Estimating the Energy Value of Ruminant Feedstuffs

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Feedstuffs can be chemically assayed for a number of constituents that define nutritive value. However the energy value of a feedstuff, which is the nutritive characteristic that often defines much of its economic value, is not a chemical constituent and cannot be chemically assayed. This situation has challenged agronomists and ruminant nutritionists for decades, and provided the impetus for development of numerous equations and systems that purport to estimate the energy value of feedstuffs from one or more chemical constituents. These equations and systems may have worked well, or not so well, although it is virtually impossible to critically evaluate them, since energy values of feedstuffs have not been regularly measured in animals since the late 1960's. Thus there are no 'standards' to which predicted energy values can be critically compared.

It has long been recognized that the two key factors that determine the energy value of a feedstuff are its content of lipid, due to its high energy value, and the digestibility of its structural fiber, due to its generally high content in forages. The former can be dealt with by chemical analysis although the latter has proven to be more difficult to estimate. In North America the tendency has been to rely upon the basic similarity of structural fiber, within a forage type, to develop unique energy prediction equations for each forage type. This approach has been followed by the National Forage Testing Association (NFTA), which lists numerous equations at its web site to predict the total digestible nutrient (TDN) value of specific forages. A problem with this approach is that the botanical description of the forages must be known in order to decide which equation to use. This provides intractable problems for unknown and mixed forages. In addition, these equations tend to be region specific. This can be a problem for forages, such as alfalfa hay, that are transported to markets outside their region of origin. In contrast, European countries have tended towards use of in vitro fiber digestibility to estimate actual fiber digestibility. This approach eliminates the concerns about accurate botanical description of the test feedstuff, but introduces the complexity, cost and uncertainty of the in vitro procedure. However new in vitro procedures, and the commercial availability of these procedures, have overcome many of the concerns about use of a biological test, such as the in vitro digestibility of fiber, to estimate the energy value of ruminant feedstuffs.

The purpose of this article is to present unified equations that can be used to predict the net energy for lactation (NE_l) value of any potential ruminant feedstuff. The accuracy of the equations are dependent upon availability of all the assays that comprise it.

ENERGY CALCULATIONS

The traditional, and still most common, approach to estimating the energy value of feedstuffs has been to calculate its total digestible nutrient (TDN) level using a summative equation based upon analyzable components of feedstuffs. Although the exact TDN equation has changed over the years as feedstuff analyses have improved, the principle has remained unchanged. Currently accepted equations calculate TDN as the sum of digestible crude protein (CP), digestible fat (multiplied by 2.25), digestible neutral detergent fiber (NDF), and digestible non-structural carbohydrate (NSC) all corrected for a metabolic cost of digestion. The TDN value, calculated in this manner, can then be used to estimate the digestible energy (DE), metabolizable energy (ME), and NE_l values of individual feedstuffs by assuming that all of these energy values are proportional to TDN (see 'Interpreting Your Forage Test Report', posted 3/15/99).

One major problem with the approach described above is that the digestibility of NDF varies widely among and within feedstuffs. Analytical procedures (e.g., lignin), have been used to estimate the digestibility of NDF in specific feedstuffs, but these are highly inaccurate due to analytical error and the poor relationship between lignin levels of feedstuffs and their digestibility at commonly assumed residence times in the rumen. The only reliable methods currently available to accurately semi-quantitatively estimate ruminal digestibility of NDF are the in vitro and in situ rumen digestion procedures.

The following equations define estimates of the TDN and NE_lvalues of feedstuffs for cattle fed at a low level of intake (i.e., a maintenance level of intake (1xM)), as well as how to modify that energy value for animals fed at higher or lower levels of intake.

Estimation of the TDN and NE_l (1xM) in Mcal/kg of Dry Matter

TDN (1xM) = ((CP-ADICP)*(FT/5)*.98) + ((CP-ADICP)*(1-(FT/5))*.8) + ((EE-1)*.98*2.25)

+ (NDF*dNDF) + (.98*(100-ASH-EE-NDF-CP)))

NE_l (1xM) = ((TDN(1xM))*.0266) - .12

Where:	CP	=	crude protein (% of DM)
	ADICP	=	acid detergent insoluble CP (% of DM)
	FT	=	feed type (silages = 1, wet by-products = 2, others = 3)
	EE	=	ether extract (% of DM)
	NDF	=	ash-free NDF assayed with sodium sulfite & amylase (% of DM)
	dNDF	=	in vitro or in sacco NDF digestibility at 30 hrs (% of NDF)
	ASH	=	ash (% of DM)

However, the energy content of a feedstuff is not a constant value. As feed intake increases, the energy content tends to decline, whereas when feed intake decreases, the energy content tends to increase. The extent of the change, referred to as the energy discount value, or simply energy discount, quantifies the extent of this change. The energy discount is a reflection of the NDF and NFC content of the feedstuff, and it can be calculated as '% per unit of energy intake' (as a % of maintenance energy requirements of the ruminant in question) as:

Discount = ((.033 + (.132*NDF(% DM))) – (.033*NE_l (1xM, Mcal/kg))) + (NFC(% DM)*.05)

Where: NDF = ash-free NDF assayed with sodium sulfite & amylase (% of DM)
NE_l = energy value at 1xM intake
NFC = non-fiber carbohydrate calculated as: 100-ASH-EE-NDF-CP

The energy discount is important as it defines the rate of change in the energy value of a feedstuff as the energy intake of the target ruminant changes relative to its energy requirements for maintenance.

Estimation of NE_l (3xM) in Mcal/kg of Dry Matter

The NE_l values reported by the National Research Council (NRC) in its 1989 booklet outlining the nutrient requirements of dairy cattle are expressed at three times maintenance energy requirements (i.e., 3xM) as this was considered to represent the energy intake of a high producing dairy cows in 1989. The NE_l value at 3xM is calculated from the value at 1xM and the energy discount as:

NE_l (3xM) = NE_l (1xM) - (NE_l (1xM) * (Discount*2/100))

The same approach can be used to estimate the NE_l value of any feedstuff at any known level of energy intake relative to maintenance energy requirements.

These equations, which rely upon chemical analysis and in vitro determinations of the digestibility of structural fiber are applicable to all potential ruminant feedstuffs.

CONCLUSIONS

It is possible to estimate the energy value of ruminant feedstuffs using unified equations if some chemical assays of the feedstuffs, and the estimated in vitro digestibility of its structural fiber, are determined. These assays are all available commercially. While the actual accuracy of the resulting energy values cannot be evaluated absolutely, it provides a better approach when forages of mixed, or unknown, botanical descriptions make up a portion of the feedstuff base.

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