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The 2004 UC Davis Recommended Forage Energy Prediction Equations

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The fundamental characteristic of rations for cattle, around which all other nutrients are structured, is its energy content. Expressed variably as TDN (total digestible nutrients) or NE_l (net energy for lactation), the level of energy in a ration is the sum of the energies of its component feeds. And therein lies the rub since, unlike chemical components such as crude protein (CP) or acid detergent fiber (ADF), the energy content of a feedstuff cannot be chemically analyzed, as energy only represents the potential of a feed's chemical components to do work as biological products, such as meat or milk, or as heat. Nevertheless, an accurate knowledge of the energy content of feeds is central to formulation of cattle rations that maximize the animal's output of usable products.

It has long been recognized that the two key factors that determine the energy value of a forage for cattle are its content of fat, due to its high energy value, and the digestibility of its total structural fiber (i.e., neutral detergent (ND) fiber; NDF), due to its high level in forages. The former can be dealt with by chemical analysis, although the latter has proven to be more difficult. The most common approach to estimate the energy value of feedstuffs has been to calculate its TDN value using an equation based on analyzable components of feedstuffs. Although the TDN equation has changed over the past 120 years, as feedstuff analyses have improved, the principles have remained unchanged. TDN is calculated based on digestible CP, digestible fat, digestible NDF, and digestible non-fiber carbohydrate (NFC), all corrected for a metabolic cost of digestion by the animal. The TDN value can then be used to estimate the net energy for lactation (NE_l) value of individual feedstuffs. This UC Davis approach has been validated and published (Robinson et al. 2004; Animal Feed Science and Technology, 114: 75-90).

However the package of chemical and biological characteristics of feeds that is required to calculate TDN, and/or NE_l, costs up to $70 with a turnaround time of 3 to 14 days. Cattle feeders require faster response times and lower costs. Over the past 3 to 4 years a number of California corn silages, small grain cereals, alfalfa hays and rice hays have had their TDN and NE_l values estimated at UC Davis by this expensive, and time consuming, approach that includes numerous analyses on each sample. Fortunately, the number of forage samples with these analyses is now sufficiently large to allow simpler equations to estimate the TDN and NE_l values, based upon a much smaller number of chemical assays, to be recommended. This simpler predictive approach relies upon the basic similarity in the chemical and biological structure of these forages within California, and surrounding areas with similar climates, to allow the actual TDN and/or NE_l, calculated from the complete set of chemical and biological assays, to be estimated from a much smaller number of assays.

However, as in all cases where corners are cut to save time and money, some predictive accuracy is lost. Thus the equations, within forage, are presented from best to worst with the r^2 value indicated, where r^2 is a statistical value that describes the ability of the equation to predict the calculated energy values (where an r^2 of 1.00 is perfect prediction and 0.00 is no prediction at all). Since both NDF and ADF are used extensively in the industry, equations are presented based upon both, with or without the addition of CP or organic matter (OM; which is all the DM except ash), but only if they provide substantive improvements in predictability over NDF or ADF alone.

The 2004 UC Davis Recommended Forage Energy Prediction Equations

All of the following equations, within forage, are recommended, even though their predictive accuracy varies within and among forages. However as samples arriving in commercial California forage testing laboratories vary in terms of requested assays, the laboratories require the ability to predict TDN and/or NE_l from assays such as ADF, NDF, OM and/or CP. Thus it is the decision of each laboratory to decide which equation to use, based upon available assays and the relative accuracy (i.e., the r^2 value) of the equations, since, within forage, each of the TDN or NE_l equations predict TDN or NE_l.

All values of NDF, ADF, CP, OM, as well as TDN, are as a % of DM, whereas NE_l is expressed in Mcal/lb of DM. Both NDF and ADF are expressed with residual ash, and NDF is assayed with the inclusion of sodium sulfite in the ND and the use of a heat stable alpha amylase during ND extraction. Although wet chemical analysis is very popular in California, values based upon near infrared (NIR) procedures are acceptable if they have been calibrated based upon appropriate wet chemical assay sets. TDN is estimated at 1xM (i.e., low feed intake), as this is the most common usage of TDN when we use it amongst ourselves, whereas NE_l is estimated at 3xM (i.e., high feed intake), as this is the most common usage of NE_l when we use it amongst ourselves.

Alfalfa Hay

Recommended equations to predict the TDN value of California alfalfa hays are:

$TDN = 97.36 – (0.68627 * NDF) – (0.27333 * CP)$ $r^2 = 0.75$
$TDN = 90.21 – (0.69137 * ADF) – (0.16483 * CP)$ $r^2 = 0.73$
$TDN = 85.37 – (0.52179 * NDF)$ $r^2 = 0.71$
$TDN = 83.49 – (0.58531 * ADF)$ $r^2 = 0.70$

Recommended equations to predict the NE_l value of California alfalfa hays are:

$NE_l = 1.049 – (0.00939 * NDF) – (0.00289 * CP)$ $r^2 = 0.74$
$NE_l = 0.960 – (0.00965 * ADF) – (0.00158 * CP)$ $r^2 = 0.73$
$NE_l = 0.922 – (0.00765 * NDF)$ $r^2 = 0.72$
$NE_l = 0.896 – (0.00863 * ADF)$ $r^2 = 0.71$

Within alfalfa hay, there is very little difference in the predictive accuracy of NDF vs. ADF due to the very high inter-correlation between them. Addition of CP to the equations to predict TDN or NE_l provides only a slight increase in predictive accuracy.

NOTE: The equation listed above to predict the TDN value of alfalfa hay from ADF will result in higher estimates of TDN than those predicted by the Western States Equation (WSE) of: TDN = 82.38 – (0.7515 * ADF), published by Bath and Marble (1989) in 'Testing Alfalfa for its Feeding Value'. [For example a hay with 27% ADF on a DM basis would increase from 55.9% TDN (90% as fed basis) to 60.9% TDN (90% as fed basis)]. This probably reflects the emphasis of alfalfa seed companies over the past 20 years on increasing ruminal fermentability of NDF and ADF, by appropriate cultivar selection within their breeding programs, and so the new equation will more accurately represent the true feeding value of the hay relative to other hays and feedstuffs. However since the WSE remains the official equation to estimate the TDN value that is used to value alfalfa hay for trading purposes, its use will remain required in many situations.

Corn Silage

Recommended equations to predict the TDN value of California corn silages are:

TDN = -40.58 – (0.99417 * NDF) + (1.66003 * OM)	r^2 = 0.71
TDN = 119.07 – (1.06677 * NDF)	r^2 = 0.63
TDN = -31.91 – (1.05137 * ADF) + (1.39908 * OM)	r^2 = 0.56
TDN = 103.32 – (1.16829 * ADF)	r^2 = 0.50

Recommended equations to predict the NE_l value of California corn silages are:

NE_l = -0.306 – (0.01169 * NDF) + (0.01611 * OM)	r^2 = 0.78
NE_l = 1.243 – (0.01239 * NDF)	r^2 = 0.71
NE_l = -0.169 – (0.01265 * ADF) + (0.01277 * OM)	r^2 = 0.62
NE_l = 1.065 – (0.01371 * ADF)	r^2 = 0.58

Within corn silage, the predictive accuracy of NDF is higher than ADF, and the increase in predictive accuracy with the addition of OM is significant for both NDF and ADF.

Rice Hay

Recommended equations to predict the TDN value of California rice hays are:

TDN = -12.13 – (0.61931 * NDF) + (1.13472 * OM)	r^2 = 0.61
TDN = 37.85 – (0.98864 * ADF) + (0.62155 * OM)	r^2 = 0.60
TDN = 108.88 – (1.37413 * ADF)	r^2 = 0.53

Recommended equations to predict the NE_l value of California rice hays are:

NE_l = -0.079 – (0.00680 * NDF) + (0.01071 * OM)	r^2 = 0.61
NE_l = 0.458 – (0.01074 * ADF) + (0.00514 * OM)	r^2 = 0.60
NE_l = 1.046 – (0.01393 * ADF)	r^2 = 0.55

Within rice hay, there is very little difference in the predictive ability of NDF vs. ADF if OM is included. However if OM is unavailable, then ADF is acceptable. The TDN and NE_l prediction equations using only NDF are not included, as their predictability is low.

Small Grain Cereals (Barley, Oats, Triticale, Wheat)

Recommended equations to predict the TDN value of California small grain cereals are:

$$TDN = 80.54 - (0.52858 * NDF) + (0.43147 * CP) \qquad r^2 = 0.66$$
$$TDN = 70.47 - (0.56338 * ADF) + (0.48811 * CP) \qquad r^2 = 0.61$$
$$TDN = 105.79 - (0.88447 * NDF) \qquad r^2 = 0.56$$
$$TDN = 97.32 - (1.17585 * ADF) \qquad r^2 = 0.50$$

Recommended equations to predict the NE_l value of California small grain cereals are:

$$NE_l = 0.820 - (0.00661 * NDF) + (0.00557 * CP) \qquad r^2 = 0.74$$
$$NE_l = 0.689 - (0.00690 * ADF) + (0.00635 * CP) \qquad r^2 = 0.68$$
$$NE_l = 1.146 - (0.01121 * NDF) \qquad r^2 = 0.63$$
$$NE_l = 1.038 - (0.01487 * ADF) \qquad r^2 = 0.55$$

Within small grain cereals, the predictive accuracy of NDF is higher than ADF, and the increase in predictive accuracy with the addition of CP is substantive for both the NDF and ADF based equations.

Conclusions

The TDN and NE_l contents of California alfalfa hay, corn silage, rice hay and small grain cereals can be estimated based upon their NDF or ADF content alone (except NDF for rice hay). However in several cases the addition of CP or OM increases predictive accuracy sufficiently to justify its analysis and inclusion. California forage testing laboratories can use these predictive equations to provide the most cost effective estimates possible of the energy value of these four types of California forages.

However forages change with time, primarily due to introduction of new cultivars, and so it is to be expected that these predictive equations will change with time. We will endeavor to updates these equations annually.

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