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A Study of Estimated Net Energy Intake for Maintenance and Milk Production of Louisiana Dairy Cows by Use of Electronic Data Records.

Nolan Joseph Matherne

Louisiana State University and Agricultural & Mechanical College

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A STUDY OF ESTIMATED NET ENERGY INTAKE FOR MAINTENANCE AND MILK PRODUCTION OF LOUISIANA DAIRY COWS BY USE OF ELECTRONIC DATA RECORDS

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Dairy Science

by

Nolan Joseph Matherne
B.S., Berry College (Mt. Berry, Ga.), 1937
B.S., Louisiana State University, 1941
M.S., Louisiana State University, 1955
May, 1965
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ABSTRACT

Monthly herd data from Dairy Herd Improvement Association (DHIA) records for the period from January, 1962 through March, 1964 were used to determine the value of estimated net energy (ENE) intake from sources of feed used in Louisiana feeding programs on 1.) maintenance and milk production, and 2.) income over feed cost.

One thousand and fourteen (1014) herd month observations were made. All records were converted to 4 per cent fat corrected milk (FCM). The feeding programs were evaluated by using total Therms of ENE intake from concentrates, silage, hay, and pasture consumed per cow days in milk.

The average level of ENE intake per cow per day from different sources of feed in these data was: concentrates, 8.80 Therms; silage, 2.01; hay, 2.56; and pasture, 3.78. Concentrates supplied 51.21 per cent of the total ENE intake for the period covered in this study. The remaining 48.79 per cent of ENE was supplied by forage and came from the following sources: silage, 11.60 per cent; hay, 14.98 per cent; and pasture, 22.05 per cent. Concentrates exhibited a small monthly range (48.11 - 55.81 per cent).

The regression equation obtained from the regression of FCM on the five variables studied is:

\[ Y = -65.5749 + 0.1510X_1 + 1.3438X_2 + 1.0935X_3 + 0.3723X_4 + 1.0519X_5 - 0.0009X_2^2 - 0.0017X_3^2 - 0.0019X_5^2. \]
\[ Y = FCM, \ X_1 = \text{Days in milk}; \ X_2 = \text{Therms ENE from concentrates}; \ X_3 = \text{Therms ENE from silage}. \ X_4 = \text{Therms ENE from hay}; \ X_5 = \text{Therms ENE from pasture}. \]

Maximum milk production could be obtained by increasing ENE intake with concentrates from 8.80 to 46.40 Therms (66.30 pounds concentrates); or, by increasing ENE intake with silage from 2.01 to 20.09 Therms (143.50 pounds silage); or, by increasing ENE intake with pasture from 3.78 to 17.26 Therms. Feeding hay was linear to the limits of these data. It was determined that by increasing ENE intake from 0 to 10 Therms, the following number of Therms per additional pound of FCM were needed from the different sources of feed: concentrate, 0.75; silage, 0.92; hay, 2.69; or pasture, 0.97.

The regression equation obtained from the regression of income over feed cost on the five variables studied is:

\[ Y = -74.3608 + 0.9685X_1 + 1.3479X_3 - 1.1333X_4 - 0.0099X_3^2 - 0.0041X_4^2 + 0.0070X_5^2. \]

\[ Y = \text{income over feed cost}. \]

It was determined, by using the first derivative of \(1.3479X_3 - 0.0099X_3^2\) in the above equation, that if concentrates, hay, and pasture are fed at the average level of ENE intake shown in this study, 4.25 Therms ENE intake from silage (30.40 pounds silage) per cow per day would be needed to maximize income over feed cost. Linear and curvilinear effects for concentrates were not significant. It was also determined that increasing ENE intake with silage from 0 to 10 Therms resulted in an increase of 12.48 cents income over feed cost per cow per day. Increasing ENE intake
with pasture from 0 to 10 Therms resulted in an increase of 0.70 cents; whereas, increasing ENE intake with hay from 0 to 10 Therms resulted in a decrease of 13.75 cents income over feed cost per cow per day.
I. INTRODUCTION

Underfeeding is generally considered to be a major factor contributing to the low level of milk production in many dairy herds in the South. This low level of milk production constitutes one of the major problems confronted by Louisiana's Dairy Industry. However, some progress has been made. This improvement is indicated by the fact that the average commercial dairy cow in Louisiana produced only 3,110 pounds of milk annually in 1958 as compared to approximately 6,000 in 1963 (100). Further evidence of progress is found in the fact that in 1958 the average dairy cow on production records in Louisiana produced 6,426 pounds of milk annually as compared to 8,252 in 1963 (157). Increased milk production of the average dairy cow has been brought about by improved management, greater participation in the use of records, more rigid culling of low-producing cows and the use of bulls with proven ability to transmit high production. Proven bulls were made available through the state-wide artificial breeding program.

Research workers throughout the nation have reported many significant findings in the subject matter area of dairy cattle nutrition. However, some of the studies dealing with energy requirements and physiological response of dairy cattle conducted in other states may not apply to Louisiana because of the high humidity, extreme heat, and large fluctuations in temperature which prevail in the state. Because of the
present Louisiana average yearly production per cow and high investment and operational costs, and in light of the limited nutritional information available under Louisiana conditions, it is of vital interest to determine the sources of nutrients in feeding dairy cattle and their relation to milk production in Louisiana. This is important from the standpoint of additions to fundamental knowledge and as a possible key to a source of nutrients or a combination of sources that would lead to increased production per cow in the most efficient way. The dairy farmer is faced with the important problem of the source of feed nutrients for economical use in his dairy herd. This problem must be approached from the capabilities of his farm to produce feed, the consumption of feed by his dairy cows, and finally his ability to predict the physiological response. Data from nutritional studies and determination of digestion coefficients for various feed ingredients can make major contributions to the problem. However, eventually the entire feeding program must be evaluated with milk production response of lactating dairy cows.

Research and Extension workers have recognized the limitations on production by low energy intake in many herds. To reach the higher levels of milk production dairymen must be provided with feeding standards that will induce the high ability cows to produce at a rate in keeping with their ability. However, economic factors in the individual herd should be used in determining profitable feeding levels. Present-day feeding standards, based on data of Haecker (57, 58) are adequate for low production levels but are in no way capable of maintaining and inducing production for today's high potential cows.
The importance of an adequate energy supply in the rations of dairy cattle has been stressed by numerous writers. Flatt (42) stated that "A limited energy supply more frequently retards the growth of dairy cattle and lowers milk production than does a deficiency of any other nutrient." Present day research relating lactation responses to energy intake coupled with more accurate forage quality evaluation, points up the need for adjustments in present-day feeding standards.

There are various methods by which energy metabolism of large animals and net energy values of feeds may be experimentally determined. Such results can be used in basic research. However, most of the studies concerned with the ratio of forage to concentrate deal with the effect upon digestibility (3, 17, 40, 62, 101, 113, 130).

The electronic calculations of feeding recommendations through electronic data processing machine (EDPM) dairy herd production records program make use of estimated net energy in applying the established feeding standard to the problem of feeding each individual cow. There is need to use these available data from EDPM-DHIA records to study the relationship of milk production and body maintenance to estimated net energy of dairy cattle rations in Louisiana.

This study was concerned with the physiological response of dairy cows to estimated net energy intake as measured by the total amount of fat-corrected milk (FCM) produced. The primary objectives of this study were: 1.) to study the level of estimated net energy intake from various sources of feeds used in feeding Louisiana dairy cows enrolled in DHIA records; 2.) to determine the amount of estimated net energy intake from these feed sources needed for maximum milk production per cow; 3.) to determine whether the presently recommended estimated net energy intake
for maintenance and milk production is adequate for dairy cows in Louisiana; and 4.) to determine the amount of estimated net energy intake from the different sources of feeds used in this study needed for maximum income over feed cost per cow. More specifically, the regressions of milk produced and income over feed cost on amount of concentrates, silage, hay, and pasture consumed were determined. The data for this study were obtained from Louisiana DHIA records processed by Electronic Data Processing Machines (EDPM). The model was a multiple linear regression function. The effects of the various sources of feed nutrients, as well as plane of nutrition, were studied by months. The ultimate objective was to evaluate and improve the individual year-round feeding programs on Louisiana dairy farms and increase efficiency in milk production.
II. REVIEW OF LITERATURE

Forms and Measures of Energy Values of Feeds

The expression Food Energy was used by Maynard and Loosli (109) to denote the value of food for its largest function, that is to furnish energy for body processes and to form the non-nitrogenous, organic matter of tissues and secretions. The catabolism of carbohydrates, fats, and protein in the body releases free energy, which is trapped by adenosine triphosphate (ATP) and in turn used to support endergonic reactions such as synthesis. This is the principal mechanism by which food serves as a source of energy for body process (35, 87, 109).

This energy, released from biological reactions and available for useful work, such as the production of milk, is called the free energy change (ΔF) as distinguished from heat energy (ΔH). The two reactions involved are 1.) exergonic reactions in which all body reactions proceeding under the influence of a catalyst release energy, and 2.) endergonic reactions, which require energy. The endergonic reactions cannot take place unless the needed free energy is simultaneously released from some exergonic reaction. These two reactions involved are called coupled reactions and can be shown as follows:

Exergonic = ATP + H₂O → ADP + H₃PO₄  [- ΔF]

Endergonic = Glucose → Glycogen  [+ ΔF]
Here we see that the formation of glycogen from glucose requires energy. This energy is furnished by the formation of adenosine diphosphate (ADP) from adenosine triphosphate (ATP), an exergonic reaction. The free energy is provided by splitting of a "high energy" or "energy rich" phosphate bond in ATP. Thus, the energy of the process appears as heat and in a form which can be used for work by living cells (35, 53, 87, 109).

Since all forms of energy are converted into heat, it has been found convenient to evaluate food intake and body products in terms of heat units. The net energy values of livestock feeds are commonly expressed in Therms, which is the amount of heat required to raise the temperature of 1,000 kilograms of water 1°C centigrade, or to raise the temperature of 1,000 pounds of water about 4°F Fahrenheit. The small calorie is defined as the amount of heat required to raise 1 gram of water 1°C. The large calorie, written with a capital "C" to distinguish it from the small calorie, is the amount of heat required to raise 1 kg. of water 1°C. The large calorie is the unit used in expressing the energy value of foods and is also called kilocalorie (kcal). A Therm is 1,000 kilocalories or one megacalorie (megcal or mcal). It has been used as a matter of convenience when large values are involved, as in expressing the net energy values of livestock feed (35, 87, 109, 116).

In discussing the determination of the use of food in the body, and thereby obtaining a measure of the relative value of various feeds, Henderson and Reeves (63) stated that the "coefficient of digestibility" tells the percentage of the food that is assimilated by the body, but it does not tell what use the animals make of the nutrients after they are once within the body. The use animals make of nutrients after they are
once within the body has to be determined by a complete balance of nutrition, in which the entire intake is balanced against the entire outgo. The intake includes air, food, and water; the outgo includes the feces, urine, gases, and heat. By measuring each of these, it is possible to determine exactly how much of the gross energy of the feed the animal has been able to use for growth, fattening, work, or milk production (35, 63, 87, 109, 116).

**Methods of Expressing Energy Values of Feeds**

In order to determine the sources of energy for dairy animals, the amount of nutrients furnished by the various available feeds must be known. This problem of assessing the value of animal feeds is not new. For centuries work has continued in many and varied forms dedicated to the end of being able to predict the nutritive value of a feeding stuff from some sort of experimental evidence. Three of the basic measures of nutritive value in common usage over the years have been: 1.) Total digestible nutrients (TDN), 2.) metabolizable energy (ME), and 3.) net energy (NE). More recently digestible energy (DE) has received attention. Also, estimated net energy (ENE) values are being used to determine quality codes for various feedstuffs in reporting the quality of forage consumed by cows enrolled in dairy production records which are computed by electronic data processing machines.

**Historical Aspect**

The total digestible nutrient (TDN) system has been in use in the United States for many years. Crampton and Lloyd (35) have pointed out that the present day TDN system of feed description and of expressing
requirements in North American feeding standards was developed from the original standard proposed by Wolff in 1816. The starch equivalent scheme originated by Kellner in 1907 led to the net energy system of expressing food values and animal requirements. The net energy system was developed in America by Armsby. In it the energy requirements were expressed as Therms of net energy rather than as starch values.

In 1917 Armsby published net-energy values for a considerable list of feeds. These energy values were computed from factors based on net-energy investigations with steers and on the experiments of Kellner. Morrison (116) claimed that Armsby's method of computation was faulty and some of his values were decidedly incorrect. Because of their limitations, the Armsby net-energy values and the Kellner starch values have never been widely used in the United States. It is believed that the Armsby values, like the Kellner starch values, should now be considered as having only historical importance.

The Scandinavian countries use a system in which the value of one pound of barley is taken as the standard. In this system, called "The Scandinavian Feed-Unit System," the feed-unit value for any feed is the amount of that feed which is estimated to have the same productive value as 1.00 pound of barley. Thus, the value of corn grain given as 0.95 pound means that it takes 0.95 pound of corn to equal 1.00 pound of barley in feeding value. Morrison (116) has noted that this feed-unit system has never been widely used in the United States because it is not a true expression of net energy. In this system feeds rich in protein are given higher values than feeds low in protein which actually furnish the same amount of net energy.
Fraps (48, 49) arrived at what he referred to as "productive energy" from published experiments and the results of his own feeding trials with sheep, chickens, and rats. The method for determining the productive energy involved the slaughtering of a check group of animals at the start and one experimental group at the end of feeding trials. By analysis of the carcasses of the two groups for fat and protein and by calculation of the gross calories thus represented, the energy gained as a result of the ration or feed under test could be determined. Morrison (116) claimed that Fraps' values seemed to be more accurate estimates of values of different feeds for productive purposes than Kellner's starch values or Armsby's net-energy values. For this reason considerable use was made of Fraps' values in preparing the estimated net-energy values in Morrison's "Feed and Feeding" (116).

Møllgaard's values give recognition to the fact that the net-energy values of feeds are higher for milk production than for fattening animals (116). These were the results of extensive respiration studies with dairy cows in Denmark and published feed units for milk production.

**Measures of Energy**

All measures of feed energy, with the exception of TDN, are expressed in kilocalories or Therms. The relationship of these measures of energy to each other is shown by Maynard and Loosli (109) in the chart shown on the following page.
Gross Energy

The starting point in determining the energy value of feeds is by obtaining the gross energy, or heat of combustion. This is the total energy furnished in a feed. When a substance is completely burned to its ultimate oxidation products, that is, carbon dioxide, water, and other gases, the heat given off is considered as its gross energy, or heat of combustion. These gross energy values are determined by oxidation in a bomb calorimeter.

The gross energy values of some pure nutrients and feeding stuffs have been calculated (109). It is noted that among the pure nutrients fats have approximately twice the energy values of the carbohydrates and that the proteins occupy an intermediate position. The following values were derived by Atwater and Bryant (7).

- Carbohydrates . . . . . . . . . . . . . . . 4.15 kcal. per gram
- Fats . . . . . . . . . . . . . . . . . . . . . . 9.40 kcal. per gram
- Protein . . . . . . . . . . . . . . . . . . . . . 5.65 kcal. per gram
**Digestible Energy**

*Digestible energy* is obtained by subtracting the heat of combustion of the feces from the gross energy of the feed. Digested energy measurements take into account digestion losses only. It can be determined by measuring the gross calories in feed and feces, or it can be calculated from the digested nutrients by the use of the gross calorie factors: carbohydrates, 4.15; fat, 9.40; protein, 5.65. Since these factors were designed to apply to the average human diet, their use with animal feeds and rations cannot be expected to give as reliable values as are obtained in direct measurements. Data for digested energy (DE) can be obtained by calculation from TDN values using the factor 2000 kcal. per pound TDN, as shown in the reports on nutrient requirements by the National Research Committee on animal nutrition. The factor 2000 kcal. per pound TDN is an average figure based on studies primarily with swine data by Crampton and associates (32) and with cattle and sheep by Swift (149).

**Metabolizable Energy**

*Metabolizable energy* is defined as the energy of the feed minus the energy lost in the feces, urine and rumen combustible gases. It is also defined as the energy capable of conversion into other forms in the body. These forms represent the feed energy which is transformed into heat plus body gain and milk production. It is relatively uninfluenced by external factors. In ruminants a considerable volume of methane, a combustible gas, is produced by bacterial fermentation in the rumen and exhaled in respiration. It has been reported by various workers (35, 59, 84, 109, 147) that the energy lost in combustible gases represents about 10 per
cent of the gross energy of the ration and about 19 per cent of the total heat production of the animal.

By taking account of all the losses in the urine and combustible gases as well as those in the feces, metabolizable energy represents a step beyond digested nutrients or digested energy, as a measure of nutritive value. It is a better measure than one that considers digestion losses only. However, it falls short of being the final measure because a portion of the metabolizable energy is lost as heat not useful to the body. Its determination involves additional steps beyond a digestion trial. The urine must be collected, and its energy value determined. More important, the determination of the losses in combustible gases calls for the use of a respiration chamber. Because of these limitations, actually determined metabolizable energy values are available for only a few feeds. Maynard and Loosli (109) reported that there are many published figures that have been calculated from digested nutrients using factors developed from experiments in which both TDN and metabolizable energy have been determined. However, it is questionable whether or not the metabolizable energy thus calculated has sufficient reliability to make it a more significant measure of useful energy than the TDN values on which they are based.

Clearly, metabolizable energy is a better measure of useful energy than is the digestion measure above, but whether or not it is sufficiently better than digestible energy for practical purposes to justify the establishment of feed and requirement data on this basis remains to be determined by further research. In this connection, its value compared with net energy also needs consideration. Several investigators (29, 59, 84, 151) have reported metabolizable energy to be a
very satisfactory and accurate measure of the nutritive value of feeds. Hardison (59) further reported that because relatively constant proportions of metabolizable energy are put into such functions as milk production, maintenance and body gains, the best practical measure of the productive value of forage that can be obtained, with facilities in all laboratories, is through a measure of digestible energy.

A special case where metabolizable energy provides a much better measure than does TDN has been reported by Cook and co-workers (29). In their study, certain species of forage were found to have high gross energy and high TDN values due to essential oils, but low metabolizable values because the oils, though absorbed, were not metabolizable, and thus there was a large energy loss in the urine.

Net Energy

The net energy system conceives of the measurement of that portion of the feed which is completely useful to the body (109). Net energy, according to this concept, is that portion of the ingested energy which actually is produced as a product, that is, milk, meat, or work. Theoretically, one Therm of net energy in feed corresponds to one Therm of energy actually produced in the form of milk or meat. On this basis it represents a more nearly exact measure of the usefulness of feed than any of the others, which fail to account for one or more of the losses always involved.

Net energy is theoretically the best method for evaluating feed since it takes into account all energy losses (147). However, heat increment which is measured by this method may not be a loss. Net energy is expensive to determine because an animal calorimeter is needed. It is important in the ruminant to measure heat production in a post-absorptive
condition. This is not scientifically possible since rumen activity is essential to normal function.

**Heat Increment** - Maynard and Loosli (109) further stated that the distinguishing feature of the net energy system is an accounting for the loss as heat increment of that portion of the metabolizable energy which is not converted into body substance or product. In the case of ruminants, 15 to 30 per cent of the gross energy appears as heat. This represents a loss of 35 to 50 per cent or more of the metabolizable energy, indicating that the latter is a very incomplete measure of energy actually utilized. The percentage of heat thus lost is greater for roughages than for concentrates, which is an important reason why TDN measure over-evaluates roughages for productive purposes.

Dubois (39) discussed an important aspect of nutrition, which he referred to as "the neglected field of heat loss." The loss, also referred to as "heat increment," reflects the wastage of food energy in the course of its metabolism. Heat increment results in a significant loss of the ingested energy, the extent of which is influenced by various factors. Armstrong and Blaxter (5) studied the varying nature of microbial process in the rumen as an important variable in the loss as heat increment. The heat produced from the fermentation process itself has been found to range from 1.5 to 11 per cent of the gross energy of mixed rations.

Forbes and Swift (45) showed that the heat of a ration is not necessarily the sum of the values of its feed components. The relative proportion in which the various nutrients are present in a ration influences the percentage of the gross or metabolizable calories that are lost as heat increment. For example, Forbes and Swift (45) found that
the substitution of fat for carbohydrates in a diet can result in a more economical use of the energy fed because of the lesser amount of energy dissipated as heat. There is evidence that other factors being equal, if the ration is unbalanced with respect to any nutrient in terms of physiological needs, the wastage of heat tends to be greater accordingly. The percentage of total protein in the ration has a definite effect on heat loss. The decreased heat losses with increasing protein level had the practical effect of increasing the net-energy value.

The variations in heat increment resulting from various factors explain why the same intake of total digestible nutrients or metabolizable energy can produce different results in terms of animal performance in different feeding operations. Just how a given combination of foods may affect the heat loss cannot be predicted. These variations also have an important bearing on the practical usefulness of the net energy system as a measure of food energy.

**Total Digestible Nutrients (TDN)**

Total digestible nutrients (TDN) has been used as a general measure of the nutritive value of a feed. Digestion coefficients are used to compute its TDN content. The composition of the feed, i.e., crude protein, crude fiber, nitrogen-free extract, and ether-extract as determined by chemical analysis is multiplied by the digestion coefficients to obtain digestible nutrients. The coefficient of digestible fat is multiplied by the factor 2.25 because it has that much more energy value than the other nutrients. Digestion trials have provided data for the calculation of average digestion coefficients for protein, fat, and carbohydrates in the various feeds and thus in turn for the calculation of their TDN content. Such data have been compiled by Morrison (116) and Schneider (136).
A number of investigators (97, 107, 130, 149, 150) have questioned the accuracy of the measure of useful energy arrived at in the determination of TDN. Kane (84) claimed that the TDN system over-evaluates the nutritive energy of forages. Schneider et al. (135) have made a most comprehensive approach to utilizing information gained by proximate analysis by deriving prediction equations for various classes of forages. These equations were multiple regressions involving the organic portions of the feedstuffs and based on extremely large numbers of analyses. From these equations one could predict the digestibility of a given feed sample provided he could validly categorize the particular feed sample. Schneider (134) also pointed out that TDN lacks in scientific concept and nutrition theory as compared with other measures of nutritive energy. One of his main criticism was the number of chemical analyses required and the inaccuracy of the methods especially that of determining the carbohydrates portions.

Digestible Energy Versus TDN

Apparent digestible energy, a caloric measurement, is the most recent addition to the feed evaluation methods in this country. It is somewhat similar to the total digestible nutrient (TDN) method in that it does not take into account the losses in the urine and combustible gases. However, it is difficult to understand why digestible energy has not been adopted in favor of TDN since it is simpler to determine and is a more direct measure of the disappearance of the organic nutrients present in a feedstuff as it passes through the digestive tract of the ruminant (147).

Achacoso (1) pointed out that since a major function of feedstuffs, especially carbohydrates, is to furnish energy, it is logical to concentrate attention on digestible energy without regard as to whether it
originates from starch, cellulose or crude fiber. The determination of
digestible energy is one of the most accurate analyses performed in the
laboratory and is a valuable and direct method of determining digestibility of feedstuff. It is more accurate than TDN and serves the same pur-
pose (1).

Overman and Gaines (120) advocated the use of digestible energy
in place of the indirect TDN procedure some 30 years ago. Favorable
replies were received by Swift (149) from prominent workers in the field
on his suggestion of the adoption of digestible energy in place of TDN.
Swift (150) also reported that the Northeast Regional Technical Committee
had adopted digestible energy as the common yardstick in comparing the
nutritive value of forages.

Of all the measures of food energy, digestible nutrients are the
easiest to compute. This largely accounts for the fact that digestion
coefficients are available for all of the common feeds. This is impor-
tant from the standpoint of their usefulness in practice. As pointed
out earlier, the limitation of TDN as a measure of food energy is that
it does not take into account losses through combustible gases and heat
loss. The heat losses are of considerable importance and relatively
larger for roughages than concentrates. A pound of TDN in roughage
has considerably less value for productive purpose than a pound in
concentrates (109). Moore and Associates (114) reported the following
approximate relationship between TDN and net energy:

1 pound TDN in corn = 1 Therm net energy

1 pound TDN in better hays = 0.75 Therm net energy

1 pound TDN in poor roughage = 0.5 Therm net energy
Thus, as the roughage component of the ration, especially low-grade roughage, is substituted for grain, the productive value drops when the substitution is made on a TDN basis. The recognition of this limitation of the TDN measure constitutes an important reason why active consideration is being given to other measures which account for additional losses, especially the heat loss. Stone (147) stated that TDN is not scientifically accurate since the values are arrived at by empirical analytical procedures, commonly referred to as proximate analysis.

Lofgren (97) and Swift (149, 150) were of the opinion that the practical procedure to overcome these uncertainties of TDN values was to determine the gross energy content of the feed and feces by means of a bomb calorimeter and to express the difference between the two values as digestible energy. Lofgren (97) presented a procedure for calculating TDN values by the calorimetric method, which is as follows: a.) determine moisture, ash, ether-extract, and energy in the feed; b.) determine moisture and energy in the feces; c.) calculate per cent gross energy which is digested; d.) calculate the conversion factor (F) by the following formula (A), where O.M. = per cent organic matter in the feed and E. E. = per cent ether-extract in the organic matter:

\[
F = \frac{0.01}{100} \times \frac{100 (E.E. \times 2.25) - E.E.}{0.01}
\]

e.) multiply the percentage of digestible energy by the conversion factor (F) to obtain the value comparable to TDN. This procedure was presented by Lofgren (97) because he felt that the TDN values calculated by the calorimetric method resulted in a more accurate estimation of energy value of a feed or ration than the conventional method, and because the bomb calorimeter gave the various nutrients their proper heat combustion values.
Crampton and Lloyd (35) reported that the net energy system has not been accepted as generally in North America as has the total digestible nutrient scheme, although since about 1950 there has been a trend toward the use of digestible energy expressed as calories or Therms in place of TDN. Conversion from one term to another can be made when desirable. With the more common use of bomb calorimeters it seems probable that the energy values of animal feeds and the feeding standards that describe the energy requirements of animals will be increasingly expressed in calories or Therms.

**Estimated Net Energy (ENE)**

A method of estimating net energy values from feeding trials using corn as the base was presented by Morrison (116) in 1937. Estimated net energy (ENE) values for long lists of feeds, according to Morrison (116), are based on a study of all available data on the relative productive value of feeds with chief reliance placed on results of hundreds of feeding trials conducted by experiment stations comparing the values of different feeds. These estimated net energy values are presented in Appendix II of Morrison's "Feeds and Feeding" (116). While Morrison admitted that judgment was used in computing ENE values, and that ENE values are only approximate and subject to revision as additional data become available, he believed it possible to evaluate the most important feeds more correctly on an estimated net energy basis than by TDN.

Kane (84) reported on several procedures for converting TDN into estimated net energy. In Kane's study, regression equations of ENE on TDN for six classes of feeds, as well as a general equation for the combined classes, were computed. All six feed class regression coefficients
were found to differ significantly from the general regression coefficient. The feed classes, except silage, apparently had similar slopes for their ENE to TDN relationships, and the reason why the general regression line was significantly different was because the feed classes operated at different levels of energy. In converting TDN to ENE values by using Morrison's data, Kane also reported that the appropriate feed class regression appears to be more accurate than a general regression.

Several plans for converting TDN into ENE have been proposed. Hecker's (58) standard and Morrison's (116) table of requirements, as reported by Blaxter (15), gave a value of 1.870 Therms net energy per kilogram TDN. Moore et al. (114) developed a general regression equation of the ENE/TDN relationship for all classes of feeds. This equation was $Y = -34.63 + 1.393X$; where $Y = $ ENE and $X = $ TDN. The combined equation of Kane (84) was $Y = -31.48 + 1.346X$. These authors stated that while the use of a regression equation to calculate the energy value of a specific feed was open to question, the regression of ENE on TDN offered a means of approximation and might serve as a guide to establishing more accurate productive values.

Estimated Net Energy Versus TDN

Loosli et al. (98) conducted double reversal trials comparing the replacement of forage with concentrate on a TDN basis and on an estimated net energy (ENE) basis. An average of the data from all trials showed that the cows produced 2.5 pounds more FCM per head per day when 6.8 pounds of concentrates replaced 10.2 pounds of hay containing almost equal TDN but more ENE.
In another study Davis et al. (36) showed that milk production increased when part of the TDN from hay was replaced by an equal part of TDN from grain. They also studied the effect of replacing part of a legume hay ration with 40 pounds of well-eared corn silage on an equal TDN basis which also increased the production of FCM. These workers concluded from these results that the TDN system over-estimates the value of forages as compared with concentrates. In summarizing feeding trial data from fattening cattle and for milk production, Morrison (116) found that the TDN system over-estimated the productive value of forages, with the difference becoming greater in poorer quality forages.

Bloom et al. (18) conducted experiments on each of four energy ratios of hay to concentrate (75 : 25; 55 : 45; 35 : 65; and 15 : 85). Milk production and energy inputs (expressed as Therms above maintenance) were plotted over a 26-week time period. Each pound of FCM was expressed in terms of its energy content (0.3 Therms) so that the graphs for FCM and feed input were directly comparable. These data indicated that, on the basis of the four ratios of hay to concentrate, milk production closely followed the ENE inputs of feed above maintenance requirements. These workers also reported that regardless of the ratio of concentrates to hay fed, that the inherent ability of cows to produce milk was more significant than the intensity of feeding.

Smith et al. (142) fed alfalfa hay without concentrates to five Holstein cows for periods of three to nine weeks which was followed by a period of 28 days in which 5 to 10 pounds of hay were replaced with concentrates. This procedure in turn was followed by another period of three to nine weeks of hay only. This pattern of feeding was
followed throughout the lactation and total digestible nutrient intake was held constant during all periods. This study showed that when hay alone was fed, milk production was 84.5 per cent of the previous period. When concentrates replaced part of the hay, milk production was 96.2 per cent. These workers concluded that the rations on a net energy basis resulted in milk yields of approximately 100 per cent of expected yields. In another study Irvin et al. (78) fed alfalfa hay alone and hay plus concentrate to observe the effects of such rations upon milk production. This study was on an ENE basis versus TDN. Cows were fed hay alone until milk production and body weight had declined to a leveling off point. Calculation of the ration at this point on ENE basis showed that cows were producing as would be expected. Results of this work further illustrated that when part of the hay was replaced by a concentrate, such as corn, on a net energy basis, no significant increase in milk production was obtained.

Saarinen et al. (131) studied the adequacy of an all-alfalfa hay ration for milk production. Eight cows in early stages of lactation were fed on the basis of Morrison's net energy requirements, using the upper limits for both maintenance and milk production. The increases or decreases in the net energy content of the rations were calculated and expressed as the expected change in milk yield, assuming that one pound of 4 per cent FCM is equivalent to 0.3 Therm. Milk production changes paralleled the net energy changes so closely that the variations in the net energy intake could account for all the variations found in milk yield. Martin et al. (105) studied the effects of varying rates of hay feeding on level of milk production. Rates of hay
feeding were established at 0.50, 1.17, 1.83, and 2.50 pounds of hay daily per 100 pounds body weight. Data from this study showed no significant effect of level of hay feeding on milk production if TDN or ENE was held constant. TDN available for milk production was highly correlated with milk production (coefficient of correlation 0.941). ENE available for milk production had a coefficient of correlation of 0.942 with milk production.

**Milk Production Responses to Various Sources of Feed Energy**

**Effect of Different Ratios of Forage to Concentrate**

The dairy farmer is confronted with the problem of determining the forage-to-grain ratio and the forage and grain production system, as well as the production rate per cow, that will maximize returns to his fixed resources. Reynolds and Kline (128) reported on a project to determine the best profit level of production among dairy farms in Virginia. They found an optimum forage-to-grain feeding ratio for the 9,000 pounds milk production rate per cow to be 35 per cent of the estimated net energy (ENE) from forage to 65 per cent of the ENE from grain when milk was sold at $5.73 per hundredweight. The optimum forage-to-grain ratio for producing 11,000 pounds of milk per cow was 43 per cent forage ENE to 57 per cent grain ENE. For the 13,000 pounds of milk production per cow, 38 per cent forage ENE to 62 per cent grain ENE was an optimum forage to grain feeding ratio.

The feeding of unlimited quantities of forages as being the most economical way to feed dairy cows has been seriously questioned in recent years. Some research workers (64, 68) have produced spectacular
increases in production by restricting forage intake and allowing high producing cows to eat bulky concentrate rations free-choice. Fosgate (47) reported on a study conducted in Georgia in which it was found that differences in the amount of concentrates fed accounted for about 41 per cent of the between herd differences in milk production. Since feeding standards, based on Haeker's (58) work, were first published, feeding programs have been tied to digestible dry matter (DDM) intake and to total digestible nutrient (TDN) intake rather than to animal response. These are measures of the chemical and physical composition of the feedstuffs and are only indirectly related to the physiological response of animals (79). Fosgate (47) stated that most feeding studies have been concerned with the ratio of forage to concentrates and their resulting interactions with regard to total dry matter intake and over-all digestibility. Some of the recorded findings of these studies included: a.) milk production and digestibility (except crude fiber) have increased as the percentage of concentrates in the ration have increased; b.) milk returns per unit of input diminished as total feed inputs and milk production increased; c.) when the plane of nutrition was raised to a high level, digestibilities frequently decreased; d.) theoretical milk yields based upon feeding standards and average digestibility values did not coincide with actual production yields at the highest levels of feed intake. Fosgate also emphasized the economic importance of this last finding because it showed that the law of diminishing return from additional increments of input also held true for milk production.
Putnam and Loosli (124) fed rations in which either 80 per cent, 60 per cent, or 40 per cent of the dry matter content came from forages and the balance from concentrates. There was no significant difference in the amount of milk produced by the animals consuming the different rations. However, there was a slight difference in the amount of milk produced per pound of total digestible nutrients (TDN) fed. The range was from 2.10 to 1.93 pounds FCM per pound of TDN for the 80 per cent and 40 per cent forage rations, respectively. Data from the digestion trials showed that the coefficients of apparent digestibility of the mixed rations increased for dry matter, crude protein, ether extract, N-free extract, as well as TDN values, as the proportion of concentrates in the ration increased. The coefficient of apparent digestibility for crude fiber decreased as the proportion of concentrate in the ration increased. Other investigators (17, 62, 93) have corroborated this work and found increased digestibility of dry matter, ether extract, and nitrogen-free extract as per cent of concentrates in the ration increases. This study as well as another study by Elliot and Loosli (40) suggested that plane of nutrition, rather than decreased digestibility, caused the decreased efficiency in utilization of TDN for milk production as the TDN (concentrate) increased.

Blaxter et al. (10) fed Jersey cows two grain rates of 0.66 and 0.33 pound for each pound of 4 per cent FCM above 8 pounds FCM daily with alfalfa and lespedeza hays. The cows were initially challenged by feeding 3 pounds more grain daily than the indicated rate until there was no additional response in milk production or grain was refused. All the cows fed the higher grain rate failed to consume
their indicated grain for part of the lactation. The cows fed the moderate grain rate consumed both their indicated rate and the challenged grain for the time it was fed. The rates of grain consumed were 0.60 and 0.40 pounds, respectively, for each pound FCM above 8 pounds FCM daily. Digestive disorders, which occurred frequently among the cows fed high grain, adversely affected milk production. Twenty pounds of grain daily appeared to be the upper level at which all cows in this study could consume safely without digestive upset.

There was no significant difference in FCM production due to grain level. Feeding Jersey cows the higher grain rate was not economical in this study when compared with moderate grain feeding. However, Clifton et al. (27) in another study with 24 Holstein and Jersey cows found that the cows on a higher grain level (1 pound grain : 2 pounds milk) produced significantly more milk and FCM, and consumed less forage dry matter than cows fed on a low concentrate level. The difference in FCM amounted to 0.45 pound more milk for each additional pound of concentrate.

Huffman (68) stated that "it is apparent that good cows with large appetites and inherently high milk production potential are capable of high levels of economic production. It is necessary, however, to treat the data for such cows as individuals. The liberal grain feeding of good cows will make possible the increased profits to dairymen; aid in bull proofs; and aid in the selection of high-potential cows to use in milk-production studies. A testing program is necessary for successful heavy grain feeding." Huffman (68) also reported on an experiment in Denmark in which 10 cows with an average production of
607 pounds of fat per year were fed according to appetite under ideal conditions. At peak of milk production as much as 40 pounds of concentrate plus 7 pounds of hay, 30 pounds of grass silage, and 50 pounds of beet top silage were fed each cow. The cows produced an average of 24,341 pounds of FCM during the first year and 25,622 pounds of FCM the second year.

Mead and Goss (110) studied ruminant digestion without forage feeding. They reported that dairy animals could be reared to four years of age on a concentrate diet, provided it was supplemented with calcium carbonate and vitamin A. The animals were reported to be normal in size and showed no abnormalities other than frequent bloating and lack of regular rumination. In an earlier study, Beach (11) showed that digestible nutrients from corn were more useful for maintenance and for milk production than digestible nutrients from roughages. This phenomenon was also observed by Huffman and Duncan (71, 72, 73, 75). A number of studies in which alfalfa hay was fed alone was conducted by these workers (69, 70, 71, 73, 74, 75, 76). From their results it was indicated that cows, placed on alfalfa hay alone after calving, made efficient use of the TDN for two to three months and then declined in milk production. This was referred to as a depletion technique, since it appeared that some unidentified factors stored in the body were being withdrawn to balance the TDN in the hay. When part of the TDN from the hay was replaced by an equal amount of TDN from concentrates, milk production increased. This increase in milk production was against the natural tendency for cows to decline with advance in lactation. There was no increase in milk production, however, when either corn starch or
corn sugar was added to the ration of the depleted cows. Kane et al. (85) studied the effect of corn starch on digestibility of alfalfa hay. Their work revealed that when corn starch was abruptly added to a ration, dry matter digestibility was decreased. However, these workers found that after a 20-day preliminary period up to six pounds of starch per day did not significantly decrease dry matter digestion.

Kottke (89) arranged DHIA data according to milk production. As the amount of milk increased, the efficiency per pound of feed increased. Mather et al. (106) found that cows with a potential milk production of 8,906 pounds of FCM per 245-day lactation gave 0.58 pound of FCM per pound of grain; whereas, those with a 245-day potential of 11,708 pounds of FCM gave 1.35 pounds of FCM per pound of grain. The high-potential cows showed no evidence of diminishing returns and there was relatively little for the low-potential cows. Charron (26) reported that milk production increased 2,031 pounds per cow due to higher grain feeding. While 90 per cent of the cows responded with extra milk production, only 40 per cent of the cows showed increased profit.

**Effect of Supplementing Pasture with Grain**

The effects of supplementing forage intake from pasture with various levels of grain feeding have been studied. Seath (138) studied the effect on milk production of feeding alfalfa silage or an extra amount of grain to dairy cows on pasture during the months of July, August, September, and October. Results varied with the season and the kind of pasture that the cows were grazing. In general, there was no significant change in level of milk production while cows were grazing bluegrass and ladino clover or orchard grass and ladino clover. However, there were
significant increases in milk production from feeding alfalfa silage or extra grain when cows were grazing Kentucky 31 fescue. In another experiment, Seath et al. (139) fed either corn silage or an extra amount of grain mixture to Holstein and Jersey cows on pasture from August 1 to September 11, 1949. They reported that this supplementation with grain or silage prevented the summer decline in milk production which occurred even though the cows were grazing better than average pastures. This study showed a decline of 2.73 pounds of milk per cow per day for the controls; a decline of 1.25 pounds of milk for the cows receiving the silage; and, an increase of 1.12 pounds of milk for cows receiving the extra allowance of the grain mixture. Dowden et al. (38) conducted two grain-feeding trials involving the continuous employment of 24 and 18 lactating dairy cows during the 1956 and 1957 pasture seasons, respectively. Pastures used were orchard-grass, ladino clover plus sudan grass or Kentucky bluegrass - white clover. Grain feeding had no significant effect on persistency of milk production during the first part of the trial when pasture was good. The effect of grain feeding was reported to be highly significant during the last 28 days when pasture became short and of low quality. Grain feeding, however, did lower the dry matter intake from pasture.

High Grain Feeding and Health of Cows

Huffman (68) reported that many dairymen are reluctant to feed high levels of grain because of the belief that such a practice aggravates mastitis and udder edema and tends to produce off-feed. However, Huffman reported on a study in which he fed five cows cottonseed meal
and five cows linseed meal at levels of 5 to 12 pounds per cow daily over a 6-month period and failed to show that these protein concentrates aggravated mastitis. Huffman further reported that many experiments show that the occurrence of mastitis and udder edema is not due to heavy grain feeding.

Moore et al. (115) conducted an experiment of feeding a high corn grain ration to 20 cows for a period of two years. They concluded: "There appears to be no significant difference in the incidence or severity of mastitis between the group receiving the heavy corn ration and the group fed a normal ration as fed in this experiment." These investigators in further studies, could not find any difference in the incidence or severity of mastitis when first-calf heifers were fed the above control rations at the rate of 1 pound per 3.5 pounds of milk compared to a low level of grain. Charron (26) studied the effects of higher grain feeding on 48 dairy farms in New York and New Jersey. His data did not show that grain feeding resulted in more udder infection. Greenhalgh and Gardner (55) found that feeding grain up to 9 pounds per day per heifer and up to 12 pounds per cow per day for about a 6-week period before calving gave no evidence that grain feeding increased edema of the udder.

Schmidt and Schultz (132) also reported that heavy grain feeding before and after calving did not appear to increase the severity of udder edema. In their study they fed one group of cows no grain, a second group received 6 pounds daily, and a third group received 15 pounds of grain per day during the 8-week dry period. On the day after calving, the cows were fed 10 pounds of grain and the amount was increased one pound daily until the cows received the amount of grain warranted by
their milk production. In another experiment by Borland et al. (19) 22 cows fed unlimited grain remained in good health with no more digestive, breeding or udder troubles than cows on a low level of grain feeding. In a two-year study by Jensen et al. (81) udder troubles were not excessive even in the highest grain fed group. The level of feeding had no effect on reproductive failures. Although there was an upward trend in the number of cases of off-feed as the level of feeding increased, very few of the cases were serious.

Input - Output Relationships

Reid (125) stated that "the problems concerned with providing sufficient energy to high-producing cows are becoming increasingly acute and demand reappraisal of the adequacy of existing feeding standards." He pointed out that feeding standards are based chiefly on the data of Haeker (57, 58) which were obtained with low-producing cows. In the experiments conducted by Haeker, the average yield of 4 per cent FCM was only 24.4 pounds per cow per day. Today there are a number of cows producing 15,000 pounds or more milk per year, and almost all herds have at least a few cows which produce more than 60 pounds of milk per day for at least a few months. The feeding standards set forth in Morrison's "Feed and Feeding" (116) are, by and large, the same ones developed by Haeker before 1914. The average intake of TDN in Haeker's experiments was approximately 1.9 times the amount needed for maintenance. At the low levels of milk production and conversely of feed intake, the TDN requirement was estimated to be 0.316 pound per pound of 4 per cent FCM (57, 58). However, later research by Jensen (81) indicated that cows producing
about 11,000 pounds of 4 per cent FCM per year require, above the maintenance allowance, approximately 0.5 pound of TDN per pound of FCM produced.

Studies concerned with feed input to milk output relationships have been undertaken by several workers (15, 18, 22, 80). These workers have reported a diminishing return from increased feed inputs. They have also hypothesized that part of the diminishing returns may be due to a decline in digestibility.

Jensen et al. (81) studied the principle of diminishing returns as applied to milk production to determine to what degree milk output could be raised by more intensive feeding. In the herds studied, it was found that 15 to 20 per cent more milk was obtained from cows at high levels of feeding than from cows fed at standard, and 45 per cent more than from cows fed at 70 - 80 per cent of standard. They stated that the law of diminishing physical output applies to milk production. The response to increased feed was less at the high levels than at the low levels. There was 0.6 pound of 4 per cent FCM produced for each additional pound of digestible nutrients at the highest level and 1.7 pounds of 4 per cent FCM produced for each additional pound of digestible nutrients at the lowest level. This study also pointed out that, on the average, cows returned about 3 pounds of milk per pound of digestible nutrients consumed above maintenance; but, for each additional pound of total digestible nutrients added to a normal ration there was an increase of only about 1.0 - 1.5 pounds of FCM obtained.

Larson and Eskedal (92) showed a considerable increase of 4 per cent FCM as a result of high-level grain feeding and improved milking
and sanitary practices. Their data indicated that although a part of the increase in the response of the cows was due to improved milking methods and health measures, the major part of the response was undoubtedly the result of the greatly increased input of energy. There are other examples which showed that many cows producing at low levels would yield much more milk if they were provided with more energy (125). Charron (26) conducted a field study in which he induced farmers to feed one-half of 442 cows on test approximately 20 per cent more TDN than the farmers had been accustomed to feeding. An average increase of 2,030 pounds of milk was obtained for all cows in the test. Fifty-seven per cent of the cows showed an annual increase of 2,000 lb. or more milk and 10 per cent of the cows showed an increase of 4,000 pounds or more.

Borland, Beam and Jones (19) studied the relationship between rate of grain feeding to milk production. These workers were able to demonstrate that milk production could be significantly increased with liberal levels of grain feeding. In this study the cows that were fed at the 120 per cent level produced 50 per cent more milk than cows fed at 70 to 80 per cent of the recommended standard level. However, it is evident from the work of Borland et al. that, as the grain allowance increased, the law of diminishing returns operated. Each pound of grain fed to cows at 80 per cent of standard returned 4 pounds of milk, but at the 120 per cent level each pound of grain produced approximately 2 pounds of milk. Harr (60) reported on studies conducted by USDA scientists at Beltsville, Maryland, who found that a group of cows on unlimited feed produced about the same amount of milk as a group fed a
controlled amount of grain. The ad libitum group consumed 17 per cent more total energy than the contemporary group, and 71 per cent of the total energy consumed was in the form of concentrates. Because of the additional energy consumed, and because of the variation in response for yield, the ad libitum group gained more weight and were less efficient than the contemporary group. These workers further observed that although the economic aspects of ad libitum feeding were not discussed, it was apparent from the results of these studies that all cows will not respond favorably to unlimited quantities of feed. Thus, it would be unwise for the dairyman to feed a herd in this manner on an "across the board" basis. In any program where it is desirable to increase the feed intake, it should be done on an individual cow basis. Cows that do not have the genetic potential for milk production will not result in increased milk production from an increased level of feed intake. Therefore, each cow in a herd has to be challenged in order to seek out those who will respond.

In a study by Jarrett (79) one of the most striking things found was how close the fluctuations in milk production month to month followed the net energy intake. This study also indicated that approximately 0.5 Therm net energy was needed to produce each pound of milk. This was 50 per cent more net energy than is recommended by Morrison's standards. The range was 0.3 Therm per pound of milk at the lowest levels of production to 0.6 Therm per pound of milk at the highest level of production. It was also apparent in this study that when herds averaged 9,125 pounds or more milk per cow that they reached a plateau in production where the input - output relationship was no longer linear.
It was also brought out that it is important to realize that the efficiency with which a cow can convert net energy to milk production declines with increased inputs, and therefore the net energy intake resulting in the maximum net income may be less than the potential maximum intake per cow. In further discussing this matter of fluctuations in milk production from month to month, Fosgate (47) pointed out that it is clearly evident that low milk production in the summer months is primarily due to low net energy intake. This may be a voluntary restriction by the cow due to the fact that as forages mature, they become less palatable, or it may be due to the fact that dairymen over-estimate the productivity of their summer pastures and the necessary net energy for high production is unavailable to the cow.

Reid (125) also stated that another point of significance in the feeding of the individual cow is the consequence of the mal-distribution of energy during the lactation cycle. Some cows receive enough total feed per year, but the feed is ineffectively distributed relative to time and need. Reid (125) discussed the work of Warner (160) who found that quite often too little feed is provided early in lactation and too much late in lactation. Data obtained for two DHIA herds in New York State was used to demonstrate this feeding defect. It was noted that the milk yields of the two herds were the same in the first month of lactation. However, Herd 1 was more persistent and produced more milk in all subsequent months than did Herd 2. This difference in responses of the two herds was partially explained by the fact Herd 1 was fed enough concentrates during early lactation to provide enough energy to
exceed the recommendations of present-day energy standards. Herd 2, how­
ever, was greatly underfed during early lactation a * 1 overfed during the
fourth and subsequent months of lactation. In spite of the fact that
the cows in Herd 2 received a considerably larger total amount of con­
centrates than was recommended for the entire lactation period, the milk
yield declined to a low level quite rapidly, with the result of a low
total yield. It was concluded that the superior yield and the persis­
tency of output of Herd 1 appeared to result partly from the higher
energy input and partly from the more satisfactory distribution of the
energy input.

The findings of several workers (50, 91, 102, 137, 158) have
suggested that it is important that cows be provided enough energy to
produce as much milk as possible as soon after calving as possible.
This is because the milk yield during monthly segments of the lactation
period (even during very early lactation) reflects the total lactation
period. Also, the response in milk production to energy inputs during
the dry period and early lactation has been found to be cumulative over
the lactation period. Continued feeding of high levels of energy after
calving has extended the increased output of milk over the entire lac­
tation period, according to some workers (16, 44, 95). Reid (125) re­
ported that it is reasonable to suspect that when milking cows are fed
according to present-day standards, the body tissue gained during late
lactation and the dry period provides a considerable part of the energy
needed to support subsequent lactation. It has been shown that a cow
which gained 100 pounds of body fat prior to calving could produce as
much as 880 pounds of milk from the catabolism of body fat alone, when
fed only enough feed to satisfy her maintenance requirements during the ensuing lactation period (16, 44, 125). Because of this, a need for dietary energy greater than the amount of TDN recommended in present-day standards may not become evident except when cows produce a large amount of milk for extended periods of time. Reid (125) further stated that "if the maximum yield of potentially high-producing cows is to be realized, it would appear that either less dependence should be put on the body tissue stores or their utilization should be more effectively distributed, and greater reliance should be put on the energy provided by the ration fed concurrently with lactation."

Conrad et al. (28) determined voluntary dry feed intake and dry matter digestibility in 114 trials with lactating dairy cows. He concluded that physical and physiological factors regulating feed intake change in importance with increasing digestibility. At low digestibility the factors were: body weight (reflecting roughage rate of passage) and dry matter digestibility. At higher digestibilities intake appeared to be dependent on metabolic size, production and digestibility. Mosely et al. (117) found that 82 per cent as much milk was produced by cows fed forages alone as by cows fed forages and a limited amount of grain. Sherwood and Dean (141) reported that cows which were fed alfalfa hay alone produced 79 per cent as much milk as when fed alfalfa hay and grain. Graves et al. (54) fed cows at four different planes of nutrition. Results of this work showed that cows receiving grain at the ratio of 1 pound grain to 6.1 pounds of 3.1 per cent milk saved 863 pounds of hay and at the same time resulted in the production of 2,048 pounds more milk.
In view of the literature cited herein, a conclusion made by Loosli (98) would seem to be appropriate:

After parturition, the amount of milk produced is the result of an equilibrium among several factors, such as (a) the hormonal stimulation for production, (b) the nutrients available and (c) limitations set by the cow's genetic ability for production. Nutrients available for milk production can come from two sources; daily feed and stores in the animal's body. Animals well managed at parturition usually have large body stores of energy as well as high impulse for production. As long as body stores last and no disease is present, production will be limited by hormonal stimulation or genetic capacity (which may be the same). However, when body stores of energy become depleted, the daily intake of energy becomes a limiting factor in production. At this time the animal becomes very sensitive to fluctuations in the energy value of its feed.

**Economic Aspects**

Morrison (116) reported that the cost of feed is by far the largest single item of expense, generally forming up to one-half of the total cost of milk production. This expense varies widely depending on the price of feeds, the average production of the herds, and the economy of the rations used. This is in agreement with statements by other workers. In a study on cost of milk production in Louisiana, Anderson (4) found that in the distribution of costs, purchased feed constituted 49.29 per cent of cash costs. Beneke (12) also stated that feed costs constituted about 50 per cent of the cost of producing milk. He further stated that the following factors must be considered in determining the most profitable amount and combination of feeds for dairy cows: 1.) individual cows vary greatly in their capacity to convert feed into milk; 2.) the amount of milk resulting from each additional pound of feed declines as cows are fed at higher rates; 3.) feeding more grain reduces
the amount of hay that cows will consume; 4.) it is profitable to give dairy cows more feed when the price of milk is high relative to the price of feed; 5.) feeding high-quality forage reduces the amount of grain to produce a given output of milk.

DHIA records in Louisiana (157) have shown that the average feed costs per cow were $60 for forage and $105 for concentrates for 2,447 cows in the 1962-63 testing year. This was a total feed cost of $165 out of a gross return of $461 per cow, or 35.8 per cent of the average gross returns. In 1957 these records showed that the average feed costs per cow were $51 for forage and $83 for concentrates. This was a total feed cost of $134 out of a gross return of $285 per cow, or 49 per cent of the average gross returns. Anderson (4) reported on a study in Tennessee which showed that feed costs varied from $1.96 per 100 pounds of milk in the 8,000 to 10,245 pound herds to $3.52 in herds averaging between 2,000 and 3,999 pounds of milk per cow annually in 1957. The average feed cost per 100 pounds of milk produced for all 93 farms in the study was $2.23. This was less than that found in a Louisiana study (4) where in 1955 average feed costs were $3.40 per 100 pounds of milk produced. The DHIA Herd Summary (157) for the 1962-63 testing year showed a feed cost of $2.08 per 100 pounds of milk produced by 2,447 Louisiana dairy cows averaging 7,845 pounds of 4.1 per cent milk per year. Appendix Table 1a shows the 1962-63 Louisiana DHIA Yearly Herd Summary grouped by pounds of milk produced per cow.

Brown et al. (20) reported that for many years forages have played a dominant role in dairy cattle rations, primarily because they were recognized as the most economical sources of energy. In this respect,
Anderson (4) stated in his study completed in 1959 that it is almost universally agreed that dairy cattle should obtain 75 to 80 per cent of total digestible nutrients in the form of forage crops. At that time it was recommended in Louisiana that from 75 to 85 per cent of the total digestible nutrients in a dairy ration should be obtained in the form of forages. Also the rates most often recommended for feeding concentrates at the time were one pound of concentrates for each three pounds of milk produced by the small breeds, and a ratio of one to four for the larger breeds. However, in recent years the idea that forages fed in unlimited quantities is the most economical way to feed cows has been seriously questioned. Brown (20) has pointed out that because of the increased yields of corn, the cost of 100 pounds of TDN from ear corn in many cases has been less than that from hay-crop silage or hay.

From an economic standpoint, maximum use should be made of the most economical source of energy. Huffman (68) reviewed high-level feeding of dairy cows and reported that research workers in Michigan have produced spectacular economical increases in production by restricting forage intake and allowing high-producing cows to eat bulky concentrates free-choice. Charron (26) observed that in a 10-week trial in New York 95 per cent of the cows responded in milk production to increased grain feeding, with approximately 40 per cent showing a profitable response. Brown et al. (20) conducted an experiment to determine the milk production response of cows fed different levels of grain and hay. Cows fed high level or ad libitum grain and limited amounts of alfalfa hay were more profitable than cows fed unlimited amounts of alfalfa hay and restricted amounts of grain. When only the four highest
producers from each group were considered, the return over feed cost was approximately $60 per cow higher for the cows fed unlimited amounts of grain and 5 pounds of alfalfa hay per day than the cows fed one pound of grain for each 3.5 pounds of milk produced and unlimited amounts of alfalfa hay. In the calculation of the above the following prices were assumed: grain, $40 per ton; hay, $20 per ton; corn silage, $7 per ton; and 4 per cent FCM, $4.60 per 100 pounds.

Reid (125) has pointed out that an important aspect in the feeding of dairy cows is that certain economic conditions need to be superimposed in feeding practices upon the consideration of the relationship between the amounts of nutrients of which the cow is capable of utilizing and the amounts of nutrients provided, and the nutritive values of feeds. The degree to which the amount of nutrients that the cow is capable of utilizing is satisfied by the nutritive value of the ration. This influences to a great extent the profits in milk production. From many feeding alternatives it is the responsibility of the researcher and extension worker to guide the dairyman in the selection of a feeding program which currently and under local conditions, though not necessarily reducing costs, will result in maximum profits.

Huffman (68) found greater profits above feed cost due to increased grain feeding to high-producing cows. The effect of higher grain feeding on economic efficiency of milk production is identical with the cow-testing concept of enabling dairymen to cull unprofitable cows. Therefore, to evaluate the effects of increased grain feeding on the economics of milk production, it is necessary to consider the cow as an individual, or arrange the groups of cows on the basis of different levels of milk
production. In using such an arrangement Ross et al. (129) took the results of a study of 15 cow-testing associations and reported that "feeding for maximum production is subject to the economic law of increasing costs, while increasing the potential ability for high production is subject to the law of decreasing costs." Hillman (64) arranged Michigan DHIA records into four classes according to milk production and found the return above feed costs of the highest group (14,727 pounds milk) to be $438 as compared with $157 for the lowest producing group (7,345 pounds milk). This conforms with data from other studies (116, 154, 162) which also suggested that the increased returns above feed cost followed increased grain feeding. Reid (125) also stated that high milk yield per cow is an economic necessity and that the economic efficiency of the high-producing cow is usually greater than that of the low-producing cow even though the energetic efficiency of lactation may be somewhat greater for the low producer.

In reporting on a project to determine the best profit level of production, Reynolds and Kline (128) reported that it is possible to feed past the profit mark. Forage to grain input coefficients were developed for individual forage-to-grain ratios at each of three rates of milk production. An optimum forage-to-grain feeding ratio for a 9,000 pound annual milk production rate per cow was 35 per cent forage ENE to 65 per cent grain ENE. For producing 11,000 pounds of milk per cow, an optimum forage-to-grain feeding ratio was 43 per cent forage ENE to 57 per cent grain ENE. At the 13,000 pound production level per cow, 38 per cent forage ENE to 62 per cent grain ENE was an optimum forage-to-grain feeding ratio. It has been pointed out that the per cent of the feed cost
or the per cent ENE which should come from concentrates is not constant (144). At lower milk production rates and higher intake of quality forages, the net energy requirements may be met from forages alone. However, cows soon reach a limit to their capacity to consume forage. As production increases, the requirements for net energy can no longer be met with forages alone, and a higher per cent of the net energy must come from concentrates. Because forages tend to be cheaper sources of net energy than concentrates, total feed costs usually decrease as more forage is consumed and more concentrates are replaced. At times, however, price relationships do favor use of grain. Individual cows reach a maximum consumption of a given quality of feed. Until the cow reaches this limit of forage intake, the forage should be substituted for concentrates as long as the cost of the net energy in the concentrate saved is greater than the cost of the net energy in the forage required to save it (144).

The economic consequences of feeding variable quantities of grain and forage to lactating cows for five combinations of milk and feed prices was studied by Hoglund (65). The four feeding levels included 3,000, 4,500, 6,000, and 7,500 pounds grain mixture per cow per year. Quality of forage was assumed to be average. With grain at $50 per ton, hay at $22 per ton and milk at $4.15 per hundredweight net at the farm, the most profitable level of grain feeding was 6,000 pounds with a milk output of 11,000 pounds per cow. When milk in excess of 10,500 pounds per cow per year was sold at $3.00 per hundredweight, the optimum feeding rate was reduced to 5,000 pounds of grain. When all the milk was sold at $3.00 per hundredweight, the optimum rate was only 4,000 pounds of grain. With
a high grain price of $65 per ton and a low hay price of $22 per ton the most profitable feeding rate was 4,500 pounds of grain. This compared with an optimum feeding rate of 6,000 pounds with a low grain price of $50 per ton and a high hay price of $35 per ton. Hoglund concluded from the above study that from an economic standpoint, it is not necessary to pinpoint exactly the most profitable level of grain feeding. A range of plus or minus 500 pounds of grain feeding per year from the economic optimum will show small variations in returns above feed costs. Missing the economic optimum by over- or under-feeding grain by 1,000 pounds, or 20 per cent, resulted in $6.00 lower return over cost of feed per cow.

Hoglund (65), as well as Jensen et al. (81), maintained that for any given cow, as more grain is fed, one can expect higher TDN requirements per unit of milk output and increased total cost of feed. With this in mind, the following statement by Hoglund seems appropriate:

Dairy farmers need to be more concerned about maximizing returns over costs per cow or per farm than attaining the lowest cost per unit of milk output. The highest net return per cow is usually achieved at a point short of the maximum attainable production but above the lowest unit cost of milk output. Production responses of individual cows to increased grain feeding and price relationships determine this economic optimum in feeding grain.
III. ESTIMATED NET ENERGY AND FEEDING STANDARDS

Use of Estimated Net Energy (ENE) in Calculations of Feed Recommendations

The calculations of feeding recommendations through the machine processed dairy herd records program make use of estimated net energy (ENE) in applying the established standards to the problem of feeding each individual cow. This is done in the following manner.

The quantities of nutrients provided by the various feeds and rations consumed are reported as Therms of estimated net energy intake from concentrates, succulent feed (silage and green-chop), dry forage, and pasture. On the basis of several studies (61, 83, 90, 125), concentrates are estimated to yield 70 Therms of net energy per 100 pounds of feed stuff. Quality codes are used for reporting the estimated net energy value of forage consumed by the cows enrolled in the electronic data machine processed dairy production records program. The quality codes used in Louisiana and instructions for reporting these quality codes are shown in Appendix Table 2a. These quality codes indicate the Therms of net energy per hundred pounds of feed in the case of hay and dry forage; and, depending on species of plant, has a range of 28 to 40 Therms ENE per 100 pounds of hay. In the case of succulent feeds, the quality codes indicate the Therms of net energy per hundred pounds of dry matter in silage or green chop, and depending on species of plant and stage of maturity, has a range of 28 to 61 Therms ENE per 100
pounds dry matter. The quality codes for pasture represent the estimated net energy consumed per hundred weight of body size. These quality codes were developed from Morrison's (116) ENE values adjusted to Louisiana conditions.

Quality codes for reporting estimated net energy values of Louisiana forages are provided to the DHIA Supervisors in the "Instruction Manual for Reporting Individual Cow Records and Herd Data for Central Processing" (143). They report on a herd basis the daily amount of forage actually eaten, the quality of the forage, and in case of succulent feeds, the estimated per cent of dry matter. These values, in addition to the reported body size, daily milk production and butterfat test, are used for calculating the daily pounds of concentrates recommended for each cow.

Daily net energy requirement for each cow is first calculated by use of the following formula (I):

\[
\frac{4.7 + .55(X-7)}{100} + Y \left( .28 + .05(Z-3.0) \right) \left( \frac{93 + \frac{y^2}{200}}{100} \right) = \text{Daily Net Energy Requirements in Therms,}
\]

Where:  
\( X \) = Cow's body weight in cwt.  
\( Y \) = Daily milk production  
\( Z \) = butterfat test.

The above formula (I) was developed by Jones (83) on the basis of nutritional studies on energy requirements of milk producing cows by Anderson et al. (3), Hawkins et al. (61) and Reid (125). This formula readily adapts to electronic data processing machine calculation. The first
part of formula (I) \[ 4.7 + .55(X-7) \] calculates the individual cow's energy requirement for maintenance. The second section \[ Y \left( .28 + .05(Z-3.0) \right) \] develops the energy requirement per pound of milk at the individual cow's level of butterfat test. The third section of the formula \[ \left( 93 + \frac{y^2}{200} \right) \] increases the energy requirement at an increasing rate as daily production increases.

After determining the daily net energy requirements for each cow, the daily estimated net energy consumed from forage by the average cow in the herd is determined as shown in Table 1.

**TABLE 1**

<table>
<thead>
<tr>
<th>Kind of Forage</th>
<th>Lb/day</th>
<th>Quality</th>
<th>% D.M.</th>
<th>Ave. Body Wt. (cwt.)</th>
<th>Estimated Net Energy (Therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay</td>
<td>10</td>
<td>X</td>
<td>.40</td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>Silage (corn)</td>
<td>20</td>
<td>X</td>
<td>.50</td>
<td>X 26</td>
<td>2.6</td>
</tr>
<tr>
<td>Pasture</td>
<td></td>
<td>.40</td>
<td>X</td>
<td>12</td>
<td>4.8</td>
</tr>
<tr>
<td><strong>Total Daily ENE from Forage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>11.4</strong></td>
</tr>
</tbody>
</table>

The Therms of ENE consumed from forage by the average cow in the herd is divided by the average body weight of the cows in the herd to determine the amount of ENE consumed per hundred pounds body weight of cow. In Table 1, the average cow consumed 11.4 Therms ENE from forage and weighed 1,200 pounds. Dividing 11.4 by 12 equals to .95 Therms ENE consumed per 100 pounds of body weight by all cows in the herd. This factor (.95), called the forage factor (FF), is then used to adjust forage consumption for each cow in the herd according to her size. It is
assumed that given the opportunity cows within the same herd will consume forage in proportion to body size. Thus a 1,000 pound cow in this herd would consume \((10 \times 0.95)\) or 9.50 Therms ENE from forage daily.

The daily estimated net energy consumed from forage is then subtracted from the daily net energy requirement for each cow. This leaves the amount of estimated net energy needed from grain. The estimated net energy needed from the concentrate mixture is multiplied by the reciprocal of the per cent estimated net energy for the concentrate mixture (1.43 for 70 per cent ENE) to determine the pounds of concentrates to feed each cow.

The following is an example of calculating the pounds of concentrates recommended for a 1,050 pound cow producing 27.53 pounds of 4 per cent FCM. Forage fed per cow per day is 10 pounds alfalfa hay with quality code 40; 20 pounds corn silage with quality code 50; and grazing fair pasture. Average body weight of the herd is 1,200 pounds.

- Daily net energy requirement (Therms) \(15.34\)
- Using formula developed by Jones (83).
- Total daily ENE from forage (Therms) \(9.98\)
- Forage Factor \(0.95\) \(\times\) cwt. body wt. \((10.5)\)
- ENE needed from grain (Therms) \(5.36\)
- Grain needed (pounds) \(7.66\)
  \((5.36 \times 1.43)\)

This recommendation of 7.70 pounds of grain is reported on the dairyman's monthly DHIA report as the pounds of concentrates indicated to feed this cow according to pounds of milk produced, butterfat test, body weight, the amount and quality of forage being consumed, and the energy value of the concentrates.
Value of Quality Codes for Reporting Actual ENE (Farm) Value of Feeds

Reid (125) has pointed out that the use of indirect methods of nutritive evaluation and the use of high-speed computing devices in various dairy production records processing centers has made it possible to compute accurately the amount and kinds of concentrates needed by the individual cow and relay the information to the dairymen as a practical feeding recommendation. Senger (140) of North Carolina stated that reports of dairymen indicate that when the quantity and quality of forage is accurately reported, the concentrates recommended can be followed almost literally and with excellent production results.

Jones (83) reported that the system used in computing grain requirements on centrally processed DHIA records offers the dairymen the most accurate method he has ever had available to him in feeding for high profitable production. However, there are limitations to the system which can result in faulty grain feeding recommendations. These limitations are the need for: 1.) accuracy in reporting forage quality; 2.) accuracy in reporting daily intake of forage; 3.) accuracy in reporting dry matter content of silages; and 4.) accuracy in reporting body weight of cows. The following note was made in the "Instruction Manual for Reporting Individual Cow Records and Herd Data for Central Processing" (143).

Errors in reporting amounts and quality of forages consumed and body weights will cause errors in the amount of concentrates indicated to feed each cow as follows:
Error in Reporting

<table>
<thead>
<tr>
<th>Effect on Pounds of Concentrates Indicated per Cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 pounds hay per cow per day</td>
</tr>
<tr>
<td>5 pounds silage per cow per day</td>
</tr>
<tr>
<td>1 grade in quality</td>
</tr>
<tr>
<td>2 per cent in dry matter</td>
</tr>
<tr>
<td>100 pounds body wt. of cow</td>
</tr>
</tbody>
</table>

Errors in reporting amounts and quality of forage and amount of concentrates will also result in erroneous feeding index, rate of forage feeding, per cent net energy from various sources of feed, feed cost and income over feed costs. (143)

Educational efforts to improve dairy cattle feeding have been slowed because of the lack of facts on quality of forages. Jones (83) also stated that when the electronic data processing machine record system was being set up in Alabama the lack of knowledge of forage quality became a real problem in developing quality codes that supervisors would use. Here was a program that provided the greatest help in feeding that had been offered dairymen, yet desired results were not being obtained because of limited knowledge in assigning quality codes to forages being fed by dairymen. As a possibility for developing better quality codes for reporting forage quality, several states have conducted studies to determine the reliability of a chemical analysis of forage when used to develop grain feeding needs. As a result of these studies (83), a number of states have developed formulas for calculating feed value and quality codes from the results of chemical analysis of the forage. The calculated feed value of the forage on an "as fed" basis is given for estimated digestible protein, total digestible nutrients, and estimated net energy. The quality codes are available for use by the DHIA supervisor to report the quality of forages on the monthly DHIA record.
Costs of ENE in Feeds as Reported and Calculated in the Machine Processed Dairy Herd Records Program

The electronic data processing machine system of calculating costs of ENE from forage charges all harvested forages at their "good" hay equivalent values (quality code 40) and pasture at one-half of its "good" hay equivalent (143). Appendix Tables 3a, 4a, 5a, 6a, and 7a show how to determine quality ratings of excellent, good, fair, and poor for various forages. Table 2, developed by Extension Dairy Specialists working with production testing in the South-eastern states, shows the relative dollar value of hays and succulent feeds according to their quality code.

### TABLE 2
Relative Dollar Value of Hays and Succulent Feeds According to their Quality Codes

<table>
<thead>
<tr>
<th>Feed</th>
<th>Quality Code</th>
<th>Dollar Value per Ton of &quot;Good&quot; Hay Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$20</td>
</tr>
<tr>
<td>&quot;Good&quot; Hay Equivalent</td>
<td>40</td>
<td>$20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hay</th>
<th>Price of Hay per Ton According to Quality Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>23 29 35 41 47 52 58</td>
</tr>
<tr>
<td>41</td>
<td>19 24 28 33 38 43 48</td>
</tr>
<tr>
<td>37</td>
<td>17 22 26 30 34 39 43</td>
</tr>
<tr>
<td>31</td>
<td>14 18 22 25 29 33 36</td>
</tr>
<tr>
<td>---</td>
<td>25 12 15 17 20 23 26 29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grass silage or other succulent feed</th>
<th>Price of Silage per Ton According to Quality Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>7 10 11 12 14 16 18</td>
</tr>
<tr>
<td>56</td>
<td>7 8 10 12 13 14 17</td>
</tr>
<tr>
<td>48</td>
<td>6 8 9 11 12 13 15</td>
</tr>
<tr>
<td>46</td>
<td>6 8 9 11 12 13 15</td>
</tr>
<tr>
<td>41</td>
<td>6 7 8 10 11 13 14</td>
</tr>
<tr>
<td>34</td>
<td>5 7 8 9 11 12 13</td>
</tr>
<tr>
<td>Corn silage</td>
<td>61 9 11 13 15 18 20 22</td>
</tr>
<tr>
<td></td>
<td>52 7 8 10 11 13 15 16</td>
</tr>
<tr>
<td>---</td>
<td>42 5 6 8 9 10 12 13</td>
</tr>
</tbody>
</table>
To use the table, DHIA Supervisors obtain from the dairyman the price of his hay corresponding with the approximate quality code. The dollar value of "good" hay equivalent, given at the top of the column, is reported on the barn sheet. For example, if hay quality code 37 is priced at $30 per ton, the price to report on a "good" hay equivalent basis is $35 per ton. If two or more forages are being fed, an average or proportionate price that is representative of the herd is reported. For example, if corn silage quality code 52 is being fed with the above hay, and priced at $8 per ton, the $8 shown opposite quality code 52 is followed to the top of the column and $25 is found as the "good" hay equivalent value per ton for the silage. An average of the $25 and $35 would be $30, the price to be reported on the barn sheet for the hay equivalent of hay and silage.

This reported price of "good" hay equivalent is used to calculate the cost of estimated net energy per Therm in hay and succulent feeds. For example, if "good" hay equivalent (quality code 40) is priced at $30 per ton, the calculations are as follows:

\[
\begin{align*}
2000 \times .40 &= 800 \text{ Therms/Ton} \\
$30 \div 800 &= $0.0375 \text{ per Therm}
\end{align*}
\]

Pasture is charged at one-half the price of "good" hay. The net cost per ton of the concentrate mixture delivered to the barn is also reported on the barn sheet. The cost of estimated net energy per Therm in a concentrate mixture (70 Therms ENE per cwt.) priced at $60 per ton would be calculated as shown below:

\[
\begin{align*}
2000 \times .70 &= 1400 \text{ Therms/Ton} \\
$60 \div 1400 &= $0.0429 \text{ per Therm}
\end{align*}
\]
IV. STATEMENT OF THE PROBLEM

The Louisiana dairyman is concerned with the important problem of what should be the source of feed nutrients and at what level these should be fed for high level of milk production and maximum income over feed cost per cow. Research workers throughout the nation have reported many significant findings in studies of dairy cattle nutrition. Many of these studies have been concerned with the ratios of forage to concentrate and deal with their effects upon digestibility. Studies dealing with energy requirements and physiological response of dairy cattle conducted in other states may not apply to Louisiana because of the state's high humidity, extreme heat, and large fluctuations in temperature. In light of the limited information on how to feed the dairy cow for maximum return over feed cost under Louisiana conditions, it is of vital interest to study the level and sources of nutrients and their relation to milk production and income over feed cost in Louisiana. This should be important from the standpoint of fundamental information and as a possible key to a source of nutrients or a combination of sources that would lead to increased production per cow in the most efficient way.

The importance of an adequate supply of energy in the rations of dairy cattle has been stressed by numerous writers. Flatt (42) reported that "A limited energy supply more frequently retards the growth of dairy cattle and lowers milk production than does a deficiency of any other nutrient." The review of literature has made it apparent that underfeeding
is a major factor contributing to the low level of milk production in many of the dairy herds in the South. This low level of milk production constitutes one of the major problems confronting the dairy industry in Louisiana. Research and Extension workers have recognized for years the limitation placed on production by low energy intake in many herds. To reach the higher levels of milk production, dairymen must be provided with feeding standards that will allow the high potential cows in their herds to produce at a rate in keeping with their ability, limited by economic factors in the individual herd that will determine profitable feeding levels. Present day feeding standards may be adequate for low production levels but are in no way capable of maintaining and inducing production from today's high potential cows.

The calculations of feeding recommendations through electronic data processing machine (EDPM) dairy herd production records program make use of estimated net energy in applying the established feeding standards to the problem of feeding each individual cow. There is need to use these available data from EDPM dairy production records to determine the adequacy of estimated net energy intake from dairy cattle rations in Louisiana for milk production and maintenance. This information can be of value in assisting Louisiana dairymen in evaluating and improving their year-round feeding program, thus resulting in increased efficiency of milk production.

The primary objectives of this study were:

(1) To determine estimated net energy intake from various sources of feeds used in feeding Louisiana dairy cows enrolled in DHIA records.
(2) To determine the amount of estimated net energy intake from these feed sources needed for maximum milk production per cow.

(3) To determine whether the presently recommended estimated net energy intake for maintenance and milk production is adequate for dairy cows in Louisiana.

(4) To determine the amount of estimated net energy intake from the various sources of feeds used in this study needed for maximum income over feed cost per cow.

The following hypotheses were developed to guide this study:

(1) That there is considerable variation in concentrate to forage ratio in dairymen's feeding programs throughout the year in Louisiana.

(2) That Therms of estimated net energy intake from different sources of feed (concentrate, silage, hay, pasture) are equally effective in increasing milk production.

(3) That there is a linear relationship between milk production and estimated net energy intake.

(4) That the present feeding recommendation of 15.4 Therms of estimated net energy per day for a Louisiana dairy cow weighing 1,050 pounds and producing 27.53 pounds of 4 per cent milk daily is adequate.

(5) That an increase in estimated net energy intake resulting in an increase in milk production per cow in Louisiana will also increase income over feed cost per cow.
V. EXPERIMENTAL PROCEDURE

Data for this study were obtained from Dairy Herd Improvement Association (DHIA) records on a monthly herd total basis. The monthly herd totals for the period from January, 1962 through March, 1964, using Louisiana Jersey, Guernsey and Holstein herds, whose records were processed by electronic data processing machines (EDPM) were used. One thousand and fourteen (1,014) herd month observations were made representing 1,604,846 cow days in milk.

The EDPM number 10 card (Monthly Herd Total) and the EDPM number 2 card (Monthly Herd Feed Input) were provided by the Dairy Records Processing Center, Raleigh, North Carolina for use in the study. The information obtained from these cards and used in this study is shown on page 57 in the layout of the master card developed from the EDPM number 10 and number 2 cards.

The feeding programs were evaluated by using total Therms of estimated net energy (ENE) from concentrates, silage, dry forage (hay), and pasture consumed for cow days in milk. Concentrates were estimated to yield 70 Therms of net energy per 100 pounds of feedstuff. Therms of estimated net energy intake from each class of forage fed were calculated on the basis of reported quality as determined from tables furnished the DHIA supervisors. These quality codes, based on species of plant and stage of maturity, indicate the Therms of net energy per pound of feed
<table>
<thead>
<tr>
<th>Month</th>
<th>Herd Code</th>
<th>Year</th>
<th>Cow Days on Test</th>
<th>Cow Days in Milk</th>
<th>Total pounds Milk - cwt.</th>
<th>Total pounds B.F. - 10 pounds</th>
<th>Total pounds 4 per cent Milk - cwt.</th>
<th>Concentrates - cwt. Therms ENE</th>
<th>Silage - cwt. Therms ENE</th>
<th>Dry Forage (Hay) - cwt. Therms ENE</th>
<th>Pasture - cwt. Therms ENE</th>
<th>Value of Product $10 Unit</th>
<th>Cost of Concentrates $10 Unit</th>
<th>Cost of Forage $10 Unit</th>
<th>Income Over Feed Cost $10 Unit</th>
<th>Av. Body Wt. to 10 pounds for Herd</th>
</tr>
</thead>
</table>

in the case of hay or dry forage and the Therms of net energy per pound of dry matter in the case of succulent feeds. The quality codes for pasture represent the estimated net energy consumed per cwt. of body size. Dry matter content of succulent forages were based on similar tables.

All records were converted to 4 per cent fat-corrected milk (4 per cent FCM) by a formula developed by Gaines (51). This was done in order
to make energy input to milk output studies possible on an equal energy basis. The average cow in this study weighed 1,050 pounds. On the basis of this weight each cow had a daily maintenance requirement of 6.63 Therms. There were 346,186 cow days dry in this study. The maintenance ENE for the dry cows were removed in obtaining the data for cows in milk.

Regression of 4 per cent fat-corrected milk (4 per cent FCM) on estimated net energy intake was made to show the value of ENE intake from different sources of feed on milk production. Test for curvilinearity was also made. The statistical treatment of the data was a least square analysis (96, 119). The mathematical model was as follows:

\[ Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_2^2 + b_7X_3^2 + b_8X_4^2 + b_9X_5^2; \]

Where:

- \( Y \) represents FCM (in cwt. on a herd month basis)
- \( a \) represents the \( Y \) intercept (the level of \( Y \) at \( X = 0 \))
- \( X_1 \) represents cow days in milk (where one cow milking one day equals one cow day in milk)
- \( X_2 \) represents Therms of ENE from concentrates (in cwt. on a herd month basis)
- \( X_3 \) represents Therms of ENE from silage (in cwt. on a herd month basis)
- \( X_4 \) represents Therms of ENE from hay (in cwt. on a herd month basis)
- \( X_5 \) represents Therms of ENE from pasture (in cwt. on a herd month basis)
- \( b_i \) are partial regression coefficients.

Regression of income over feed cost on estimated net energy intake was also made to determine the value of ENE intake from different sources of feed on income over feed cost.
VI. RESULTS AND DISCUSSIONS

Sources of Estimated Net Energy

Sources of estimated net energy (ENE) for maintenance and milk production by months for 1,014 herd month observations are shown in Table 3. Concentrates, supplied 51.21 per cent of the total ENE for the period covered in this study, which was from January, 1962 through March, 1964. The remaining 48.79 per cent supplied by forage came from the following sources: silage, 11.76 per cent; hay, 14.98 per cent; and pasture, 22.05 per cent.

The influence of concentrates as a major source of estimated net energy is readily apparent. The percentage of total ENE supplied by concentrates ranged from 48.11 to 55.81. Regardless of the availability of ENE from other sources, concentrates supplied about an equal proportion of total ENE for each month of the year. There was very little variation in concentrate to forage ratio throughout the period of this study. The average concentrate to forage ratio was 51.21 : 48.79 with a range of 48.11 : 51.89 in the month of December to 55.81 : 44.19 in the month of May.

Silage supplied an average of 11.76 per cent of the total ENE intake with a range of from 3.95 per cent during the month of April to 17.65 per cent during the month of October. This is as expected since few dairymen in Louisiana are including silage in their feeding program. Data in Table 3 show that the greatest amounts of silage was fed during
### TABLE 3

Average Sources of Estimated Net Energy (ENE) for Maintenance and Milk Production by Months for 1,014 Herd Month Observations

<table>
<thead>
<tr>
<th>Month</th>
<th>FCM/Cow/Day (lb.)</th>
<th>ENE/Cow/Day (Therms)</th>
<th>Per cent of Total ENE from</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Concentrates</td>
</tr>
<tr>
<td>January</td>
<td>27.13</td>
<td>18.23</td>
<td>49.26</td>
</tr>
<tr>
<td>February</td>
<td>26.52</td>
<td>17.60</td>
<td>49.19</td>
</tr>
<tr>
<td>March</td>
<td>26.71</td>
<td>16.70</td>
<td>49.22</td>
</tr>
<tr>
<td>April</td>
<td>27.58</td>
<td>14.85</td>
<td>53.39</td>
</tr>
<tr>
<td>May</td>
<td>26.94</td>
<td>15.00</td>
<td>55.81</td>
</tr>
<tr>
<td>June</td>
<td>26.46</td>
<td>15.83</td>
<td>53.72</td>
</tr>
<tr>
<td>July</td>
<td>27.54</td>
<td>17.57</td>
<td>50.56</td>
</tr>
<tr>
<td>August</td>
<td>28.28</td>
<td>17.72</td>
<td>50.98</td>
</tr>
<tr>
<td>September</td>
<td>28.63</td>
<td>16.62</td>
<td>54.24</td>
</tr>
<tr>
<td>October</td>
<td>28.28</td>
<td>16.48</td>
<td>54.35</td>
</tr>
<tr>
<td>November</td>
<td>27.95</td>
<td>17.87</td>
<td>51.81</td>
</tr>
<tr>
<td>December</td>
<td>28.40</td>
<td>18.58</td>
<td>48.11</td>
</tr>
<tr>
<td>Mean (X)</td>
<td>27.53</td>
<td>17.15</td>
<td>51.21</td>
</tr>
<tr>
<td>Range</td>
<td>26.46 to 28.63</td>
<td>14.85 to 18.58</td>
<td>48.11 to 55.81</td>
</tr>
</tbody>
</table>

The monthly averages are from January, 1962 through March, 1964.
the months of October through January. The least amounts of silage was fed during the months of April through July. This is also as expected since a larger amount of silage is fed during periods of less available pasture. Most other states, including the southern states, make greater use of silage in their feeding programs than Louisiana. Jarrett and Fosgate (79) found that silage provided 23 per cent of the total ENE intake consumed by dairy cows in the state of Georgia.

Dry forage (hay) supplied a larger per cent of the total ENE intake than silage. An average of 14.98 per cent of the total ENE intake came from hay with a range of from 6.08 per cent during the month of August to 23.65 per cent during the month of February. Data in Table 3 indicate that, similar to silage, more hay was fed during periods of less available pasture.

Pasture contributed an average of 22.05 per cent of the total ENE intake with a range of from 12.05 per cent during the month of January to 36.15 per cent during the month of July for the period studied. The average of 22.05 per cent is below expectations for normal Louisiana conditions. However, the abnormally dry and cold weather conditions during 1962 and 1963 probably accounted for this small contribution to milk production by pasture in Louisiana during this period. A similar situation was found in Georgia by Jarrett and Fosgate (79) who found that pasture contributed only 23 per cent of the total ENE intake during the period from February, 1960 through April, 1962. However, these workers found that the partial regression of Therms ENE on pounds FCM was significantly higher \((P < .01)\) from a pasture source than from concentrates, hay, or silage.
Data in Table 4, "Average Daily Milk Production and Estimated Net Energy (ENE) Intake for Maintenance and Milk Production by Months for 1,014 Herd Month Observations," indicate that 0.62 Therms ENE was needed for maintenance and milk production by the average cow in this study. This resulted in 1.61 pounds FCM produced per Therm ENE intake. The average cow in this study weighed 1,050 pounds and produced 27.53 pounds FCM per day.

One of the hypotheses developed to guide this study was that there is considerable variation in the concentrate to forage ratio in the dairy feeding programs in Louisiana. The average per cent and range by months of the total ENE furnished from different sources is given at the bottom of Table 3. Concentrates exhibited a small monthly variation (48.11 - 55.81 per cent). This indicates that regardless of the quantity and quality of forages available, Louisiana dairymen depend on concentrates to furnish approximately 51 per cent of the monthly ENE per cow. This is slightly above the figure reported by Jarrett and Fosgate (79) who found that Georgia dairymen depend on concentrates to furnish approximately 42 per cent of the monthly ENE per cow. Forages in Louisiana supplied about 49 per cent of the total ENE. However, the ranges in per cent of ENE supplied by each of the classes of forages were very wide. There was a considerably wider range exhibited by each class of forage than that exhibited by concentrate to forage ratio. This was because dairy cows in Louisiana do not get the same forages each month for a 12-month period. Also, the amount of ENE furnished by forages was less than expected.

Concentrate to forage ratio appeared to have no effect upon milk production per cow per day. Data in Table 3 show the month of December
### TABLE 4

Average Milk Production and Estimated Net Energy (ENE) Intake for Maintenance and Milk Production by Months for 1,014 Herd Month Observations\(^a\)

<table>
<thead>
<tr>
<th>Month</th>
<th>FCM/Cow/Day (lb)</th>
<th>ENE/Cow/Day (Therms)</th>
<th>Therms/lb FCM</th>
<th>Lb FCM/Therm</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>27.13</td>
<td>18.23</td>
<td>0.67</td>
<td>1.49</td>
</tr>
<tr>
<td>February</td>
<td>26.52</td>
<td>17.60</td>
<td>0.66</td>
<td>1.51</td>
</tr>
<tr>
<td>March</td>
<td>26.71</td>
<td>16.70</td>
<td>0.62</td>
<td>1.60</td>
</tr>
<tr>
<td>April</td>
<td>27.58</td>
<td>14.85</td>
<td>0.54</td>
<td>1.85</td>
</tr>
<tr>
<td>May</td>
<td>26.94</td>
<td>15.00</td>
<td>0.56</td>
<td>1.79</td>
</tr>
<tr>
<td>June</td>
<td>26.46</td>
<td>15.83</td>
<td>0.60</td>
<td>1.67</td>
</tr>
<tr>
<td>July</td>
<td>27.54</td>
<td>17.57</td>
<td>0.64</td>
<td>1.57</td>
</tr>
<tr>
<td>August</td>
<td>28.28</td>
<td>17.72</td>
<td>0.63</td>
<td>1.59</td>
</tr>
<tr>
<td>September</td>
<td>28.63</td>
<td>16.62</td>
<td>0.58</td>
<td>1.72</td>
</tr>
<tr>
<td>October</td>
<td>28.28</td>
<td>16.48</td>
<td>0.58</td>
<td>1.72</td>
</tr>
<tr>
<td>November</td>
<td>27.95</td>
<td>17.87</td>
<td>0.63</td>
<td>1.56</td>
</tr>
<tr>
<td>December</td>
<td>28.40</td>
<td>18.58</td>
<td>0.65</td>
<td>1.52</td>
</tr>
<tr>
<td>Mean ((\bar{X}))</td>
<td>27.53</td>
<td>17.15(^b)</td>
<td>0.62</td>
<td>1.61</td>
</tr>
</tbody>
</table>

\(^a\)The monthly averages are from January, 1962 through March, 1964.

\(^b\)The average cow in this study weighed 1,050 lb. and produced 27.53 lb. FCM per day.
to be one of the months with highest milk production per cow per day.
However, December was also the month with the highest ENE intake per cow
per day. This is in agreement with other studies (18, 78, 79, 105, 124)
which demonstrated that net energy available for production is the limiting
factor in the amount of milk produced.

**Significance of Sources of ENE for Maintenance and Milk Production**

The regression of FCM on the five variables studied and the result
of test for significance of sources of ENE for maintenance and milk produc­
tion is presented in Table 5. This table contains partial regression coe­
cfficients (b) along with the standard error and t values for each of the
nutrient variables studied. Quadratic effects are also shown for concen­
trates ($X_2^2$), silage ($X_3^2$), and pasture ($X_5^2$). Curvilinear effect for hay
($X_4^2$) was not significant.

The regression equation (II) obtained from these data is:

$$Y = -65.5749 + 0.1510X_1 + 1.3438X_2 + 1.0935X_3 + 0.3723X_4 + 1.0519X_5 - 0.0009X_2^2 - 0.0017X_3^2 - 0.0019X_5^2$$

$$R^2 = 0.9253; \quad \text{Where:}$$

$Y$ = FCM (in cwt. on a herd month basis)

$X_1$ = cow days in milk (where one cow milking one day equals one cow
day in milk)

$X_2$ = Therms ENE from concentrates (in cwt. on a herd month basis)

$X_3$ = Therms ENE from silage (in cwt. on a herd month basis)

$X_4$ = Therms ENE from hay (in cwt. on a herd month basis)

$X_5$ = Therms ENE from pasture (in cwt. on a herd month basis)
### TABLE 5
Regression Coefficients, Standard Error, and t Values, Regression of FCM on Five Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>b</th>
<th>S_b</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_1^b$</td>
<td>0.1510</td>
<td>0.0066</td>
<td>23.0304**</td>
</tr>
<tr>
<td>$x_2$</td>
<td>1.3438</td>
<td>0.0880</td>
<td>15.2622**</td>
</tr>
<tr>
<td>$x_3$</td>
<td>1.0935</td>
<td>0.0860</td>
<td>12.7117**</td>
</tr>
<tr>
<td>$x_4$</td>
<td>0.3723</td>
<td>0.0497</td>
<td>7.4981**</td>
</tr>
<tr>
<td>$x_5$</td>
<td>1.0519</td>
<td>0.8286</td>
<td>12.6955**</td>
</tr>
<tr>
<td>$x_2^2$</td>
<td>-0.0009</td>
<td>0.0001</td>
<td>6.8239**</td>
</tr>
<tr>
<td>$x_3^2$</td>
<td>-0.0017</td>
<td>0.0003</td>
<td>6.5749**</td>
</tr>
<tr>
<td>$x_5^2$</td>
<td>-0.0019</td>
<td>0.0002</td>
<td>8.8515**</td>
</tr>
</tbody>
</table>

- n 1014
- $b_0$ -65.5749
- $R^2$ 0.9253

**aUsing herd month observations.**

**b** $x_1$ = Days in milk, $x_2$ = Therms ENE from concentrates, $x_3$ = Therms ENE from silage, $x_4$ = Therms ENE from hay, $x_5$ = Therms ENE from pasture.

**Highly significant at $P \leq .01$.**
The coefficient of determination ($R^2$) indicates that the variables under consideration accounted for 92.50 per cent of the variation in FCM production. All variables shown in the above regression equation (II) had highly significant linear and curvilinear effects on FCM, except the curvilinear effect for hay ($X^2_4$).

In order to maximize milk production it was determined from the above regression equation (II) that if silage, hay, and pasture is fed at the average level in these data, 46.40 Therms of ENE from concentrates (66.30 pounds concentrates) per cow per day would be needed. (See Appendix Table 10a.) The average level of ENE intake per cow per day from different sources of feed in these data was: concentrates, 8.80 Therms; silage, 2.01 Therms; hay, 2.56 Therms; and pasture, 3.78 Therms. When feeding concentrates, hay and pasture at the average level in these data, an ENE intake of 20.09 Therms per cow per day from silage would be needed for maximum milk production. This means that if silage has an ENE value of .14 Therms per pound silage on an as fed basis, up to 143.50 pounds of silage should be fed for maximum milk production. This level of feeding for maximum milk production is very high and exceeds the limits of the data in this study by a considerable degree. Therefore, this should be interpreted with caution. These higher levels of ENE intake from various feeds, as calculated for increased milk production, appears to be due to underfeeding of cows in Louisiana.

Using the first derivative of $1.0519X_5 - 0.0019X^2_5$ in the above regression equation (II), it was determined that 17.26 Therms of ENE intake per cow per day from pasture would result in maximum milk production if concentrate, silage and hay are fed at the average level in these data. According to the pasture quality codes given in Appendix Table 2a,
excellent pasture would provide 11.55 Therms per cow per day when grazed by the average cow weighing 1,050 pounds as shown in these data (10.50 x Quality code of 1.1). Feeding hay was linear to the limits of these data. Thus, within the limits of the total amount of hay fed in these data, hay was getting linear response in milk production. This could indicate that Louisiana dairymen are not feeding as much good quality hay as they should for maximum milk production.

The general prediction equation (III) for showing changes in FCM production with changes in ENE intake is:

\[
(III) \quad \text{FCM} = \bar{Y} + b_{i1} (X_1 - \bar{X}_1) + b_{i2} (X_2 - \bar{X}_2).
\]

Where:

- \( Y \) = mean FCM per cow per day
- \( X_1 \) = Therms ENE intake
- \( b_i \) = partial regression coefficients

When feeding silage, hay, and pasture at the average level shown in these data, the general prediction equation (III) for concentrates becomes:

\[
(IV) \quad \text{FCM} = 27.53 + 1.3438(X_2 - \bar{X}_2) - 0.0009(X_2 - \bar{X}_2); \quad \text{Where:}
\]

- \( X_2 \) = Therms ENE intake from concentrates

From this equation (IV) it was determined that increasing ENE intake with concentrates from 0 to 10 Therms resulted in an increase of from 14.70 to 28.09 pounds FCM or an increase of 13.39 pounds FCM. Increasing ENE intake with concentrates from 0 to 46.4 Therms (amount needed for maximum production) resulted in an FCM production of 75.11 pounds, or an increase of 60.41 pounds FCM.

When feeding concentrates, hay, and pasture at the average level in these data, the general prediction equation (III) for silage becomes:
\[
(V) \quad \text{FCM} = 27.53 + 1.0935(X_3 - \bar{X}_3) - 0.0017(X_3^2 - \bar{X}_3^2),
\]

where:
\[
X_3 = \text{Therms ENE intake from silage}.
\]

From this equation it was determined that increasing ENE intake with silage from 0 to 10 Therms resulted in an increase of 10.87 pounds FCM. Increasing ENE intake with silage from 0 to 20.09 Therms (amount needed for maximum production) resulted in a total production of 46.47 pounds FCM, or an increase of 21.29 pounds. Substituting coefficients and means for hay and pasture in the general prediction equation (III) showed that an increase of ENE intake with hay from 0 to 10 Therms would increase production only 3.72 pounds FCM, while an increase from 0 to 10 Therms as pasture increased production by 10.33 pounds FCM.

Using the results of FCM increase by increasing ENE intake from 0 to 10 Therms from the above prediction equations, the following number of Therms per additional pound of FCM were needed from the different sources of feed: concentrates, 0.75 Therms; silage, 0.92; hay, 2.69; and pasture, 0.97. Thus, with these data, when ENE intake was increased from 0 to 10 Therms, hay was only 28 per cent as effective as concentrate, silage 81 per cent, and pasture 77 per cent. It should be pointed out, however, that concentrates exhibited a small monthly range (Table 3). This could have confounded the data for showing the significance of concentrates as compared to silage, hay, or pasture. The ranges in per cent of ENE supplied by each of the classes of forages were very wide (Table 3).

Pucnam and Loosli (124) reported that as the per cent of forage in the ration increased, the coefficient of apparent digestibility of dry matter decreased. No digestion trials were made in this study. However, their report is in agreement with the data in Tables 3 and 4 which indicate that as the per cent of total ENE intake from concentrates increased,
the pounds FCM per Therm ENE also increased. The one exception to the above statement is the data for the month of April. Table 4 shows that April was the month with the highest pounds FCM per Therm ENE (1.85). It is seen from the corresponding data in Table 3 that 53.39 per cent of the total ENE came from concentrates and 35.38 per cent came from pasture. This high per cent of ENE from pasture during the month of April, correlated with April being the month with the highest pounds of FCM per Therm ENE, could indicate that early spring pastures were more digestible than the more mature grass later in the season.

The nonlinear relationship in regression of FCM on nutrient variables as shown in Table 5 lends support to the hypothesis by Jarrett and Fosgate (79) that herds averaging high levels of production have reached a plateau in milk production beyond which point the relationship between Therms NE input and pounds FCM output is nonlinear. The production level in this study was 8,268 pounds FCM per cow per year (157). It is noted in Table 5 that there was a quadratic effect in the regression of FCM on all nutrients with the exception of hay ($X_4^2$) which was not significant.

Input-Output Relations

Figure 1, plotted from data obtained in Table 6, presents the estimated net energy intake and milk output relation from DHIA herds in Louisiana. This graph shows that there were distinct fluctuations in milk production per cow per day and in quantity of ENE intake throughout the year. Bloom et al. (18) have presented evidence that milk production is in direct proportion to NE intake. These workers studied four different methods of feeding. They plotted Therms of energy input above maintenance
Figure 1. Energy Intake and Milk Output Relation from DHIA Herds in Louisiana.

*Therm of ENE required per lb of FCM was 0.38. See Table 6.
available for milk production. Likewise, each pound of FCM was scaled in Therms of its energy content so that the graphs for FCM and feed inputs were directly comparable. Their data showed that milk production closely followed ENE inputs of feed above maintenance requirements.

Data in Table 6 and presented in Figure 1 show that high production per cow per day was obtained in September. The significance of stage of lactation as reflected by the regression of FCM on days in milk in Table 5 is shown here. This high production per cow per day during the month of September is probably due to the large per cent of the dairy cows that were bred to freshen in the early fall in Louisiana. There was an increase in milk production per cow per day from August to September with a decrease in ENE intake during this period. However, as stage of lactation progressed, milk production per cow per day dropped although consuming approximately the same amount of ENE. Then, beginning in the latter part of November and during the month of December, ENE intake per cow per day increased followed by a corresponding increase in FCM production per cow per day. December was the month of highest ENE intake per cow per day. Also, in spite of advanced lactation of cows, December had next to the highest FCM production per cow per day.

The significance of different sources of ENE intake was also reflected during this period. Table 3 in this study showed December to be the month with the lowest per cent of total ENE intake from concentrates. December was also next to the lowest month from the standpoint of pound FCM produced per Therm ENE intake (Table 4). The increase in the ENE intake per cow per day during the months of November through February was parallel to an increase in the amounts of hay and silage
TABLE 6

Average Daily Milk Production and Estimated Net Energy (ENE) Intake Above Maintenance Requirements per Cow Adjusted to 1,050 Lb. Body Weight\textsuperscript{a}

<table>
<thead>
<tr>
<th>Month \textsuperscript{b}</th>
<th>FCM/Cow/Day (lb)</th>
<th>ENE/Cow/Day (Therms)</th>
<th>Therms/lb FCM</th>
<th>Lb FCM/Therm</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>27.13</td>
<td>11.63</td>
<td>0.43</td>
<td>2.33</td>
</tr>
<tr>
<td>February</td>
<td>26.52</td>
<td>11.00</td>
<td>0.41</td>
<td>2.41</td>
</tr>
<tr>
<td>March</td>
<td>26.71</td>
<td>10.10</td>
<td>0.38</td>
<td>2.64</td>
</tr>
<tr>
<td>April</td>
<td>27.58</td>
<td>8.25</td>
<td>0.30</td>
<td>3.34</td>
</tr>
<tr>
<td>May</td>
<td>26.94</td>
<td>8.40</td>
<td>0.31</td>
<td>3.21</td>
</tr>
<tr>
<td>June</td>
<td>26.46</td>
<td>9.23</td>
<td>0.35</td>
<td>2.87</td>
</tr>
<tr>
<td>July</td>
<td>27.54</td>
<td>10.97</td>
<td>0.40</td>
<td>2.51</td>
</tr>
<tr>
<td>August</td>
<td>28.28</td>
<td>11.12</td>
<td>0.39</td>
<td>2.54</td>
</tr>
<tr>
<td>September</td>
<td>28.63</td>
<td>10.02</td>
<td>0.35</td>
<td>2.86</td>
</tr>
<tr>
<td>October</td>
<td>28.28</td>
<td>9.88</td>
<td>0.35</td>
<td>2.86</td>
</tr>
<tr>
<td>November</td>
<td>27.95</td>
<td>11.27</td>
<td>0.40</td>
<td>2.48</td>
</tr>
<tr>
<td>December</td>
<td>28.40</td>
<td>11.98</td>
<td>0.42</td>
<td>2.37</td>
</tr>
<tr>
<td>Mean (X)</td>
<td>27.53</td>
<td>10.55</td>
<td>0.38</td>
<td>2.61</td>
</tr>
</tbody>
</table>

\textsuperscript{a}The average cow in this study weighed 1,050 lb and required 6.6 Therms per day for maintenance.

\textsuperscript{b}The monthly averages are from January, 1962 through March, 1964.
fed, with a particularly large increase in the per cent ENE supplied by hay during the months of December, January, and February. Coinciding data in Table 6 showed these three months with the lowest FCM production per Therm ENE; i.e., the values being 2.37, 2.33, and 2.41, respectively, as compared to the average of 2.61 and a high of 3.34 for the month of April. This further confirms the previous statements concerning the relatively greater influence of concentrate as compared to hay for milk production (Table 5). In the second section of this chapter it was stated that when ENE intake was increased from 0 to 10 Therms, hay was only 28 per cent as effective as concentrates. Huffman and Duncan (69, 74) showed that cows on hay alone would increase milk production against the natural tendency to decline with advance in lactation when concentrates were added to the all-hay rations.

The data presented in Table 6 show a lower ENE intake and a lower FCM production per cow per day during the spring months of April and May than during the late fall and early winter months of November and December. However, the FCM production per Therm ENE was the highest in April and May. The months of April and May are the natural months for spring flush of pasture with highly digestible, low fiber grass. They are also the months when little silage or hay is normally fed in Louisiana. This is confirmed in Table 3, which revealed that a very small per cent of the total ENE came from silage or hay during these two months. This combination of a high per cent of the total ENE supplied by concentrates and spring pasture during the months of April and May in this study resulted not only in the highest FCM production per Therm ENE, but also in the highest income over feed cost per Therm ENE as is shown in Table 11 and
to be discussed under the section entitled "Economic Aspects" of this chapter.

It is noted in Figure 1 that there was a decline in milk production from 27.58 pounds per cow per day during the month of April to a low of 26.46 pounds per cow per day during the month of June. This occurred even with a slight increase in ENE intake per cow per day from April to June. Several workers (38, 138, 139) have shown that there is a definite slump in milk production when pasture plants in the advanced stage are not properly supplemented. Seath et al. (149) supplemented summer pasture with both corn silage and grain and reported that this supplementing did prevent the summer decline in milk production. Control cows in the study declined 2.73 pounds per cow per day; whereas, the cows receiving the silage decreased only 1.25 pounds, and the cows receiving the extra allowance of grain increased 1.12 pounds milk per cow per day. This is in agreement with this study as well as with the study by Jarrett and Fosgate (79) which showed a sharp decline in milk production and nutrient intake beginning in May and reaching a low for the year in July. Part of the decline in milk production during this period in both studies could be due to the advanced lactation of cows which freshened in the fall. However, both studies indicated that as grain and silage feeding was increased and thereby increasing the total ENE intake per cow per day, there was a corresponding increase in milk production. The increase in ENE intake during the month of July and August shows an increase in milk production per cow per day but a decrease in pound FCM produced per Therm ENE intake (Table 6). This should further substantiate the contention of lower digestibility of late summer grass, or the over-evaluation of millet and other summer
supplemental grasses, since the data in Table 3 show that a large per cent of the total ENE came from pasture during the months of July and August.

Another hypothesis developed to guide this study was that there is a linear relationship of milk production to estimated net energy intake. The nonlinear relationship in the regression of FCM on nutrient variables shown in Table 5 in this chapter indicated that the law of diminishing output applies to milk production. With the exception of hay \((X^2)\), there was quadratic effect highly significant at \(P < .01\) in the regression of FCM on all sources of nutrients. There are indications from the data in Table 6 of this study that as ENE intake goes up, pounds of FCM per Therm ENE go down. Jansen et al. (81) found similar results in studies of input-output relationship. These workers showed that cows on a normal ration, based on Haeker's (58) standard, returned 3 pounds of FCM for each pound of total digestible nutrients (TDN) consumed above maintenance; but for each additional pound of TDN added to a normal ration, an increase of only 1.0 to 1.5 pounds of FCM was obtained. Other workers (15, 18, 22, 80) also showed a diminishing output from increased feed inputs. They hypothesized that part of the diminishing output were due to a decline in digestibility. The average of 2.61 pounds FCM per Therm ENE of this study (Table 6) is higher than the average of 2.22 pounds FCM per Therm ENE in the study by Jarrett and Fosgate. This could be due to the fact that 51.21 per cent of the total ENE intake came from concentrates in this study; whereas, only 42 per cent of the total ENE intake was supplied by concentrates in the study by Jarrett and Fosgate (79).
An immediate objective of this study was to determine the adequacy of the amount of feed recommended for maintenance and milk production of Louisiana dairy cows as calculated by present feeding standards. The hypothesis developed to guide the study of this objective was that the present feeding recommendations of 15.40 Therms ENE per day for a Louisiana dairy cow weighing 1,050 pounds and producing 27.53 pounds FCM is adequate. The data presented in Tables 7, 8, and 9 of this study indicate that present feeding standards being used in calculating feed needed by Louisiana dairy cows are too low.

The data in Table 7 give the level and sources of ENE for maintenance and milk production by body weights for 1,014 Louisiana dairy herd month observations during the period studied which was from January, 1962 through March, 1964. The average cow in this study, weighing 1,050 pounds and producing 27.53 pounds FCM per day consumed 17.15 Therms ENE per day. The per cent of total ENE intake from the various sources were as follows: concentrates, 51.21 per cent, silage 11.76 per cent, dry forage (hay) 14.98 per cent, and pasture 22.05 per cent. The average cow in this study consumed 0.62 Therms ENE per pound FCM for maintenance and milk production and produced 1.61 pounds FCM per Therm ENE consumed.

Table 8 presents the level and ENE intake for maintenance and milk production by body weights for 135 selected Louisiana dairy herd month observations during the same period that the data for the 1,014 herd month observations in Table 7 were obtained. The selected dairy herds used for obtaining the data in Table 8 were those located at Louisiana
TABLE 7

Level and Source of ENE Intake for Maintenance and Milk Production by Body Weights for 1014 Louisiana Dairy Herd Month Observations

<table>
<thead>
<tr>
<th>Body Weights (lb)</th>
<th>FCM/Cow/Day (lb)</th>
<th>ENE/Cow/Day (Therms)</th>
<th>Per cent of Total ENE from</th>
<th>Therm/Lb</th>
<th>ENE/Therm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Concentrates</td>
<td>Silage</td>
<td>Dry Forage</td>
</tr>
<tr>
<td>&lt; 800</td>
<td>27.74</td>
<td>14.20</td>
<td>50.42</td>
<td>6.45</td>
<td>11.00</td>
</tr>
<tr>
<td>800-890</td>
<td>24.36</td>
<td>14.12</td>
<td>55.88</td>
<td>5.08</td>
<td>14.46</td>
</tr>
<tr>
<td>900-990</td>
<td>25.39</td>
<td>15.62</td>
<td>51.29</td>
<td>8.34</td>
<td>19.46</td>
</tr>
<tr>
<td>1000-1090</td>
<td>27.64</td>
<td>17.10</td>
<td>52.08</td>
<td>11.05</td>
<td>15.48</td>
</tr>
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<td>1100-1190</td>
<td>28.63</td>
<td>18.17</td>
<td>50.43</td>
<td>17.27</td>
<td>12.85</td>
</tr>
<tr>
<td>1200-1290</td>
<td>31.74</td>
<td>19.76</td>
<td>49.28</td>
<td>13.47</td>
<td>12.94</td>
</tr>
<tr>
<td>1300-1390</td>
<td>33.25</td>
<td>24.09</td>
<td>50.62</td>
<td>11.60</td>
<td>7.30</td>
</tr>
<tr>
<td>1400 and &gt;</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean (X) = 1050</td>
<td>27.53</td>
<td>17.15</td>
<td>51.21</td>
<td>11.76</td>
<td>14.98</td>
</tr>
</tbody>
</table>

*The monthly observations are from January, 1962 through March, 1964.*
<table>
<thead>
<tr>
<th>Body Weights (lb)</th>
<th>FCM/Cow/Day (lb)</th>
<th>ENE/Cow/Day (Therms)</th>
<th>Per cent of Total ENE from</th>
<th>Therms/ENE/lb FCM</th>
<th>Lb FCM/Therm</th>
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</thead>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Concentrates</td>
<td>Silage</td>
<td>Dry Forage</td>
</tr>
<tr>
<td>&lt; 800</td>
<td>31.62</td>
<td>15.17</td>
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<td>26.23</td>
<td>16.11</td>
<td>47.51</td>
<td>15.76</td>
<td>9.86</td>
</tr>
<tr>
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<td>44.43</td>
<td>10.42</td>
<td>23.61</td>
</tr>
<tr>
<td>1000-1090</td>
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<td>19.60</td>
<td>48.25</td>
<td>17.99</td>
<td>18.30</td>
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<td>1100-1190</td>
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<td>46.83</td>
<td>27.70</td>
<td>13.40</td>
</tr>
<tr>
<td>1200-1290</td>
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<td>19.65</td>
<td>55.01</td>
<td>8.47</td>
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<td>36.75</td>
<td>28.92</td>
<td>42.06</td>
<td>13.61</td>
<td>9.08</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mean (X) = 1100</strong></td>
<td>29.85</td>
<td>18.19</td>
<td>49.15</td>
<td>17.13</td>
<td>14.00</td>
</tr>
</tbody>
</table>

*Selected Dairy Herds are: Louisiana State University, Southeast Louisiana Dairy and Pasture Experiment Station, North Louisiana Experiment Station, and North Louisiana Hill Farm Experiment Station.*
State University, Southeast Louisiana Dairy and Pasture Experiment Station, North Louisiana Experiment Station, and North Louisiana Hill Farm Experiment Station. These selected dairy herds were managed by trained college graduates who assisted the DHIA Supervisors in reporting the estimated net energy values of forages (quality codes) as per instructions in Appendix Table 2a. The average cow in these selected herds, as shown in Table 8, weighed 1,100 pounds, produced 29.85 pounds FCM per day and consumed 18.19 Therms ENE per day. The per cent of total ENE intake from various sources were: concentrate, 49.15 per cent; silage, 17.13 per cent; dry forage (hay), 14.00 per cent; and pasture, 19.72 per cent. Also, the average cow in the selected herds required 0.61 Therms ENE per pound FCM for maintenance and milk production as compared to 0.62 Therms ENE per pound FCM for the average cow in the entire study; and, both averages, as shown in Table 7 and 8, were almost identical in producing 1.64 and 1.61 pounds FCM per Therm ENE, respectively.

The data in both Tables 7 and 8 show a decrease in pound FCM per Therm ENE intake as body weights of animals increased. It is seen in Table 7 that the pound FCM per Therm decreased from a high of 1.95 pounds for cows weighing less than 800 pounds to a low of 1.38 for cows weighing between 1,300 and 1,390 pounds. The data in Table 8 are similar except that the range of from 2.08 pounds to 1.27 pounds from the small to the larger cows in Table 8 is greater than the range in Table 7. This indicated higher efficiency of milk production per Therm ENE consumed by the small cows is in agreement with the statement by Conrad (28) that small cows are more efficient than larger cows, if they produce the same amount of 4 per cent milk per unit of time and all other conditions are equal.
However, Conrad (28) also found that the efficiency of the smaller cows decreased more rapidly than the efficiency of the larger cows as the digestibility of the rations decreased. The data in Table 7 indicate that the smaller cows obtained a larger per cent of the total ENE intake from concentrates, which has already been indicated to produce more FCM per Therm ENE consumed than the other three sources of nutrients studied.

The data in Table 9 compare the level of ENE intake for maintenance and milk production consumed by dairy cows in this study to the recommended level when calculated by present feeding standards. The average cow in this study, as shown on the bottom line of Table 9, consumed 17.15 Therms ENE per day for maintenance and milk production; whereas, Morrison's feeding standard (116) and the formula by Jones (83) would have recommended 15.41 and 15.34 Therms ENE per day, respectively. In Appendix Table 8a there is presented the data from Morrison's feeding standard that was used in calculating feed needed by each individual cow on the EDPM program prior to the adoption of the formula developed by Jones (83) shown in Appendix Table 9a.

The formula by Jones (83) was adopted by the Dairy Records Processing Center, North Carolina State College, in an attempt to meet more adequately the energy requirements of high-producing cows. The data presented in Table 9 indicated that the average cow in this study consumed approximately 12 per cent more ENE per cow per day for maintenance and milk production than is presently being recommended by the formula used in calculating feed needed by each individual cow on the electronic data processing machine records program (EDPM). Cow days in milk were used so as to obtain the best possible estimate of FCM per cow per day with these available data.
## TABLE 9

Level of ENE Intake for Maintenance and Milk Production of Louisiana Dairy Cows Compared to Recommended Level of ENE Intake as Calculated by Present Feeding Standards

<table>
<thead>
<tr>
<th>Body Weights (lb)</th>
<th>FCM/Cow/Day (lb)</th>
<th>ENE/Cow/Day (Therms)</th>
<th>Morrison's Feeding Standards ENE/Cow/Day (Therms)a</th>
<th>EDPM Calculated ENE Requirement Thers/Cow/Dayb</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 800</td>
<td>27.74</td>
<td>14.20</td>
<td>13.78</td>
<td>13.84</td>
</tr>
<tr>
<td>1000-1090</td>
<td>27.64</td>
<td>17.10</td>
<td>15.46</td>
<td>15.46</td>
</tr>
<tr>
<td>1100-1190</td>
<td>28.63</td>
<td>18.17</td>
<td>16.31</td>
<td>16.35</td>
</tr>
<tr>
<td>1200-1290</td>
<td>31.74</td>
<td>19.76</td>
<td>17.86</td>
<td>17.99</td>
</tr>
<tr>
<td>1300-1390</td>
<td>33.25</td>
<td>24.09</td>
<td>18.89</td>
<td>19.09</td>
</tr>
<tr>
<td>1400 and &gt;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>MEAN (X)</strong> = 1050</td>
<td>27.53</td>
<td>17.15</td>
<td>15.41</td>
<td>15.34</td>
</tr>
</tbody>
</table>

*a* Calculated from Morrison's (116) Feeding Standards as given in Appendix Table 8a.

*b* Calculated from the formula developed by Jones (83) as given in Appendix Table 9a.
No attempt was made in this study to determine the reasons for this greater ENE intake needed by Louisiana dairy cows as indicated by the data obtained in this study for the period of January, 1962 through March, 1964. However, several reasons for this higher ENE intake to FCM production may be hypothesized. One reason could be that Louisiana's high humidity, extreme heat, and large fluctuations in temperature could have adversely affected dairy cattle performance during the period covered by this study. Poor management practices or even low genetic potential could account for some of the lower FCM production per Therm ENE consumed. Overrating the quality of forages, as well as overestimating the amount of forage consumed by cows in this study, could have caused a higher indication of ENE intake than actually existed. Regardless of the reasons that may have caused this indicated high ENE need by Louisiana dairy cows, this study shows the need for a forage evaluation program coupled with further research on digestibility and the physiological response of dairy cows as measured by the total amount of fat-corrected-milk (FCM) produced.

**Economic Aspect**

The regression of income over feed cost on the five variables studied and the result of test for significance of sources of estimated net energy (ENE) on changes in income over feed cost is presented in Table 10. This table contains partial regression coefficients (b) along with the standard error and t values for each of the significant nutrient variables. Linear effects for concentrates ($X_2$) and pasture ($X_3$) were not significant. Quadratic effects are also shown for silage ($X_3^2$), hay ($X_4^2$),
TABLE 10

Regression Coefficients, Standard Error, and t Values,
Regression of Income over Feed Cost
on Five Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>b</th>
<th>S_b</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>0.9685</td>
<td>0.0259</td>
<td>37.3486**</td>
</tr>
<tr>
<td>$X_3$</td>
<td>1.3479</td>
<td>0.5421</td>
<td>2.4866*</td>
</tr>
<tr>
<td>$X_4$</td>
<td>-1.1333</td>
<td>0.5286</td>
<td>2.1440*</td>
</tr>
<tr>
<td>$X_2^3$</td>
<td>-0.0099</td>
<td>0.0016</td>
<td>6.2433**</td>
</tr>
<tr>
<td>$X_2^4$</td>
<td>-0.0041</td>
<td>0.0016</td>
<td>2.5417*</td>
</tr>
<tr>
<td>$X_2^5$</td>
<td>0.0070</td>
<td>0.0005</td>
<td>14.3882**</td>
</tr>
</tbody>
</table>

N 1014
$bo$ - 74.3608
$R^2$ 0.8185

*Using Herd Month Observations.

$X_1^b$ = Days in milk, $X_2$ = Therms ENE from concentrates, $X_3$ = Therms ENE from silage, $X_4$ = Therms ENE from hay, $X_5$ = Therms ENE from pasture.

**Highly significant at $P < .01$.

*Significant at $P < .05$. 
and pasture ($X_5^2$). Curvilinear effect for concentrate ($X_2^2$) was not significant.

The regression equation (VI) obtained from the data is:

$$ (VI) \hat{Y} = 74.3608 + 0.9685 X_1 + 1.3479 X_3 - 1.1333 X_4 - 0.0099 X_3^2 - 0.0041 X_4^2 + 0.0070 X_5^2. $$

$$ R^2 = 0.8185. $$

Where:

$Y$ = Income over feed cost (in $10 unit on a herd month basis)

$X_1$ = Cow days in milk (where one cow milking one day equals one cow day in milk)

$X_3$ = Therms ENE from silage (in cwt. on a herd month basis)

$X_4$ = Therms ENE from hay (in cwt. on a herd month basis)

$X_5$ = Therms ENE from pasture (in cwt. on a herd month basis)

The coefficient of determination ($R^2$) indicates that the variables under consideration accounted for 81.85 per cent of the variation in income over feed cost. Linear effect for days in milk ($X_1$) was highly significant ($P < 0.01$). Linear effects for silage ($X_3$) and hay ($X_4$) were significant ($P < 0.05$). Curvilinear effects for silage ($X_3^2$) and pasture ($X_5^2$) were highly significant ($P < 0.01$) and curvilinear effect for hay ($X_4^2$) was significant ($P < 0.05$).

In order to maximize income over feed cost, it was determined by using the first derivative of $1.3479 X_3 - 0.0099 X_3^2$ in the above equation (VI) that if concentrates, hay, and pasture are fed at the average level in these data, 4.25 Therms in ENE intake from silage per cow per day would be needed. If this silage has an ENE value of .14 Therms per pound silage on an as fed basis, this would be 30.40 pounds silage per cow per day; or, 16.0 pounds more silage (2.24 Therms) than fed at the average level in these data. (See Appendix Table 11a.)
Linear and curvilinear effects for concentrates were not significant. The increased value of milk produced by increasing the ENE intake from concentrates above the average level fed in these data was not significantly more than the cost of the concentrates.

Increasing ENE intake as hay significantly decreased income over feed cost. When feeding concentrates, silage, and pasture at the average level in these data, the prediction equation for hay becomes:

\[(VII) \text{Income over feed cost} = 89 - 1.1333(X_4 - \bar{X}_4) - 0.0041(X_4^2 - \bar{X}_4^2).\]

Where:

\[X_4 = \text{Therms ENE from hay.}\]

Average income over feed cost per cow per day in this study was found to be $0.89. From the above equation (VII) it was determined that increasing ENE intake with hay from 0 to 10 Therms resulted in a decrease of 13.75 cents income over feed cost. Increasing ENE intake with pasture from 0 to 10 Therms resulted in an increase of 0.70 cents income above feed cost.

When feeding concentrates, hay, and pasture at the average level in these data, the prediction equation for silage becomes:

\[(VIII) \text{Income over feed cost} = 89 + 1.3479(X_3 - \bar{X}_3) - 0.0099(X_3^2 - \bar{X}_3^2).\]

Where:

\[X_3 = \text{Therms ENE from silage.}\]

From this equation (VIII) it was determined that increasing ENE intake with silage from 0 to 10 Therms increased income over feed cost from 86.23 to 98.71 cents, or an increase of 12.48 cents.
These data relating to the regression of income over feed cost on nutrient variables indicated that silage was the most profitable of the four sources of nutrients studied, followed by pasture, concentrates, and hay in descending order. The data relating to regression of FCM on nutrient variables indicated that increasing concentrates resulted in the greatest increase in milk production followed by silage, pasture, and hay in descending order. This difference between the response of milk production and the response of income over feed cost to increases in estimated net energy intake from the various sources of feed used in this study should indicate that planning a feeding program for obtaining maximum milk production may not maximize income over feed cost. Many Louisiana dairymen are designing their feeding programs with the objective of increasing milk production per cow without considering the effect of this feeding program on income over feed cost.

The relationship of level and sources of ENE intake per pound FCM to income over feed cost by months for 1,014 herd month observations is shown in Table 11. The data indicate that during the period from January, 1962 through March, 1964 the average cow in this study, weighing 1,050 pounds and producing 27.53 pounds FCM per day, returned 4.79 cents income over feed cost per Therm ENE consumed, with a range of from 3.92 cents in the month of January to 6.94 cents in the month of April. This was 89 cents per cow per day with a range of 75 cents per cow per day in the month of January to $1.10 during the month of April. The average cost of forage per Therm ENE consumed was 3.36 cents with a range of from 2.71 cents in the month of April to 3.70 cents in the month of January. The average cost of concentrate per Therm ENE consumed was 4.39 cents with a range of
### TABLE 11

Relationship of Level and Sources of ENE Intake per Lb FCM to Income Over Feed Cost by Months

<table>
<thead>
<tr>
<th>Month</th>
<th>Income Over Feed Cost/ Cow/Day (dollars)</th>
<th>Therms ENE/lb FCM</th>
<th>Per cent of Total ENE from Concentrate</th>
<th>Cost of Concentrate/ Therm ENE (cents)</th>
<th>Cost of Forage/ Therm ENE (cents)</th>
<th>Income Over Feed cost/ Therm ENE (cents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.75</td>
<td>0.67</td>
<td>49.26</td>
<td>15.40</td>
<td>23.29</td>
<td>12.05</td>
</tr>
<tr>
<td>February</td>
<td>0.78</td>
<td>0.66</td>
<td>49.19</td>
<td>10.22</td>
<td>23.65</td>
<td>16.94</td>
</tr>
<tr>
<td>March</td>
<td>0.87</td>
<td>0.62</td>
<td>49.22</td>
<td>9.05</td>
<td>17.64</td>
<td>24.09</td>
</tr>
<tr>
<td>April</td>
<td>1.10</td>
<td>0.54</td>
<td>53.39</td>
<td>3.95</td>
<td>6.83</td>
<td>35.83</td>
</tr>
<tr>
<td>May</td>
<td>0.97</td>
<td>0.56</td>
<td>55.81</td>
<td>4.11</td>
<td>9.42</td>
<td>30.66</td>
</tr>
<tr>
<td>June</td>
<td>0.91</td>
<td>0.60</td>
<td>53.72</td>
<td>7.21</td>
<td>11.82</td>
<td>27.25</td>
</tr>
<tr>
<td>July</td>
<td>0.94</td>
<td>0.64</td>
<td>50.56</td>
<td>5.27</td>
<td>8.02</td>
<td>36.15</td>
</tr>
<tr>
<td>August</td>
<td>0.97</td>
<td>0.63</td>
<td>50.98</td>
<td>10.96</td>
<td>6.08</td>
<td>31.98</td>
</tr>
<tr>
<td>September</td>
<td>1.01</td>
<td>0.58</td>
<td>54.24</td>
<td>9.51</td>
<td>7.24</td>
<td>29.01</td>
</tr>
<tr>
<td>October</td>
<td>0.94</td>
<td>0.58</td>
<td>54.35</td>
<td>17.65</td>
<td>10.20</td>
<td>17.70</td>
</tr>
<tr>
<td>November</td>
<td>0.82</td>
<td>0.63</td>
<td>51.81</td>
<td>16.86</td>
<td>16.00</td>
<td>15.33</td>
</tr>
<tr>
<td>December</td>
<td>0.81</td>
<td>0.65</td>
<td>48.11</td>
<td>16.51</td>
<td>19.69</td>
<td>15.69</td>
</tr>
<tr>
<td>Mean (X)</td>
<td>0.89</td>
<td>0.62</td>
<td>51.21</td>
<td>11.76</td>
<td>14.98</td>
<td>22.05</td>
</tr>
<tr>
<td>Range</td>
<td>0.75</td>
<td>0.54</td>
<td>48.11</td>
<td>3.95</td>
<td>6.08</td>
<td>12.05</td>
</tr>
<tr>
<td></td>
<td>to</td>
<td>to</td>
<td>to</td>
<td>to</td>
<td>to</td>
<td>to</td>
</tr>
</tbody>
</table>

*Monthly averages for 1,014 herd month observations are from January, 1962 through March, 1964.

*bThe average cow in this study weighed 1,050 lb and produced 27.53 lb FCM per day.
from 4.30 cents in the months of April and May to 4.49 cents in the month of August. January was the month requiring the highest Therm ENE intake (0.67) per pound FCM produced, and having the highest cost of feed per Therm ENE and the lowest income over feed cost per Therm ENE (3.92 cents). The month of April had the lowest Therm ENE intake (0.54) per pound FCM produced, the lowest cost of feed per Therm ENE and the highest income over feed cost per Therm ENE consumed (6.94 cents). The data in Table 4 of this study show that the 18.23 Therms ENE intake per cow per day in the month of January was considerably higher than the 14.85 Therms ENE intake per cow per day in the month of April although the pounds FCM per cow per day were about the same, which was 27.13 and 27.58 pounds, respectively, for the months of January and April.

The results of this study indicate the need for more research to determine the level of estimated net energy from various sources of feeds used in Louisiana dairy feeding programs resulting in maximum income over feed cost. Studies of this nature were made by Hoglund (65) for the Western, Pacific, and Midwestern areas of the United States and he found indications that some dairymen are feeding grain at uneconomical levels. Another study using data from DHIA records is presently under way in Louisiana to determine feeding programs that will result in maximum income over feed cost.
VII. SUMMARY AND CONCLUSIONS

Monthly herd data from Louisiana Dairy Herd Improvement Association (DHIA) records for the period from January, 1962 through March, 1964 were used to: 1.) Study the level of ENE intake from various sources of feeds used in feeding Louisiana dairy cows enrolled in DHIA records; 2.) Determine the amount of estimated net energy intake from these feed sources needed for maximum milk production per cow; 3.) Determine the adequacy of recommended ENE intake for maintenance and milk production of Louisiana dairy cows; and 4.) Determine the amount of estimated net energy intake from the various feed sources used in this study needed for maximum income over feed cost per cow.

One thousand and fourteen (1,014) herd month observations, using Jersey, Guernsey, and Holstein herds whose records were processed by Electronic Data Processing Machines (EDPM) were made. All records were converted to 4 per cent FCM. The average cow in this study weighed 1,050 pounds, and on the basis of this weight each cow had a daily maintenance requirement of 6.63 Therms. The feeding programs were evaluated by using total Therms of estimated net energy (ENE) from concentrates, silage, dry forage (hay), and pasture consumed minus the maintenance energy consumed by dry cows. Regression of FCM on estimated net energy intake was made to show the value of ENE intake from different sources on milk production and maintenance. Regression of income over feed cost on estimated net energy intake was made to show the value of ENE intake from different sources on income over feed cost.
Concentrates supplied 51.21 per cent of the total ENE for the period covered in this study which was from January, 1962 through March, 1964. The remaining 48.79 per cent supplied by forage came from the following sources: silage, 11.76 per cent; hay, 14.98 per cent; and pasture, 22.05 per cent. Concentrates exhibited a small monthly range (48.11 - 55.81 per cent). This indicates that regardless of the quantity and quality of forages available, Louisiana dairymen depended on concentrates to furnish approximately 51 per cent of the monthly ENE consumed per cow.

Forages in Louisiana supplied about 49 per cent of the total ENE consumed. The average concentrate to forage ratio was 51.21 : 48.79 with a range of 48.11 : 51.89 in the month of December to 55.81 : 44.19 in the month of May. There was a considerably wider range exhibited by each class of forage than that exhibited by concentrate to forage ratio. Silage supplied an average of 11.76 per cent of the total ENE intake with a range of from 3.95 per cent during the month of April to 17.65 per cent during the month of October. Hay supplied an average of 14.98 per cent of the total ENE intake with a range of from 6.08 per cent during the month of August to 23.65 per cent during the month of February. Pasture contributed an average of 22.05 per cent of the total ENE intake with a range of from 12.05 per cent during the month of January to 36.15 per cent during the month of July for the period studied.

The regression equation (II) obtained from the regression of FCM on the five variables studied is:

\[ Y = -65.5749 + 0.1510X_1 + 1.3438X_2 + 1.0935X_3 + 0.3723X_4 + 1.0519X_5 \]
\[ - 0.0009X_2^2 - 0.0017X_3^2 - 0.0019X_5^2 \]

\[ R^2 = 0.9253, \] Where:
\[ Y = FCM \text{ (in cwt. on a herd month basis)} \]

\[ X_1 = \text{Cow days in milk (where one cow milking one day equals one cow day in milk)} \]

\[ X_2 = \text{Therms ENE from concentrates (in cwt. on a herd month basis)} \]

\[ X_3 = \text{Therms ENE from silage (in cwt. on a herd month basis)} \]

\[ X_4 = \text{Therms ENE from hay (in cwt. on a herd month basis)} \]

\[ X_5 = \text{Therms ENE from pasture (in cwt. on a herd month basis)} \]

All variables shown in the above regression equation (II) had highly significant effects on milk production. The average level of ENE intake per cow per day from different sources of feed in these data was: concentrates, 8.80 Therms; silage, 2.01 Therms; hay, 2.56 Therms; and pasture, 3.78 Therms. Maximum milk production could be obtained by increasing ENE intake with concentrates from 8.80 to 46.40 Therms (66.30 pounds concentrate); or, by increasing ENE intake with silage from 2.01 to 20.09 Therms (143.50 pounds silage); or, by increasing ENE intake with pasture from 3.78 to 17.26 Therms per cow per day. Feeding hay was linear to the limits of these data.

The prediction equation (III) used for showing changes in FCM production with changes in ENE intake from different sources is:

\[(III) \quad FCM = \overline{Y} + b_{11} (X_1 - \overline{X}_1) + b_{12} (X_1^2 - \overline{X}_1^2).\]

Where:

\[ \overline{Y} = \text{mean FCM per cow per day (27.53)} \]

\[ X_1 = \text{Therms ENE intake} \]

\[ b_i = \text{partial regression coefficients.} \]

Using the results of FCM increase by increasing ENE intake from 0 to 10 Therms from the prediction equations, the following number of Therms per additional pound of FCM were needed from the different sources of feed: concentrates, 0.75; silage, 0.92; hay, 2.69; and pasture, 0.97.
Input-output studies showed that ENE intake above maintenance closely followed FCM production. The data in this study showed distinct fluctuations in milk production per cow per day and in quantity of ENE intake throughout the year. It was found that one Therm of ENE intake above maintenance produced 2.61 pounds of FCM on the average, ranging from a low of 2.33 pounds FCM per Therm ENE during the month of January to a high of 3.34 pounds FCM per Therm ENE during the month of April. There was a higher ENE intake above maintenance per cow per day (11.63 Therms) and a higher per cent of total ENE intake from hay (23.29 per cent) during the month of January as compared to a lower ENE intake per cow per day (8.25 Therms) and a lower per cent of total ENE intake (6.83 per cent) from hay during the month of April. The nonlinear relationship in the regression of FCM on nutrient variables indicated a diminishing output at the higher levels of ENE intake. There was a quadratic effect in the regression of FCM on all nutrients with the exception of hay ($X^2_4$) which was not significant.

The data presented in this study indicate that present feeding standards being used in calculating feed needed by Louisiana dairy cows were too low. The average cow in this study, weighing 1,050 pounds and producing 27.53 pounds FCM per day, consumed 17.15 Therms ENE per day for maintenance and milk production. This is about 12 per cent more ENE per cow per day for maintenance and milk production than is presently being recommended by the formula used in calculating feed needed by each individual cow on the Electronic Data Processing Machine Records (EDPM). Overrating the quality of forage, as well as overestimating the amount of forage consumed by cows in this study, could have caused a higher indication of ENE intake than actually existed.
The regression equation (VI) obtained from the regression of income over feed cost on the five variables studied is:

\[ Y = -74.3608 + 0.9685X_1 + 1.3479X_3 - 1.1333X_4 - 0.0099X_3^2 - \\
    0.0041X_4^2 + 0.0070X_5^2. \]

\[ R^2 = 0.8185. \]

Where:

- \( Y \) = Income over feed cost (in $10 Unit on a herd month basis)
- \( X_1 \) = Cow days in milk (where one cow milking one day equals one cow day in milk)
- \( X_3 \) = Therms ENE from silage (in cwt. on a herd month basis)
- \( X_4 \) = Therms ENE from hay (in cwt. on a herd month basis)
- \( X_5 \) = Therms ENE from pasture (in cwt. on a herd month basis)

In order to maximize income over feed cost, it was determined, by using the first derivative of \( 1.3479X_3 - 0.0099X_3^2 \) in the above equation (VI), that if concentrates, hay, and pasture are fed at the average level in these data, 4.25 Therms ENE intake from silage (30.4 pounds silage) per cow per day would be needed. Linear and curvilinear effects for concentrates were not significant. Using the prediction equations for showing changes in income over feed cost with changes in ENE intake from different sources, it was determined that increasing ENE intake with silage from 0 to 10 Therms resulted in an increase of 12.48 cents per cow per day. Increasing ENE intake with pasture from 0 to 10 Therms resulted in an increase of 0.70 cents income over feed cost; whereas, increasing ENE intake with hay from 0 to 10 Therms resulted in a decrease of 13.75 cents.

Many dairymen in Louisiana are designing their feeding programs with the objective of increasing milk production without considering the effect of this feeding program on income over feed costs. The results
of this study indicate the need for more research to determine the level of estimated net energy from various sources of feeds used in Louisiana dairy feeding programs resulting in maximum income over feed cost.
VIII. BIBLIOGRAPHY


(57) Haecker, T. L. and Major, E. W. Investigations in Milk Production. Minnesota Agricultural Experiment Station Bul. 71. 1901.

(58) Haecker, T. L. Investigations in Milk Production. Minnesota Agricultural Experiment Station Bul. 79. 1903.


IX. APPENDIX
## APPENDIX TABLE 1a

**Louisiana DHIA Yearly Herd Summary - Testing Year, May 1, 1962 through April 30, 1963**

Grouped by Pounds of Milk Produced Per Cow - All Breeds

<table>
<thead>
<tr>
<th>Grouping</th>
<th>1000 lb Milk</th>
<th>Test %</th>
<th>Fat lb</th>
<th>Milk %</th>
<th>Days in Concentrates Fed</th>
<th>Succulent Forage Fed</th>
<th>Dry Forage Fed</th>
<th>Pasture</th>
<th>Value of Product $</th>
<th>Cost Feed $</th>
<th>Income Feed $</th>
<th>Feed Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td>35-44</td>
<td>4052</td>
<td>5.1</td>
<td>208</td>
<td>31</td>
<td>13</td>
<td>33</td>
<td></td>
<td>67</td>
<td>365</td>
<td>276</td>
<td>52</td>
<td>224</td>
</tr>
<tr>
<td>45-54</td>
<td>4973</td>
<td>4.0</td>
<td>199</td>
<td>79</td>
<td>28</td>
<td>50</td>
<td></td>
<td>13</td>
<td>10</td>
<td>41</td>
<td>90</td>
<td>118</td>
</tr>
<tr>
<td>55-64</td>
<td>6244</td>
<td>4.9</td>
<td>309</td>
<td>77</td>
<td>33</td>
<td>48</td>
<td>9</td>
<td>2</td>
<td>13</td>
<td>43</td>
<td>84</td>
<td>117</td>
</tr>
<tr>
<td>65-74</td>
<td>7139</td>
<td>4.6</td>
<td>329</td>
<td>83</td>
<td>28</td>
<td>44</td>
<td>17</td>
<td>4</td>
<td>13</td>
<td>43</td>
<td>82</td>
<td>142</td>
</tr>
<tr>
<td>75-84</td>
<td>7935</td>
<td>4.2</td>
<td>337</td>
<td>83</td>
<td>40</td>
<td>53</td>
<td>27</td>
<td>17</td>
<td>30</td>
<td>470</td>
<td>125</td>
<td>202</td>
</tr>
<tr>
<td>85-94</td>
<td>8868</td>
<td>3.6</td>
<td>321</td>
<td>84</td>
<td>46</td>
<td>55</td>
<td>26</td>
<td>6</td>
<td>16</td>
<td>30</td>
<td>142</td>
<td>192</td>
</tr>
<tr>
<td>95-104</td>
<td>9002</td>
<td>3.4</td>
<td>337</td>
<td>85</td>
<td>31</td>
<td>45</td>
<td>1</td>
<td>9</td>
<td>19</td>
<td>43</td>
<td>97</td>
<td>141</td>
</tr>
<tr>
<td>105-114</td>
<td>10975</td>
<td>3.7</td>
<td>411</td>
<td>86</td>
<td>51</td>
<td>54</td>
<td>123</td>
<td>20</td>
<td>25</td>
<td>13</td>
<td>189</td>
<td>295</td>
</tr>
<tr>
<td>115-124</td>
<td>12037</td>
<td>3.3</td>
<td>393</td>
<td>85</td>
<td>47</td>
<td>48</td>
<td>35</td>
<td>10</td>
<td>25</td>
<td>31</td>
<td>365</td>
<td>605</td>
</tr>
<tr>
<td>State Av.</td>
<td>7845</td>
<td>4.1</td>
<td>324</td>
<td>82</td>
<td>35</td>
<td>48</td>
<td>17</td>
<td>3</td>
<td>17</td>
<td>37</td>
<td>327</td>
<td>461</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grouping</th>
<th>1000 lb Milk</th>
<th>Test %</th>
<th>Fat lb</th>
<th>Milk %</th>
<th>Days in Concentrates Fed</th>
<th>Succulent Forage Fed</th>
<th>Dry Forage Fed</th>
<th>Pasture</th>
<th>Value of Product $</th>
<th>Cost Feed $</th>
<th>Income Feed $</th>
<th>Feed Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Av.</td>
<td>7845</td>
<td>4.1</td>
<td>324</td>
<td>82</td>
<td>35</td>
<td>48</td>
<td>17</td>
<td>3</td>
<td>17</td>
<td>37</td>
<td>327</td>
<td>461</td>
</tr>
</tbody>
</table>

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# APPENDIX TABLE 2a

## Hay, Silage, and Pasture Quality Codes for Louisiana Machine Processed Records

### I. HAY

<table>
<thead>
<tr>
<th>Kind</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legume Hay - 2/3 or more legume (such as Alfalfa, Clover, Soybean, Peanut)</td>
<td>1</td>
</tr>
<tr>
<td>Mixed Hay - 1/3 but less than 2/3 legumes</td>
<td>2</td>
</tr>
<tr>
<td>Grass Hay - Such as Oat, Bermuda, Johnson Grass</td>
<td>3</td>
</tr>
<tr>
<td>Corn Fodder including ears</td>
<td>4</td>
</tr>
<tr>
<td>Straw, etc. - Oat and wheat straw, cottonseed hulls, cobs and shucks.</td>
<td>5</td>
</tr>
</tbody>
</table>

#### Quality Codes

<table>
<thead>
<tr>
<th>Kind</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>40</td>
</tr>
<tr>
<td>Bermuda coastal or common</td>
<td>33</td>
</tr>
<tr>
<td>Cottonseed hulls.</td>
<td>28</td>
</tr>
<tr>
<td>Johnson Grass</td>
<td>37</td>
</tr>
<tr>
<td>Lespedeza</td>
<td>38</td>
</tr>
<tr>
<td>Millett</td>
<td>36</td>
</tr>
<tr>
<td>Mixed Hay 2/3 or more legumes</td>
<td>36</td>
</tr>
<tr>
<td>Mixed Hay less than 2/3 legumes</td>
<td>34</td>
</tr>
<tr>
<td>Oats</td>
<td>35</td>
</tr>
<tr>
<td>Soybean</td>
<td>33</td>
</tr>
</tbody>
</table>

---

*aBased on Morrison's ENE values adjusted to Louisiana conditions.

*bCodes given are for bright hay cut at proper stage and put up without rain damage or excessive bleaching. For quality less than good, see instructions. Codes indicate Therms of net energy per hundred pounds of hay.
## APPENDIX TABLE 2a (Cont'd)

### II. SILAGE

<table>
<thead>
<tr>
<th>Kind</th>
<th>Quality Code</th>
<th>% Dry Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn (45 bu. per acre and up)</td>
<td>53</td>
<td>28</td>
</tr>
<tr>
<td>Corn (less than 45 bu. per acre)</td>
<td>50</td>
<td>26</td>
</tr>
<tr>
<td>Corn and soybeans</td>
<td>52</td>
<td>26</td>
</tr>
<tr>
<td>Grass-legumes - wilted no preservative</td>
<td>45</td>
<td>31</td>
</tr>
<tr>
<td>Grass-legumes - not wilted no preservative</td>
<td>39</td>
<td>26</td>
</tr>
<tr>
<td>Grass-legumes - preservative (corn or Molasses)</td>
<td>44</td>
<td>28</td>
</tr>
<tr>
<td>Sorghum, sweet</td>
<td>47</td>
<td>25</td>
</tr>
<tr>
<td>Sorghum, tracy, sort</td>
<td>32</td>
<td>25</td>
</tr>
<tr>
<td>Oats - before milk stage no preservative</td>
<td>42</td>
<td>25</td>
</tr>
<tr>
<td>Oats - before milk stage preservative</td>
<td>47</td>
<td>28</td>
</tr>
<tr>
<td>Oats - after milk stage no preservative</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Oats - after milk stage preservative</td>
<td>34</td>
<td>30</td>
</tr>
<tr>
<td>Oats and legume (oats before milk stage)</td>
<td>48</td>
<td>26</td>
</tr>
</tbody>
</table>

### III. PASTURE

<table>
<thead>
<tr>
<th>Kind</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeded, permanent legumes - grass (New)</td>
<td>1</td>
</tr>
<tr>
<td>Improved permanent</td>
<td>2</td>
</tr>
<tr>
<td>Unimproved permanent</td>
<td>3</td>
</tr>
<tr>
<td>Supplementary - summer and winter (includes oats, rye, crimson clover, millet, Johnson grass, etc.)</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rating</th>
<th>Quality Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>1.1</td>
</tr>
<tr>
<td>Very good</td>
<td>0.8</td>
</tr>
<tr>
<td>Good</td>
<td>0.6</td>
</tr>
<tr>
<td>Fair</td>
<td>0.4</td>
</tr>
<tr>
<td>Poor</td>
<td>0.2</td>
</tr>
</tbody>
</table>

\(^{c}\)Values given are for bright good quality silage and indicate the Therms of net energy per hundred pounds of dry matter. For quality less than good, see instructions.

\(^{d}\)Codes given represent the estimated net energy consumed per hundredweight of body size.
IV. **GREEN CHOP**

<table>
<thead>
<tr>
<th>Kind</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green chop, zero pasture, soiling</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quality Code</th>
<th>% Dry Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>16</td>
</tr>
<tr>
<td>54</td>
<td>20</td>
</tr>
<tr>
<td>46</td>
<td>24</td>
</tr>
<tr>
<td>39</td>
<td>28</td>
</tr>
<tr>
<td>32</td>
<td>30</td>
</tr>
<tr>
<td>44</td>
<td>25</td>
</tr>
</tbody>
</table>

**INSTRUCTIONS FOR REPORTING QUALITY CODES**

Appropriate quality codes for pasture, hay, silage, or green chop are to be reported for those feeds being fed on test day.

The pounds fed reported for hay, silage, and green chop must be the amount consumed. Do not report the amount wasted. If cows are being fed 20 lb. hay per day, but are wasting one fourth, then report one fourth less as being fed on barn sheet (or 15 lb).

**Pounds fed** is very important. Your determination should be as accurate as possible - either by weights or very close estimates.

**HAY**

All quality codes given are for good hay, bright, put up without excessive damage or excessive bleaching. Appendix Table 3a shows how to rate hay excellent, good, fair or poor. To determine quality codes for hay less than good, use this scale:

- Fair hay - take 80% of good code
- Poor hay - take 60% of good code

Code value in between should be used if the true quality of the hay can be coded more accurately. For example, good quality alfalfa hay carries a code of 40, so fair alfalfa hay (at 80%) would be 32. If the hay being fed is a little better than fair hay, but not good quality, a code somewhere between 32 and 40 should be used.

If a dairyman is feeding two kinds of hay, determine per cent of each being fed and take corresponding per cent of quality code for each hay and add to get code. Example - feeding 30% good alfalfa hay (code 40) and 70% fair Johnson grass hay (code 30).
If a dairyman is crushing hay and feeding in milk barn - it is reported as hay, not reported with concentrates. If crushed hay is in the concentrate mixture, a more accurate record results if you will deduct the crushed hay from the pounds concentrate being fed and report the true concentrates for each cow and report the crushed hay as hay fed.

**PASTURE**

In coding pasture consider these things:

1. Are cows on grazing full time or only part time daily?
2. Denseness and height of grazing available. Can cows fill up in a hurry or is pasture short?
3. Palatability of plants.
4. Fertility level. Weedy and low fertility pastures should rate only fair during lush growing season and poor rest of season.
5. Stage of maturity of plants. As plants approach maturity, their value as feeds decreases. Most legumes or grasses reach their peak before heading or before blooming.
7. Appendix Tables 5a, 6a, and 7a show how to rate pastures excellent, good, fair, or poor.

**HANDLING PART TIME GRAZING**

1. Excellent and very good pasture.
   Give full quality code credit if grazing (time cow actually spends eating each day) is 2½ or more hours. For every half hour less than 2½ reduce quality code by 20%. **Example** - Cows grazing 1½ hours on very good pasture. Reduce the 0.8 quality code by 40% (or .32) and code 0.5.

2. Good and fair and poor pasture.
   Give full credit if grazing five hours or more. Reduce quality code by 20% for every hour less than five. **Example** - Cows grazing on good pasture three hours daily. Reduce the 0.6 quality code by 40% (or .24) and code 0.4.

**SILAGE**

Quality codes and percentage dry matter given are for bright good quality silages. For quality other than good, see instructions under hay for handling poorer quality. Appendix Table 4a shows how to rate silage excellent, good, fair, or poor.
GREEN CHOP

The stage of growth of the plant or plants and dry matter being fed is the important determination in reporting quality code. Pounds fed can be very misleading. Weigh a trailer or wagon load, if possible. In estimating weight 20 lb. per cubic foot seems to work well for good quality lush green chop. As plants mature the weight per cubic foot will be lower.

APPENDIX TABLE 3a

Quality Rating for Hay

<table>
<thead>
<tr>
<th>If hay is cut at:</th>
<th>If it has:</th>
<th>If the color and condition is:</th>
<th>Rate your hay:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial bloom or earlier</td>
<td>50% or more leaves</td>
<td>bright green</td>
<td>Excellent</td>
</tr>
<tr>
<td>1/4 bloom</td>
<td>30-49% leaves</td>
<td>medium green</td>
<td>Good</td>
</tr>
<tr>
<td>3/4 bloom</td>
<td>10-29% leaves</td>
<td>slightly brownish</td>
<td>Fair</td>
</tr>
<tr>
<td>Late bloom or seed</td>
<td>Less than 10%</td>
<td>brown or moldy</td>
<td>Poor</td>
</tr>
</tbody>
</table>

APPENDIX TABLE 4a

Quality Rating for Silage

<table>
<thead>
<tr>
<th>If the color is:</th>
<th>If odor is:</th>
<th>If moisture is:</th>
<th>Rate your silage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural or olive</td>
<td>clean and pleasant</td>
<td>65-70% (balls up when squeezed)</td>
<td>Excellent</td>
</tr>
<tr>
<td>Green to slightly yellowish</td>
<td>somewhat sour</td>
<td>70-74% (balls but soggy)</td>
<td>Good</td>
</tr>
<tr>
<td>Green to slightly brownish</td>
<td>medium burnt</td>
<td>60-65% (balls but dry)</td>
<td></td>
</tr>
<tr>
<td>Deep brown to black</td>
<td>moldy, musty or putrid</td>
<td>80% or more (juice runs freely)</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50% or less (dry)</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX TABLE 5a

Quality Ratings for Oat, Millet or Sudan Pasture (rows or broadcast)

<table>
<thead>
<tr>
<th>If the stand&lt;sup&gt;a&lt;/sup&gt; is: (Per cent)</th>
<th>If the growth length is: (Inches)</th>
<th>If the vigor is indicated by:</th>
<th>Rate your pasture:</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 and over</td>
<td>8-24</td>
<td>fast growth and greenness</td>
<td>Excellent</td>
</tr>
<tr>
<td>70-89</td>
<td>over 24</td>
<td>slow growth, moderate greenness</td>
<td>Good</td>
</tr>
<tr>
<td>50-69</td>
<td>heading out</td>
<td>slow growth, paleness</td>
<td>Fair</td>
</tr>
<tr>
<td>Below 50</td>
<td>headed out</td>
<td>paleness, lack of new growth</td>
<td>Poor</td>
</tr>
</tbody>
</table>

<sup>a</sup>In rows, a plant every 4-6 inches is a full stand; broadcast, 4 or 5 plants per square foot is a full stand.

APPENDIX TABLE 6a

Quality Ratings for Pure Grass Pasture (Dallis, Bahai, Bermuda and Small Grains)<sup>a</sup>

<table>
<thead>
<tr>
<th>If the stand is: (Per cent)</th>
<th>If the growth length is: (Inches)</th>
<th>If the vigor is indicated by:</th>
<th>Rate your pasture:</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 and over</td>
<td>2-6</td>
<td>fast growth and greenness</td>
<td>Excellent</td>
</tr>
<tr>
<td>70-89</td>
<td>1-2 or over 6</td>
<td>slow growth and moderate greenness</td>
<td>Good</td>
</tr>
<tr>
<td>50-69</td>
<td>0-1 grass headed</td>
<td>paleness</td>
<td>Fair</td>
</tr>
<tr>
<td>Below 50</td>
<td>0 no new growth</td>
<td>paleness</td>
<td>Poor</td>
</tr>
</tbody>
</table>

<sup>a</sup>Nitrogen fertilizer is critical on pure grasses. Color and growth rates are associated with time and rate of nitrogen applied.
### APPENDIX TABLE 7a

Quality Ratings for Legume-Grass Pasture Mixture

<table>
<thead>
<tr>
<th>If the stand is: (Per cent)</th>
<th>If the legume content is: (Per cent)</th>
<th>If the growth length is: (Inches)</th>
<th>If its vigor is indicated by:</th>
<th>Rate your pasture:</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 and over</td>
<td>40-60</td>
<td>3-8</td>
<td>fast growth</td>
<td>Excellent</td>
</tr>
<tr>
<td>70-89</td>
<td>20-39</td>
<td>2-3 or 8-10</td>
<td>slow growth</td>
<td>Good</td>
</tr>
<tr>
<td>50-69</td>
<td>5-19</td>
<td>below 2 or headed out</td>
<td>no new growth</td>
<td>Fair</td>
</tr>
<tr>
<td>Below 50</td>
<td>Below 5</td>
<td>mature</td>
<td>brownness</td>
<td>Poor</td>
</tr>
</tbody>
</table>

*Pastures in this category are clovers, vetch or Singletary peas with cereals, rye grass, Dallis, Bermuda or Bahai.*
APPENDIX TABLE 8a

**Morrison's Feeding Standards Used in Calculating Feed Needed by Each Individual Cow on the Electronic Data Processing Machine Records Program (EDPM)**

<table>
<thead>
<tr>
<th>Body Weight (lb)</th>
<th>Net Energy/Day (Therm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>4.6</td>
</tr>
<tr>
<td>800</td>
<td>5.2</td>
</tr>
<tr>
<td>900</td>
<td>5.8</td>
</tr>
<tr>
<td>1000</td>
<td>6.3</td>
</tr>
<tr>
<td>1100</td>
<td>6.9</td>
</tr>
<tr>
<td>1200</td>
<td>7.4</td>
</tr>
<tr>
<td>1300</td>
<td>8.0</td>
</tr>
<tr>
<td>1400</td>
<td>8.5</td>
</tr>
<tr>
<td>1500</td>
<td>9.0</td>
</tr>
</tbody>
</table>

II. Production Requirements

<table>
<thead>
<tr>
<th>% B.F.</th>
<th>Net Energy/lb Milk (Therm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>.28</td>
</tr>
<tr>
<td>3.5</td>
<td>.30</td>
</tr>
<tr>
<td>4.0</td>
<td>.32</td>
</tr>
<tr>
<td>4.5</td>
<td>.34</td>
</tr>
<tr>
<td>5.0</td>
<td>.36</td>
</tr>
<tr>
<td>5.5</td>
<td>.38</td>
</tr>
<tr>
<td>6.0</td>
<td>.40</td>
</tr>
<tr>
<td>6.5</td>
<td>.42</td>
</tr>
<tr>
<td>7.0</td>
<td>.44</td>
</tr>
</tbody>
</table>

*aFrom: Morrison, F. B. Feeds and Feeding. 22nd Ed. The Morrison Publ. Co. Ithaca, N. Y. 1956 as used prior to the formula developed by Jones (83).*
APPENDIX TABLE 9a

Daily Net Energy Requirements for Maintenance and Milk Production as Calculated for Individual Cows on the Electronic Data Processing Machine Records Program (EDPM)\(^a\)

<table>
<thead>
<tr>
<th>Body Weight (lb)</th>
<th>FCM/Cow/Day (lb)</th>
<th>Maintenance Requirement (Therms)(^b)</th>
<th>Production Requirement (Therms)(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;800</td>
<td>27.74</td>
<td>4.98</td>
<td>8.97</td>
</tr>
<tr>
<td>800-890</td>
<td>24.36</td>
<td>5.53</td>
<td>7.71</td>
</tr>
<tr>
<td>900-990</td>
<td>25.39</td>
<td>6.08</td>
<td>8.07</td>
</tr>
<tr>
<td>1000-1090</td>
<td>27.64</td>
<td>6.63</td>
<td>8.83</td>
</tr>
<tr>
<td>1100-1190</td>
<td>28.63</td>
<td>7.18</td>
<td>9.17</td>
</tr>
<tr>
<td>1200-1290</td>
<td>31.74</td>
<td>7.73</td>
<td>10.27</td>
</tr>
<tr>
<td>1300-1390</td>
<td>33.25</td>
<td>8.28</td>
<td>10.81</td>
</tr>
<tr>
<td>1400 and &gt;</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MEAN ((\bar{X}))=1050</td>
<td>27.53</td>
<td>6.63</td>
<td>8.71</td>
</tr>
</tbody>
</table>

\(^a\)Calculated by use of the following formula (I) developed by Jones (83):

\[
(I) \quad \frac{4.7 + 0.55 (X - 7)}{100} + \left( \frac{28 + 0.05 (Z - 3.0)}{200} \right) \quad = \quad \text{Daily requirements in Therms, where:}
\]

\(X = \text{Cow's Body Weight in Cwt.}\)
\(Y = \text{Daily milk production}\)
\(Z = \text{Butterfat test}\)

\(^b\)With \(\frac{4.7 + 0.55 (X - 7)}{100} = \text{Daily maintenance requirement}\)

\(^c\)and \(\frac{28 + 0.05 (Z - 3.0)}{200} = \text{Daily production requirement}\).
APPENDIX TABLE 10a

Derivation of Therms per Cow per Day for Maximum Milk Production

\[ (II) \hat{y} = -65.5749 + 0.1510X_1 + 1.3438X_2 + 1.0935X_3 + 0.3723X_4 + \\
1.0519X_5 - 0.0009X_2^2 - 0.0017X_3^2 - 0.0019X_5^2 \]

Using the first derivative of concentrate which is

\[ 1.3438X_2 - 0.0009X_2^2 = 0 \]

\[ X_2 = \frac{1.3438}{0.0018} = 744.44 \text{ cwt, Therms/ herd/month} \]

\[ 74444 \div 30^b = 2478 \text{ Therms/ herd/ day} \]

\[ 2478 \div 53.4^c = 46.40 \text{ Therms/ cow/ day} \]

\[ 46.40 \div 0.70^d = 66.30 \text{ lb concentrate/ cow/ day} \]

\[ ^aX_2 = \text{Therms ENE from concentrates (in cwt, on a herd month basis).} \]

\[ ^b30 = \text{Days per month.} \]

\[ ^c53.4 = \text{Average number of cows per herd.} \]

\[ ^d0.70 = \text{Therms ENE per lb concentrate.} \]
APPENDIX TABLE 11a

Derivation of Therms per Cow per Day
For Maximum Income Over Feed Cost

(VI) $\hat{Y} = -74.3608 + 0.9685X_1 + 1.3479X_3 - 1.1333X_4 - 0.0099X_3^2 - 0.0041X_4^2 + 0.0070X_5^2$

Using the first derivative of silage which is

$1.3479X_3 - 0.0099X_3^2$:

$1.3479 - 0.0198X_3 = 0$

$X_3 = \frac{1.3479}{0.0198} = 68.10 \text{ cwt. Therms/herd/month}$

$6810 \div 30^b = 227 \text{ Therms/herd/day}$

$227 \div 53.4^c = 4.25 \text{ Therms/cow/day}$

$4.25 \div 0.14^d = 30.40 \text{ lb silage/cow/day}$

$^aX_3 = \text{Therms ENE from silage (in cwt, on a herd month basis).}$

$^b30 = \text{Days per month.}$

$^c53.4 = \text{Average number cows per herd.}$

$^d0.14 = \text{Therms ENE per lb silage.}$
The author was born on a farm on Bayou Blue, Lafourche Parish, Louisiana on February 25, 1916. In 1928 the Matherne family bought and began operating a dairy farm near the town of Houma, Louisiana. Due to limited available land in and adjoining this farm, a larger farm was bought near the town of Bourg, Terrebonne Parish, Louisiana. The dairy operation was moved to this farm in 1929. Elementary and high school education was obtained at the Bayou Blue and Bourg Elementary Schools and Terrebonne High School. He graduated from Terrebonne High School in 1932.

In September, 1932 he entered Berry College, Mt. Berry, Georgia and graduated in 1937 with a degree of Bachelor of Science in Agriculture. He served as a student dairy employee during his undergraduate work at Berry College. Due to illness in the family in the fall of 1935 and spring of 1936, he had to leave school and assist with operation of the dairy at home.

After teaching two years at McDonnel School, Houma, Louisiana, he enrolled in Louisiana State University in 1939 and obtained a B.S. degree in Vocational Agriculture Education in 1941. Immediately after graduation in 1941, the author entered the Army of the United States as a private and was discharged in 1946 with the rank of Captain after service in the European and South Pacific Theatres.
After separation from the Army, the author taught one semester as Vocational Agriculture Teacher at Raceland High School, Lafourche Parish, Louisiana. He was then employed by the Louisiana Agricultural Extension Service and appointed Assistant County Agent in Washington Parish, in September 1946. He was promoted to County Agent in September, 1947. In 1955 he completed requirements and obtained a M.S. degree at Louisiana State University with a major in Agricultural Extension Education and a minor in Dairying.

In October, 1956, the author was made Associate Extension Dairyman with headquarters at Louisiana State University. He was promoted to Specialist (Dairying) in 1961 in which capacity he now serves.
Candidate: Nolan Joseph Matherne

Major Field: Dairy Nutrition

Estimated Title of Thesis: A Study of Net Energy Intake for Maintenance and Milk Production of Louisiana Dairy Cows by Use of Electronic Data Records.

Approved:

[Signature]
Major Professor and Chairman

[Signature]
Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

February 23, 1965