Forage Crises?

Extending Forages and Use of Non-forage Fiber Sources

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Introduction

Forage availability is sometimes limited because of poor growing conditions or because of insufficient land base on individual farms. In addition, forage fiber can limit feed intake, particularly for high producing cows, and forage quality is highly variable. Therefore, there is continual interest in alternatives to forages in diets for dairy cows. Decreasing the forage content of diets requires careful selection of ingredients for use in the dietary space created. Because cereal grains must be limited in diets to avoid ruminal acidosis, byproduct feeds with high fiber content are the most commonly discussed alternatives to forages. These can replace some, but not all, forage in diets of lactating cows. These byproduct feeds are referred to as non-forage fiber sources (NFFS) to distinguish them from other byproduct feeds. However, cereal grains also can be used in place of forages to some extent if fermentability of starch is reduced. Forage alternatives should be considered based on their ability to substitute functionally for forage. This paper discusses how forages function in diets of dairy cows, and factors to consider when selecting forage alternatives.

Forage Function

Forages are unique compared with other dietary ingredients because they provide long fibrous particles that are retained in the rumen longer and tend to ferment more slowly than smaller feed particles. This provides a consistent source of fuels to microbes in the rumen as well as a basal supply of fuels to the liver and mammary gland over time, allowing greater milk yield. Some long fibrous particles are necessary for formation of the rumen mat, which entraps small particles, increasing their ruminal digestibility. An adequate mass of digesta in the rumen is required to stimulate chewing, which increases secretion of salivary buffers.

A high supply of fuel from fiber fermentation in the rumen is highly desirable and dependent upon the digestion characteristics of the fiber source. Forage fiber should have a high turnover rate from both digestion and passage to maximize fuel supply while minimizing the filling effect of fiber over time. Increased passage of particulate matter is also expected to increase efficiency of microbial protein production by increasing passage of attached microbes before they die and are redigested in the

rumen. However, forages vary considerably in their digestion characteristics, and it is often desirable to find alternatives for poor-quality forages.

Forages also dilute rapidly fermentable feeds such as cereal grains in diets, thus preventing excessive ruminal fermentation. However, this function is not unique to forages, and the ability of feeds to slow ruminal fermentation while providing high total tract digestibility determines their value as a forage alternative. The concentration of forage diets can often be decreased while maintaining or enhancing feed intake, milk yield, and health. Thus, it is possible to provide cows low-fill, highly fermentable diets that also result in consistent fermentation over time.

Filling Dietary Space Vacated by Forages

Non-forage fiber sources

The primary advantage of NFFS is that they generally have higher energy concentrations and are much less filling than forages; feed intake is limited to a greater extent when the neutral detergent fiber (NDF) concentration of diet increases from forage compared with NFFS. They are commonly used as forage alternatives and vary widely in cost, availability, and chemical composition across type and location, and over time. Compared with cereal grains, NFFS are less likely to result in ruminal acidosis because they generally ferment more slowly, are not fermented to lactic acid, and because their rate of fermentation slows as ruminal pH declines. Like forages, NFFS often result in decreased propionate and increased acetate production in the rumen when substituted for cereal grains. A slower rate of fermentation and decreased propionate production might allow increased meal size and greater feed intake when meal size and feed intake are limited by absorbed propionate. However, substitution of NFFS for forage usually decreases the ration of acetate to propionate concentrations in the rumen and also decreases ruminal pH. Wisconsin researchers reported that NFFS were only about one half as effective as alfalfa at elevating milk fat concentration and were less effective at stimulating chewing activity when substituted for grain in low forage diets. Another Wisconsin experiment found that NFFS were only 27% as effective as alfalfa silage at increasing milk fat concentration. Therefore, when replacing forage with NFFS, the effects of NFFS, cereal grains, and other non-forage diet components on ruminal fermentation characteristics must be considered in selecting the type and amount of NFFS and the proportions of forage and grains that will be replaced.

The fiber concentrations (NDF and soluble fiber) of most NFFS are in the range observed for most forages (40 to 60% on a dry matter basis), but some NFFS have NDF concentrations exceeding 75% (oat hulls, cotton seed hulls, ground corn cobs). The primary difference in the fiber of NFFS compared with forages is that particle size of

NFFS is smaller, so NFFS cannot provide long fibrous particles to form a rumen mat. While some NFFS such as cotton seed hulls and oat hulls are poor sources of energy and protein function only to dilute rapidly fermentable grains, most NFFS are also good sources of fermentable fiber. Some have additional value because they provide fatty acids and (or) ruminally undegraded protein. Soyhulls and beet pulp are excellent sources of fermentable fiber but have low protein and fatty acid concentrations. Crude protein concentrations of distiller's grains, brewer's grains, corn gluten feed, and whole linted cottonseeds are higher than most forages, ranging from 24 to 30% of DM. Whole cottonseeds, and to a lesser extent distiller's grains, provide additional energy as fatty acids. The extent to which each NFFS should be used as a forage alternative depends upon its availability and price relative to other energy and protein sources, as well as its ability to substitute functionality for forage.

Recent research with lactating cows suggest that NFFS not only reduce the amount of starch fermented in the rumen when substituted for grain but **also reduce the ruminal digestibility of the remaining starch**. Illinois researchers substituted soyhulls for dry ground corn at 0, 10, 20, 30, and 40% of dietary DM and reported that ruminal digestibility of non-structural carbohydrates decreased from nearly 30% to less than 5% without reducing ruminal or total tract digestibility of organic matter. We recently reported similar effects on ruminal starch digestibility when pelleted beet pulp was substituted for high moisture corn at 0, 6, 12 and 24% of dietary DM. The amount of starch truly digested in the rumen decreased dramatically from 8.4 to 1.5 lb/d, partly because of the expected reduction in the starch intake from lower dietary starch concentration but also from an **unexpected reduction in true ruminal starch digestibility** from 47% to 17% as beet pulp replaced high moisture corn in diets. There was no effect of treatment on total tract starch digestibility despite this large reduction in ruminal starch digestion.

In addition, the digestibility of organic matter in the rumen was not affected by treatment because of increased NDF digestibility; increased ruminal NDF digestibility and compensatory intestinal starch digestibility of organic matter as beet pulp replaced corn in the diet. The dramatic reduction in ruminal starch digestion decreased from 11.3 to 1.7%/h and rate of starch passage from the rumen increased from 15.9% to 23.5%/h. It is not known if other NFFS have the same effects on rate of digestion and passage from the rumen, but they also might either increase or decrease ruminal starch digestion.

It might not be desirable to reduce ruminal starch digestibility to the extent observed with the highest substitution rates of beet pulp or soyhulls, but the linear responses obtained in these two experiments suggest that NFFS can be used at lower substitution rates to manipulate ruminal starch fermentability and site of starch

digestion. Therefore, substitution of NFFS for both forage and grain might be necessary to limit diet fermentability as the forage content of the diet decreases.

A limitation of NFFS as a forage alternative is that particle length is not adequate for formation of the rumen mat. In addition, passage rate is generally greater for NFFS NDF than for forage NDF, and ruminal digestibility can decrease if poor mat development reduces NDF retention time in the rumen. If adequate long particles are provided by coarse forage in the diet, NFFS can contribute to mat formation because they tend to be buoyant and become entrapped. Another limitation of NFFS is that, compared with cereal grains, NFFS provide fewer metabolic precursors of glucose, which can be limiting for lactose synthesis and therefore for milk production, particularly for high producing cows.

Cereal grains

Although one doesn't normally think of cereal grains as forage alternatives, they also can be used in the dietary space vacated by forage. Cereal grains contribute to less digesta mass in the rumen than NFFS because their retention time and water holding capacity are lower. The extent to which a cereal grain can replace forage in the diet without reducing feed intake or causing ruminal acidosis depends on its digestion characteristics. Cereal grains with moderate ruminal fermentability and high whole-tract digestibility, such as dry ground corn, are desirable to include in diets in place of forage. They are less filling than forages and have higher energy concentrations. They have an advantage over NFFS because more glucose precursors are provided from starch digestion compared with fiber digestion as previously mentioned. Highly fermentable starch sources such as finely ground high moisture corn, barley, wheat and bakery waste should be avoided to prevent excessive fermentation. Starch sources with low total tract starch digestibility such as unprocessed sorghum or coarsely cracked corn should also be avoided because they reduce the energy density of diet.

Ruminal fermentability of starch varies among cereal grains, and it might be possible to increase meal size and feed intake by reducing ruminal fermentability and propionate production. A recent experiment from our laboratory showed that meal size increased from 4.2 to 5.1 lb, and feed intake increased from 45.8 to 49.5 lb/d as dry ground corn replaced high moisture corn in high starch diets fed to lactating dairy cows. True ruminal starch digestibility decreased from 71% for high moisture corn to 47% for dry ground corn with no effect of treatment on total tract starch digestibility (95%). Although actual milk yield was similar for the two treatments, fat-corrected milk yield was similar for the two treatments, fat-corrected milk yield tended to be 6.6 lb/d higher for dry ground compared with high moisture corn treatment because of higher milk fat concentration. When forage is replaced with cereal grains, those

grains with slower ruminal fermentation are likely to improve feed intake and milk production, depending on their digestion characteristics and other dietary characteristics as discussed below.

Consideration for Feeding Low-Forage Diets

The forage concentration of diets can be reduced by forage alternatives in many situations; in some, forage alternatives can replace a large fraction of the forage, allowing very low forage diets to be fed. Ohio researchers suggested that when diets for mid-lactation cows contain whole cottonseeds, they can contain as low as 9-11% forage NDF as long as non-structural carbohydrates (starch and sugars) are no more than 30% of diet DM. Diets without whole cottonseeds should contain no less than 14-16% forage NDF and no more than 30% non-structural carbohydrates. Nebraska researchers reported that a wet corn milling product (40% NDF, 23% crude protein) has the potential to replace all of the concentrate and up to 45% of the forage in the diet for lactating cows. The forage content of diets can be minimized by considering the following recommendations.

Include forages with high fiber concentrations and long particles. Forages vary greatly in fiber concentration and particle size, and long fibrous particles distinguish forages from other feed ingredients. Therefore, the forage content of diets can be reduced if forage with higher fiber concentrations and longer particles are used. For instance, a diet formulated using a forage containing 50% NDF can contain 20% less forage to provide the same forage NDF concentration compared with a forage containing 40% NDF, because more fiber is provided per unit forage weight. However, it is also important to consider digestibility of forage NDF; increasing forage NDF by delaying harvest will decrease the rate and extent of NDF digestion, which will decrease the energy supply to microbes and to the animal. Across cuttings and maturities, NDF concentration is poorly related to digestion characteristics of NDF for alfalfa, so it is possible to purchase or select forage with both high NDF content and high NDF digestibility. Corn hybrids with high NDF and high NDF digestibility exist and can be selected when land is limited for forage production. Forages can be compared for NDF digestibility by *in vitro* rumen fermentation or by evaluating the lignin concentration as a percent of NDF; within a forage type, digestibility of NDF decreases as lignification of NDF (%lignin/%NDF) increases.

Less forage also also needed in the diet if forage is long or coarsely chopped. Fibrous particles of finely chopped alfalfa or corn silage are not as effective in forming a rumen mat as are longer particles from coarsely chopped forage. Addition of coarse fiber as chopped hay also increases rumen mat consistency and rumination time and decreases passage rate of wet corn gluten feed. The length and concentration of long

particles required in diets is not constant and depends on their digestion characteristics as well as characteristics of other diet ingredients

***Avoid rapidly fermented feeds*.** Rapidly fermented feeds containing sugars and starch should be limited. It is important to consider the fermentability of *all* diet ingredients when feeding low forage diets because most forage alternatives are more fermentable than forages and are also less effective at stimulating chewing. Limiting rapidly fermented feeds such as finely ground high moisture corn and molasses will reduce the risk of acidosis.

***Manage to avoid slug feeding*.** Diets with less coarse fiber require less chewing during eating and can be consumed more quickly, resulting in larger meals before satiety occurs. Although this might be desirable to increase feed intake in some situations, it also can result in ruminal acidosis if fermentation acids cannot be absorbed quickly enough, and the buffering capacity of ruminal contents is greatly exceeded. Overcrowding and feeding for no weighback increase competition among animals and encourage slug-feeding and should be avoided when feeding minimum forage diets.

Include dietary buffers. Although efforts should be made to reduce fermentability by limiting highly fermentable feeds, and to reduce slug-feeding by providing adequate bunk space, inclusion of buffers makes sense as another way to reduce risk of acidosis.

***Limit NFFS with high fat content*.** Concentration and availability of poly-unsaturated fatty acids might limit inclusion rates for some NFFS such as whole cottonseeds and distiller's grains because of potential milk fat depression. Limitations depend on fatty acid concentration and composition of the NFFS and other dietary ingredients.