CONSIDERING FORAGE NDF_{u30} AS A CONSTRAINT IN DAIRY RATIONS

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UNDIGESTED FIBER AND DMI

For dairy rations, it has long been known that dry matter intake (DMI) is related to dry matter digestibility (DMD) (Conrad, 1964). With the development of the NDF system, it was postulated by Goering and VanSoest that fiber digestibility was related to DMD.

DMD = NDF*NDFD + 0.98 NDS – 12.9

Mertens (2010) later mathematically rearranged this relationship to the following:

DMD = 87.1 – (0.98 – NDFD)*NDF

which was further simplified by Jones and Siciliano-Jones (2014):

DMD = 87.1 – NDF_u

This line of reasoning points to the conclusion that the size of the undigested fiber pool is related to dry matter digestibility which is in turn related to DMI. The convention of a subscript "u" is used to denote pool size whereas the capital "D" in Merten's paper is used to denote digestibility as a percent of NDF. Empirically, across a similar range of NDF content, NDFD will be related to dry matter digestibility. For some time, the dairy industry became focused on NDFD (Oba and Allan, 1999). However, across forages, NDFD was a poor predictor of DMI since it did not account for pool size. In late 2013, Cumberland Valley Analytical Services began reporting NDF_u which is the percent of dry matter that is undigested fiber.

GUT FILL

Before discussing further the linkage between undigested fiber, DMD and DMI, it is important to review the notion of gut fill. Simply stated, gut fill is the retention and accumulation of particles in the rumen. Particle retention is controlled by digestion, reduction of physical size to allow passage, and overall passage rate. It is logical that as retention increases, gut fill increases. An important aspect of relating gut fill to particle retention is that gut fill will be diet and environment dependent. Consequently, the expectation that a single factor will describe gut fill for all herds is not realistic. However, under constant passage and physical reduction rates (for instance, with consistent forage types), it is reasonable that fiber retention would increase with an increasing undigested fiber pool.

For practical reasons, many measures of a dairy cow's performance are expressed on a daily basis. If the rumen of a dairy cow is at steady state (i.e., frequent meals), the time period is unimportant. Using a day as the unit of measure, it is realistic to assume that the daily consumption will be regulated to have no net accumulation of particles. Unfortunately, determining the steady state condition is very difficult, but changes from the steady state condition should be more predictable. In other words, it is hard to predict intake but it is easier to predict if a ration change will increase or decrease intake. If passage rate and particle reduction rate are not changed, an increase in the undigested NDF pool (e.g., decreased digestibility) will decrease DMI.

The main question remaining from the above discussion is "What measure of the undigested fiber pool size is most related to gut fill?". Relative to gut fill, digestion of particles is important only to the extent that the particle has not otherwise passed from the rumen. From a practical perspective, some feeds (e.g., soy hulls) contain NDF that is resistant to digestion in the rumen (NDF_{u30} = 7.5% of DM) but they naturally pass from the rumen very quickly due to their functional specific gravity and particle size. Consequently, this undigested fiber pool has limited impact on overall particle retention. Therefore, the undigested fiber pool should only contain particles large enough to readily resist passage. To easily implement this restriction, all finely ground commodities should be excluded from the undigested fiber pool for gut fill calculation.

NDF_{u30}

Laboratory estimates of fiber digestion are largely performed in an *in vitro* system. These systems estimate the amount of NDF that would be digested if it did not otherwise pass from the rumen. Ideally, the *in vitro* system would measure NDF digestion up to the time when the particles would normally pass from the rumen. Unfortunately, the mean particle retention time is different for different feeds (grasses vs corn silage, Lund et al., 2006; legumes vs grasses, Oba and Allan, 1999) and different environments (e.g., cold and heat stress and overcrowding; Kennedy et al., 1976).

Generally, for forage particles, the mean particle retention time is longer than 24 hours but shorter than 48 hours. Relative to gut fill, the mean particle retention time is very difficult to measure. For example, inert particles are not subject to digestion or particle reduction. Simply for convenience, a standard of 30 h *in vitro* incubation has become common for NDF digestibility. Across many different forage types, a 30 hour mean retention time is reasonably appropriate.

The thesis presented in this manuscript is that the undigested forage NDF pool after 30 hours of *in vitro* digestion (NDF_{u30}) is a contributor to gut fill. The underlying assumption is that forage particles generally remain in the rumen for 30 hours before passage during which time digestion is an influence on their overall passage retention time. Once the particle has passed out of the rumen, its digestibility is no longer relevant. However, NDF_{u30} is only one component of the factors influencing overall particle retention. Overall passage rate and physical reduction cannot be ignored.

PRACTIAL USE OF NDF_{u30}

It is not practical to predict DMI simply knowing the load of forage NDF_{u30} being consumed since particle passage rates are influenced by both intrinsic and extrinsic factors (Krämer, 2013). The current industry debate about the optimal forage NDF_{u30} load is not founded given different particle passage rates. We have seen diets where the forage NDF_{u30} varies from 4 pounds to over 6 pounds per cow per day. The herds consuming only 4 pounds have specialized high byproduct diets, while the herds containing 6 pounds tend to have finer chopped forages . However, changes in DMI when the load of forage NDF_{u30} is changed can be more predictable (Jones, 2014).

There are two main uses of forage NDF_{u30} for evaluating rations. First, if the herd has an acceptable DMI, ensure that the next ration change is constrained to the current forage NDF_{u30} load expressed as pounds/day. This becomes important when new forage is introduced or forage substitution needs to occur. For example, consider changing from a corn silage with a 15% NDF_{u30} to a new crop that is 18% NDF_{u30} where corn silage makes up 20 pounds of the ration dry matter. In the first instance, the corn silage contributed 3 pounds of NDF_{u30} while in the second instance; this corn silage provided 3.6 pounds of NDF_{u30}. Without adjusting for gut fill, the DMI will probably decrease.

The second use of forage NDF_{u30} is to evaluate herds that have poor DMI. Given a specific region and forages, it is feasible to select forage NDF_{u30} load that provides a reasonable gut fill. For example, if other herds feeding similar forages have a NDF_{u30} load of 5.5 pounds per day and the problem herd is at 6.5 pounds per day, the opportunity to minimize gut fill may exist. A different scenario arises when a herd has a low forage NDF_{u30} and low intake. In this case, subclinical acidosis may be inhibiting fiber digestion which would elevate the *in vivo* NDF_{u30} compared to the *in vitro* estimate. Low ruminal pH from highly fermentable feeds can decrease rate of fiber digestion and increase the filling effect of the diet (Allen and Mertens, 1988).

It is still unclear if the undigested fiber component of whole cotton seeds (WCS) contributes to gut fill. Generally, WCS contains 40% NDF_{u30} when measured *in vitro*. If we assume that WCS passes quickly from the rumen (< 30 hours), then the rate of digestion is not significant. However, if WCS has a higher residency time (> 30 h) and that 40% of it remains undigested, then the WCS will contribute to gut fill. If this is the case, a 3 pound inclusion of WCS will result in an additional 1.2 pounds of NDF_{u30} to the gut fill load.

It needs to be noted that in February 2015, the US Patent Office issued a patent which contains claims for the use of undigested NDF and starch digestibility for ration formulation (Weakley, 2015).

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