PROBLEMS OF FEED EVALUATION RELATED TO FEEDING OF DAIRY COWS

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INTRODUCTION TO THE PROBLEM

It is intended that this paper concern some of the practical problems involved in the feeding of the modern, individual cow, and which demand the attention of the researcher, extension worker, and dairyman. Thus, this report will deal with a series of problems which begins with the nutritive evaluation of the ration and leads to the manger of the individual cow.

Aside from the continuing interest of the researcher and extension worker in feed evaluation generally, there has developed during the last 6 yr. a novel interest in the nutritive evaluation of forages by rapid and inexpensive, but indirect, means, with the hope ultimately that the amount and kinds of concentrates needed by the individual cow might be computed and the information relayed to the dairyman as a practical feeding recommendation. The use of indirect methods of nutritive evaluation has become known generally as forage testing. Recent, more general, use of high-speed computing devices in various centers has made this over-all scheme, including the rationing of concentrates, appear to be more feasible than it was previously.

Preliminary to considering parts of the over-all problem, it is essential to review the kinds of information needed to feed the individual cow. These consist of: (a) The amounts of nutrients needed (as set forth in quantitative guides to feeding), and (b) the quantities of nutrients provided by the feeds and rations ingested. The latter is the product of the nutritive value [e.g., total digestible nutrients (TDN)] per unit weight of feed and the amount of feed ingested. From the standpoint of feeding the individual cow, either the feeding standard or the index of nutritive value, without the other, is useless. Naturally, a shortcoming in one reduces the effectiveness of the other.

As a third consideration, certain economic conditions need to be superimposed in feeding practice upon the considerations 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. A wide range of intakes and of nutritive values of feeds both exists in practice and is physiologically feasible. The degree to which the amount of nutrients that the cow is capable of utilizing is satisfied by the nutritive value of the ration 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 one, which currently and under local conditions, though not necessarily reducing costs, will result in maximum profits.

PROBLEMS ASSOCIATED WITH FEEDING STANDARDS

Since it is presupposed that the information obtained as a result of a forage-testing program can be used in combination with the feeding guide to ration the individual cow, a brief review of some of the bases and limitations of existing feeding standards will be made here.

Basis of feeding-standard energy allowances. The energy allowances set forth in present-day feeding standards are based chiefly on the data of Haecker (16-19). For the most part, these data were obtained with low-producing cows. For example, in 224 cow-periods comprising the Haecker experiments, the average yield of 4% FCM was only 24.4 lb. per cow per day; only 17% of the cows produced more than 30 lb.; and only one cow produced over 40 lb. of 4% FCM per day (actually, 42.6 lb.). The average intake of TDN was approximately 1.9 times the amount needed for maintenance. At these levels of milk yield, and conversely of feed intake, the TDN requirement was estimated to be 0.316 lb. per pound of 4% FCM. On the other hand, the results of certain studies (21) of feed input—milk output indicate that cows producing about 11,000 lb. of 4% FCM per year require above the mainte-
ance allowance approximately 0.5 lb. of TDN on the average per pound of FCM produced. Although a part of this energy appears to have been used for the gain of body tissue, the size of the apparent requirement suggests that, at the level of feed intake needed to produce 11,000 lb. of 4% FCM per annum, a given quantity of TDN must have a milk-producing value per unit of weight of about 66%, of that which it would have when the same source of TDN is fed at a level slightly above that of maintenance.

Effect of level of intake on the TDN value of the ration. The TDN values recorded in tables of nutritive values and which, therefore, are used in rationing have been determined usually at levels of intake only slightly above that needed for maintenance. Though the extent of the effect of level of intake upon the digestibility of the ration is variable and is influenced by the composition of the ration, the TDN value of mixed rations comprised of concentrates and forages declines at an ever-increasing rate as the amount of ration ingested per unit of time is increased (1, 31). A hypothetical example of the plane-of-nutrition effect upon the TDN value of a given practical ration is shown in Figure 1. In working out this example, it was assumed that the TDN value of this particular hay-concentrate ration is 65%, when the level of intake is equivalent to that of maintenance, and that the composition of the ration is the same at all levels of intake of milk output. The bases of the example in Figure 1 are the original data reported, and those of others which were reviewed, in the papers of Andersen et al. (1) and Reid (31), as well as the indirect evidence represented by unpublished data on the energy requirements of high-producing cows obtained by the author and his associates between 1955 and the present time. For outputs of 0 to 65 lb. of 4% FCM per day, or their corresponding feed inputs (represented by the solid segment of the line in Figure 1), the evidence for the effect of level of intake on the TDN value has a reasonable scientific basis. On the other hand, the effect upon the nutritive value of the ration of levels of intake needed to produce 65 to 100 lb. of 4% FCM (indicated by the broken portion of the line in Figure 1) can be documented at the present time only by very scanty data indeed.

The example employed here should not be construed to represent the relationship between the TDN value and the level of intake of all rations. It is possible that the nutritive value of some rations suffers the plane-of-nutrition effect more or less than others. For example, in the studies of Larsen and Eskedal (24), involving cows which produced 20,000 to 26,397 lb. of 4% FCM per annum, there is an indication that the level of intake had less effect upon the nutritive value of the rations fed than that which has been observed with commonly used forage-concentrate rations in America. However, an uncompromised interpretation of the Danish data is not possible, for they are complicated by the fact that the cows were allowed pastureage, the intake of which was not measured. The rations employed in the Danish work were different from the common rations used in America, chiefly in that they contained: more oil-meal feeds (a total of five) constituting a large proportion (47%) of the concentrate mixture; a high level (24%) of coconut cake in the concentrate mixture; roots constituting 18% of the total feed units (i.e., available energy) provided; and a considerably smaller quantity of cereal grains than is usually fed in the United States.

Milk-producing capacity of average cow is increasing. Mainly because of improved management, but partly because of the more general use of artificial insemination employing the semen of bulls more reliably proven to transmit high production, and because of more rigid culling of low-producing cows, the average yield per cow in the United States is increasing at a greater rate than ever before. As a consequence, the number of cows producing 15,000 lb. or more of milk per year is greater now than ever before, and almost all herds have at least a few cows which produce more than 60 lb. per day for at least a few months. For example, in New York State in 1953, 30 herds had an average annual yield per cow of 500 lb. or more of fat; in 1960, 235 herds produced at this, or a higher, level. Therefore, other problems concerned with providing sufficient energy to the high-producing cow are becoming increasingly acute and demand reappraisal of the adequacy of existing feeding standards.

Many cows would respond to greater energy inputs. Undoubtedly, many cows producing at low levels currently would yield much more milk if they were provided with more energy. This was borne out in a field study involving 442 cows in 48 herds, in which Charron (8) induced farmers to feed one-half of the cows in the test approximately 20% more of TDN than the farmers had been accustomed to feed.
ing. An increase in the annual yield of milk of 2,000 lb. or more was effected in 57% of the cows, with an increase of 4,000 lb. or more in 10% of the cows, and an average increase of 2,030 lb. was secured for all cows in the test. Another example of the increased yields resulting from greater energy inputs is represented by the demonstration conducted by Larsen and Eskedal (24) with six cows. Some of the data obtained in this demonstration are recorded in Table 1. Although a part of the increase in the response of the cows in the third year over that of the first or second year is the result of improved milking methods and health measures, as well as the normal matur- ing of the cows, the major part of the response is undoubtedly the result of the greatly increased input of energy. Even though these examples support the contention that greater inputs of energy would result in greater outputs of milk by high cows, it is necessary in practice to impose economic considerations on this biological fact.

Relation of body tissue gain and utilization to dietary energy allowances. 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 caters a considerable part of the energy needed to support subsequent lactation. As a consequence, 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 quantity of milk for extended periods of time. For example, a cow which has gained 100 lb. of body fat prior to calving could produce as much as 880 lb. of milk from the catabolism of body fat alone, when fed only enough feed to satisfy her maintenance requirements during the ensuing lactation period. Thus, 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 effec-

| TABLE 1 |

Effect on milk yield of high inputs of feed and excellent general management.

<table>
<thead>
<tr>
<th>Consecutive year of demonstration</th>
<th>4% FCM yield (lb/yr)</th>
<th>Management conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9,325</td>
<td>Usual farm b</td>
</tr>
<tr>
<td>2</td>
<td>9,594</td>
<td>Usual farm b</td>
</tr>
<tr>
<td>3</td>
<td>22,042</td>
<td>Improved *</td>
</tr>
</tbody>
</table>

*Data of Larsen and Eskedal (24) obtained in demonstration with same six cows during three consecutive years; average age of cows at beginning of lactation in first year was about 4.5 yr.

A tentative energy standard for milk production. In view of the apparent limitations of present-day energy standards for milk production cited above, and the apparently more acute needs of the modern cow, an attempt has been made in Figure 2 to set forth a tentative feeding standard for milk production by cows which are neither gaining nor losing energy from the body. This standard is predicted on the basis that the true TDN value of rations made up of increasingly greater proportions of concentrates declines as the level of intake increases, and the maintenance requirement of the 1,000-lb. cow is 7.0 lb. TDN per day (14, 32, 40, 41) and varies for cows of other sizes according to body weight. 

The graduated allowances represented by Figure 2 are a hybrid of the theoretical principles governing the utilization of energy by the cow (31, 32) and the TDN requirements...
pregnancy and lactation in Holstein cows. During the dry period, the level of feeding was pared were obtained in long-time feeding trials and at weekly intervals during other times. The data from which the diagram was prepared were obtained in long-time feeding trials at Cornell, in which body weight measurements were made just before and after parturition and at weekly intervals during other times. During the dry period, the level of feeding was determined by Haecker (16-19) with low-producing cows and those of the author and his coworkers estimated from data obtained with medium- to high-producing cows. The basis of the requirement for cows yielding up to 65 lb. of 4% FCM per day (as indicated by the solid line in Figure 2) is more than that of the requirement for cows producing above this level (represented by the broken line). It is emphasized that the proposed standard is tentative, subject to change with further study, and intended to serve as a guide only until more adequate data become available.

Influence of body tissue gain and utilization on the dietary requirement for energy. Although Figure 2 is intended to represent the TDN needs of lactation by cows in energy equilibrium, lactation and its incidental processes are dynamic in nature and, therefore, influence the dietary requirement for TDN with respect to time during the lactation period and the distribution of TDN inputs during certain periods of time. Figure 3 illustrates some of the processes incidental to lactation and particularly the degree to which body tissue can be gained and lost at various stages of the lactation cycle.

The data from which the diagram was prepared were obtained in long-time feeding trials at Cornell, in which body weight measurements were made just before and after parturition and at weekly intervals during other times. During the dry period, the level of feeding was sufficient to effect a state of body condition that satisfied a subjective visual standard. During the first seven- to ten-day period after calving, 10 lb. of concentrates and 36 to 40 lb. of corn silage were fed per day and hay was provided ad libitum. When the cows were on pasture, similar quantities of concentrates were provided, but without hay or silage. Thereafter, the level of concentrates was increased gradually to meet the feeding-standard energy allowance. As a consequence, the feed input followed, rather than led, the milk output.

These data show that the loss of body weight (presumably body tissue) after calving usually reaches a maximum within 30 to 75 days post-partum. For most cows the minimum weight was recorded within 60 days post-partum. Naturally, the extent of body-tissue losses depends greatly upon the amount of feed ingested during early lactation and the amount of milk produced, as well as the amount of tissue available. It was observed that most cows fed according to the plan outlined above lost from 100 to 200 lb., with an average loss of about 150 lb. However, some of the cows lost as much as 400 lb. Body-tissue losses of similar magnitude are suspected to occur in practice. It is axiomatic that the amount of body tissue lost during early lactation determines the amount that must be gained during later lactation and the dry period. Since the use of dietary energy to gain body tissue and its subsequent conversion to milk is much less efficient energetically than the direct conversion of feed energy to milk (31), the amount of body tissue anabolized and subsequently catabolized should be kept at a minimum.

Other practical implications of the events diagrammed in Figure 3 are that: (a) Body tissue as a source of energy for milk production should be depended upon to a minimum degree, (b) the necessary gain of body tissue should occur chiefly during the dry period, when the feed intake is lower and, therefore, when the efficiency of feed utilization is greater than it is during lactation, and (c) greater attention needs to be given to the distribution of the energy inputs during the lactation cycle.

The alternate gaining and losing of body tissue exert significant influences on the utilization of dietary energy by, and, therefore, on the practical rationing of, the individual cow. Some of these effects are: (a) The use of dietary energy for body gain contributes to reduced outputs of milk per unit of feed input. (b) The energy resulting from the catabolism of body tissue supplements the energy of the diet for high-producing, and underfed, cows. Thus, some degree of body-tissue utilization is an absolute essential if the maximum yield is to be realized by those cows whose milk-producing potential exceeds the limits allowed by their appetite or stomach capacity, and the nutritive quality of the ration provided. (c) As a consequence, the anabolic-catabolic processes have a
marked effect upon the amount of dietary energy needed for lactation.

An attempt has been made in Figure 4 to diagram the approximate influence of the utilization of various quantities of body tissue during the first 75 days of lactation, upon the dietary energy requirements for the production of various quantities of milk during the same period. The bases of these data are the requirements shown in Figure 2, upon which were superimposed the calorie gains of mature Holstein steers (39) gaining body tissue at the rates required by cows during 290 days, in order to have available for catabolism during the first 75 days post-partum 0 to 400 lb. of body tissue. Although Figure 4 represents a feeding standard for milk production during the first 75 days of lactation, the level of production combined with the amount of feed ingested determines the extent of tissue utilization. But, in practice the amount of tissue available for use and the amount being used at a given time are difficult to determine. It is essential that further studies of the energy requirements for milk production by the cow take into account the incidental energy transactions of the cow’s body.

High milk yield per cow is an economic necessity. The data which constitute the basis of Figures 3 and 4 indicate that in practice it is important to provide the amount of feed the cow needs concurrently to produce the quantity of milk of which she is capable. Naturally, the superimposition of certain economic conditions will modify the degree to which the dietary needs should be fulfilled in practice. However, it is important to recognize that the mere cost of feed is by no means the only form, or necessarily the larger proportion, of monetary outlay. For example, the efficiency with which a cow producing 80 lb. of milk per day utilizes the energy ingested above the maintenance level is considerably less (therefore, she requires more feed per pound of milk produced) than that of two barn-mates, each of which is producing 40 lb. per day, or a total of 80 lb. In other words, the feed cost above maintenance for the same total milk yield favors the two lower producers rather than the one high producer. On the other hand, the body maintenance cost, the space and equipment investments, and the labor requirements are considerably lower per unit of milk produced by the high-producing cow than they are for her two lower-producing barn-mates. Thus, 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.

Maldistribution of energy inputs during the lactation cycle. Another point of significance to the feeding of the individual cow suggested by Figures 3 and 4 is the consequence of the maldistribution of energy during the lactation cycle. There is evidence that the minimum feeding standards are not being used generally or effectively in practice. Although many cows do not get enough feed at any time, some cows receive enough total feed per annum, but the feed is distributed ineffectively relative to time and need. A defect commonly encountered by extension workers is that in which too little feed is provided early in lactation and too much late in lactation. This feeding defect is demonstrated by the diagrams in Figures 5 and 6, based upon data obtained for two DHIA herds in New York State and studied by Warner (46).
In Figure 5, it will be noted that the milk yields of the two herds were the same in the first month of lactation, but that Herd 1 was more persistent and produced more milk in all subsequent months than did Herd 2. At least a partial explanation for the difference in responses of the two herds is provided in Figure 6.

The amount of concentrates fed to Herd 1 during early lactation provided enough energy to exceed the recommendations of present-day energy standards. On the same basis, Herd 2 was greatly underfed during early lactation, and overfed during the 4th, 5th, and 6th months of lactation. Despite the fact that the cows in Herd 2 received a considerably larger total amount of concentrates during the 6-mo. period than was recommended, the milk yield declined to a low level quite rapidly, with the resulting low total yield. The superior yield and the persistency of output of Herd 1 would appear to be the result partly of the higher energy input and partly of the more satisfactory distribution of the energy input.

It is important that cows be provided enough energy to produce as much milk as possible as soon after calving as possible. This is more because of the total lactation-period response than because of the response during the first few months’ lactation. The well-documented finding (13, 23, 27, 28, 36, 37, 38, 43, 44), that the milk yield during monthly segments of the lactation period (even very early in lactation) reflects the total lactation-period yield, suggests this conclusion. Furthermore, the response in milk yield to energy inputs during the dry period and early lactation has been found to be cumulative over the lactation period (5-7, 12). The size of the milk-production response to energy input during the dry period appears to be influenced by the condition of the cow upon entering the dry period and the level of intake provided after calving. Milk output, at least during early lactation, has been correlated with the input of energy during the dry period (5, 7, 12, 25). Continued feeding of high levels of energy after calving has extended the increased output of milk over the entire lactation period (5-7). The response to increased intakes during the dry period either has not occurred at all in some studies (15, 30, 35) or has diminished as lactation proceeded in others (12, 25), when the control, and high-level, cows were fed at the same rate after calving. Although the relationship of early-lactation yield to total lactation-period yield, and the cumulative effect on production of prior nutritional treatment are well established, their physiological bases have not been unraveled.

Summary of feeding-standard limitations and common defects in practical feeding. In summarization of the previous discussion, it is concluded that some of the major problems concerned with the practical feeding of the individual cow are associated with the inadequacies either of the present-day feeding guides or of their application. These are: (a) Existing feeding standards become progressively less adequate as the milk output increases per unit of time. (b) The feeding standards do not take into account the storage and use of body tissue with relation to the production of milk; as a consequence, too much reliance is put upon body tissue catabolism to provide the energy lacking in the diet. (c) The lack of acceptance, or the ineffective use, of even the minimum energy recommendations set forth in the feeding standards frequently results in the provision of too little feed and in the maldistribution of feed input during the lactation period. (d) The usual application of the feeding standards allows past milk yield to dictate future feed inputs, with the consequent accentuation of the maldistribution of feed input.

Problems concerning the nutritive evaluation and value of feeds and rations

Requirements of a forage-evaluation method to be used as a tool in rationing the individual cow. Next, some of the problems associated with feed evaluation and values will be considered in relation to the defects in present-day feeding practices discussed earlier in this report. At the onset, and in view of (a) the inadequacies of the present feeding guides, (b) the ineffective distribution of the feed inputs, and (c) the uncertainties of body-tissue usage, the question is asked: “Can feed (or forage) evaluation schemes short of direct measurements be expected to provide information which will lead to definite improvements in the milk yield per cow and in the economies of milk production?” To develop an answer to this question, it is necessary to consider the nature of the information being obtained in present-day feed-evaluation programs.

From the standpoint of feeding the individual cow, the problems of feed evaluation are chiefly those concerned with forage evaluation. This is because the commonly used mixed concentrates have a relatively constant nutritive value per unit of weight and the quantities of concentrates fed to the dairy cow are usually measured. (Nevertheless, the relation to the nutritive value of rations of various proportions of concentrates and forages, and the effect of the level of intake on the nutritive value per pound of such mixtures, need much further study.) As a consequence, the ultimate purpose hoped to be served by a forage-evaluation program is that of determining the amount of concentrates needed in the ration with a particular forage(s) to satisfy the needs of the individual cow, as indicated by the feeding standard. Reasonably accurate rationing of concentrates is possible only when both (a) the nutritive value (e.g., TDN) per unit of weight of forages and (b) the amount of forages ingested are known.
But, even with complete information on the nutrient concentration and intake of forages, the accuracy with which concentrates can be rationed is limited to the degree of adequacy of the feeding guide followed.

**Kinds of information provided by existing forage-evaluation schemes.** The forage-evaluation schemes in vogue currently provide for the prediction of the nutritive value from the concentration of certain chemical substances (2, 3, 20, 22, 29), certain criteria of in vitro fermentation by ruminal bacteria (4, 9-11, 20, 26, 34, 42), and the date when forage is harvested (33). (Only a few recent references are cited here; the reader can obtain a more extensive bibliography in these papers.) In general, the forage-testing procedures provide an estimate of the TDN value (or a related criterion) per unit weight of forage. Since the prediction equations employed in these methods were derived using the conventional digestion trial as the standard, the TDN values so estimated are representative of those which exist at about the maintenance level of intake when forage constitutes the entire ration. (Some forage-evaluation programs provide an estimate of the digestible protein value. But, since protein, as compared with energy, is relatively unimportant from both the qualitative-nutritional and economic viewpoints, provided that a certain minimum requirement is satisfied, no attention will be given to this nutrient here.) None of the forage-evaluation methods, except the Macdonald College method (9-11, 26), provides for an estimate of intake or of over-all nutritive value, and this procedure has not been examined with cattle.

**Range in TDN value and intake of forages in practice.** In practice, the TDN value of perennial forages ranges from 50 to 68% on the dry basis and the dry matter intake ranges from 1 to 3.5 lb. per 100 lb. of body weight per day. A change from the lowest to highest quality of forage used on dairy farms would result in an improvement of 36% in TDN value and of 250% in the dry matter intake. These two criteria of forage quality are to a considerable degree positively correlated, particularly for first-growth forages. Thus, as forage quality is improved, the dry matter intake increases on the average at a rate approximately seven times as great as that of the TDN value per pound. From this, it is rationalized that the increase in total energy intake from one quality of forage to another is approximately 90% attributable to the increased intake and 10% attributable to the improvement in TDN concentration. On the same basis, it is expected that a method which would provide an estimate of intake with a precision equal to the estimation of the TDN value by forage-evaluation methods would result in a great error in the prediction of the intake of forage energy.

Some practical information not provided by present forage-testing schemes. The following practical conditions are not accounted for by forage-testing schemes in their present form and, therefore, from the standpoint of feeding the individual cow, they correspondingly limit the value of the information obtained:

(a) Amount of forage eaten.
(b) Effect of the amount of concentrates fed on the amount of forage eaten.
(c) Degree of selective feeding (i.e., proportion of leaves and stems ingested). The extent of this act has an appreciable effect upon the energy concentration of the forage ingested. For example, a refusal of stems, and their replacement with leaves, equivalent to 10% of the dry matter offered, could increase the TDN concentration by as much as 5 to 12%.
(d) Effect of physical form (viz., long, chopped, finely ground, dry and wet) on milk-producing value of ration. At the present time, physical form does not represent a serious practical problem, because most forage is fed to dairy cattle in long or chopped form. Increased use of finely ground forage may make physical form more important in the future, because particle size influences the intake, digestibility, and the end products of digestion which are absorbed.
(e) Milk-production efficiency of the absorbed mixture of digested end products of varying chemical nature.
(f) Degree of wastage of absorbed matter (or conversely, efficiency with which absorbed matter is utilized).
(g) Effect of the level of intake on the nutritive value of the ration. However, the importance of this limitation is diminished to the degree that the feeding guide employed accounts for the plane-of-nutrition effect.
(h) Frequency of feeding. Although frequency of feeding has a significant effect on the response of growing cattle, it does not affect the yield of milking cows, except when it results in an increased intake of feed.

Relation of information obtained by forage-testing to the rationing of the individual cow. Since certain intangible benefits such as the possible awakening or renewal of farmer interest in forage quality might be attributable to forage testing, it is difficult to evaluate the fruits of such testing in quantitative terms. On the other hand, the ultimate aim of forage-testing programs is the rationing of concentrates to the individual cow. As a consequence, a quantitative perspective of the contribution of forage testing to the total effectiveness with which concentrates can be rationed will be
clarified in the following statements. Let us assume that the rationing of concentrates to the individual cow is 100% effective, when accurate information on the energy intake in forage and the most adequate recommendations of energy feeding standards each represents 50% of the possible total effectiveness. As rationalized earlier, increments in the total energy intake in forage as quality is changed are attributable to the dry matter intake and TDN concentration to the degree of about 90 and 10%, respectively. On this basis, knowledge of a perfectly precise TDN value for the forage would contribute only 5% of the total effectiveness with which concentrates can be rationed. (As will be pointed out later, even if this contribution were 25%, the final conclusion would be the same.) There is no doubt that forage testing represents somewhat of a refinement over the use of existing tables of TDN values of forages, or the use of a median TDN value (e.g., 50% on dry basis). For example, assuming the median TDN value of 59% to represent the range of TDN values (viz., 50 to 68%) found in practice could result in a maximum overestimation by 18% and a maximum underestimation by 15%. These figures represent the degree of potential refinement that might be effected in the estimation of the TDN value by forage testing. However, even if it is assumed that a perfect estimate of the TDN concentration is provided by forage testing, rationing concentrates on the basis of forage testing is less than 1% more effective over-all than computing the amount of concentrates on the basis that the forage contains 59% TDN. Stated in other words, this means that concentrates can be rationed to the individual cow 99% as effectively without forage testing as with it. Should there be as much as a five-fold error in this rationale, the conclusion would be very little different; concentrates could be rationed 95% as effectively without, as with, forage testing. Therefore, even if a forage-testing scheme provided a perfectly accurate estimate of the TDN value per pound, it would contribute very little information having intrinsic value to the rationing of the individual cow, entirely because, in their present form, the forage-testing methods do not appraise the intake.

There is reason to believe that refinements in estimating the intake of forage, the use in practice of more adequate and precise feeding guides, and a more effective distribution of feed during the lactation cycle would improve the effectiveness with which concentrates are rationed by as much as 40 to 50%.

Thus, it is concluded that no forage-testing program can be considered to be adequate, or even very helpful, unless both the intake and the nutritive value per unit of weight can be predicted with sufficient accuracy to ration the individual cow under practical conditions. (None of the forage-testing schemes in their present form or mode of application provides estimates of both criteria of nutritive value.) But, even if a satisfactory procedure existed, the successful execution of such a program extended ultimately to rationing the individual cow requires, in addition to information on the total energy ingested as forage, the application of a feeding standard that (a) both anticipates and satisfies the needs of current production, as well as (b) provides for the effective distribution of the feed input during the dry period and the lactation period.

The main thesis of this report is that, in order to ration concentrates to the individual cow (the ultimate aim of forage-testing programs), information on both the intake and nutritive value per unit weight of forage is needed, as well as an adequate feeding standard. Shortcomings in any of these naturally limit the accuracy with which concentrates can be rationed.

There are several serious weaknesses in present-day feeding practices associated with the inadequacies and ineffective applications of existing feeding standards. It is submitted that, if these were remedied, infinitely more would be done to improve the milk output per cow and the economics of production than can be accomplished by forage-testing schemes, particularly in their present form. Fruition of this statement requires that acceptance of certain improved practices by dairymen be gained and maintained.

Gaining farmer acceptance and maintaining farmer usage of worthwhile practices. Almost all of the improvement in milk production and monetary income attributed to forage testing by the popular press (45, 47) is really the result of feeding more concentrates and distributing the input of feed more effectively. Naturally, both of these can be done without forage testing. Nevertheless, attributing the benefits obtained to forage testing is misleading and represents an ungerenuine demonstration. This is an example of an extension-teaching method in which the tools of dramatics, rather than the subject matter being dramatized, are emphasized. It would seem that if farmer acceptance of any worthwhile program is to be gained and maintained, the extension worker must teach the farmer principles, rather than lead him to some stop-gap end with transient thumb rules, gimmicks, and temporary crutches. Principles have the peculiar qualities of stable longevity and general application, which are not shared by other foundations of teachings.

Some of the forage-testing schemes which are not based upon, or do not teach, a principle can be categorized as gimmicks. It is sometimes stated that forage testing makes the dairymen conscious of forage quality; this is an advantage, if true. But, the important question is: “For what practical purpose can the dairymen use the information gained by forage testing?” Because he is being made in-
creasingly aware of forage quality, sooner or later he will learn that the answer to this question is: "Essentially no purpose."

**A SIMPLE FEEDING PLAN**

As the dairyman is taught principles more and more, and becomes more conversant with them, he will learn why certain principles are true and what monetary value their application has. He will learn, for example, that a high milk yield per cow is an economic necessity, that the nutritive value of early-cut forage is higher than that of late-cut forage, and that the feeding-standard energy allowance is just a minimum guide line to which he can add under certain situations to exact a more profitable yield from certain cows. Dairymen can be taught certain principles which will provide them with the means to improve upon the minimum guide lines set forth in general rules of thumb. It seems far less important that the dairyman applies the rule book to the last pound than he applies principles which guide his business towards general improvement and greater profit.

For example, the dairyman who is aware of feeding principles can do a more effective job by following an informal plan, such as that outlined below, than he can by using existing feeding standards and tables of average feed values in cook-book fashion. This plan is not new, but it represents a synthesis of feeding principles. It is proposed here mainly because of the shortcomings of existing feeding standards and particularly in view of the lack of, or ineffective, use of the feeding standards in practice. This plan consists of: (a) The ad libitum feeding of the best quality forages available. (b) Flexible energy allowances during the last two months of the dry period which, in some instances and depending on the condition of the cow, would be provided by a ration ranging from all forage to forage plus 8 to 10 lb. of concentrates during the first 4 to 6 wk., and a gradually increasing level of concentrates thereafter, reaching a level of 15 to 18 lb. by the time of calving. This scheme would appear to have two benefits: the storage of body tissue and, perhaps more important, acustoming the cow to consume large quantities of feed. (c) After calving, increasing the level of concentrates as rapidly as possible to either maximum appetite or maximum milk yield, whichever is attained first. The cow should decide her level of intake at this time; the dairyman must learn by trial the rate at which the individual cow’s intake can be increased. (d) Thereafter, the level of concentrates should be reduced to the lowest level which does not reduce the milk yield. In this way feed intake tends to lead the milk output, rather than the reverse. A change in the amount of feed ingested is usually reflected in the milk yield within 30 hr. Thus, with close attention, prolonged periods of underfeeding or overfeeding can be avoided.

This plan for feeding the individual cow is simple and practical to execute, does not require the use of feeding standards and tables of feed values (therefore, it obviates the need for forage testing, and an estimate of forage intake), and provides for an effective distribution of feed during the lactation cycle. One of its major features is that of preparing the cow for a large feed intake very soon after calving. In this way, advantage can be taken of a high yield early in lactation, with the consequent cumulative effects upon the milk yield during the entire lactation period (5-7, 12) to exact a large total-lactation yield. It has been demonstrated that heavy feeding during the dry period is without effect upon the severity of udder edema, or on the incidence of milk fever or ketosis (15, 30, 35).

The plan suggested has the further advantages that the provision of feed leads, rather than follows, the output of milk, and it avoids lags in feed input relative to milk output which exist in the usual application of the feeding standard and in programs involving the series of events of forage testing, the central computation of data concerned with production and feed allowances, and the relaying of concentrate-feeding recommendations to the dairyman. Doubtless, the latter programs have the advantage of attracting interest.

Such a feeding plan, however, puts more daily management pressure on the dairyman and requires that each cow be given individual attention. Although it can be argued on some bases that, with increasing size of herds, less attention can be afforded the individual cow, the degree of individual attention that is most profitable must be considered in relation to other economic alternatives. There is no doubt that the daily rationing of feed is one of several management operations that is more profitably done on the individual cow, rather than on the less personal, herd, basis.

**SUMMARY**

To ration concentrates effectively to the individual cow, the dairyman needs to know (a) how much TDN the cow needs and how much can be fed profitably, (b) the TDN value of the forage to be fed, and (c) how much of the particular forage will be ingested. Thus, effective rationing requires a satisfactory feeding standard and information on the over-all nutritive value of the particular forage(s) to be fed. A limitation in either the feeding guide employed or the appraisal of the nutritive value of the forage naturally is reflected accordingly in the amount of concentrates fed.

Recent attempts have been made to develop rapid and inexpensive, but indirect, methods for the assessment of the nutritive value of forage in programs which have become known
as forage testing. The ultimate aim in the use of a forage-testing program is that of determining the kind and amount of concentrates that should be included in the ration of the individual cow as dictated by the feeding standard. Although forage-testing schemes in their present form and manner of application provide an estimate of the TDN value per unit weight of forage, they do not provide an estimate of the more influential determinant of the total energy intake, the expected forage intake. As a consequence of this limitation, and others which have been detailed in the text, it is concluded that forage-testing schemes contribute very little information of genuine value to the daily rationing and the improvement in milk yield of the individual cow. This is particularly true when the shortcomings of forage testing are considered in relation to the limitations of existing feeding standards and certain commonly encountered defects in practical feeding.

Existing energy-feeding standards are both inadequate and ineffectively used in dairy farming practice. Some of the apparent shortcomings of present-day energy standards are indicated by the following conditions: (a) The data on which the standards are based were obtained with low-producing cows, (b) though the degree of effect varies from ration to ration, increasing inputs of feed result in an ever-decreasing nutritive value (e.g., TDN) per unit of feed ingested and an increasing rate of body-tissue gain, (c) as a consequence, increasing inputs of energy above the existing feeding-standard allowances result in increasing outputs of milk, though at an ever-decreasing rate, (d) the milk-yielding potential of the dairy cow is increasing gradually and many more very high producers exist now than ever before; thus, existing energy standards are much too low for many cows now and are becoming progressively less adequate with passing time, even for the national average herd, (e) current feeding standards take very little, or no, account of the effects on production of dry-period feeding and the consequent storage, and subsequent utilization, of body tissue as a source of milk energy, (f) the TDN values recorded in tables of feed values and used in conjunction with feeding standards for the purpose of rationing have been determined usually at about the maintenance level of intake, and (g) in view of this [(f) above], and the depressing effect of increasing planes of nutrition on the milk-producing values of the ration [(b) above], it is obvious that the dietary energy requirement per unit of milk produced increases with increasing level of feed intake or, conversely, with increasing output of milk, per unit of time.

In view of the limitations of existing feeding standards, a tentative energy standard is presented here in which the TDN allowances are graduated in terms of milk output per day. This attempt to develop a more versatile feeding guide, which accounts for the level-of-intake effect, is based in part upon theoretical considerations and in part on directly determined requirements. In this standard the following amounts (lb.) of TDN above the maintenance allowance are recommended for the production of 1 lb. of 4% FCM, when the ranges in daily milk yield (lb.) are as follows: 0 to 10, 0.30; 11 to 20, 0.31; 21 to 30, 0.32; 31 to 40, 0.33; 41 to 50, 0.35; 51 to 60, 0.37; 61 to 70, 0.40; 71 to 80, 0.43; 81 to 90, 0.47; and 91 to 100, 0.53.

Body tissue gain or utilization modifies the dietary requirement for energy. For example, the utilization of 100 lb. of body tissue could provide sufficient energy to support the production of approximately 400 lb. of 4% FCM. As a consequence, the utilization of body tissue, which (when it occurs) usually occurs during the first 75 days of lactation, would reduce the dietary requirement correspondingly during this period of time.

The lack of, or ineffective, use of existing feeding standards contributes to other defects in feeding practice. Some cows receive insufficient amounts of energy at all times. Other cows receive a sufficient total amount of feed per year, but it is distributed ineffectively. A common expression of this defect is that of providing too little feed early in lactation and too much feed late in the lactation period.

Associated with this is the failure to make effective use of the tissue gained during the dry period. Feeding plans followed in practice during early lactation demand that too large a proportion of the energy needed for milk production be provided by the catabolism of body tissue. Some degree of tissue utilization is inevitable for those cows whose milk-producing potential exceeds the limits of their appetite or stomach capacity. Also, this process is a necessity if the high-producing cow is to realize her maximum yield. Nevertheless, the alternate gaining of body tissue and its subsequent use to support lactation is inefficient energetically and should be restricted to a minimum.

The finding by dairy-cattle geneticists that short-period lactation records reflect the total lactation-period yield suggests that feed inputs during the dry period and early lactation have a cumulative effect on the yield of milk throughout the lactation period. As a consequence, it is essential that the input of energy be so distributed that the output of milk reach the maximum level as soon as possible after calving, in order to attain the maximum yield for the total lactation period.

A related time-distribution of input defect inherent in the application of all feeding standards needs to be remedied. This one is concerned with the fact that milk output dictates what the feed input should be, with a considerable time lag.

In view of the shortcomings of forage-testing
schemes and existing feeding standards, and the common defects in practical feeding; a simple feeding plan is proposed as a remedy. The main features of this plan are (a) the ad libitum feeding of high-quality forage, (b) acclimatizing the cow to a large intake of concentrates gradually, beginning a few weeks before the end of gestation, (c) after calving, allowing the cow to set her own pace on her intake of concentrates under the careful scrutiny of the dairyman and until she attains her maximum appetite or milk yield, (d) after this stage, determining by astute experimentation the lowest level of concentrates which is without effect upon the milk yield. This plan obviates the need for energy-feeding standards and tables of feed value and provides for the effective distribution of feed during the lactation cycle. However, it requires the measurement of the milk output and close attention to the individual cow.

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Using Feed Information on the Farm

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Over the past three decades research workers, as profoundly typified by Dr. Huffman and Dr. Reid, who have presented papers at this Symposium, have researched and reported many significant findings in the subject matter area of dairy cattle nutrition. When we view the present U. S. average yearly per cow production of 7,004 lb. in the light of nutritional information available and the stepped-up genetic production potential, as brought about to a large degree by our artificial breeding associations, I believe we can only conclude that a supreme challenge is at hand for all of us vitally concerned with stimulating dairymen to effectively utilize the dairy cattle feeding information now at hand.

Agricultural extension workers have carried the primary responsibility for this monumental task of making dairymen aware of, encouraging them to try and adopt, new practices on their farms. Today, I am convinced that extension dairy specialists have a large group of men giving them a significant assist—these men are employed by feed manufacturers throughout the United States. This force is composed of the dairy specialists in feed industry research and sales departments, and the larger group of sales-service representatives who are daily calling directly on dairymen. These men and extension dairy specialists have a common primary objective: assisting dairymen to increase net profits from their dairy enterprises. In the few minutes at my disposal today, I want to apprise you of what one feed manufacturing concern is doing in this area of using feed information on the farm.

The Beacon Milling Company has had a specific dairy feeding program for over 20 yr. Somewhere along the line a vital link or two....