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DS97

# Calculation of Non-Neutral Detergent Fiber Carbohydrate Content of Feeds That Contain Non-Protein Nitrogen [1]

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What is the cost of making a 2 to 5% error in the nutrient content of a ration? How does this affect animal production or our ability to predict it? What does it do to costs? The obvious answer is that it depends on which nutrient is involved. The likelihood of making a 2 to 5 % of dry matter error is high with current methods of calculating non-neutral detergent fiber (NDF) carbohydrates (NFC). The NFC are among the most digestible nutrients, consisting of organic acids (a breakdown product of carbohydrates), sugars, starches, pectins, and any carbohydrate soluble in neutral detergent solution. Together with digestible NDF, NFC comprise the main energy sources available in the rumen.

## NFC in Dairy Rations

Nutritionists evaluate the level and type of NFC in rations in an effort to assure that the cow is receiving enough ruminally available and total energy, while limiting the overfeeding of NFC with its associated risks of low ruminal pH and acidosis. Accurately assessing NFC in the ration helps nutritionists determine the need for additional energy or undegradable protein supplements to meet cow requirements. Errors in estimating NFC can result in supplementing too much undegradable protein because microbial protein yield based on rumen degradable carbohydrate is underestimated, or feeding too much energy when the ration was in fact adequate, or in excess of the desired NFC levels.

The types of carbohydrates in a feedstuff's NFC dictate the effect of NFC accounting errors. Because different NFC have different digestion characteristics and predominate in different feedstuffs, the effects vary. There may be changes in the energy provided to the cow or microbes, decreases in microbial yield, decreases in ruminal pH, or all of the above. Understanding the nutritional characteristics of the NFC can help to predict the response to miscalculations in their amounts.

Organic acids in rations for ruminants are comprised largely of partially fermented carbohydrates, as found in silages. Unlike the other NFC, organic acids provide relatively little or no energy for the production of microbial protein in the rumen (Jaakkola and Huhtanen, 1992), although they are an energy source for the cow. Based on their digestion characteristics, they should be handled similarly to fat in determining energy contributions from the ration. Using a ruminal degradation rate near 0%/h with a high intestinal digestibility (high

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availability to the cow) would appear to accurately describe organic acid's nutritional value.

The remaining NFC support microbial growth and protein production in the rumen, although excesses of certain NFC may contribute to severe declines in ruminal pH through their fermentation to lactic acid under conditions of low ruminal pH. Sugars and starches are digested by microbes or cow, and may be fermented to lactic acid by rumen microbes (Strobel and Russell, 1986). The cow does not produce the enzymes that digest pectic substances, (1->3)(1->4)-beta-glucans, and fructans, so these carbohydrates must be fermented by microbes to be utilized. These “soluble fiber” carbohydrates differ from one another in that fructans in cool season grasses may be fermented to lactic acid (Müller and Steller, 1995), whereas pectic substance and beta-glucan fermentations do not produce lactic acid to any appreciable extent (Strobel and Russel, 1986, Van Soest, 1994). As with NDF, the fermentation of pectic substances and beta-glucans is reduced low ruminal pH (Strobel and Russell, 1986, Van Soest, 1994). Current recommendations to maximize milk production and minimize the likelihood of ruminal upset are that NFC provide 35 to 40% of ration DM when ration ingredients are high in sugar and starch, and 40 to 45% when ingredients are low in sugar and starch (Hoover and Miller, 1995). Common sources of the various carbohydrates include: Organic acids: silage; Sugars: molasses, sugar beet and citrus pulps; Starch: Corn and small grain products, potatoes; Fructans: Temperate cool season grasses; Pectic substances: Citrus and sugar beet pulps, legume forages; and (1->3)(1->4)-beta-glucans: Small grains, grasses.

## Calculating NFC

The errors in the values used to calculate NFC can underestimate its content in feedstuffs, and thereby the nutritional value of the feed. Depending upon the source of the error, computing a more accurate NFC value may be possible. The NFC content of feedstuff dry matter (DM) is a calculated value based upon nutrient percentages subtracted from 100% of feed DM by the equations:

Eqn. 1

$$\text{NFC\%} =$$

$$100\% - (\text{CP\%} + \text{NDF\%} + \text{EE\%} + \text{Ash\%})$$

or

Eqn. 2

$$\text{NFC\%} =$$

$$100\% - [\text{CP\%} + (\text{NDF\%} - \text{NDIN\%}) + \text{EE\%} + \text{Ash\%}]$$

where,

CP = crude protein,

NDF = neutral detergent fiber,

NDIN = neutral detergent-insoluble crude protein,

and

EE = ether extract (crude fat).

Although equation 1 is the most commonly used calculation for NFC, the second equation is preferred because it corrects for CP in NDF (NDIN) and so avoids subtracting NDIN twice (as part of CP and as NDF). Because it is calculated by difference, the errors from the component analyses accumulate in NFC.

**Table 1.** Factors for conversion of nitrogen to protein for foods and feeds (adapted from Jones, 1931)[1].

| Food | Factor | Food | Factor |
|---|---|---|---|
| Eggs | 6.25 | Navy beans | 6.25 |
| Gelatin | 5.55 | Lima beans | 6.25 |
| Meat | 6.25 | Soy beans | 5.71 |
| Milk | 6.38 | Peanut | 5.46 |
| Barley | 5.83 | Almonds | 5.18 |
| Corn | 6.25 | Cottonseed | 5.30 |
| Rice | 5.95 | Sesame | 5.30 |

[1] Factors determined on isolated protein fractions.

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**Table 2.** Nitrogen and crude protein contents of non-protein nitrogen sources.

| NPN Source | N% of DM | CP% as N x 6.25 |
|---|---|---|
| Ammonia | 82.35 | 514.7 |
| Ammonium ($NH_4^+$) | 77.78 | 486.1 |
| Ammonium chloride | 26.19 | 163.7 |
| Ammonium Phos (Mono) | 11.10 | 69.4 |
| Ammonium Phos (Dibasic) | 18.06 | 112.9 |
| Ammonium Sulfate | 21.46 | 134.1 |
| Nitrate | 22.56 | 141.0 |
| Urea, 45% N | 44.96 | 281.0 |
| Urea, 46.5% N | 46.56 | 291.0 |

## Correcting NFC for NPN: Method 1

One error in particular that can cause gross underestimation of feed NFC content, irrespective of how well the component assays are run, is the calculation of mass allocated to CP. Here, “mass” refers to the proportional weight of a component within a feed. For use in ruminant rations, the CP mass of feedstuffs is generally calculated as the nitrogen content (N) x 6.25. This assumes that the combined nitrogenous fractions in a feed contain an average of 16% nitrogen (1 / 0.16 = 6.25). This is not true for all feedstuffs (Table 1) and can be far off the mark for feeds containing appreciable amounts of non-protein nitrogen compounds (NPN) (Table 2, Figure 1). For example, using equation 2, the calculated NFC of a feed that contains 5% urea, 10% ash, 4% EE, 20% CP, 20% NDF, and 2% NDIN on a DM basis, would equal:

100 - [20 CP + (20 NDF - 2 NDIN) + 4 EE + 10 Ash] = 48.0%

In reality, because the urea provides 14.05% CP in the feed (281% CP in urea x 0.05 of feed DM = 14.05% CP of feed from urea), but only takes up 5% of the mass of the feed, a corrected NFC value is calculated as:

$$100 - [(20\ \mathrm{CP} - 14.05\ \mathrm{CP}_{\mathrm{urea}} + 5_{\mathrm{urea\ mass}}) + (20\ \mathrm{NDF} - 2\ \mathrm{NDIN}) + 4\ \mathrm{EE} + 10\ \mathrm{Ash}] = 57.05$$

In this case, the corrected NFC value is 9 percentage units of DM more than the commonly calculated version (also see Examples Tables 5a, b,c). This may significantly affect the estimated amount of NFC in the ration, depending upon how much of that particular feed is fed. The magnitude of the effect of NPN on NFC varies with quantity and type of NPN in the feed. The errors inherent in calculating NFC in NPN-containing feeds have the potential to affect the desired outcome of the formulation, whether providing adequate energy to the cow, avoiding ruminal acidosis, or predicting microbial yield.

As shown, the NFC content of feeds containing NPN can be calculated more accurately by replacing the CP term in the NFC calculation with a corrected term for CP mass:

Eqn. 3

Corrected CP Mass% = Total CP% - CP% from NPN + Mass % of NPN Compound

Substituing corrected CP mass for total CP in equation 2, corrected NFC is calculated as:

Eqn. 4

Corrected NFC% = 100% - [Corr. CP mass% + (NDF% - NDIN%) + EE% + Ash%]

When the mass of NPN in the feed is not known, it may be calculated as:

Eqn. 5

Mass% of NPN = (CP% in feed from NPN / CP% of NPN compound) X 100

The source of NPN (urea, ammonium, etc.) must be known so the appropriate CP% for the NPN compound may be used (Table 3).

Combining equations 3 and 5, the corrected CP mass % in a feed in which the amount of NPN compound is not given, is calculated by the equation:

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Eqn. 6

Corrected CP Mass % =

Total CP% - CP% from NPN + [(CP% from NPN / CP% of NPN compound) X 100]

Corrected NFC values for feedstuffs can be entered in ration balancing programs to provide a more accurate estimate of ration NFC. The Spartan ration balancing program (Michigan State University) automatically calculates an NFC value that contains the NPN-related errors. To calculate a corrected NFC for the entire ration using Spartan, one of the blank columns in the program can be designated as "CorrNFC" and the corrected NFC values for feeds entered there. Spartan will then calculate the "CorrNFC" content of the ration.

## Correcting NFC for NPN: Method 2

Ration formulation/evaluation programs such as the Cornell Net Carbohydrate and Protein System (CNCPS; Cornell University) or the 1996 Beef National Research Council (NRC, 1996) computer models which automatically calculate NFC content of feedstuffs do not allow the input of adjusted NFC values. With these programs, an approach that will achieve NPN-corrected NFC estimates is to partition a feedstuff containing NPN and treat it as if it contained two separate feeds: one that contains nitrogen ($\text{Feed}_N$), and one that contains the carbohydrate, fat, and ash ($\text{Feed}_C$). The two

**Table 3.** Corrected NFC content of example commercial feeds containing NPN (all values as % of feed dry matter).

| **Nutrient (% of DM)[1]** | **Liquid whey w/ammonium lactate** | **40% CP molasses supplement** | **20% CP dairy feed, 2% urea** | **32% CP dairy feed, 5% urea** |
|---|---|---|---|---|
| CP | 71.5 | 62.9 | 22.2 | 35.6 |
| NDF | 0.0 | 0.0 | 8.0 | 11.0 |
| NDIN | 0.0 | 0.0 | 1.0 | 2.0 |
| EE | 1.0 | 0.0 | 3.3 | 3.3 |
| Ash | 7.9 | 14.3 | 7.8 | 7.8 |
| CP from NPN | 60.2 | 57.1 | 6.2 | 15.6 |
| Type of NPN | ammonium | urea | urea | urea |
| Corrected CP mass | 22.9 | 25.4 | 18.2 | 25.6 |
| Corrected non-CP mass | 77.1 | 74.6 | 81.8 | 74.4 |
| Calculated NFC | 19.6 | 22.8 | 59.7 | 44.3 |
| Corrected NFC | 67.3 | 60.3 | 63.7 | 54.3 |

[1] CP = crude protein, NDF = neutral detergent fiber, NDIN = CP in NDF, EE = ether extract, NFC = non-neutral detergent fiber carbohydrates.

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"subfeeds" are used proportionally so that the sum of their pounds of DM equals that of the original feed.

The first step is to calculate the corrected CP mass % as shown in equation 6. Then, the corrected non-CP mass % (carbohydrate, fat, ash) of the feed DM is calculated as:

Eqn. 7

Corrected Non-CP Mass % = 100% DM - Corr. CP mass %

To allocate the feed into nitrogenous ($\text{Feed}_N$) and non-nitrogenous ($\text{Feed}_C$) portions, the corrected CP mass % and non-CP mass % are used to proportionally divide the feed components. For all nitrogenous components, their proportion of $\text{Feed}_N$ equals the concentration of the component in the original feedstuff DM divided by the corrected CP mass % for that feed. Just as urea contains 281% CP, the components of $\text{Feed}_N$ will add up to more than 100%, which simply reflects the difference between the CP value (N x 6.25), and the true mass of the CP.

Eqn. 8

CP% of $\text{Feed}_N$ = (CP% of original feed / Corr. CP mass %) x 100

Eqn. 9

NDIN% of $\text{Feed}_N$ = (NDIN% of original feed / Corr. CP mass %) x 100

The proportions of soluble, degradable, and undegradable proteins as a percentage of CP remain the same in $\text{Feed}_N$ as in the original feedstuff.

For all carbohydrate, mineral, and fat components, their proportions in $\text{Feed}_C$ equal the concentration of that component in the original feedstuff divided by the corrected non-CP mass % for that feed. $\text{Feed}_C$ should contain 0% CP, since all CP is included in $\text{Feed}_N$. Accordingly, NDIN is subtracted from NDF so that only the non-CP portion of NDF is included in $\text{Feed}_C$. The components included in $\text{Feed}_C$ add up to 100%.

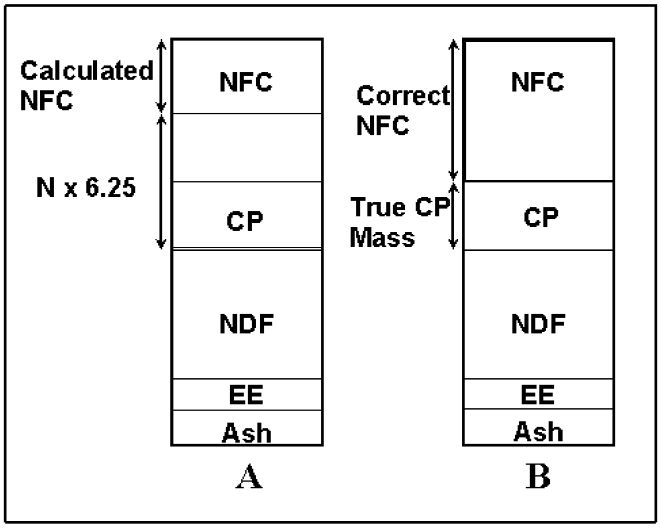

**Figure 1.** Differences in calculated NFC mass as affected by estimate of crude protein mass.

Eqn. 10

Corr. NFC% of $\text{Feed}_C$ = Corr. NSC% / Corr. non-CP mass %

Eqn. 11

NDF% of $\text{Feed}_C$ = (NDF% - NDIN%) / Corr. non-CP mass %

Eqn. 12

EE% of $\text{Feed}_C$ = EE% / Corr. non-CP mass %

Eqn. 13

Ash% of $\text{Feed}_C$ = Ash% / Corr. non-CP mass %

Eqn. 14

Mineral Ca % of $\text{Feed}_C$ = Mineral Ca% / Corr. non-CP mass %

The same energy values given for the original feed are entered in the analyses for both $\text{Feed}_N$ and $\text{Feed}_C$. In this way, the same total number of Mcal of NE or pounds of TDN in the original feed will be provided by the combination of $\text{Feed}_N$ and $\text{Feed}_C$. For instance, if a feed has an NEL, Mcal/lb of 0.78, the NEL of both $\text{Feed}_N$ and $\text{Feed}_C$ are 0.78.

To calculate the number of pounds of DM from the original feed to allocate to $\text{Feed}_N$ and $\text{Feed}_C$, multiply the corrected mass percentages times the pounds of DM of the original feed:

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Eqn. 15

$\text{Feed}_N$ DM lb = Original Feed DM lb X Corr. CP mass %

Eqn. 16

$\text{Feed}_C$ DM lb = Original Feed DM lb X Corr. non-CP mass %

In summary, to use this approach with a ration balancing program,

1. Calculate corrected CP mass % and non-CP mass %.
2. Calculate the compositions of $\text{Feed}_N$ and $\text{Feed}_C$.
3. Enter the compositions of $\text{Feed}_N$ and $\text{Feed}_C$ into the ration balancing program.
4. Take the pounds of the original feed DM and multiply by the corrected CP mass % to use as the number of pounds of $\text{Feed}_N$, and multiply by the corrected non-CP mass % to use as the number of pounds of $\text{Feed}_C$.
5. Enter all protein solubility and degradability values (% of CP) under the analysis for $\text{Feed}_N$ as the same percentages given for the original feed.
6. Enter energy values (NEL, TDN, ME) for both $\text{Feed}_N$ and $\text{Feed}_C$ as the same energy value given for the original feed.

(See Example Box for sample calculations and Table 4 for equations.)

Recalculation of NFC based on NPN content allows for more accurate accounting of the nutrient content of feedstuffs. Examples of differences in calculated NFC content of commercial feeds are given in Table 4. The impact that the correct calculation of NFC has on ration formulation using the standard and NPN-modified methods of calculation is a function of the degree of inaccuracy of the NFC value, the quantity of the NPN-containing feed that is fed, and the types of carbohydrate in the NFC. One example is a case where 6.5 lb (4.0 lb DM) of a liquid feed containing ammonium lactate (analysis in Table 3) was included in a milking herd ration for cows producing approximately 80 lb milk and consuming 56 lb of DM. Both Spartan and CNCPS calculated the feed's NFC as 19.6% of DM. After correcting for NPN, the NFC content was given as 67.3% of DM, and ration NFC rose from 38% to 42% of DM. In CNCPS, the combined A and B1 carbohydrate pool (A = sugars and organic acids, B1 = starch and pectin) contribution from the liquid feed rose from 355 g to 1236 g after the division of the feed into nitrogen-containing and nitrogen-free components.

## Summary

Non-neutral detergent fiber carbohydrates (NFC) are a very digestible, diverse group that vary in their digestion characteristics. Because NFC content is calculated by difference, the accuracy of the value is affected by errors in its component analyses. One error in particular that can cause gross underestimation of NFC is due to miscalculation of the mass contributed by non-protein nitrogen (NPN). Correction for the NPN-related error provides a more accurate NFC value for use in ration formulation. Similar corrective calculations may also find application in the estimation of TDN and digestible energy (J. E. Moore, personal communication). To predict energy supply to the cow, or energy to support ruminal microbe production, accurate accounting of all carbohydrate fractions is essential.

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**Table 4.** Equations for correcting NFC for NPN

| | Eqn. |
|---|---|
| **Corrected Method 1** | |
| NFC% = 100% - (CP% + NDF% + EE% + Ash%) | 1 |
| NFC% = 100% [CP% + (NDF% - NDIN%) + EE% + Ash%] | 2 |
| Corrected CP Mass% = Total CP % - CP% from NPN + Mass % of NPN Compound | 3 |
| Corrected NFC% = 100% - [Corr. CP mass % + (NDF% - NDIN%) + EE% + Ash%] | 4 |
| Mass% of NPN = (CP% in feed from NPN / CP% of NPN compound) x 100 | 5 |
| Corrected CP Mass % = Total CP% - CP% from NPN + [(CP% from NPN / CP% of NPN compound) x 100] | 6 |
| **Corrected Method 2** | |
| Corrected Non-CP Mass % = 100% DM - Corr. CP mass % | 7 |
| CP% of Feed$_N$ = (CP% of original feed / Corr. CP mass %) x 100 | 8 |
| NDIN% of Feed$_N$ = (NDIN% of original feed / Corr. CP mass %) x 100 | 9 |
| Corr. NFC% of Feed$_C$ = (Corr. NFC% / Corr. non-CP mass %) x 100 | 10 |
| NDF% of Feed$_C$ = [(NDF% - NDIN%) / Corr. non-CP mass %] x 100 | 11 |
| EE% of Feed$_C$ = (EE% / Corr. non-CP mass %) x 100 | 12 |
| Ash% of Feed$_C$ = (Ash% / Corr. non-CP mass %) x 100 | 13 |
| Mineral Ca % of Feed$_C$ = (Mineral Ca% / Corr. non-CP mass %) x 100 | 14 |
| Feed$_N$ DM lb = Original Feed DM lb x Corr. CP mass % | 15 |
| Feed$_C$ DM lb = Original Feed DM lb x Corr. non-CP mass % | 16 |

**Table 5a.** Examples Correcting NFC for NPN

| **Feed X Analysis (DM basis)** | |
|---|---|
| CP% | 71.5% |
| CP% from NPN | 60.2% |
| NDF% | 5.0% |
| NDIN% | 0.5% |
| EE % | 1.0% |
| Ash % | 7.9% |
| NPN Source | urea |

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**Table 5b.**

| **Uncorrected NFC% of DM for Feed X** | Equation |
|---|---|
| = 100 - (71.5 CP + (5.0 NDF - 0.5 NDIN) + 1.0 EE + 7.9 ash) = 15.1% NFC | (2) |
| **Method 1.** To calculate a corrected NFC for feed X: | |
| Corrected CP Mass % | (6) |
| = 71.5% CP - 60.2% $CP_{urea}$ + [(60.2% $CP_{urea}$/281% $CP_{urea}$) x 100] | |
| = 11.3% non-urea CP + 21.4% mass from urea | |
| = 32.7% corrected CP mass % | |
| Corrected NFC% of DM | |
| = 100 - (32.7 Corr. CP mass + (5.0 NDF - 0.5 NDIN) + 1.0 EE + 7.9 Ash) | (4) |
| = 53.9% corrected NFC% | |
| Corrected Non-CP Mass% = 100 - 32.7 = 67.3 | |

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**Table 5c.**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Method 2.** To calculate CP-containing ($\text{Feed}_N$) and CP-free ($\text{Feed}_C$) fractions for use in ration formulation programs that automatically calculate NFC. | | | | | | |
| Corrected CP Mass | | | | | | (7) |
| Corrected Non-CP Mass % = 100 - 32.7 = 67.3 | | | | | | (7) |
| Feed Fraction | % in Original Feed X on a DM basis | | Corrected CP Mass % | | Fraction % Feed $X_N$ | |
| CP | (71.5 | / | 32.7) X 100 | = | 218.7 | (8) |
| NDIN | (0.5 | / | 32.7) X 100 | = | 1.5 | (9) |
| Feed Fraction | % in Original Feed X | | Corrected Non-CP Mass % | | Fraction % Feed $X_C$ | |
| NDF-NDIN | (5.0-0.5=4.5 | / | 67.3) X 100 | = | 6.7 | (11) |
| EE | (1.0 | / | 67.3) X 100 | = | 1.5 | (12) |
| Ash | (97.9 | / | 67.3) X 100 | = | 11.7 | (13) |
| Corr. NFC | (53.9 | / | 67.3) X 100 | = | 80.1 | (10) |
| Calculation of pounds allocated to $\text{Feed}_N$ and $\text{Feed}_C$ from 10 pounds of the original feed DM:<br>Feed $X_N$ DM lb = 10 lb Feed X DM X 32.7% Corr. CP Mass = 3.27 lb (15)<br>Feed $X_C$ DM lb = 10 lb Feed X DM X 67.3% Corr. Non-CP Mass = 6.73 lb (16) | | | | | | |