Prot. Available for Production	T.D.N's. Available for Production	Dig. Prot. Required per 100# of Milk	T.D.N's. Required per 100# of Milk	Dig. Prot. Required per 1# of Fat	T.D.N's. Required per 1# of Fat
		Yrs.-	Mos.	days	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	Yes	6	4	305	12,614.9	456.0	11,885.9	1125.0	6592.8	1150	245.5	2776.1	879.5	3816.7	7.4	32.1	1.9	8.4
1	"	7	4	365	9,423.5	334.9	8,792.9	1038.3	6256.1	1100	281.0	3181.7	757.2	3074.4	8.6	35.0	2.3	9.2
1	"	8	6	326	13,848.7	496.9	12,993.0	1272.4	7672.1	1150	262.4	2967.3	1009.9	4704.9	7.8	36.2	2.0	9.5
1	"	10	8	365	12,360.1	399.6	10,936.5	1026.6	6621.5	1100	281.1	3181.7	745.5	3439.8	6.8	31.5	1.9	8.6
2	"	2	4	341	10,549.5	428.0	10,639.8	861.2	5475.9	950	226.8	2563.3	634.5	2912.6	6.0	27.4	1.5	6.8
2	No	3	4	293	4,676.0	182.2	4,603.4	568.7	3753.9	950	194.8	2202.5	373.8	1551.4	8.1	33.7	2.1	8.5
2	Yes	4	3	361	10,687.2	427.1	10,687.2	1012.4	6602.9	1050	265.3	2999.9	747.1	3602.9	7.0	33.7	1.7	8.4
2	"	5	5	310	6,997.4	275.5	6,931.5	739.5	4844.4	1100	238.7	2702.3	500.8	2142.1	7.3	30.9	1.8	7.8
2	No	6	6	284	6,101.0	239.6	6,034.4	603.2	3957.2	1050	208.7	2360.0	394.5	1597.2	6.5	26.5	1.6	6.7
2	"	7	5	274	5,081.7	195.7	4,968.2	545.6	3668.1	1000	191.8	2171.4	353.8	1496.6	7.1	30.1	1.8	7.6
3	Yes	2	3	365	16,140.0	616.5	15,703.5	1275.0	7969.5	1000	255.5	2892.6	1019.5	5076.8	6.5	32.3	1.7	8.2
3	Yes	5	0	365	16,887.2	705.8	17,311.9	1693.4	10799.9	1350	344.9	3900.8	1348.5	6899.1	7.8	39.8	1.9	9.8
3	"	6	4	365	19,490.0	754.9	19,121.0	1707.7	10914.8	1350	344.9	3900.8	1362.8	7014.0	7.1	36.7	1.8	9.2
3	"	7	8	316	10,397.8	389.4	10,000.1	917.5	6115.3	1250	276.5	3126.8	641.0	2988.5	6.4	29.9	1.6	7.7
4	"	2	8	350	9,462.6	370.2	9,338.0	1150.9	7058.5	1050	257.2	2908.5	893.3	4150.0	9.6	44.4	2.4	11.2
4	No	3	8	230	2,484.5	101.1	2,501.3	488.7	3382.0	1050	169.1	1911.3	319.6	1470.7	12.8	58.8	3.2	14.6
4	"	4	7	301	5,415.9	202.0	5,196.4	643.9	4268.8	1100	231.8	2623.8	412.1	1645.0	7.9	31.7	2.0	8.1
4	Yes	5	11	305	15,413.0	585.4	14,946.2	1275.4	8102.9	1300	277.6	3142.1	997.9	4960.8	6.7	33.2	1.7	8.5
4	"	6	11	296	8,724.2	332.9	8,483.2	786.2	5198.4	1250	259.0	2928.9	527.2	2269.5	6.2	26.8	1.6	6.8
4	"	7	11	297	9,767.8	354.8	9,229.1	892.3	5691.9	1250	259.9	2938.8	632.4	2753.0	6.9	29.8	1.8	7.8
5	"	2	11	365	10,531.4	420.9	10,531.4	939.1	5946.8	1150	293.8	3322.8	645.3	2624.5	6.1	24.9	1.5	6.2
5	"	4	1	299	7,828.0	308.1	7,752.7	636.6	4676.9	1200	251.2	2840.5	385.5	1836.4	5.0	23.7	1.4	6.0
5	"	5	2	159	5,401.8	206.5	5,258.2	463.7	2857.8	1250	137.4	1553.5	326.4	1304.3	6.2	24.8	1.6	6.3
5	No	6	2	285	7,536.7	293.2	7,412.7	762.8	4881.5	1300	259.3	2936.1	503.4	1945.5	6.8	26.2	1.7	6.6
5	"	7	2	300	7,317.9	294.8	7,349.2	830.7	5397.2	1200	252.0	2850.0	578.7	2547.2	7.9	34.7	2.0	8.7
5	"	8	1	365	8,529.6	331.9	8,390.3	1051.8	6990.5	1200	306.6	3467.5	745.3	3523.0	8.9	42.0	2.3	10.6
6	Yes	4	11	365	10,518.7	393.4	10,108.5	1064.1	6643.3	1200	306.6	3467.5	757.8	3175.8	7.5	31.4	2.0	8.1
6	No	6	3	290	8,484.3	316.8	8,145.7	757.2	4756.1	1250	253.8	2869.6	503.5	1886.6	6.2	23.2	1.6	6.0
6	"	7	2	350	10,402.9	403.2	10,209.2	910.1	6050.8	1200	294.0	3325.0	616.1	2725.8	6.0	26.7	1.5	6.8
6	Yes	8	5	301	9,174.9	301.7	8,195.4	869.7	5669.4	1150	242.3	2739.7	627.4	2929.7	8.0	35.7	2.0	9.7
6	"	9	7	365	9,926.8	357.1	9,328.7	869.6	5819.5	1150	293.8	3322.2	575.8	2497.3	6.2	26.8	1.6	7.0
6	No	10	11	365	9,126.7	326.9	8,555.7	804.9	5284.4	1150	293.8	3322.2	511.1	1962.2	6.0	22.9	1.6	6.0

TABLE I - Continued

Index Number of Cow	Test (No or Yes)	Age at Beginning of Record Yrs.	Mos.	Length of Lactation Period days	Milk Produced during Period lbs.	Total Butter Fat for Period lbs.	Fat Corrected Milk lbs.	Dig.Prot. in Feed Consumed lbs.	T.D.N's. in Feed Consumed lbs.	Average Weight of Cow lbs.	Dig.Prot. for Maintenance lbs.	T.D.N's. for Maintenance lbs.	Dig.Prot. Available for Production lbs.	T.D.N's. Available for Production lbs.	Dig.Prot. Required per 100# of Milk lbs.	T.D.N's. Required per 100# of Milk lbs.	Dig.Prot. Required per 1# of Fat lbs.	T.D.N's. Required per 1# of Fat lbs.
7	Yes	2	11	356	10,735.4	433.8	10,801.2	884.5	5593.6	1150	286.6	3240.3	597.9	2353.3	5.5	21.8	1.4	5.4
7	"	4	0	286	8,277.0	329.1	8,247.3	744.3	4739.8	1100	220.3	2493.1	524.0	2246.7	6.4	27.2	1.6	6.8
7	"	4	11	312	10,418.5	388.9	10,000.9	896.9	5630.8	1200	262.1	2964.0	634.8	2666.8	6.3	26.7	1.6	6.9
7	No	5	11	304	9,222.1	340.6	8,797.8	750.1	4862.4	1200	255.3	2888.0	494.9	1974.4	5.6	22.4	1.5	5.8
8	Yes	7	3	365	13,439.2	476.7	12,526.2	1214.2	7095.7	1300	332.1	3760.2	882.3	3335.5	7.0	26.6	1.9	7.0
8	"	8	6	365	17,124.4	625.2	16,227.8	1474.8	9118.6	1300	332.2	3760.2	1142.7	5358.4	7.0	33.0	1.8	8.6
8	No	9	10	365	7,280.9	251.8	6,689.4	815.4	5482.7	1250	319.4	3611.7	496.1	1871.0	7.4	28.0	2.0	7.4
8	Yes	11	5	326	9,985.0	347.3	9,203.5	865.0	5561.4	1150	262.4	2967.3	602.6	2594.1	6.5	28.2	1.7	7.6
9	"	2	3	300	11,633.4	392.9	10,546.9	1014.9	5719.5	1050	220.5	2493.0	794.4	3226.5	7.5	30.6	2.0	8.2
9	"	3	3	365	14,408.3	464.8	12,735.3	1268.2	7667.8	1200	306.6	3467.5	961.6	4200.3	7.6	33.0	2.0	9.0
9	"	4	5	365	12,940.2	433.7	11,681.6	1241.2	8206.7	1250	319.4	3611.7	921.9	4594.9	7.9	39.3	2.1	10.6
9	"	5	7	346	12,900.9	432.1	11,641.9	1184.9	6810.7	1250	302.8	3423.7	882.1	3387.1	7.6	29.1	2.0	7.8
9	"	6	8	365	14,836.5	501.8	13,461.6	1431.1	9194.3	1250	319.4	3611.7	1111.7	5582.6	8.3	41.4	2.2	11.1
9	"	8	0	365	18,000.1	654.5	17,017.9	1478.5	9415.1	1300	332.2	3760.2	1146.4	5654.9	6.7	33.2	1.8	8.6
9	"	9	4	365	10,876.2	378.6	10,029.5	1037.1	6672.6	1200	306.6	3467.5	730.5	3205.1	7.3	32.0	1.9	8.5
10	"	2	4	305	7,882.9	307.4	7,764.2	860.2	5486.1	950	202.8	2292.7	657.4	3193.4	8.5	41.4	2.1	10.4
10	"	3	4	298	6,334.0	240.6	6,142.6	645.6	4294.4	1100	229.5	2597.7	416.1	1696.7	6.8	27.6	1.7	7.1
10	"	4	5	246	6,681.0	252.6	6,461.4	610.5	4015.1	1200	206.6	2337.0	403.8	1678.1	6.2	26.0	1.6	6.6
10	"	5	5	228	6,033.2	232.5	5,900.8	573.4	3622.9	1100	175.6	1987.5	397.8	1635.5	6.7	27.7	1.7	7.0
10	No	6	5	230	6,329.6	248.1	6,253.3	539.8	3492.7	1100	177.1	2004.9	362.7	1487.8	5.8	23.8	1.5	6.0
11	"	2	3	365	7,426.0	282.0	7,200.4	682.1	4373.7	950	242.7	2743.7	439.4	1630.0	6.1	22.6	1.6	5.8
11	Yes	3	7	365	10,416.9	385.6	9,950.8	1151.8	7119.7	1050	268.3	3033.1	883.5	4086.5	8.9	41.1	2.3	10.6
11	No	4	10	305	7,898.0	324.5	8,026.7	744.1	5111.7	1100	234.8	2658.7	509.2	2453.1	6.3	30.6	1.6	7.6
11	"	5	10	308	7,526.2	267.6	7,024.5	761.3	5076.9	1200	258.7	2926.0	502.6	2150.9	7.2	30.6	1.9	8.0
11	Yes	6	10	301	9,191.1	334.5	8,693.9	836.6	5348.8	1200	252.8	2859.5	583.8	2489.3	6.7	28.6	1.7	7.4
11	"	8	1	207	8,593.8	321.3	8,257.0	713.5	4308.8	1250	181.1	2048.3	532.4	2260.5	6.4	27.4	1.7	7.0
11	No	9	10	362	8,989.4	303.4	8,148.3	861.8	5660.4	1150	291.4	3294.9	570.4	2365.5	7.0	29.0	1.9	7.8
11	"	11	0	341	10,625.2	409.8	10,397.1	1060.1	6956.7	1150	274.5	3103.8	785.6	3852.9	7.6	37.1	1.9	9.4
12	"	2	4	365	7,928.4	292.9	7,564.9	749.4	4779.2	1000	255.5	2892.6	493.9	1886.6	6.5	24.9	1.7	6.4
12	Yes	3	10	318	8,523.8	319.2	8,197.5	950.6	6865.1	1100	244.9	2772.0	705.8	4093.1	8.6	49.9	2.2	13.2
12	No	4	11	365	8,591.0	308.5	8,063.9	799.7	5276.9	1150	293.8	3322.2	505.8	1954.7	6.3	24.2	1.6	6.3
12	"	6	1	345	8,935.5	372.4	9,116.2	838.6	5590.7	1150	277.7	3140.2	560.9	2450.5	6.1	26.8	1.5	6.6

TABLE II

Data on Guernsey Cows

Index Number of Cow	Test (No or Yes)	Age at Beginning of Record Yrs.	Mos.	Length of Lactation Period days	Milk Produced during Period lbs.	Total Butter Fat for Period lbs.	Fat Corrected Milk lbs.	Dig.Prot. in Feed Consumed lbs.	T.D.N's. in Feed Consumed lbs.	Average Weight of Cow lbs.	Dig.Prot. for Maintenance lbs.	T.D.N's. for Maintenance lbs.	Dig.Prot. Available for Production lbs.	T.D.N's. Available for Production lbs.	Dig.Prot. Required per 100# of Milk lbs.	T.D.N's. Required per 100# of Milk lbs.	Dig.Prot. Required per 1# of Fat lbs.	T.D.N's. Required per 1# of Fat lbs.
13	No	2	1	365	5,419.8	261.0	6,082.9	585.3	3790.7	800	204.4	2314.1	380.9	1476.6	6.3	24.3	1.5	5.7
13	"	3	2	327	4,500.1	227.1	5,206.5	535.7	3500.6	850	194.6	2199.1	341.1	1301.6	6.6	25.0	1.5	5.7
13	"	4	2	365	4,515.7	222.8	5,148.3	606.4	4051.6	900	229.9	2603.2	376.5	1448.4	7.3	28.1	1.7	6.5
13	"	5	8	228	2,982.1	137.9	3,262.8	395.3	2596.6	950	151.6	1713.8	243.7	882.7	7.5	27.1	1.8	6.4
14	Yes	2	10	365	8,056.3	355.6	8,556.5	904.5	5539.3	850	217.2	2454.6	687.4	3084.7	8.0	36.1	1.9	8.7
14	"	4	2	365	11,284.0	485.8	11,800.6	1067.1	6416.2	950	242.7	2743.7	824.4	3672.5	7.0	31.1	1.7	7.6
14	"	5	6	365	11,421.8	477.6	11,732.7	1127.8	6736.9	1000	255.5	2892.6	872.3	3844.3	7.4	32.8	1.8	8.0
14	No	6	6	346	5,635.1	222.8	5,596.0	647.0	4254.7	900	218.0	2467.7	429.1	1787.0	7.7	31.9	1.9	8.0
14	Yes	7	10	365	8,661.8	383.9	9,223.2	865.8	5406.2	1050	268.3	3033.2	597.6	2373.1	6.5	25.7	1.6	6.2
14	No	9	4	365	6,225.1	280.8	6,702.0	723.0	4610.8	1000	255.5	2892.6	467.5	1718.1	7.0	25.7	1.7	6.1
14	"	11	0	365	6,648.0	282.5	6,896.7	610.7	3975.6	850	217.2	2454.6	393.5	1520.9	5.7	22.1	1.4	5.4
15	Yes	6	10	365	7,924.1	316.1	7,911.1	798.0	5125.8	950	242.7	2743.7	555.3	2382.1	7.0	30.1	1.8	7.5
15	No	8	3	330	4,643.6	193.1	4,753.8	583.8	3815.7	900	207.9	2353.6	375.9	1462.1	7.9	30.8	1.9	7.6
15	"	9	3	344	5,273.9	209.9	5,259.6	635.0	4190.6	950	228.8	2585.8	406.3	1604.7	7.7	30.5	1.9	7.6
15	"	10	4	332	4,566.0	176.5	4,473.9	607.9	4160.4	950	220.8	2495.6	387.2	1664.7	8.7	37.2	2.2	9.4
16	"	2	0	365	4,943.1	252.2	5,760.2	519.9	3594.2	650	166.6	1892.5	353.9	1702.7	6.1	29.6	1.4	6.8
16	Yes	3	3	239	5,425.5	265.5	6,152.7	491.8	3195.3	750	125.5	1423.3	366.3	1772.0	6.0	28.8	1.4	6.7
16	"	4	3	282	5,745.8	286.5	6,595.8	543.5	3519.8	800	157.9	1787.9	385.6	1731.9	5.8	26.3	1.3	6.0
16	"	5	4	360	6,585.3	302.8	7,177.6	567.8	3631.1	900	163.8	1854.3	404.0	1776.7	5.6	24.8	1.3	5.9
16	No	6	7	365	8,560.8	415.0	9,449.3	742.0	4923.6	900	229.9	2603.2	512.0	2320.4	5.4	24.6	1.2	5.6
16	"	7	11	365	6,967.1	341.2	7,904.8	718.1	4725.5	850	217.2	2454.6	500.9	2270.9	6.3	28.8	1.5	6.7
17	Yes	2	8	365	9,083.5	466.1	10,624.9	1020.8	7309.7	1000	255.5	2892.6	765.3	4417.1	7.2	41.6	1.5	8.8
17	"	4	0	248	4,251.7	212.3	4,885.2	546.7	3381.3	1000	173.6	1965.4	373.1	1415.9	7.6	29.0	1.8	6.7
17	"	5	2	365	11,984.0	578.4	13,469.6	1102.5	7033.6	1100	281.1	3181.7	821.4	3851.9	6.1	28.6	1.4	6.7
17	"	6	2	318	4,076.6	186.9	4,434.1	698.7	4047.9	1100	244.9	2772.0	453.8	1276.0	10.2	28.8	2.4	6.8
17	"	7	3	332	10,066.6	476.0	11,166.6	902.3	5828.2	1150	267.3	3021.9	635.1	2806.3	5.7	25.1	1.3	5.9

TABLE III

Data on Holstein Cows

Index Number of Cow	Test (No or Yes)	Age at Beginning of Record		Length of Lactation Period	Milk Produced during Period	Total Butter Fat for Period	Fat Corrected Milk	Dig.Prot. in Feed Consumed	T.D.N's. in Feed Consumed	Average Weight of Cow	Dig.Prot. for Maintenance	T.D.N's. for Maintenance	Dig.Prot. Available for Production	T.D.N's. Available for Production	Dig.Prot. Required per 100# of Milk	T.D.N's. Required per 100# of Milk	Dig.Prot. Required per 1# of Fat	T.D.N's Required per 1# of Fat
		Yrs.-	Mos.	days	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
18	Yes	2	6	365	13,767.3	449.6	12,250.9	1204.1	7439.9	1100	281.1	3181.7	923.1	4258.2	7.5	34.8	2.1	9.5
18	"	3	9	365	17,116.2	580.6	15,555.5	1455.5	8868.1	1250	319.3	3611.7	1136.2	5256.4	7.3	23.8	2.0	9.1
18	No	5	1	365	10,176.7	326.8	8,972.7	810.4	5652.3	1100	281.1	3181.7	529.4	2470.6	5.9	27.6	1.6	7.6
18	Yes	6	6	365	20,683.2	694.7	18,693.8	1476.7	9373.0	1300	332.2	3760.2	1144.6	5612.8	6.1	30.0	1.6	8.1
18	"	8	2	287	8,288.0	314.8	8,037.2	685.4	4533.9	1300	261.2	2956.7	424.2	1577.2	5.3	19.6	1.3	5.0
19	"	5	1	365	27,398.2	810.4	23,115.3	1825.7	11053.2	1450	370.5	4190.2	1455.2	6862.9	6.3	29.7	1.8	8.5
19	"	7	3	365	27,044.1	783.9	22,577.6	1761.3	10764.6	1450	370.5	4190.2	1390.8	6574.4	6.2	29.1	1.8	8.4
19	No	8	7	365	12,323.9	412.1	11,111.1	1067.7	5785.3	1350	344.9	3900.7	722.8	1884.6	6.5	16.9	1.8	4.6
20	Yes	4	2	305	12,264.5	426.0	11,295.8	1242.2	7234.5	1350	288.2	3259.5	954.0	3975.0	8.4	35.2	2.2	9.3
20	"	5	2	365	19,260.8	786.9	19,260.8	1535.4	9460.7	1400	357.7	4049.7	1177.7	5411.1	6.1	28.1	1.5	6.9
20	"	6	5	365	16,162.5	572.4	15,052.5	1385.2	8606.3	1400	357.7	4049.7	1027.5	4556.6	6.8	30.3	1.8	8.0
20	"	7	8	365	21,068.0	775.0	20,052.2	1662.1	10368.2	1500	385.1	4338.8	1277.1	6029.4	6.4	30.1	1.6	7.8
20	"	9	0	365	19,779.9	722.5	18,749.4	1596.4	10116.1	1600	410.6	4663.6	1185.8	5452.5	6.3	29.1	1.6	7.5
20	"	10	1	365	17,456.0	632.0	16,462.4	1589.8	10004.8	1600	410.6	4663.6	1179.2	5341.2	7.2	32.4	1.9	8.5
20	"	13	5	360	9,536.3	340.6	8,923.5	1077.5	6824.9	1500	379.8	4279.3	697.8	2545.6	7.8	28.5	2.0	7.5
21	"	6	1	365	14,699.9	488.2	13,201.4	1392.7	7885.4	1200	306.6	3467.5	1086.1	4417.9	8.2	33.5	2.2	9.1
21	"	7	3	365	12,201.8	417.8	11,147.7	1053.6	6532.5	1200	306.6	3467.5	746.9	3065.0	6.7	27.5	1.8	7.3
21	No	8	8	350	6,892.9	214.3	5,971.7	820.4	5277.9	1200	294.0	3325.0	526.4	1952.9	8.8	32.7	2.5	9.1
22	Yes	2	7	365	9,640.6	356.4	9,202.2	1098.7	6882.6	1000	255.5	2892.6	843.2	3989.9	9.2	43.4	2.4	11.2
22	"	3	11	365	15,292.1	533.3	14,114.8	1409.9	8782.6	1400	357.7	4049.7	1052.2	4732.9	7.5	33.5	2.0	8.9
22	"	5	7	343	9,482.1	323.6	8,646.8	969.1	6262.5	1400	336.1	3805.6	632.9	2456.9	7.3	28.4	2.0	7.6
22	"	6	8	365	10,364.8	350.5	9,403.4	1076.8	6793.9	1400	357.7	4049.7	719.1	2744.2	7.6	29.2	2.1	7.8
22	"	8	1	244	8,597.8	298.1	7,910.6	779.9	5947.1	1400	239.1	2707.2	540.8	3239.9	6.8	41.0	1.8	10.9
23	"	2	7	365	16,956.2	628.6	16,211.5	1415.9	9119.0	1400	357.7	4049.7	1058.2	5069.4	6.5	31.3	1.7	8.1
23	"	4	3	365	22,699.4	849.9	21,829.8	1827.5	11617.7	1600	410.6	4663.6	1416.9	6954.1	6.5	31.9	1.7	8.2
23	"	6	2	365	18,870.0	722.8	18,390.0	1552.6	10027.4	1600	410.6	4663.6	1141.9	5363.7	6.2	29.2	1.6	7.4
23	"	7	4	294	11,063.8	459.3	11,313.5	1064.1	6669.8	1600	330.7	3756.4	733.4	2913.3	6.5	25.8	1.6	6.3
24	"	2	5	365	14,824.9	511.6	13,602.5	1258.7	8105.4	1200	306.6	3467.5	952.1	4637.9	7.0	34.1	1.9	9.1
24	"	4	0	365	13,506.5	461.6	12,326.6	1302.7	8263.4	1300	332.1	3760.2	970.6	4503.2	7.9	36.5	2.1	9.8
24	"	5	9	365	18,392.8	648.9	17,090.6	1381.2	8806.9	1500	385.1	4338.8	996.1	4468.2	5.8	26.1	1.5	6.9
24	No	7	4	324	11,103.1	403.1	10,487.7	985.2	6338.0	1400	317.5	3594.8	667.6	2743.2	6.4	26.2	1.7	6.8

TABLE IV

Data on Jersey Cows

Index Number of Cow	Test(No or Yes)	Age at Beginning of Record		Length of Lactation Period	Milk Produced during Period	Total Butter Fat for Period	Fat Corrected Milk	Dig.Prot. in Feed Consumed	T.D.N's. in Feed Consumed	Average Weight of Cow	Dig.Prot. for Maintenance	T.D.N's. for Maintenance	Dig.Prot. Available for Production	Dig.Prot. Required per 100# of Milk	T.D.N's. Required per 100# of Milk	Dig.Prot. Required per 1# of Fat	T.D.N's. Required per 1# of Fat
		Yrs.-	Mos.	days	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
25	Yes	2	5	365	4,704.2	291.1	6,248.2	674.2	4429.3	750	191.6	2173.6	482.6	7.7	36.1	1.7	7.7
25	"	3	9	280	5,229.0	323.6	6,945.6	682.5	4277.5	800	156.8	1775.2	525.7	7.6	36.0	1.6	7.7
25	"	4	9	239	4,297.2	246.6	5,417.9	418.3	2746.9	800	133.8	1515.3	284.4	5.2	22.7	1.2	5.0
25	"	5	10	228	5,450.0	344.6	7,349.0	471.5	3113.5	900	143.6	1646.1	327.9	4.5	20.0	1.0	4.2
25	"	6	10	365	7,101.0	439.6	9,434.4	741.9	5061.8	850	217.2	2454.6	524.7	5.6	27.6	1.2	5.9
26	No	6	10	297	5,367.0	297.9	6,346.8	622.6	3960.0	850	176.7	1997.3	445.9	7.0	30.9	1.5	6.6
26	"	7	10	340	4,071.1	209.9	4,778.4	528.0	3463.7	900	214.2	2424.8	313.8	6.6	21.7	1.5	4.9
26	"	8	11	276	3,406.4	185.5	4,145.1	443.7	2972.1	850	164.4	1856.1	279.3	6.7	26.9	1.5	6.0
26	"	9	11	312	4,386.5	231.6	5,228.6	529.5	3560.0	900	196.6	2225.2	332.9	6.4	25.5	1.4	5.8
27	"	2	6	365	5,074.0	280.2	6,232.6	610.1	4017.5	800	204.4	2314.1	405.7	6.5	27.3	1.4	6.1
27	Yes	3	11	365	7,227.0	354.1	9,133.7	830.7	5269.4	950	242.7	2743.7	588.0	6.4	27.7	1.5	8.6
27	No	5	2	318	3,223.0	158.2	3,662.2	546.4	3478.8	950	211.5	2390.4	334.9	9.1	29.7	2.1	6.9
27	Yes	6	3	365	8,006.4	367.7	8,718.1	883.6	5642.9	950	242.7	2743.7	640.9	7.4	33.3	1.7	7.9
28	"	4	10	320	9,324.0	524.3	11,594.1	1076.5	6379.8	950	212.0	2405.4	863.7	7.5	33.4	1.6	7.4
28	"	6	0	365	7,975.0	469.4	10,331.0	669.8	4671.2	1000	255.5	2892.6	414.3	4.0	17.4	0.9	3.8
28	"	7	4	319	8,077.1	478.2	10,403.8	952.2	5996.2	1000	223.3	2528.1	728.9	7.0	33.3	1.5	7.3
28	No	8	5	365	6,369.2	362.6	7,986.7	687.7	4613.1	950	242.7	2743.7	445.0	5.6	23.4	1.2	5.2
29	"	2	4	365	4,094.7	252.6	5,426.9	633.3	4007.9	850	217.2	2454.6	416.2	7.7	28.6	1.6	6.2
29	"	3	6	281	3,777.7	238.4	5,087.1	505.6	3208.2	900	177.0	2004.1	328.6	6.5	23.7	1.4	5.1
29	"	4	5	332	4,889.7	287.9	6,274.4	581.6	3804.2	950	220.8	2495.6	360.8	5.7	20.9	1.3	4.5
29	"	5	5	259	3,506.6	191.1	4,269.1	456.4	2906.2	1000	181.3	2052.6	275.1	6.4	20.0	1.4	4.5
29	"	6	3	365	4,204.9	237.8	5,250.4	669.0	4435.1	1000	255.5	2892.6	413.5	7.9	29.4	1.7	6.5

Variation Between Breeds in Nutrients Required for Milk Production. A summary of the figures for each of the four breeds is presented in Table V. This has been determined from the figures as arranged in Tables I to IV inclusive.

The superiority of the Jerseys as economical producers of butter fat is demonstrated. When the economy of milk production of the different breeds is considered on the basis of "fat-corrected milk" rather than actual production, as has been done throughout in this study, the Jerseys again appear to be the most economical producers. The Jerseys are ordinarily discriminated against when comparing milk production records because the true energy value of the product which this breed produces has not been given due consideration. The Holstein breed has regularly received credit for being the most economical producers because of their greater yield of milk, yet producers of a product which is comparatively low in energy value. Economy of production, as referred to, merely means the nutrients required for a certain unit of production. Other factors would have to be considered to use this term in its broadest sense. For example, no charge of nutrient has been made for the dry period of each cow. The wide variation in this one factor would alter economy figures to some extent.

This study shows the Jerseys to be the most efficient producers of milk and butter fat with the other breeds listed in the following order: Guernseys, Holsteins and Ayrshires.

TABLE V

Summary of Data on Breeds Studied

Breed	Number of Lactation Periods	Length of Lactation Period	Milk Produced during Period	Total Butter Fat for Period	Fat Corrected Milk
		days	lbs.	lbs.	lbs.
Ayrshires	64	322.3	9863.9	366.5	9443.1
Guernseys	26	338.3	6748.0	308.3	7393.7
Holsteins	31	351.7	15061.4	525.7	13910.1
Jerseys	22	322.1	5443.7	307.9	6796.0
All Breeds	143	331.5	9744.1	381.4	9618.6

Breed	Dig.Prot. in Feed Consumed	T.D.N's. in Feed Consumed	Average Weight of Cow	Dig.Prot. for Maintenance	T.D.N's for Maintemance
	lbs.	lbs.	lbs.	lbs.	lbs.
Ayrshire	926.0	5923.0	1156.3	259.5	2933.6
Guernsey	713.2	4590.8	925.0	219.2	2477.7
Holstein	1282.7	8045.1	1369.4	337.6	3830.0
Jersey	646.1	4182.5	902.3	202.9	2297.2
All Breeds	921.6	5873.1	1121.3	260.2	2942.7

Dig.Prot. Available for Production	T.D.N's. Available for Production	Dig.Prot. Required per 100# of Milk	T.D.N's. Required per 100# of Milk	Dig.Prot. Required per 1# of Fat	T.D.N's. Required per 1# of Fat
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
666.5	2989.4	7.1	31.7	1.82	8.2
494.0	2113.1	6.7	28.6	1.60	6.9
945.1	4215.1	6.8	30.3	1.80	8.0
443.2	1885.3	6.5	27.7	1.44	6.1
661.4	2930.4	6.9	30.5	1.73	7.7

<u>Relation of Age to Efficiency of Production.</u> An interpretation of the data summarized in Table VI reveals the fact that cows between the ages of 4 and 8 years are the most efficient producers of milk, with the 7 year old cows showing up most favorably.

The fact that the younger cows do not show up so well may be attributed to the method of making these determinations. Immature cows require a certain amount of nutrients for the growth and development of their bodies. No allowance has been made for this.

The higher requirements of the mature cows, 8 years and over, may be due to their lowered efficiency. Considering the data presented in this study, one would hesitate to place much emphasis on this statement until cows had reached the age of at least 10 years. The small number of cases involved for the older groups renders a definite statement inadvisable concerning the efficiency of the same.

TABLE VI

Relation of Age to Efficiency of Production
On the Basis of Yearly Intervals

Age of Cow			Number of Cases Involved	Dig.Protein Required to Produce 100# of Milk	T.D.N's. Required to Produce 100# of Milk
yrs-mos.	to	yrs-mos	cows	lbs.	lbs.
2-0	to	2-11	19	7.1	31.9
3-0	to	3-11	13	7.7	34.0
4-0	to	4-11	20	6.8	29.5
5-0	to	5-11	21	6.6	28.1

TABLE VI - Continued

Age of Cow			Number of Cases Involved	Dig.Protein Required to Produce 100# of Milk	T.D.N's. Required to Produce 100# of Milk
yrs-mos	to	yrs-mos	cows	lbs.	lbs.
6-0	to	6-11	24	6.8	29.1
7-0	to	7-11	17	6.7	28.6
8-0	to	8-11	13	7.1	30.7
9-0	to	9-11	8	6.9	28.2
10-0	to	10-11	4	7.2	31.0
11-0	to	11-11	3	6.6	29.1
13-0	to	13-11	1	7.8	28.5

Relation of Length of Lactation Period to Efficiency of Production. In Table VII an effort has been made to determine approximately wherein the length of the lactation period might influence the efficiency of production. It appears that cows with lactation periods between 245 and 304 days in length are the most efficient producers. This is probably due to the fact that cows in these groups pass through the peak of production and dry off more rapidly than the cows producing for a longer period of time. In this way these cows are not charged for nutrients for so many days when their production is quite low. If we should consider the longer dry period of cows with shorter lactation periods and take into account the nutrients consumed during this time as a part of that charged against a cow for her lactation period, the cows with shorter lactation periods would probably not appear to be the really efficient producers. In this problem cows were charged for nutrients only during the time that they were producing.

About the only way to account for the high requirements of cows with lactation periods less than 245 days in length is to consider them the poorer cows of the group. However, in some cases, some physical disorder may have been responsible for the shortened lactation period and increased requirement of nutrients per unit of production.

TABLE VII

Relation of Length of Lactation Period to Efficiency of Production

Length of Lactation Period	Number of Cases Involved	Dig.Protein Required to Produce 100# of Milk	T. D. N's. Required to Produce 100# of Milk
days	cows	lbs.	lbs.
Under 245	10	6.8	30.2
245 - 274	5	6.9	26.6
275 - 304	22	6.7	28.1
305 - 334	23	7.3	30.5
335 - 364	15	7.1	29.4
365	68	6.9	29.6

Comparison of Herd and Test Conditions in Efficiency of Production. In Table VIII an attempt has been made to demonstrate the comparative efficiency of the production of cows under herd and test conditions. Cows carried under herd conditions appear to be the more efficient producers.

Test cows require about 9% more nutrients per unit of production than cows kept under herd conditions according to figures derived from this study.

In grouping the cows for this study all cows that were carried for at least one month under test conditions were considered test cows. It must be understood that all of the cows in the test group did not necessarily complete a 305 or 365 day record under test conditions. The higher requirements for test cows are due to the liberal feeding of these cows, even above what was really needed, to encourage greater production. Again, some cows were carried under test conditions when there might have been a question as to whether their production would warrant such care.

TABLE VIII

A Comparison of Herd and Test Conditions in Efficiency of Production

	Number of Cases Involved	Dig.Protein Required to Produce 100# of Milk	T. D. N's. Required to Produce 100# of Milk
	cows	lbs.	lbs.
Test Conditions	92	6.93	30.73
Herd Conditions	51	6.98	28.19

Relation of Body Weight to Efficiency of Production. A summary of the data to show the relation between body weight and efficiency of production is presented in Table IX. Here it appears that, for the most part, cows weighing less than

1000 pounds are the most efficient, with the cows in the 800 to 900 pound group having the lowest average nutrient requirements per unit of production.

Since the Jerseys and Guernseys have been shown to be perhaps the most efficient producers, and in consideration of the fact that cows in these two breeds for the most part fall in the lower weight intervals, it would be expected that the cows in these groups would appear as the most efficient producers. In this sense, this particular weight study develops into practically another breed study from a different angle.

The author wishes to make it plain that these data should not be interpreted to mean that the small cows within the breed are the more efficient producers. For the study, cows of all four breeds were grouped together on basis of body weight.

TABLE IX

Relation of Body Weight to Efficiency of Production Based on 100 Pound Intervals

Weight of Cows	Number of Cases Involved	Dig. Protein Required to Produce 100# of Milk	T. D. N's. Required to Produce 100# of Milk
lbs.	cows	lbs.	lbs.
600 to 699	1	6.1	29.6
700 to 799	2	6.8	32.4
800 to 899	13	6.5	27.9
900 to 999	24	6.9	28.4
1000 to 1099	19	7.5	32.7
1100 to 1199	27	6.9	29.9

TABLE IX - Continued

Weight of Cows	Number of Cases Involved	Dig.Protein Required to Produce 100# of Milk	T. D. N's. Required to Produce 100# of Milk
lbs.	cows	lbs.	lbs.
1200 to 1299	27	7.0	30.0
1300 to 1399	12	6.9	30.6
1400 to 1499	10	6.8	30.7
1500 to 1599	3	6.7	28.2
1600 to 1699	5	6.5	29.7

Effect of Plane of Lactation on Efficiency of Production

The figures which have been assembled to show the effect of the plane of lactation on the efficiency of production are presented in Table X.

From this study it appears that cows producing between 4000 and 12,000 pounds of milk in one lactation period are the most efficient producers, with the cows classed in the 6000 to 8000 pound interval showing the lowest nutrient requirements per unit of production.

These lower production records have been made by the smaller cows, and those which have shorter lactation periods. Previous studies in this thesis have shown that cows with short lactation periods, and the smaller cows appear to be the most efficient producers.

TABLE X

Effect of Plane of Lactation on Efficiency of Production

Amount of Milk Produced	Number of Cases Involved	Dig.Protein Required to Produce 100# of Milk	T. D. N's. Required to Produce 100# of Milk
lbs.	cows	lbs.	lbs.
2000 to 3999	3	9.8	38.5
4000 to 5999	23	7.3	28.3
6000 to 7999	29	6.5	28.0
8000 to 9999	32	7.0	30.4
10000 to 11999	27	6.8	29.6
12000 to 13999	8	7.9	33.9
14000 to 15999	5	7.0	30.6
16000 to 17999	6	6.8	32.6
18000 to 19999	6	6.7	31.1
20000 to 21999	2	6.5	32.0
22000 to 23999	2	6.3	29.4

DISCUSSION

A comparison of the nutrient requirements derived from this study with Morrison's (22), Haecker's (21) and Savage's (33) shows quite close agreement. The author's figures are higher for the digestible crude protein requirements and appear to be slightly below the average for the amount of total digestible nutrients required. This is probably due to the fact that the rations fed to the dairy herd at this station are richer in protein than were those fed by Haecker or Savage in their experimental work. A comparison of these different requirements is shown below:

Nutrients Required for the Production of
100 Pounds of 4% Milk

Authority	Digestible Crude Protein	Total Digestible Nutrients
Morrison	5.4 to 6.5	31.1 to 34.6
Haecker	5.4	34.1
Savage	6.5	34.9
Thesis	6.9	30.5

SUMMARY AND CONCLUSIONS

A total of 143 lactation periods for 29 cows in the dairy herd of the Kansas State College are included in this study. Summaries have been made of the nutrients required for production by the different breeds, and for all cows considered as a whole. Cows were classified irrespective of breeds in the study of the factors influencing the efficiency of production. To determine the nutrient requirements for production, cows have only been charged for nutrients consumed during the period of actual lactation. No consideration has been given to the dry period. With these facts in mind the following conclusions have been made in this study:

1. Jerseys were the most efficient producers of butter fat and when compared to other breeds on the basis of "fat-corrected milk" (4% milk), appear to be the most efficient producers of milk. The other breeds studied may be listed

in the following order: Guernseys, Holsteins and Ayrshires.

2. Cows between 4 and 8 years of age appear to be the most efficient producers of milk and butter fat, with the 7 year old group showing up most favorably.

3. Cows kept under test conditions require about 9% more total nutrients per unit of production than do those carried under herd conditions.

4. Cows with lactation periods from 245 to 304 days in length appear to produce more efficiently than those with longer periods.

5. Cows weighing from 800 to 900 pounds appear to be more efficient as producers than those found in any other 100 pound weight interval.

6. Cows producing between 6000 and 8000 pounds of milk in one lactation period appear to be on the most efficient plane of lactation.

7. An average sized cow (1100 pounds) will require about 6.9 pounds of digestible crude protein and 30.5 pounds of total digestible nutrients to produce 100 pounds of 4% milk. This same cow will require about 1.7 pounds of digestible crude protein and 7.7 pounds of total digestible nutrients to produce one pound of butter fat.

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