Assessing and Adjusting the Energy Value of Feeds

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Take Home Message

- The ultimate method of assessing feed energy is to compare calculated energy balance with observed energy balance (i.e., change in body condition score).
- Feed NEL values calculated using the 2001 NRC will average about 5% lower than values most nutritionists used previously. Overall the new values appear more accurate.
- For different types of corn (ground, high moisture, steam-flaked) and corn silage (kernel processed, mature, different hybrids), NEL values obtained using the 2001 NRC system may need to be increased or decreased by up to 10% (specific adjustment factors are presented).

Introduction

Accurate estimates of dietary concentrations and intake of net energy for lactation (NEL) are needed for ration formulation and for ration evaluation. Daily net energy balance (intake of NEL minus NEL used for maintenance, milk production, and fetal growth) determines changes in body condition and body weight. If NEL concentrations of feeds (actually diets) are accurate and if the equations used to calculate NEL requirements are accurate, then the calculated balance (negative, zero, or positive) should be reflected in changes in body condition score (loss, no change, or gain, respectively). Actual change in body condition compared with calculated change is the ultimate method of assessing energy value of diets. Accurate estimates of NEL balance will allow for the proper management of changes in body condition.

Most evaluations of the NEL system used by NRC before 2001 suggest that NEL concentrations of diets were overestimated by as much as 7%. In 2001, a new revised edition of the Nutrient Requirements of Dairy Cattle was published (NRC, 2001). A major goal of the subcommittee was to make the energy system used in the new NRC (2001) balanced, i.e., energy supply should equal energy output. The NRC (2001) completely changed the approach used to obtain feed energy values. The resulting NEL values for many feeds differed substantially from previous NEL estimates but, on average, are much more accurate. However, estimated NEL values for diets based on some feeds can be substantially incorrect and some adjustments, or fine-tuning, are needed. This paper will briefly review the 2001 NRC method of determining feed energy values and present approaches to fine-tune NEL values of selected feeds so that the NEL value of the final diet is more accurate.

▪ Brief Overview of the NRC 2001 Method of Calculating Feed NEL

Feed NEL values are obtained by first estimating digestible energy (DE) concentration of feeds when fed at maintenance intake from feed composition data. A discount factor is calculated using dry matter intake and TDN of the total diet to estimate DE at productive levels of intake. The discounted DE is converted to metabolizable energy (ME) which is then converted to NEL (Figure 1). This approach allows for variation in feed composition, intake, and diet composition. This approach also means that NEL values of feeds will not be constant. The DE (at maintenance) concentrations of most feeds are calculated using equations based on concentrations of neutral detergent fiber (NDF), crude protein (CP), ash, lignin, crude fat (or fatty acids), acid detergent insoluble CP (ADICP), and neutral detergent insoluble CP (NDICP). For most feeds, actual values should be used for NDF, CP, ash, and lignin, and table values can be used for fat, ADICP, and NDICP. If a feed has an appreciable concentration of fat (e.g., cottonseeds), a fat analysis is recommended. Concentrations of ADICP and NDICP should be measured in heat-damaged forages and in byproducts that have high concentrations of NDF and CP (e.g., brewers grains).

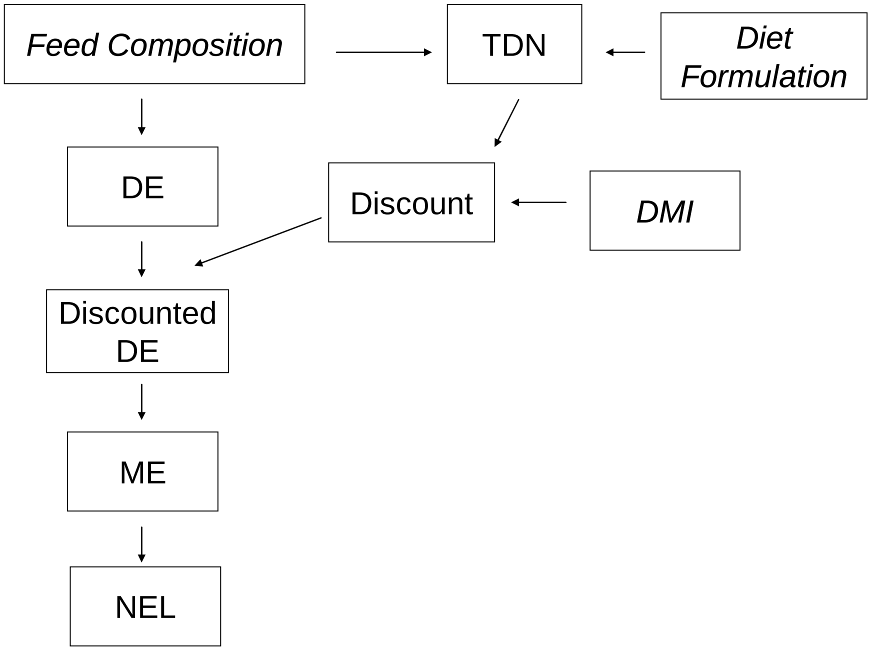

Figure 1. Overview of the method (NRC, 2001) used to calculate NEL in feeds. Terms in italics are entered by the user; all other values are calculated using NRC software. The 'TDN' value is the TDN (at maintenance) of the entire diet and DMI = dry matter intake.

Because feed processing can affect digestibility, but not necessarily feed composition, a method was needed to account for processing effects. Starch digestibility of different feeds relative to the value for ground dry corn was used to develop a Processing Adjustment Factor (PAF). The estimated digestibility of the nonfiber carbohydrate (NFC) fraction is multiplied by the PAF to account for processing effects. Ground dry corn was given a PAF of 1.0. Feeds that had starch digestibility greater than ground dry corn were give PAF values greater than 1 and feed with starch digestibility less than dry ground corn were given values less than 1.

Main Differences Between 1989 NRC and 2001 NRC Feed NEL Values

The biggest difference is that NEL concentrations of feeds are not constant in the 2001 system; they vary depending on feed composition, diet composition, and DM intake. A common observation by users of the 2001 NRC model is that replacing forage with starchy feeds (e.g., corn grain) often does not increase the calculated NEL concentration of the diet. This is not a 'bug' in the program, but rather reflects the negative effect of starch on fiber digestion. Increasing the proportion of concentrate in a diet often does not increase digestibility of the diet (i.e., energy content) but usually increases DM intake resulting in increased NEL intake. We conducted a study comparing orchardgrass silage with alfalfa silage fed in diets with 20, 40, or 60% concentrate on a DM basis (the concentrate was mostly corn grain and soybean meal). Although diets differed tremendously in NDF concentration and forage to concentrate ratio, TDN of the diets did not differ. Intake of TDN, however, increased with decreasing dietary NDF concentration and increasing concentrate (Table 1).

Table 1. Effect of decreasing the forage to concentrate ratio on intake and TDN values of diets when fed to lactating dairy cows (Weiss and Shockey, 1991)[1].

			Intake, kg/day	
Diet	NDF, %	TDN, %	DM	TDN
Alfalfa silage				
+ 20% concentrate	35.4	63.1	21.3	13.4
+ 40% concentrate	30.6	61.7	22.4	13.8
+ 60% concentrate	25.6	63.9	23.3	14.8
Orchardgrass silage				
+ 20% concentrate	45.8	66.2	17.1	11.3
+ 40% concentrate	39.1	65.7	20.3	13.4
+ 60% concentrate	30.9	69.1	21.5	14.9

[1] The forage to concentrate ratio (DM basis) did not affect TDN concentrations but DM and TDN intake increased linearly ($P < 0.05$) with increasing concentrate.

On average, dietary concentrations of NEL will be about 5% lower with the 2001 system, but differences for specific feedstuffs can be much greater (approximate range is -20% to +15%). Some of the differences are caused mainly by the different approach used to calculate feed NEL and some of the differences are caused by changes in feed composition. A comparison of NEL values of some select feeds is shown in Table 2. If an 8% discount is used (same as used in NRC, 1989), the estimated (NRC, 2001) NEL content of mature, low quality forages will be 20 to 25% lower and 10 to 15% higher for oilseed meals than 1989 values. On average, estimated (NRC, 2001) NEL values for high quality hay crop forages and for starchy concentrates will be similar to 1989 values. The NEL concentrations for corn silage and whole cottonseed are about 10 and 13% lower, respectively than 1989 values (assuming an 8% discount). Based on published data, the new values appear much more realistic than the 1989 values. Nutritionists are urged to use the 2001 NRC approach to calculate feed NEL values and if necessary 'fine-tune' those values.

Table 2. Comparison of NEL concentrations (Mcal/kg of DM) estimated using the 2001 NRC system and 1989 table values. To eliminate effects of dry matter intake, the 2001 values assume an 8% discount (identical to that used in the 1989 NRC).

Feedstuff	NRC, 1989	NRC, 2001[1]	
		1989 Comp.	2001 Comp.
Orchardgrass, full head	1.21	0.88	1.12
Alfalfa, immature	1.50	1.50	1.39
Alfalfa, midbloom	1.30	1.17	1.28
Corn silage, normal	1.61	1.36	1.45
Corn, ground	1.96	2.07	2.00
Citrus pulp	1.76	1.63	1.76
Wheat middlings	1.56	1.69	1.67
Whole cottonseed	2.22	2.16	1.94
Soybean meal, 44% CP	1.94	2.18	2.13

[1] The column identified as 1989 Comp. used the 2001 NRC equations with the nutrient composition data from the 1989 NRC feed composition table. The column identified as 2001 Comp. used the 2001 NRC equations and feed composition data from the 2001 feed composition table.

▪ Fine-tuning Feed NEL Values

The Starting Point

To fine-tune the NEL concentration of a diet, you must have an initial NEL value, and the amount of fine-tuning required depends on the accuracy of the initial value. For this paper, the initial NEL values will be those calculated using the NRC (2001) model and standard feed composition inputs (CP, NDF, ash, lignin, and neutral detergent insoluble and acid detergent insoluble CP). A standard discount of 8% was used to calculate NEL-3X concentrations.

General Approach

For the feeds listed below the general approach for fine-tuning NEL concentrations are outlined in Tables 3 and 4. The first step is to calculate NEL-3X concentrations using NRC (2001) equations using accurate feed composition data. Those values are then either increased or decreased by a certain percentage. The proposed adjustments are empirical and are based on changes in digestibility, milk yield, yield of components and (or) changes in gross efficiency (yield of fat-corrected milk divided by dry matter intake).

Table 3. Suggested method to estimate NEL values of feeds.

Step	Procedure
1	Calculate DE of feeds using Equation 2-8 (NRC, 2001)
2	Assume an 8% discount factor (i.e., multiply value from step 1 by 0.92)
3	Calculate ME of feeds using Equation 2-10 (NRC, 2001)
4	Calculate NEL of feeds using Equation 2-12 (NRC, 2001)
5	Apply necessary adjustments to NEL value for certain feeds

Table 4. Proposed adjustments of NEL values for selected feeds[1].

Feed	Adjustment
Cracked dry corn (mean particle size > 1 mm)	NEL-3X times 0.975
Ground dry corn (mean particle size < 1 mm)	NEL-3X times 1.025
High moisture ground corn (DM = 75%)	NEL-3X times 1.10
Steam-flaked corn (density = 13 kg/bu)	NEL-3X times 1.035
Mature corn silage	For every 1 percentage increase in DM above 28%, reduce PAF by 0.0075 units
Processed immature corn silage	NEL-3X times 0.925
Processed mature corn silage	NEL-3X times 1.075
Corn silage with high NDF digestibility	Calculate NEL-3X using measured NDF and lignin

[1] The NEL-3X value is initially calculated as described in Table 2.

Corn Grain

Diets for lactating cows typically contain between 20 and 35% starch (dry basis) and total tract starch digestibility measured using lactating dairy cows ranges from about 70% to 100% with a mean of 91% (Firkins et al., 2001) Assuming an average dietary starch concentration of 28% and no interactions between starch digestibility and digestibility of other nutrients, a range in starch digestibility equal to the mean (91%) plus or minus two standard deviations (7%) would cause DE concentrations of diets to vary by + 0.15 Mcal/kg from the DE value calculated using average starch digestibility (approximately + 5% of a reasonable average for DE concentrations of dairy diets). Varying NFC digestibility using the Processing Adjustment Factor in the NRC model will only vary discounted DE concentrations by about + 2% suggesting that additional fine-tuning may be required for corn grain.

Dry Grinding Assuming all differences between diets based on ground corn and those based on cracked corn are caused by the corn, diets with ground corn appear to have 1 to 6% more energy than do diets with cracked corn. That conclusion was based on digestibility, milk production, and measured NEL. This difference is greater than the difference estimated by the NRC model (< 1%) suggesting that the NRC model underestimates the NEL of ground corn, overestimates the NEL of cracked corn, or both. Proposed adjustment: Reduce NEL-3X value for cracked corn by 2.5% and increase NEL-3X value for ground corn by 2.5%. These values were derived by assuming diets with cracked corn have on average 1.5% less NEL than diets with ground corn and by assuming corn comprised 30% of the diet.

High Moisture Corn By all measures, diets with high moisture corn have more energy than diets with dry corn. Based on digestibility and lactation studies the difference is between 4 and 8%. Presumably, as moisture concentration of high moisture corn becomes more similar to dry corn, differences between the two would diminish; however, this does not mean that extremely wet high moisture corn has more energy than average high moisture corn. Proposed adjustment: Increase NEL-3X value of high moisture corn (rolled or ground) by 10%. This value was derived by assuming that diets with high moisture corn have 4% more NEL than diets with dry ground corn and that the NRC model underestimates differences between ground dry corn and high moisture corn by 3%, and by assuming corn comprised 30% of the diet. As the DM concentration of high moisture corn increases above 75%, a smaller adjustment would presumably be appropriate.

Steam-Flaked Corn Empirical data suggests that diets with steam-flaked corn have 1 to 2% more NEL than diets with ground dry corn. On average the NRC estimates that diets with steam-flaked corn have about 0.5% more NEL than diets with ground corn. To fine-tune the energy value of steam-flaked corn, flake density must be known. As flake density increases above about 13 kg/bushel, steam-flaked corn becomes more similar to ground corn. The relationship between flake density and energy value is likely not linear. Extremely low density flakes may have detrimental effects on ruminal digestion and may result in lower, not higher, dietary NEL values. Proposed adjustment: For steam-flaked corn with a density of approximately 13 kg/bu, NEL-3X values should be increased by 3 or 4%. This value was derived by assuming that diets with steam-flaked corn have 1.5% more NEL than diets with dry ground corn, that the NRC model underestimates that difference by 1 percentage unit, and that corn comprised 30% of the diet. As density increases, the adjustment will be less.

Chemical Structure of Starch Corn starch can be branched (amylopectin) or linear chains (amylose) of glucose. Corn grain with mostly amylopectin is less dense and more floury when ground than corn with a high proportion of amylose (more flinty). Across corn hybrids, the structure of starch is a continuum ranging from very floury to very flinty. Average dent corn is intermediate. Vitreousness is a measure of flintiness (flinty corn has high vitreousness). In situ and in vitro studies have shown that vitreousness has a strong inverse relationship with ruminal starch digestibility suggesting that ruminal starch digestibility in vivo will be higher for floury corn than for flinty corn with dent corn being intermediate. Very little data are available comparing different types of corn grain on total tract digestibility or milk yield with lactating dairy cows. Based on two studies, diets with waxy corn (very low vitreousness) had about 4% more energy than diets based on dent corn. Proposed adjustment: None at this time, but the NEL of very dense, highly vitreous corn is probably overestimated and floury corn may be under estimated. More data with lactating cows are necessary before this relationship can be quantified.

Corn Silage

Corn silage contains appreciable concentrations of both starch and NDF and variation in digestibility of either fraction can have a substantial effect on its energy value. The digestibility of starch provided by corn silage and the digestibility of NDF provided by corn silage cannot be directly measured in lactating dairy cows fed typical mixed diets because diets contain other sources of starch and NDF. Digestibility of total dietary starch by lactating dairy cows ranged from about 88 to 98% when corn silage provided 20 to 65% of the dietary starch, which is within the range of starch digestibilities when most of the starch comes from corn grain. Digestibility of dietary NDF by lactating dairy cows fed mixed diets when corn silage was the sole forage fed and provided most of the dietary NDF ranged from 46 to 55%.

Maturity Effects The DM concentration of corn silage is positively correlated with maturity (drier plants tend to be more mature). Data from three different published experiments were used to derive an equation to calculate the PAF of average corn silage based on DM (i.e., maturity). The resulting equation was: PAF = 1 - (0.0075 x (DM - 28)), where DM = % dry matter in the silage. If the silage DM was less than 28, PAF = 1. When the calculated PAF was used in addition to actual feed composition data, the resulting NEL concentrations were accurate. Undoubtedly the effect of plant maturity on NEL of corn silage is dependent on hybrid. For example, for a hybrid in which the vitreousness of the grain did not change appreciably with maturity, the measured DE did not change appreciably, but for a hybrid in which vitreousness increased with maturity, DE concentrations decreased with maturity (Johnson et al., 2003). This suggests that more accurate estimates of energy from corn silage will require information regarding vitreousness. Proposed adjustment: Analyze the silage for standard nutrients and calculate NEL-3X. For silages with DM concentrations equal or less than 28%, set PAF at 1.00 and for every 1 unit increase in DM concentration decrease PAF by 0.0075.

Hybrid Effects Corn silage hybrids have been developed to have increased NDF digestibility, different concentrations of nutrients (e.g., starch, NDF and fatty acids), and different physical characteristics of starch. These differences should lead to differences in available energy concentrations. However, reported differences (within experiments) in DE, digestible organic matter, TDN, or NEL concentrations between diets with different corn silage hybrids have been remarkably small. Interactions have been found between hybrid and kernel processing, and hybrid and maturity for dietary energy values. At the current time we do not have adequate data to quantify the effects of these interactions based on measurable inputs. Proposed adjustment: Current data do not support adjusting NEL-3X values from those calculated from measured nutrient composition specific to each hybrid.

Kernel Processing On average, kernel processing of corn silage has little effect on energy values (e.g., DE, TDN, DM digestibility) of diets when fed to lactating cows. An interaction between processing and corn silage maturity has been reported (Johnson et al., 2002). In that study, diets with processed immature corn silage tended to have less DE than diets with unprocessed corn silage but processing tended to increase dietary DE with mature corn silage. Proposed adjustment: The NEL-3X value of immature corn silage (< one-third milk line) that has been processed should be reduced 7.5% and the NEL-3X of mature corn silage (> two-thirds milk line) should be increased by 7.5%. These values were derived by assuming processing reduced DE concentrations by 3% when immature corn silage was processed and increased DE concentrations by 3% when mature corn silage was processed and by assuming corn silage comprises 40% of the diet. Corn silage from different hybrids probably responds differently to processing but those changes cannot be quantified at this time.

Use of In Vitro NDF Digestibility The NRC system estimates NDF digestibility using lignin. In vitro and in situ disappearance are two other options that can be used to estimate NDF digestibility. Brown midrib corn (bmr) silage generally has higher IVNDFD than its isogenic control, however when fed to lactating dairy cows as a component of a mixed diet in vivo NDF digestibility has not been consistently higher when bmr silage is fed. A diet with bmr corn silage had the same measured NEL concentration as a diet with the isogenic hybrid when fed to lactating cows at ad libitum intakes. Intake of NEL was significantly increased when bmr was fed, but energy concentration was not affected by hybrid. Other studies have shown similar results with other types of corn silage. Available in vivo data with lactating cows fed mixed diets do not support the use of IVNDFD to estimate available energy concentrations of corn silage (but it may be a good index of energy intake).

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