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Prediction of the Energy Value of Feeds for Lactation

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Summary

Knowledge of the energy requirement and energy value of the ration is essential for the determination of the quantity of feed required by a lactating cow. Net energy is, in theory, the most precise measure of energy requirement of the cow and energy value of feeds. Cost and complexity of measuring net energy have resulted in a system where net energy value of feeds is predicted from TDN generally measured at or near maintenance intake in non-lactating animals. It is well established that TDN value of a feed fed to a lactating cow is significantly lower than when fed at maintenance intake. Prior to the seventh revised edition of Nutrient Requirements of Dairy Cattle, it was assumed that TDN of all feeds were depressed to the same extent in the prediction of net energy value. The 7th revised edition predicts net energy value from metabolizable energy values rather than TDN. ME values in turn are derived from digestible energy predicted from chemical composition of the feed and discounted by a factor based upon energy density of the total diet fed and intake of ration relative to that required for maintenance. This revision of the estimation the net energy value of feeds for lactation is a significant improvement compared to the system in place since 1971.

Introduction

Feeding standards are tables (or equations) showing the quantity of feed and nutrients that should be provided in the ration of farm animals to support different biological functions such as maintenance, growth, fattening, and lactation, among others. Feeding standards serve as ***guides*** in the development of practical feeding systems. Although determination of the absolute quantity of ration required is an essential component of any feeding standard, accurate determination of the relative value of alternative feeds is generally the issue of greatest interest in practice. It is interesting to note that the first recorded feeding standard is the 'hay value' system of Thaer proposed in 1810 to measure the relative nutritive value of feeds. His 'hay value' system used the sum of material extracted by water, alcohol, dilute acid and dilute alkali to rank the nutritive value of different feeds as the nature of organic nutrients was not yet appreciated. By the middle of the 19th century it was recognized that protein, carbohydrate and fat were the essential organic nutrients and the content of these nutrients began to be used for feeding standards. During the latter half of the 19th century, the concept of digestibility was recognized and incorporated into feeding standards. During the same time the concept of energy balance and '*net energy*' evolved leading to the proposal of feeding standards based upon the net-energy value of feeds by Kellner in Europe and Armsby in the United States.

A major deterrent to the development of a net energy standard is the complexity and cost associated with the determination of the net energy value of an individual feedstuff. Measurement of net energy requires not only measurement of energy lost in feces, but energy lost in urine, in combustible gases such as methane, and as heat produced by the animal. As a consequence, the net energy value of only a limited number of individual feeds were measured prior to the middle of the 20th century. An additional issue in the measurement of net energy for lactation is the necessity to feed a ration that contains two or more feedstuffs to support reasonable levels of milk yield during the measurement. Consequently, the Total Digestible Nutrient (TDN) system evolved as the system of choice in the United States. The Estimated Net Energy (ENE) system published by Morrison, 1956, gained some use, but ENE values were based upon relative animal performance when the feedstuff of interest was substituted for corn grain in the ration.

The TDN value of a feed is the sum of digestible protein, digestible carbohydrate and 2.25 times digestible fat, all expressed as a percentage of dry matter intake. Crude protein contains a higher energy content than carbohydrate, but energy content of protein is reduced to that of carbohydrate because of the additional loss of energy in urine associated with excretion of nitrogen. The use of 2.25 for fat is attributable to the higher gross energy content of fat relative to carbohydrate. The overestimation of the net energy value of TDN derived from forage was demonstrated experimentally prior to the 20th century, but was generally ignored in the application of the TDN system. Moore and coworkers published a comprehensive review of data in 1953 (Moore, et al., 1953) which demonstrated that the net energy value of TDN in poor quality forage is half that of TDN from corn grain. It should be noted, however, that this comparison was based upon net energy for growth rather than net energy for lactation. This demonstration of the over estimation of the energy value of forage relative to concentrate by the TDN system was instrumental in the development of the energy metabolism facility for dairy cattle by the Agricultural Research Service at Beltsville, Maryland. The justification for the significant allocation of resources for this facility was to develop a net energy system for dairy cattle to eliminate the bias inherent in the TDN system. A parallel effort initiated at Beltsville during the late 1950's was an effort to improve the description of the fiber in forages compared to the crude fiber system. These two initiatives started under the direction of L. A. Moore have resulted in the development of the net energy system for lactation currently incorporated in the NRC Nutrient Requirement of Dairy Cattle and in the detergent fiber analysis system used to describe the fiber in feeds for livestock.

Net Energy for Lactation System

The development of a net energy system first requires a clear and measurable unit of measurement. In the case of the net energy for lactation system developed at Beltsville by Moe, et al. (1972a), the net energy for lactation value of a feed was defined as the energy produced in milk. Energy produced in milk is rather uncomplicated to measure requiring total weight of milk produced and energy content of the milk. Unfortunately, the biology of a lactating dairy cow is more complicated. A portion of the energy absorbed from the diet is required to support necessary biological functions not associated with milk synthesis. For example, a cow that is producing no milk requires a significant amount of feed (energy) simply to stay alive, a function generally defined as maintenance. Dairy cows are often pregnant and there is feed (energy) required to support the developing fetus. Depending upon nutritional status of the cow, body tissue may be utilized to support lactation, or excess feed consumed may be used for the synthesis of body tissue. Therefore, it is necessary to measure total energy balance of lactating cows in order to be able to account for the distribution of dietary energy among these biological functions.

Simply stated, the net energy value for lactation of a feed (or ration) is the increase in milk energy yield associated with an increase in feed intake; or the slope of the regression of milk energy yield on feed intake. This assumes that all other functions remain constant during the measurement of milk yield at two or more levels of intake. The 1972a publication by Moe, et al. describes how these issues were resolved. Energy required to support pregnancy was described by Moe, et al., 1972b. This data was used to convert the energy in products of conception to the quantity of maternal body tissue that would have been produced from the equivalent amount of metabolizable energy consumed. For cows in positive tissue energy balance, that quantity was assumed to have the same efficiency of metabolizable use as for milk synthesis. Body tissue loss was assumed to be converted to milk with an efficiency of 84%. Therefore, adjusted milk equivalent energy balance was estimated to be energy in milk plus positive tissue energy balance or plus 0.84 times negative tissue energy balance, recognizing that the latter is a negative number. Adjusted milk energy balance, expressed as kcal/MBS was then regressed on metabolizable energy intake expressed as kcal/MBS where MBS is body weight raised to the 0.75 power. The ME intake where milk yield is zero is defined as maintenance. In the initial analysis, two distinct data sets were evident which related to two extensive series of experiments, one series where crude protein levels were significantly higher than requirements, and the second series where protein levels were lower and closer to requirements. Adjusted energy balance was significantly lower for high protein diets. Tyrrell, et al., 1970 developed estimates of the increase in heat production associated with the consumption of protein in excess of requirements. When energy balance was increased by 7.2 kcal for each gram of digestible nitrogen consumed in excess of requirements and the regression of adjusted energy balance on metabolizable energy intake repeated, one regression line fitted both high and normal protein diets. The adjusted energy balance regression on metabolizable energy intake had a zero intercept of –73.3 kcal/MBS, a value nearly identical to the fasting heat production (73.5 kcal/MBS) of non-pregnant, non-lactating, mature dairy cows. This means that the partial efficiency of ME use for maintenance is the same as for milk production in dairy cows and that net energy for maintenance can be expressed in the same unit as net energy for lactation unlike the two separate net energy values required to define net energy for growing cattle.

Practical Application of the Net Energy Value for Lactation System

With the information described in the preceding paragraph, the adjusted net energy content of each of the 32 diets fed was computed, expressed as Mcal/kg DM. A series of equations were developed relating net energy value to other estimates of energy value including TDN expressed as a percent of DM. This equation, NE = .0266 (TDN) - .12, was adopted by the National Research Council to estimate the net energy value of individual feedstuffs in the absence of more reliable estimates of the net energy value for lactation. Two critical factors were incorporated into the NRC application of this equation: that tabular TDN values generally reported in the literature were measured using animals fed at or near maintenance intake; and that TDN value generally declines as intake is increased above that required for maintenance at a rate of 4 percent for each increase in intake equal to that required for maintenance. It was the consensus decision on average that cows consume dry matter at three times maintenance intake, which is two times above maintenance intake. Thus, TDN value was reduced by 8%; or the TDN value determined at maintenance intake was multiplied by .92 for estimation of the net energy value for lactation when using the equation above.

The 2001 revision of the NRC Nutrient Requirements of Dairy Cattle has adopted a more realistic approach to the prediction of net energy values for lactation. The reader is encouraged to review the detailed methodology described in that publication. The process predicts net energy value from metabolizable energy value using the equation published by Moe, et al., 1972 modified to adjust for diets with added fat. ME value is estimated from DE value at production level of intake. DE value at maintenance intake is estimated from chemical composition of the feed fed rather than tabular values. DE at production level of intake is determined by using a discount factor based upon TDN content of the total ration fed rather than of individual feed ingredients. TDN value is estimated from chemical composition of the feed ingredient rather than a tabular value. Fundamental improvements introduced in the 2001 revision of the NRC publication incorporate the concept that energy value is a reflection of the chemical composition of the diet consumed, that intake effects are not the same for all feed ingredients, but rather are a function of the total ration fed, and that intake effects are probably non-linear reaching a lower limit rather than continuing to decline at very high levels of intake. Although not perfect, the latest revision of NRC represents a significant step forward in the prediction of the net energy value of feeds for lactation.

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