WHAT ARE DAIRY NUTRITIONISTS LOOKING FOR IN ALFALFA HAY ?

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ABSTRACT

Dairy cattle nutritionists value alfalfa hay for its high energy value which supports milk production, its rapidly rumen digested structural fiber which stimulates feed intake, its coarse structural fiber that stimulates ruminative chewing and salivation which results in rumen buffering, its structural fiber which has a high buffering capacity, its high protein level which supports animal protein needs, and the relatively high proportion of its protein that escapes the rumen undegraded which minimizes dietary requirements for high cost protein supplements. Many of these nutritional attributes can be maximized by selection of the most appropriate cultivars and proper harvest management. New cultivar development offers the possibility to further improve these nutritional attributes. However it would be undesirable if, in the drive to create higher energy alfalfa hays, the fiber level of new cultivars of alfalfa hays were further reduced. Alfalfa hay is a forage and its structural fiber gives it many of its strengths as a feed for dairy cattle. Efforts to increase the energy level of alfalfa hay should concentrate on increasing the rate and extent of digestion of structural fiber in the rumen, without losing the positive nutritional characteristics, and quantity, of the structural fiber.

Key Words: alfalfa hay, fiber, energy, dairy cattle

INTRODUCTION

Alfalfa hay has been a significant feedstuff in rations of California dairy cattle for a long time. Indeed, it can and has been argued that the availability of high quality alfalfa hay allowed the dairy industry to become established in California. However as prices of alfalfa hay soared to as high as $190 per ton last winter, many dairy ranchers searched for ways to reduce, or eliminate, alfalfa hay from dairy rations while maintaining milk production. This proved to be a difficult, often economically impossible, task since alfalfa hay combines a number of beneficial nutritional attributes that are seldom found in the same feedstuff.

The objective of this presentation is to highlight some of the key nutritional attributes of alfalfa hay, identify some nutritional problems with alfalfa hay, and suggest strategies for future development of new alfalfa cultivars that will maximize their economic value to growers and feeders.

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WHAT IS RIGHT ABOUT ALFALFA HAY ?

Alfalfa hay has a number of beneficial nutritional attributes that make it a high quality feedstuff for dairy cows. Some of these attributes are outlined in Table 1.

Energy. Alfalfa hay generally contains between 25 and 30% of its dry matter as rapidly digested non-structural carbohydrates (NSC), such as pectins, sugars and starches, that quantitatively contribute to the level of total digestible nutrients (TDN) in the hay. In addition, the total structural fiber in alfalfa hay, ranging between 35 and 40% of total hay dry matter (DM) as neutral detergent fiber (NDF), is rapidly digested by microorganisms in the rumen leading to a high proportional contribution to the hay's TDN value. The high protein level, generally ranging between 18 and 24% of DM, is also highly digestible (80 to 90%), which further contributes to the high TDN value of the hay.

Structural Fiber. Alfalfa hay fiber, measured as NDF, is ideal for stimulating ruminative chewing in dairy cows. This is not an insignificant nutritional attribute, as ruminative chewing (i.e., chewing the cud), stimulates the flow of saliva to the rumen. Saliva has a high buffering capacity and so its flow to the rumen will help prevent rumen pH from declining and potentially inducing the metabolic problems associated with rumen acidosis. In addition, alfalfa hay NDF has a high buffering capacity, which increases the overall amount of buffering that results from intake of alfalfa hay.

However, the low level of NDF in alfalfa hay, compared to competing forages, where values as high as 60% NDF occur for cereal or grass hays and silages, is also important in determining maximum DM intake, as NDF is often the main nutritional component that limits DM intake by dairy cattle. This is because NDF is, in general, relatively slowly digested in the rumen and must be reduced in size before it can pass out of the rumen to the lower digestive tract. Until it passes from the rumen, or is digested in it, NDF acts as a limit to further intake. Because the NDF level in alfalfa is relatively low, and because alfalfa NDF is relatively rapidly digested in the rumen, it clears the rumen more quickly than the NDF in most grass hays and silages thereby promoting further intake of feed.

Table 1. Nutritional characteristics of alfalfa hays of various quality categories*.

Category	CP (% DM)	SolP (% CP)	ADIP (% CP)	UIP (% CP)	NDF (% DM)	ADF (% DM)	TDN (% AF)	NEl (Mcal/lb)
X-Premium	24.0	25	7.0	27	33	26.0	56.6	.575
Premium	22.0	24	7.3	29	36	28.0	55.2	.559
Good	20.5	22	7.7	31	39	30.5	53.5	.540
Fair	18.0	21	8.0	33	43	33.5	51.5	.518

* CP is crude protein; SolP estimates CP instantly soluble in the rumen; ADIP estimates indigestible CP; UIP estimates CP that escapes the rumen intact; NDF estimates total structural fiber; ADF estimates the portion of NDF that is not hemicellulose; TDN is total digestible nutrients; NEl is net energy for lactation. TDN is calculated as: (82.38 – (.7515 x ADF %)) x 0.9 and NEl is calculated from TDN as: ((.0245 x TDN %) - 0.12) x 0.454.

Protein. Alfalfa hay generally contains a level of crude protein (CP) that is much higher than in competing forages such as cereal silages. In addition, alfalfa hay protein has a relatively low proportion that is soluble in rumen fluid, often about half the level in cereal silages, and this leads to an undegradable intake protein (UIP) proportion of 25 to 35% of total CP. Because the performance of dairy cows, particularly high producing dairy cows, is often limited by dietary supplies of dietary UIP, this means that dietary supplementation with high-cost protein supplements that are rich in UIP can be reduced, thereby lowering the cost of the overall ration to the dairy producer.

Minerals. Alfalfa hay is relatively high in several minerals that are required by lactating dairy cows. These include calcium, phosphorus, potassium and magnesium, although alfalfa hay also contains significant levels of most other macro and trace minerals. However, unlike the previously discussed nutritional attributes, minerals have a relatively low economic value, as they can be inexpensively supplemented to a dairy ration from inorganic sources.

WHAT IS WRONG WITH ALFALFA HAY ?

In a nutshell, there is not much that is wrong with alfalfa hay, as it has few nutritional characteristics that make it a poor quality feed for dairy cows.

Energy. Alfalfa hay has a high energy value relative to competing forages.

Structural fiber. Alfalfa hay structural fiber, as estimated by NDF, is close to the ideal structural fiber for dairy cows.

Protein. The high level of CP with a relatively high proportion that is UIP makes alfalfa hay CP a high quality protein for dairy cows.

Minerals. While the minerals in alfalfa hay have nutritional and some economic value under most circumstances in meeting the nutritional requirements of dairy cows, they can be replaced in dairy rations from inorganic sources easily and inexpensively. Indeed, alfalfa hay would be more valuable if all minerals could be eliminated and replaced by fiber, protein or NSC. While this is not biologically possible, minerals such as potassium, and perhaps magnesium, have increased in recent years to levels that are causing diet formulation problems for dairy cattle nutritionists. Reduction of the levels of these minerals in alfalfa hay would be advantageous from this regard, as well as increasing the energy value of the hay, as minerals in alfalfa have no energy value.

WHAT CAN BE IMPROVED IN ALFALFA HAY ?

There is no ideal forage, and it is clear that the nutritional attributes of alfalfa hay can be improved to increase its relative economic value.

Energy. Alfalfa hay is a forage with an energy value that is lower than concentrate ingredients such as grains, and it is bought and sold as such. There is no question that the value of alfalfa hay increases as its energy value increases. For this reason the focus of alfalfa improvement and harvesting in the recent past in California has emphasized methods to increase the energy value of alfalfa hay by reducing the level of structural fiber, which is generally approximated by its acid detergent fiber (ADF) component. Thus the estimation of the TDN level of alfalfa hay is directly related to its ADF content (i.e., as alfalfa hay ADF declines the TDN increases; indeed according to equations currently used in California there is NO OTHER WAY to increase the energy (i.e., TDN) value of alfalfa hay other than to reduce its ADF level). While this strategy has been beneficial on the short term, to increase the energy and economic value of alfalfa hay by increasing the higher energy NSC and protein fractions of alfalfa hay, it is a strategy of diminishing returns that should now be seriously reconsidered since it is having the undesirable side-effect of making alfalfa less 'forage-like' and more 'concentrate-like' than it has been in the past.

It is an easy argument to make that the level of structural fiber in alfalfa hay is now low enough, at even 40% NDF in DM, that further reductions will be counter-productive to increasing the economic value of alfalfa hay since it will reduce the quantitative impact of the high quality alfalfa hay NDF. A far more promising and effective strategy to increase the energy value of alfalfa hay is to increase the rate and extent of digestion of alfalfa hay NDF in the rumen in order to increase its digestibility and energy value. This can only be accomplished through plant breeding to develop new cultivars, in association with early cutting strategies. Nevertheless, such a strategy offers the potential of increasing the energy value of alfalfa hay while maintaining its description as a forage. The impact on the TDN value of 'Premium Alfalfa Hay' by changing only the digestibility of NDF is shown in Table 2.

Table 2. Changes in the TDN value of 'Premium Alfalfa Hay' by changing only the digestibility of its structural fiber*.

	CP (% DM)	SolP (% CP)	ADIP (% CP)	UIP (% CP)	NDF (% DM)	dNDF (% NDF)	ADF (% DM)	TDN (% AF)
20% higher	22.0	24	7.3	29	36	68	28.0	60.7
10% higher	22.0	24	7.3	29	36	58	28.0	57.9
Assumed now	22.0	24	7.3	29	36	48	28.0	55.2
10% lower	22.0	24	7.3	29	36	38	28.0	52.5

* CP is crude protein; SolP estimates CP instantly soluble in the rumen; ADIP estimates CP that is truly indigestible; UIP estimates CP that escapes the rumen intact; NDF estimates total structural fiber; dNDF estimates NDF that is digested in the rumen; ADF estimates the NDF that is not hemicellulose; TDN is total digestible nutrients.

It is clear from the values in Table 2 that it is possible to sharply increase the TDN value of alfalfa hay without changing its fiber content if the digestibility of the structural fiber is increased. The current California system of predicting the TDN value of alfalfa hay from the ADF level assumes that digestibility of structural fiber is negatively correlated with the ADF content of the alfalfa hay (i.e., as the ADF level increases, the digestibility of the NDF fraction declines). This is not true, as both alfalfa cultivar and maturity are well accepted to influence digestibility of the structural fiber in alfalfa hay. This is probably the reason why some alfalfa hays 'feed better' and some alfalfa hays 'feed worse' than their calculated TDN value would suggest.

Structural Fiber. Alfalfa hay is close to the ideal fiber for dairy cows and, with the exception of increasing its rate and extent of digestion in the rumen, there is very little that can be done to improve it as a forage for dairy cows. Unfortunately the current strategy to increase the energy value of alfalfa hay, by decreasing the ADF level, is reducing the level of structural fiber in alfalfa hay.

Protein. The high level of CP, with a relatively high proportion that is UIP, makes alfalfa hay CP a high quality protein for dairy cows. However, currently accepted requirements of higher producing lactating dairy cows for dietary CP suggest that the total proportion of dietary CP that should be UIP probably ranges between 35 to 45%. Thus plant breeding efforts to decrease the rumen digestibility of alfalfa hay CP will, under most circumstances, lead to a higher value product.

IS THE VALUE OF ALFALFA HAY PERCEIVED CORRECTLY ?

The economic value of alfalfa hay in California is currently based to a very high degree on its estimated TDN value which, as previously noted, is actually its ADF value. Of all of the positive attributes of alfalfa hay that have been discussed above, it seems odd that the value of alfalfa hay is based to such a high degree on such an obscure nutritional parameter with so little direct nutritional value. The reason that ADF is used so widely is that it is a fast and inexpensive chemical assay and appears to accurately predict the energy value of the hay. However the underlying assumptions that are required to justify this reliance upon ADF as a predictor of the energy value of alfalfa hay are more obscure and difficult to defend. For example correlations between ADF level and NDF level, as well as the digestibility of NDF in the rumen, and ADF and protein level, as well as the digestibility of protein in the rumen, cannot be shown to exist. Indeed, there is substantial evidence that they do not exist.

The nutritional parameters upon which diets for lactating dairy cows are based have become considerably more complex over the past 5 to 10 years. Most rations for lactating dairy cattle are now formulated by nutrition professionals using computer software programs. The beneficial characteristics of alfalfa hay are often not completely described in these programs either because the programs do not include the characteristic (e.g., buffering capacity of the feeds) or because little effort has been devoted to accurately describing the characteristic (e.g., rate and extent of digestion of alfalfa hay

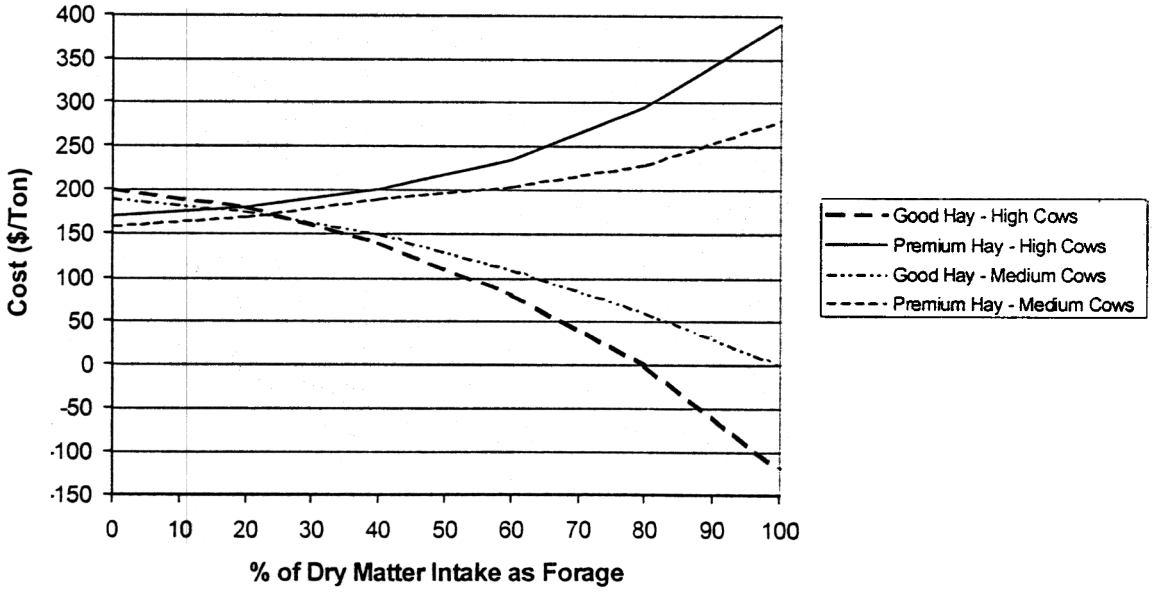
NDF). In order for alfalfa hay to be accurately priced, many more of its nutritional characteristics must be chemically analyzed and used in association with its sale.

One of these key nutritional characteristics, as demonstrated in Table 2, is the large affect of rumen digestion of NDF on the estimated energy value of individual samples of alfalfa hay. For this reason, the author and Dr. D.H. Putnam of UC Davis, have initiated a study to both examine the degree of variation of rumen digestion of NDF in commercial samples of alfalfa hay as well as develop a rapid system to estimate the energy value of alfalfa hay based upon rumen digestion of NDF in alfalfa hay, as well as some other nutritional characteristics of alfalfa hay. The overall objective of this effort is to develop a system that would be suitable for use in commercial laboratories in California.

IS THE PRICE DIFFERENTIAL BETWEEN CATEGORIES OF ALFALFA HAY ALWAYS THE SAME ?

Experience suggests that the market price of 'Premium' Alfalfa Hay is not always the same proportion of 'Good' Alfalfa Hay. To a certain extent, the relative relationship between the prices of hays of different categories depends upon the availability of alfalfa hay, relative to the demand, as well as the cost of competing forages (i.e., fiber). In general, as the price of competing forages rises and/or the availability of alfalfa hay relative to demand declines, then the price differential between categories of alfalfa hays will increase. This is shown schematically on the figure below.

Figure. Value of Alfalfa Hay as Influenced by Hay Quality and Cow Production*.



Intended to demonstrate the relationships. Costs are not absolute.

The figure demonstrates that the price differential between categories of alfalfa hay depends, to a large degree, upon why the alfalfa hay is being added to the dairy ration. For example, as the proportion of forage in the ration declines below about 50%, which is a typical proportion for a high production dairy string on a California dairy ranch, the price differential will narrow since providing sufficient energy in the ration becomes less of a concern than does meeting the minimum level of structural fiber (NDF) required in the ration to prevent acidosis and other metabolic upsets of the rumen associated with a lack of structural fiber in the diet. Since the level of structural fiber in alfalfa hay increases as its quality declines, the price of a poorer category of alfalfa hay will rise relative to a higher quality category. Indeed, if the availability of forages were so restricted that the dairy producer was forced to rely very heavily upon non-forage ingredients, then the value of the lower category hay may actually rise above that of the higher category hay. Conversely, as the availability of forages increases, and their prices decline, then the contribution of forages to the diet will increase. As the amount of forage in the ration increases, the concern about providing sufficient structural fiber in the diet will change to a concern about providing sufficient energy to meet the needs of the cows. Thus the price differential between categories of alfalfa hay will increase. Indeed, if the availability of non-forages became so restricted that forages made up almost all of the diet, only a theoretical possibility to be sure, then the true value of the lower quality categories could fall to near zero, or lower. Nevertheless, the relationships in the chart demonstrate why the price differential between categories of hay narrows in years of low harvests (i.e., diet forage inclusion levels decline) and widens when harvests are high (i.e., diet forage inclusion levels increase). It also demonstrates that the relative value of higher category alfalfa hays will rise as the productive potential of the dairy cows to which it is to be fed increases.

SUMMARY

Alfalfa hay has been, and continues to be, the premier forage crop for dairy cows in California. It combines a number of nutritional attributes, such as rapidly digested structural fiber and high protein levels, that are seldom found in the same feedstuff. While it is not the perfect forage for dairy cows, caution is warranted in attempts to 'improve' it. Indeed the current improvement strategy of driving the fiber (i.e., ADF) out of alfalfa hay as a means of increasing its energy value is a strategy of diminishing returns to increased efforts, and in fact may increase the agronomic costs associated with production of alfalfa hay while decreasing its value as a forage for dairy cattle. More pragmatic improvement strategies should focus on enhancing rumen digestion of structural fiber in alfalfa hay, rather than attempting to eliminate it.