Applications of uNDF in Ration Modeling & Formulation

Jim Paulson, University of Minnesota

Fiber digestibility and indigestibility are critical factors when assessing forage quality and formulating diets. Digestion characteristics of NDF influence feeding and rumination behavior, rate of particle breakdown, ruminal turnover and fill, dry matter intake, and overall efficiency of milk component output. Traditionally, nutritionists have focused primarily on measures of fiber digestibility, but recently the focus has included indigestible fiber because of the recognition of its importance in setting the extent and influencing the rate(s) of fiber fermentation in the rumen. For nutritional modeling, indigestible NDF is required as the end point for fermentation to allow accurate estimation of the potentially digestible NDF fraction and its rate(s) of digestion. Measuring true NDF indigestibility would require infinite time, so in the actual rumen of a dairy cow or in an artificial rumen system, true indigestibility is never reached. The standard nomenclature is "indigestible NDF (iNDF)" (Mertens, 1993; Huhtanen et al., 2006); however, to improve the accuracy of the standard terminology used to describe fiber fermentation dynamics, Mertens (2013) coined the term "undigested NDF (uNDF)" as the laboratory measure (typically in vitro or in situ) of indigestible NDF at a specified fermentation time. You will see both terms used, and for the most part, they are interchangeable as long as you know the method and time point used to determine the NDF digestion endpoint. However, moving forward, we will standardize our terminology to uNDF. To achieve iNDF requires estimations out to infinite time and that estimated residue might not be consistent with the interactive behavior of the forage and feed with rumen function.

Biological Importance of uNDF

Determination of uNDF should be included in routine forage and feed analysis because indigestible NDF is a uniform feed fraction with a predictable digestibility (i.e., zero). By contrast, total NDF is a non-uniform feed fraction; it contains multiple pools that digest predictably as a function primarily of lignification (Van Soest, 1994).

Undigested NDF is the functional fiber fraction that influences physical effectiveness, gut fill, and digestion/passage dynamics of forages. Undigested NDF is important biologically because:

- It can be used to estimate potentially digestible NDF (pdNDF) (NDF - uNDF).
- The uNDF fraction together with earlier time points of fermentation can be used to estimate the fast and slow pools of NDF digestion and their digestion rates (Raffrenato and Van Amburgh, 2010).
- Measures of NDF pools and rates of digestion based on uNDF can help explain feeding and ruminating behavior, especially when chemical composition (i.e., ADL, NDF, ADF) are similar.
- Chewing response to physically effective NDF (peNDF) is likely influenced by uNDF.
- Estimates of the slow pool of NDF and its rate of digestion plus the uNDF are related to dry matter intake and passage from the rumen.
- uNDF plays a critical role in maintaining ruminal digesta load.
- uNDF predicts forage quality because of the relationship between uNDF and organic matter digestibility (Nousiainen et al., 2003).

At any given time, rumen fiber fill is a function of dietary uNDF, slowly fermenting NDF, and undigested fast-pool NDF. The rumen space resulting from turnover of the fast fiber together with the slow fiber and uNDF allows for more dry matter intake. The more rapidly rumen space is made available (i.e., the greater the turnover), the higher the intake that can be attained. The total mass of uNDF within the rumen can be thought of as a "baseline" of fill which constrains the possible NDF flux. We propose that there is a maximum and minimum amount of ruminal uNDF to avoid limits on feed intake and to maintain proper ruminal health, respectively. Undigested NDF can improve the precision of estimating dry matter intake by telling us, for example, how much uNDF in a total mixed ration (TMR) a cow can consume before filling her rumen, and conversely, how much uNDF must be consumed to maintain rumen fill and digestive efficiency.

There may be an optimal mass of digesting NDF within the rumen; above this amount fill limits intake, while below this amount intake could increase further although possibly at the expense of feed efficiency (Weakley, 2011). Although the effect on dry matter intake of adjusting dietary NDF is two to three times greater than changing the NDF digestibility (Mertens, 2009), in many practical feeding situations where dietary NDF has reached the maximum fill potential in high-producing cows, then NDF digestibility (or indigestibility) becomes most important (Weakley, 2011). We believe that uNDF measured at 240 hours of in vitro fermentation (uNDF240) is a forage fraction that accurately assesses the indigestible component of NDF.

It is also important to point out that other measures of undigested NDF are currently being used in the field to predict dry matter intake of various forages. One published example is uNDF measured at 30 hours of fermentation (termed NDFu30) as described by Jones (2014). This measure of rumen fill appears to be working well in the field as a means to predict dry matter intake, especially for cattle consuming high-forage diets.

Details of the projects conducted at Miner Institute have been previously published by Grant and Cotanch (2012). The objectives of the initial study were to measure the passage kinetics of large, medium, and small particle pools for diets differing in amount and (in)digestibility of NDF from corn silage when lactating cattle are fed a TMR consisting of either conventional or brown midrib (bmr) corn silage. To complement the studies, researchers at the University of Bologna have focused on evaluation of alfalfa and grass as major forage sources and Cornell researchers are focusing on non-forage sources of fiber.

From this information it appears that, for diets based on corn silage and haycrop silage, maximum NDF intake is ~10 kg/d or 1.5% of body weight. Likewise, maximum rumen mass of NDF is ~8.5 kg or 1.3% of body weight. The intake of uNDF appeared to be maximized at 2.6 kg/d or ~0.40% of body weight. The rumen mass of uNDF ranged between 0.48-0.62% of body weight. Fecal output of uNDF balanced the uNDF intake for each diet. Interestingly, the ratio of rumen uNDF:intake uNDF was ~1.6 for all diets. We need to determine if this ratio is similar for diets based on other forage types and for cows at other stages of lactation including dry cows.

Combined data sets from Cornell, Bologna, and Miner indicate:

- Daily uNDF intake equals uNDF output in the feces.
- Maximum uNDF mass in rumen is ~0.48 to 0.62% of BW.
- Maximum NDF intake is ~10 kg/d or 1.47% of BW (1.27-1.47).
- Maximum uNDF intake is 0.39% of BW (Miner data) to 0.48% (Bologna data).
- Ratio of rumen uNDF:intake uNDF is 1.60 regardless of diet.

Condensed and adapted from article by Cotanch, Grant, William Miner Agricultural Research Institute; Van Amburgh, Zontini, Cornell University; Fustini, Palmonari, Formigoni, University of Bologna.