NASEM 2021 – Carbohydrates

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Introduction

Carbohydrates are key players in dairy cattle diets: they make up 70 to 80% of the diet dry matter and provide the nutrition and chewable fiber that keep cows healthy and productive. The 2021 Nutrient Requirements of Dairy Cattle, 8th edition from the National Academies of Sciences, Engineering and Medicine (NASEM, 2021) keeps much of the familiar landscape of carbohydrates we've been using, but provides some new additions, revisions, and applications (Figure 1).

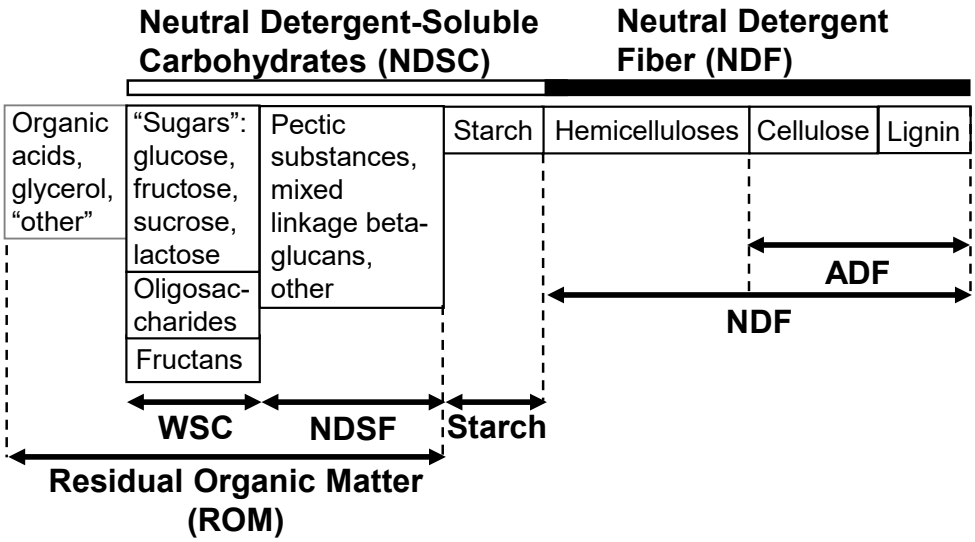

Figure 1. Carbohydrate fractions in feeds. ADF = acid detergent fiber, NDSF = neutral detergent-soluble fiber, WSC = water-soluble carbohydrates.

Carbohydrate Fractions

The neutral detergent soluble carbohydrates fraction (NDSC) replaces nonfiber carbohydrates (NFC) as a more accurate description of this fraction: these are the carbohydrates soluble in neutral detergent. It includes the more readily fermentable carbohydrates: starch, water-soluble carbohydrates (WSC), and neutral detergent-soluble fiber. Starch consists of chains of glucose that can be digested by microbes or the animal. The WSC include sugars, fructans from cool season grasses, and oligosaccharides (short chains of sugars). Total sugars as invert can be used as the WSC value for molasses. Soluble fiber is a kind of fiber not in NDF. It includes pectins and other polysaccharides extracted by neutral detergent and not digestible by mammalian enzymes. Neither WSC nor soluble fiber as such are used to calculate nutrient

supply in NASEM 2021 because there was not enough published research to define their specific impact. Of the NDSC, starch receives the most focus. Not surprising since most NDSC research has centered on starch. Why? Besides accounting for a substantial portion of many dairy cattle diets, we have good, relatively easy methods to measure starch in feeds, diets, and feces to assess its digestibility, something we lack for soluble fiber and WSC. Recommended methods of analysis to get the inputs needed for the NASEM 2021 equations and model are listed in the Feed Analysis chapter.

The 2001 NRC recommendations relied on NFC calculated by-difference to describe the pool of readily available carbohydrates. NASEM 2021 omitted NFC, made starch its own fraction, and came up with a new by-difference fraction: residual organic matter (ROM) that is used in energy supply calculations. ROM covers carbohydrates not accounted for by starch and NDF. It is calculated as a percentage of dry matter as: 100 – ash – NDF – starch – (fatty acids/fatty acid factor) – (crude protein – 0.64 x supplemental nonprotein nitrogen). The fatty acid factor = 1 if the source is fatty acids or fatty acid soaps, or 1.06 for all other feeds. The ROM contains WSC, soluble fiber, fermentation acids like those in silage, glycerol, and other feed components not measured in the main nutrient fractions. Similar to NFC, ROM is estimated to be 96% truly digestible. Nutritionists: Before you get bothered that a variety of fractions we can measure were combined into ROM, remember two things: 1) using ROM and starch reduces the size of the "nutritional black box" that NFC was, and 2) the NASEM committee didn't find enough published data to describe the impact of the ROM carbohydrates. The only way to find out whether parsing NDSC further will improve how well we can predict nutrient supply and cow performance is to do the research to explore those questions.

Neutral detergent fiber (NDF), acid detergent fiber (ADF), and sulfuric acid lignin – the "insoluble" fiber fractions – stay as they have been in previous editions. The NDF is analyzed for using heat-stable alpha-amylase (the "a" in aNDF or aNDFom) and sodium sulfite to remove starch and protein. But, there can be 2 NDF options to choose from on feed analyses: which should be used with NASEM 2021? On feed analyses, you may see "NDF" and "NDFom". The "om" stands for "organic matter" or "ash-free" meaning the ash in NDF was subtracted out of NDFom, but not from NDF. The NASEM 2021 nutritional model uses NDF values that include ash that was not extracted with neutral detergent because that was the version of NDF used in the research studies used to develop the recommendations. Typically, ash is a minor part of NDF. However, if a feed sample and NDF show heavy ash/soil contamination, resampled feed should be analyzed or NDFom should be used to avoid counting the excess ash as carbohydrate.

Application of Carbohydrate Values

What you find in NASEM 2021 is that the Carbohydrate chapter gives guidelines related to feeding carbohydrates that maintain desired rumen function, and the Energy and Protein chapters use various carbohydrate fractions in equations for predicting nutrient supply.

NASEM 2021 took the approach of allowing energy supply values from starch and NDF to be affected by the diets they're in. This is handled by calculating energy predictions from a base or starting point total tract digestibility (TTD) of a nutrient in a feed. For starch, the base TTD for a feed is assigned in the feed library, ranging from 96% for finely ground high moisture corn to 77% for coarsely ground dry corn. If you have information on starch digestibility specific to your feeds, it can be entered into the feed analyses in the NASEM 2021 model. For NDF, the base TTD of a feed is calculated from either a laboratory-measured 48 hour NDF in vitro fermentation digestibility, or from NDF and lignin analyses. Next, the diet TTD of that nutrient is modified based on the dietary factors that affect it. Both starch and NDF TTD, and so the energy available from them, decrease with increasing dry matter intake as a percentage of body weight. The NDF TTD also decreases as dietary starch concentration increases. NASEM 2021 mentioned that a having a factor for starch fermentability as it affects NDF digestibility would have been useful, but there was not enough data to define it. Lastly for the carbohydrate contributions to energy, TTD of ROM is estimated to be 96% and is unaffected by other factors.

Microbial protein production, an important source of protein to the cow, is calculated from predictions of how much starch and NDF are fermented in the rumen. A number of factors affect these predictions. The amounts of fermented starch and NDF are both affected by dry matter intake. The fermented NDF value is also affected by dietary concentrations of crude protein, wet forage, and ADF/NDF. The fermented starch value is influenced by dietary concentrations of forage NDF, wet forage, and starch (yes, starch). The forage NDF likely affects passage and how long feeds are retained in the rumen to be fermented. Crude protein may relate to meeting the needs of the fiber digesters, whereas starch concentration may relate to maintaining a population of microbes that ferment starch.

Physical form and NDF are crucial to maintaining proper rumen function and health. The NDF in forages is particularly important. Its typically larger particle size encourages rumination, and the slower fermentation and breakdown of NDF maintains that form and makes it available to be chewed for a longer time. It also affects the ruminal retention of feeds. Factors affecting a cow's fiber needs are complex and we do not have all the needed measurements to pinpoint precise relationships with rumen function. However, as a starting point for maintaining good rumen function, NASEM 2021 has a table for recommended dietary minimum total NDF and minimum forage NDF and maximum starch concentrations with forage NDF increasing to balance as starch increases and total NDF decreases. Additionally, recommended directional changes in forage NDF inclusion are intended to counterbalance diet, management, and behavioral effects that could reduce ruminal pH and disturb rumen function (Table 1).

Another approach in NASEM 2021 is physically adjusted NDF (paNDF) which works with the interaction of forage NDF, starch, particle sizes on the Penn State Particle Separator (PSPS), and other elements in the diet that affect ruminal pH. It integrates these to give recommendations for the proportion of the diet dry matter that should be on the PSPS 8 mm / 0.315 inch sieve. There was a free paNDF app (MUNCH for Dairy Cows) that was available from the App Store or

Google Play Store – but through some glitch it was taken down. We're working to get it back up and available. University of Nebraska extension bulletin G2316 gives more information on the app (https://extensionpubs.unl.edu/). For now, we suggest not changing diet protein or cow bodyweight in the app (once the app is available again).

Table 1. Based on NASEM 2021 Figure 5-2

Suggested direction for adjusting for optimal forage NDF
17% <------- Forage NDF% of diet dry matter -------> 27%
←--Higher dry matter intakes
←--Added buffers in diet
Forage chop length – Finer--→
Higher starch% of diet --→
Starch degradability – Higher--→
Bunk space is limited --→
Slug feeding -- Yes--→
Daily variation is high in diet and mixing --→

References

NRC. 2001. Nutrient Requirements of Dairy Cattle. 7th rev. ed. Natl. Acad. Sci., National Academy Press, Washington, DC.

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