FORAGE QUALITY: IMPORTANT ATTRIBUTES & CHANGES ON THE HORIZON

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BACKGROUND

I arrived at UC Davis in October 1979, back in the Stone Ages. I can still remember my first UC Davis Dairy Cattle Day presentation (1980) in 194 Chemistry. I presented data from my Ph.D. research on forage quality at Penn State. In my research project the main forage was corn silage along with about three pounds of long alfalfa hay per cow daily. After my talk, a dairy producer came up to introduce himself, to say hello, and to tell me “Ed, corn silage is for low producing cows. In California we feed alfalfa hay to high producing cows.” True, when I came alfalfa hay (hay or cubes) was the predominate forage in the diet of high producing dairy cows.

But there have been changes. In a recent survey of 40 dairy farms in Merced County that looked at 104 Total Mixed Rations (TMR), 102 of the TMR had alfalfa hay (Castillo et al. 2012). The average Dry Matter Intake (DMI) of alfalfa was 4.26 kg per cow (approximately 10.4 pounds As Fed Basis). The range in alfalfa DMI was 0.95 to 9.09 kg per cow, which is roughly 2.3 to 22.3 pounds of alfalfa AS Fed Basis. Unfortunately there are no historical data that I am aware of, but it is likely that proportion of alfalfa hay in diets of lactating dairy cows decreased over the past two decades with increased proportions of corn and cereal silages. There are many reasons for this shift in forage type fed ranging from the cost of alfalfa hay to the fact that corn and cereal silages fit a double cropping system that allows management of nutrients excreted by cows.

INTRODUCTION

Forage quality can be defined many ways. One of the simpler definitions is that forage quality is the production output of a given animal (e.g. milk yield by dairy cows, body weight gain for beef or sheep) in response to forage consumption and utilization of the available nutrients and energy. Therefore, forage quality is a product of voluntary intake and nutrient and energy digestibility of the forage in question. Forage quality is a function of the rate and level of intake, the rate and extent of digestion, and the efficiency with which nutrients and energy are utilized by the animal (Barnes and Marten 1979). Animal performance is a biological assessment of forage quality.

To measure the quality of a forage in terms of animal performance, three general criteria must be met: (1) animals must have the potential to produce a product, (2) forage availability must not be limiting, and (3) the forage provides the dietary supply of nutrients and energy (Moore 1978).

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There are many factors that affect forage quality. The more important are plant maturity, climate, and forage species. These will be discussed only briefly from the view of an animal scientist. However, there are many factors affecting forage quality of alfalfa including hybrid type, water stress, soil fertility, harvest and storage methods, dormancy, insect damage, to name a few, which are beyond the scope of this paper and would be better explained by a plant scientist.

Maturity: Most forage decline in quality with advancing maturity. This relationship is strongest with first-cut material. As the alfalfa plant matures, there is an increase in lignin and cell wall components and a decrease in protein content. These changes result in an overall decrease in organic matter digestibility of the alfalfa. If digestibility is decreased, the energy obtained by the animal is decreased so that animal performance will be reduced – indicating lower forage quality.

The effect of maturity is difficult to separate from the impacts of increasing temperature and light that occur in the spring. But for the most part as the alfalfa plant progresses from the bud to full bloom stage, forage quality declines.

Temperature: In general, as temperature increases the nutritive value of the alfalfa decreases. As temperature increases, the metabolic activity of the plant increases and new cells and plant substances are produced. Lignin content often increases with increasing temperature, and the effect of increased lignin has been a decrease in *in vitro* dry matter digestion.

Light Intensity: Sunlight is the source of energy for photosynthesis that produces chemical energy in the plant. Light intensity (independent of temperature) increases the water soluble carbohydrate content of the plant. This has come into perspective more recently with discussion of cutting hay at night or in the morning to influence forage quality.

ALFALFA HAY TESTING IN CALIFORNIA

In California there is a system to predict the quality of alfalfa hay based on the acid detergent fiber (ADF) concentration in the alfalfa hay. It is a prediction system because as stated earlier the true measure of forage quality is the performance of an animal fed the forage – an *in vivo* measure. Feeding animals to measure forage quality is not realistic to we must predict forage quality. The California Hay Testing system is based on the relationship that as ADF content of the alfalfa plant increases, its digestibility (energy content) decreases. Total digestible nutrients (TDN) measurement was the basis for the estimates of digestibility.

The empirical relationship on a 100% Dry Matter (DM) basis is:

TDN (% DM) = 82.38 – (0.7515 x %ADF)

NEL (Mcal/kg DM) = 1.8983 – (0.0184 x %ADF)

In the California hay marketing system, TDN is used and TDN is expressed on a 90% DM basis. Nutritionists use NEL when formulating rations for animals so in the future the system should move from TDN to NEL (net energy for lactation).

At the current time, we are revisiting a data set for alfalfa digestion that was generated by Bill Garrett to look at how these data compare with the equation used by the California Hay Testing Program. There will be more to come in the future.

UNIQUE ATTRIBUTES OF ALFALFA FOR DAIRY COWS

It is likely that every nutritionist would have different unique attributes for alfalfa hay. Therefore, the list provide is my view and is somewhat limited based on my experiences.

Alfalfa hay is an excellent source of digestible protein. The protein is rumen degradable protein (approximately 80% of the protein is degraded in the rumen) to support a robust microbial population (Getachew et al 2006). The rate and extent of alfalfa protein in the rumen is potentially something that could be a concern with respect to efficient utilization of the protein for retention in product (e.g. milk and meat) (Getachew et al. 2006). There are efforts to reduce the rate and extent of rumen protein degradation to enhance the efficiency of nitrogen utilization.

Alfalfa hay is consumed at high levels of intake. Legumes were often consumed in higher amounts than grasses (Van Soest 1995). The amount and digestibility of the NDF (neutral detergent fiber or the cell wall content) are factors that impact DMI (Mertens 1987). Oba and Allen (1999) stated that “digestibility of NDF is an important parameter for forage quality”. Within a forage family, high NDF digestibility was related to increased DMI and milk yield. For a range of forages, as the cell wall content increased, organic matter intake by sheep decreased (Van Soest 1994). Legumes such as alfalfa are in general lower in NDF content than grasses. Early work by Van Soest (1995) also demonstrated that a similar DM digestibility, intake of legumes was higher than grasses. Even though alfalfa contains more lignin content than most grasses, NDF digestion in the rumen is still better than grasses. Spanghero and Zanfi (2009) performed a meta analysis of studies feeding dairy cows diets with varying proportion of alfalfa hay and corn silage as the forage component and for studies that performed whole tract NDF digestibility of the diet. As NDF content of the diet increased, DMI by the lactating cows decreased. Energy corrected milk yield was not affected dietary NDF concentration and the authors proposed reasons for this lack of response although changes in milk yield are often difficult to detect in short term studies. Finally, diets based on alfalfa hay had higher whole tract digestibility of NDF compared with diets based on corn silage.

The NDF of alfalfa also contains considerable pectin, which is a cell wall carbohydrate that has a high rate and extent of degradation in the rumen (Bourquin and Fahey 1994; Van Soest 1995). In a recent review of forage silages, cows fed legume silages produced more milk and had higher feed intake than cows fed grass silages further supporting the advantage of legumes (Steinshamn 2010)

Alfalfa hay provides ruminal buffering capacity. Buffering capacity is promoting by the fiber aspects of the NDF that promote cud chewing and rumen contractions (rumination). The act of cud chewing reduces the particle size of plant material to enhance digestion by microbes and stimulates the production of saliva with bicarbonate and phosphate buffers to help neutralize the acids produced during anaerobic fermentation in the rumen (Allen 1997). Rumen contractions present the acid end products of anaerobic fermentation to the papillae lining the rumen wall for acid absorption to help maintain rumen pH (Allen 1997; Dijkstra et al. 2012). Pectin although it is rapidly fermented is not fermented to lactic acid, a strong acid. Lignin and pectin, cell wall constituents present in alfalfa as well as other feedstuffs, impart buffering capacity (Salimei et al. 1994). Cation exchange of metal cations on fiber for hydrogen ions (H+) affects rumen pH. Total in vitro buffering capacity of alfalfa hay was high (Fadel 1992). However, the impact of total buffering capacity of feeds in the diet may have little impact within the normal pH range (5.5 to 6.8) in the rumen (Allen 1997). Regardless, the buffer capacity of alfalfa fiber should not be ignored and it deserves further study.

Alfalfa particles in the rumen might also more readily provide adsorptive surface for long change fatty acids (Palmquist and Yang 1999). Dietary lipids are subjected to hydrolysis in the rumen by microbial lipases. These unesterified fatty acids can inhibit growth of various microbial populations by adsorption to microbial surfaces. In theory, adsorption of long chain fatty acids to feed particles could reduce the inhibitory effect of fatty acids on microbial growth. In their *in vitro* study (Palmquist and Yang 1999), alfalfa hay particles adsorbed more C17:0 than particles of timothy hay and wheat straw. The authors discussed three possible mechanisms of action. These authors also reported that alfalfa silage particles adsorbed more fatty acids than corn silage particles. Thus, alfalfa fiber might offer unique properties when included in diets with feedstuffs high in fat, for example distillers grains. Granted, these data (Pamquist and Yang 1999) are *in vitro* data, but again as with buffering capacity discussed previously – this effect of fiber binding fatty acids deserves further study.

FUTURE CHANGES

There are many changes that will happen in the future that will change how the quality of alfalfa hay is predicted.

Down regulated lignin alfalfa is on the horizon. These varieties of alfalfa have been genetically engineered to reduce lignin synthesis. As a result the digestibility of cell wall (cellulose and hemicellulose) is increased. How this down regulation of lignin impacts the California Alfalfa Hay Testing Program's equations is uncertain, but it is likely to have a dramatic impact. The negative relationship between %ADF and organic matter digestibility may not be as great as with the non-genetically engineered alfalfa.

Alfalfa protein may continue to increase in value as costs of protein supplements increase. One issue for alfalfa protein is its high rumen degradability. The high rumen degradability reduces nitrogen utilization and retention in animal products. But there are research efforts to insert a gene for tannins into alfalfa with the goal of reducing alfalfa protein degradability in the rumen – either rate of degradation or extent of degradation. The research is in the early stages so there is more to come.

New approaches to formulating diets for dairy cows are always being developed. An interesting approach being pursued is to use ruminal digestibility of carbohydrates including starch and NDF. This approach is from Calibrate Technologies of Forage Genetics International (www.calibratetechnologies.com). This approach goes beyond starch and NDF content of the diet and is based on digestibility of entities within feedstuffs to promote rumen function, high DMI, and high milk yield.

ALFALFA'S CHANGING ROLE IN DAIRY DIETS

A summary of a small, informal phone survey of dairy nutritionists who are formulating diets on commercial dairy farms was conducted.

Forage Quality:

Forage quality is still important. Want hays that are 55 to 57% TDN in diets of lactating cows. However, how high is too high for forage quality? You still need fiber to promote rumen mat formation and optimum digestion and utilization of nutrients. It is not uncommon to include 1 to 2 pounds of straw, wheat hay, or oat hay into the diet when corn silage is a high proportion of the forage to obtain the effective fiber aspects missing when alfalfa hay is low in the diet. These feeds increase the NDF content of the diet to promote the mat formation and slow rate of passage. Prefer to use low lignin and higher NDFd30 alfalfa hay for the highest producing cows.

Important Attributes:

Calcium. Alfalfa is an excellent source of available calcium. There are attempts to reduce ration costs by reducing the mineral supplement fed. Calcium is alfalfa hay then becomes more important as a dietary nutrient.

Protein. With soybean meal at $/ton and canola meal at $/ton, the protein in alfalfa becomes more important. In the past protein was not as important.

Quantities of Alfalfa Hay Fed:

Less fed now than in the past, but the range is large. In the past, most cows were fed some alfalfa hay with the lowest amount around 3 to 5 pounds (As Fed) per cow daily. Now, there are some dairy farms feeding no alfalfa hay up to 16 to 17 pounds of alfalfa hay per cow daily. Nutritionists are also using almond hulls to stretch their forage needs. Feeding 3 to 5 pounds of almond hulls per cow daily was very common 10 to 20 years ago. Now with high priced forage cows are fed 8 to 10 pounds of almond hulls.

Why the difference? Possible reasons include the following. Some dairy farms do not own enough land to grow the silage (corn and cereal) needed so they must buy forage. Some dairy farms are finding it more difficult to have neighboring farms grow their silage because of competing crops. It might be more profitable for a neighboring farmer to grow almonds than corn for silage. Price of hay is higher now and with international demand for alfalfa hay increasing, this impacts local hay prices. Why do growers want to haggle over a ½ point of TDN in the local market where in the international market the purchaser is willing to pay the price.

Feed way less alfalfa hay now. Feeding less alfalfa hay because it is overpriced.

What Are Important Attributes of Alfalfa Hay to Consider:

Rate and extent of digestion should be considered. NDFd is important with respect to extent, but the rate is also important. Rate and extent determine how a diet is formulated.

Quality and consistency are important when purchasing hay.

Improve digestibility.

SUMMARY

There is less alfalfa hay fed in dairy diets now than 10 to 20 years ago. However, forage quality is still important. Genetic modification to enhance chemical components will be important factors determine the future role of alfalfa hay in dairy diets.

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