Basics of dairy diet design: Feeds and how they are included in diets

Enrique Schcolnik, DVM
Progressive Dairy Solutions, Inc., Stockton, CA 95207

Abstract

The challenges of feeding dairy cows to maximize production while doing it in an economically sustainable way, requires dairy nutritionists and veterinarians to have a great understanding of rumen microbial output and the feeds we utilize to feed the rumen. It is the purpose of this presentation to describe and explain some very basic concepts of rumen dynamics and microbiology that are utilized to make decisions on how to include different feeds into diets while maintaining rumen and cow health and maximizing rumen output.

Key words: dairy, diet, design, feeds

Introduction

With the diversity of feeds available to feed dairy cattle and the challenges of feeding high-producing dairy cows, it is easy to lose perspective of the big picture of what is necessary to make a healthy and profitable diet. I would like to distill the tremendous amount of information for balancing dairy diets into a few basic concepts that may help you get started understanding dairy cattle feeds and how we feed them.

Rumen Microbes, Environment and Microbial Output

The most important concept to understand about the ruminant dairy cow when it comes to feeding them is that the cow is actually fed by an amazing microbial population that lives in the environment of the rumen, producing energy and protein primarily in the form of volatile fatty acids and microbial protein. It is these nutrients produced by the rumen microbes that feed the cow for maintenance, with the surplus nutrients used to produce milk. The remainder of nutrients not produced in high-enough amounts, or at all, by the rumen microbes, such as vitamins, minerals, soluble protein, fats, amino acids etc., are supplemented by us.

With the help of dynamic nutritional modeling software (CNCPS-based models), we are able to measure rumen output and get information on how to properly balance diets to maximize rumen output and also to get information on what nutrients are needed to be supplemented.[3] Energy rumen output is measured in metabolizable energy (ME) and protein rumen output is measured in metabolizable protein (MP).

Rumen nutrients and environment are key to keeping the rumen microbial population large and healthy in order to maximize rumen output. Therefore, a consistent supply of nutrients and a stable rumen pH are extremely important in order to keep the ME and MP outputs consistent. It is the constant outputs of ME and MP that keeps milk production consistent and increasing over time.

In order to keep the rumen microbial population fed, we always need to have feed available to the cow, keep the feed consistently mixed, have the feed not easy to sort, have the feed pushed up within reach of the cow at all times, and keep the feed fresh and palatable.

Types of Nutrients

We can divide the types of nutrients fed to cows into 5 general categories: carbohydrates, protein/amino acid/nitrogen sources, fats, minerals, and vitamins. Because carbohydrates are typically the rate-limiting nutrient when it comes to rumen microbial output, they are considered the most important nutrient to drive rumen output, and carbohydrates are generally used as the center for which the rest of the diet is built. Carbohydrates also have the greatest potential for altering rumen environment, and therefore should be carefully evaluated not only in quantity, but also for the magnitude of effect they may have upon rumen pH based on their rates of fermentation. The faster-rate carbohydrates have the greatest potential to increase rumen output as well as the greatest potential to exceed the natural rumen buffering capacity. This is because carbohydrates drive volatile fatty acid production (lactic, acetic, butyric) and as their name implies, these fatty acids, if produced in excess of rumen buffering capacity, will drop the rumen pH, with the concomitant negative effect upon the rumen microbial population and health.[1]

Structural vs Nonstructural Carbohydrates

Carbohydrates can be broken down into 2 classes: nonstructural and structural. Nonstructural carbohydrates are found inside the cells of plants. They are more digestible. They don't play much of a role in keeping plants standing. Structural carbohydrates are part of plant cell wall and they are less digestible. They play an important role in keeping plants upright. Therefore, the more mature the plants in the field, the higher their structural carbohydrate content.

The most important nonstructural carbohydrates in plants are starches, sugars and pectins, and we use them as a unit of measure for feeds and for diets. We measure their amount in feeds and diets as a percent, and we also measure

Predicted ruminal pH

Minimum ruminal pH	5.90
Maximum ruminal pH	5.31
Range pH	6.51
Time below pH 5.6, hours/d	1.19
Time below pH 5.8, hours/d	5.87
	9.20

pH NDS | Feeding Frequency | pH Fluctuations
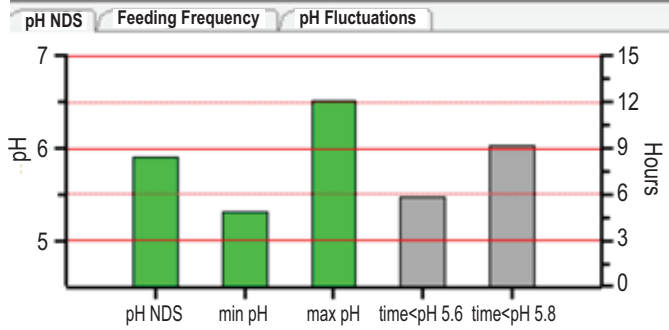
(From NDS – Nutritional Dynamic System – Professional)

their relative rates of fermentation in order to estimate total VFA and subsequent ME output. By measuring these parameters, we can estimate the impact they'll have on rumen pH.

Structural carbohydrates are composed of cellulose, lignin, and hemicellulose. They are often measured by ADF (cellulose and lignin) and also by NDF (includes cellulose, lignin and hemicellulose). They are overall less digestible than nonstructural carbohydrates. They promote chewing and saliva production, have a slower passage rate and are a big contributor to rumen fill, so they can limit feed intakes. Just like structural carbohydrates, different feeds have different rates of fermentation (kd's). The feeds with higher NDF digestibility will yield higher energy.

In order to keep a healthy rumen environment, there are some guidelines for minimum fiber recommendations. These minimum fiber recommendations are the minimum fiber necessary to stimulate necessary cud chewing. It is the floating mat in the rumen that stimulates the regurgitation reflex with the concomitant chewing of the feed and saliva production. Adult cows typically don't chew their

NFC Breakdown

Feedstuff	Sugar	Starch	Pectin	VFAs
			% of NFC	
Alfalfa silage	0	24.5	33.0	42.5
Corn silage	0	71.3	0	28.7
Corn grain	20.9	80.0	0	0
Barley	9.1	81.7	9.2	0
Beet pulp	33.7	1.8	64.5	0
Soyhulls	18.8	18.8	62.4	0
Soybean meal	28.2	28.2	43.6	0

Minimum Fiber Recommendations

Min Forage NDF	Min Dietary NDF	Max Dietary NFC	Min Dietary ADF
19	25	44	17
18	27	42	18
17	29	40	19
16	31	38	20
15	33	36	21

(Adapted from NRC 2001 and NRC 1989)

feed when they eat. They only chew after they regurgitate their cud. It is the chewing that generates saliva production. No regurgitation=no chewing=no saliva production=no buffering=lower pH=dead or unhealthy rumen microbial population.

There are differences in the NDF measured in forages vs NDF measured in grains. Non-forage fiber has a larger pool of degradable NDF, its particle size is smaller (may not contribute much to the top of the rumen mat) and has a faster passage rate (less of a contributor to rumen fill). Also, some digestible NDF may escape ruminal fermentation.

When we look at NDF recommendations for dairy diets, we have to look at them in the context of:
- Starch availability
- Forage particle size
- Supplements (rumensin, yeast, etc.)
- Farms management (overcrowding, cow comfort, lock up times, etc)
- Consistency of feeds

In addition to carbohydrates, when discussing maximization of rumen microbial production it is important to consider that rumen microbes need an adequate supply of rumen degradable protein. Rumen bacteria require peptides, amino acids and ammonia. Protozoa require peptides and amino acids. This is measured in diets as rumen degradable protein or RDP.

Rumen Environment

The environment in which rumen microbes grow is very important for the output they can generate. The higher the output, the higher the energy and protein available above maintenance requirements and therefore the higher milk and components produced.

In order to maintain a stable rumen environment, we need:
- Physically effective fiber
- Feed free from mold and spoilage (biogenic amines)
- Appropriate amounts/types of fats
- Feed additives

Summary of Carbohydrates

Lignin	Cellulose	Hemicellulose	Pectin	Starch	Sugars
Cell Wall	Cell Wall	Cell Wall	Cell Cytoplasm	Cell Cytoplasm	Cell Cytoplasm
ADF	ADF				
NDF	NDF	NDF	NFC	NFC	NFC

Lignin	Cellulose	Hemicellulose	Pectin	Starch	Sugars	Fats	Proteins	Minerals	Vitamins
Cell Wall	Cell Wall	Cell Wall	Cell Cytoplasm	Cell Cytoplasm	Cell Cytoplasm	Cell Cytoplasm	Cell Cytoplasm	Cell Cytoplasm	Cell Cytoplasm
ADF	ADF								
NDF	NDF	NDF	NFC	NFC	NFC	Lipids	AA's- NPN	Cation/Anion	Fat/Water Soluble

(Adapted from Feeding the Dairy Herd, NRC 2001 and NRC 1989)

General Feeding Guidelines

- Higher production requires higher ration costs
- Feeds are packages of nutrients
- Every ingredient must add value
- Look for opportunities to improve farm management
- Look for opportunities to improve forage quality

Focus on science, but don't forget the art of feeding cows. Factors that are not easy to quantify or haven't been quantified yet, can have a tremendous impact of performance.

Cliff Notes
1. Focus on rumen output
2. Supplement the rest
3. Consistency is king

Feeds and How We Feed Them

Break down feeds by their content of structural (NDF) and nonstructural (starch, sugars, pectins) carbohydrates and secondly, look at degree of digestibility of each of those (NDFd, 7 hs Starch). Once you get an overall idea of each feed, accurately load them up into your ration balancing program to address balancing.

Diet Evaluation

When evaluating a diet, it is important to check that we have enough level of effective fiber in the context of management and facilties. Check to see what level of peNDF is acceptable for the dairy. Also, assess level of fermentable carbohydrates and their respective digestibility. If we have an imbalance between the fiber and fermentable carbohydrates, it will negatively impact feed conversion and health.

Factors to Consider when Bringing a New Feed or Adding More of an Existing Feed

Consider current state of the diet and where it stands in the spectrum of amount of physically effective fiber vs fermentable carbohydrates. If one wishes to bring a highly fermentable feed into a diet that is already in the low spectrum of peNDF, you may have to limit this new feed to a low inclusion rate or you may have to adjust to feed more forage in order to bring it in to the ration and still have a healthy diet. The opposite can be true as well. If we find a good-value feed that is very high in structural carbohydrates, we may now have to shift to feeding more feeds that have a high content of nonstructural carbohydrates in order to make sure that rumen microbes have enough feed to grow.

Reasons for Bringing a New Feed

- It is more cost-effective per unit of nutrient (carbohydrates or other nutrients)
- It brings in needed peNDF or nonstructural carbs to balance other feeds currently fed
- Feed is more consistent than other feeds
- Feed is more available than other feeds
- Feed is easier to feed than other feeds
- Feed is more stable than other feeds

We can learn a lot by comparing and contrasting different feeds and getting a big picture of how they would fit into different diets. Take time to compare different byproducts such as almond hulls, citrus pulp and some odd feeds such as pizza sauce, and Twizzler candy against corn silage, rolled or ground corn. How do they stack up against them? What nutrients do they bring in that are similar to traditional forages and grains?

Conclusions

When evaluating diets and feeds, focus on rumen output, which is driven primarily by carbohydrates. Measure output in metabolizable energy production and metabolizable protein production. Always balance for the correct feed consumption, since cows don't eat in percentages but instead eat in pounds of nutrients. Create a great rumen environment in order to make microbial output for efficiency and balance the rest of the diet for nutrients that microbes are not able to produce in high-enough amounts or at all.

Build the diet around home-grown forages that are available to feed. Diets can vary from 25% forage to 75% forage, depending on forage quality and availability. Find and use by-product feeds, but make sure you have the correct information to accurately assess their value and how to balance for them. Lastly, fill in the rest with other feeds such as traditional grains.

Acknowledgement

References

1. Cannas A, Van Soest PJ, Pell AN. Use of animal and dietary information to predict rumen turnover. *Anim Feed Sci Technology* 2003;106:95-117.
2. Casper DP, Whitlock LA, Schauff D, Jones D. Consider the intake/efficiency trade-off. *Hoard's Dairyman* 2003;148:604.
3. Marins TN, Monteiro APA, Weng X, Guo J, Orellana Rivas RM, Bernard JK, Tomlinson DJ, DeFrain JM, Tao S. Response of lactating dairy cows fed different supplemental zinc sources with and without evaporative cooling to intramammary lipopolysacharide infusion: metabolite and mineral profiles in blood and milk. *J Anim Sci* 2020;98. https://doi.org/10.1093/jas/skaa323.
4. National Research Council (NRC) 2001 and NRC, 1989
5. Nutritional Dynamic System – NDS Professional Ration Formulation Software.