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Why Does the Dollar Value of Alfalfa Hay Not Continue to increase as its TDN Increases ?

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INTRODUCTION

Alfalfa hay has long been prized as the premier forage for dairy cattle in California, and many other parts of the world. Even today, when our knowledge of the nutritional requirements of dairy cattle has never been more complete, most consulting nutritionists and dairy producers like to see some alfalfa hay in their lactation rations. Alfalfa hay brings a nutritional package to the feed bunk that no other single forage can match. However the quality of alfalfa hay grown and fed in California today is a far cry from that grown even 20 years ago. A big part of the reason for the increased quality has been that growers and dairy producers have, and are, focused on increased hay quality, even at the expense of yield (for growers), or higher cost (for dairy producers).

This change in California can be traced to the introduction of a very simple mathematical formula called the 'Western States Equation' that estimated the energy (as TDN: total digestible nutrients) level of alfalfa hay from its level of ADF (acid detergent fiber). Researchers at UC Davis in the 1970's found that there was a tidy linear relationship between decreasing levels of alfalfa hay ADF and its TDN content. This equation, written as:

$$\text{TDN (\% of DM)} = 82.38 - (.7515 \times \text{ADF (\% of DM)})$$

has been adopted by virtually all California hay testing laboratories, and has served the industry very well over the years as a quick, inexpensive, precise and robust method to predict the TDN value of alfalfa hays. In a nutshell, it states that for each increase of 1% unit of ADF in alfalfa hay, you lose 0.7515 % units of TDN. Seldom has such a simple equation had such an enormous impact on an industry since, over a period of 20 years, it has become the mechanism by which alfalfa hay is priced and in so doing has influenced grower decisions on cultivar selection, fertilization strategies, irrigation strategies and, most importantly, harvesting strategies. If a high hay price is all about increasing TDN (i.e., reducing ADF), then pragmatic growers produce hay with lower ADF.

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However, as in many human endeavors, we sometimes get carried away. Whereas 53 TDN hay (air dry basis) might have been pretty good dairy hay in 1980, by 2000 it needed to be 56 TDN. This further drove grower decisions to increase hay TDN and, in so doing, hays with very high TDN values, even in excess of 60%, were produced and marketed. While this sounded like a super extra premium quality hay bonanza to growers, an odd thing happened on the way to the market – dairy producers were only prepared to pay more money for hays with increasing quality up to a level and, after that, they were not prepared to pay a dime more.

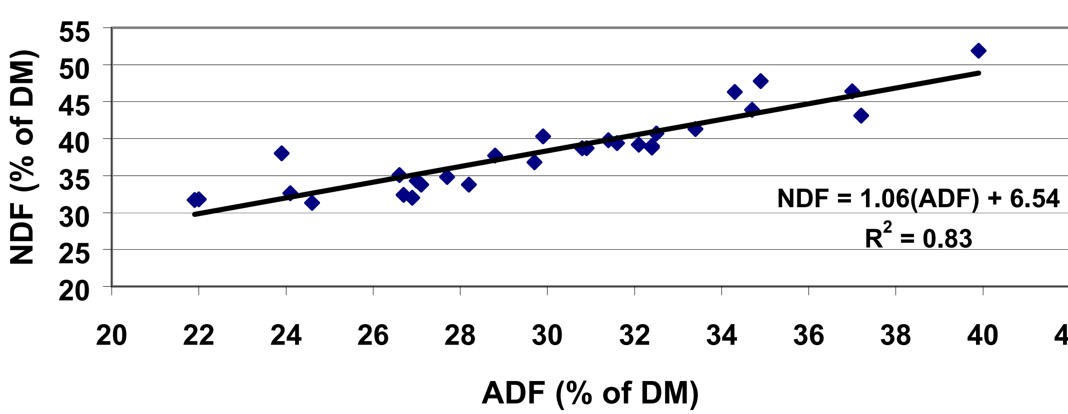
How could this be so ? The energy level was higher and so surely the price should also be higher. The purpose of this article is to examine this hay price capping practice and determine if is a rational action or a whim of those unpredictable dairy producers.

ITS NOT JUST ADF THAT IS CHANGING

The Western States Equation, and other interesting information on alfalfa hay, can be found in a publication of Dr.'s Don Bath and Vern Marble of UC Davis (Testing Alfalfa for its Feeding Value, Leaflet 21457 – WREP 109, 1989; available through any UCCE Office). Bath and Marble noted, as had others before them, that because ADF contained a high proportion of the indigestible fiber components lignin and cutin, that there was a good relationship between the ADF level of a hay and its TDN value. Combined with the speed and low cost of the ADF assay, Bath and Marble felt that ADF was an excellent assay to choose as a predictor of the TDN value of alfalfa hay. And so it was done.

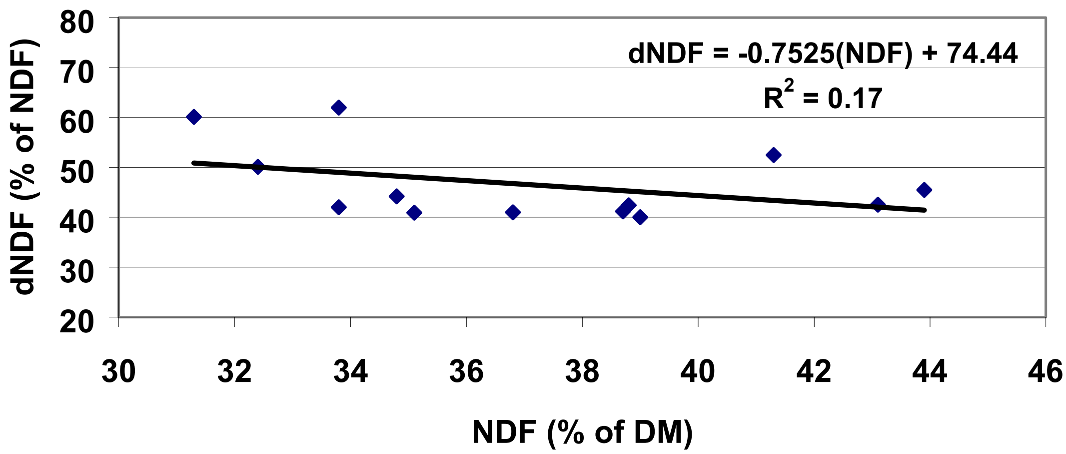
However increases in the ADF content of alfalfa hay are associated with changes in other nutrients in the hay, and all of them are bad relative to the overall energy value of the hay. The most obvious change is that as the ADF level increases, so does the NDF (neutral detergent fiber) level. NDF captures all of the structural fiber (unlike ADF that only captures about 70 to 85% of it) and since NDF is the slowest digesting portion of the plant that is digestible, its increase will reduce the energy level of the hay. Figure 1 reflects this relationship in a set of California alfalfa hays analyzed by the authors.

Figure 1. Relationship between ADF and NDF in California Alfalfa Hays.



However as ADF increases it is not just the NDF that is increasing, the digestibility of that NDF is decreasing as well (Figure 2), which means that on a unit NDF basis, there is less energy from the NDF that is in the hay. Thus the double negative whammy on TDN – more slowly digestible NDF in the hay and more of the NDF is indigestible.

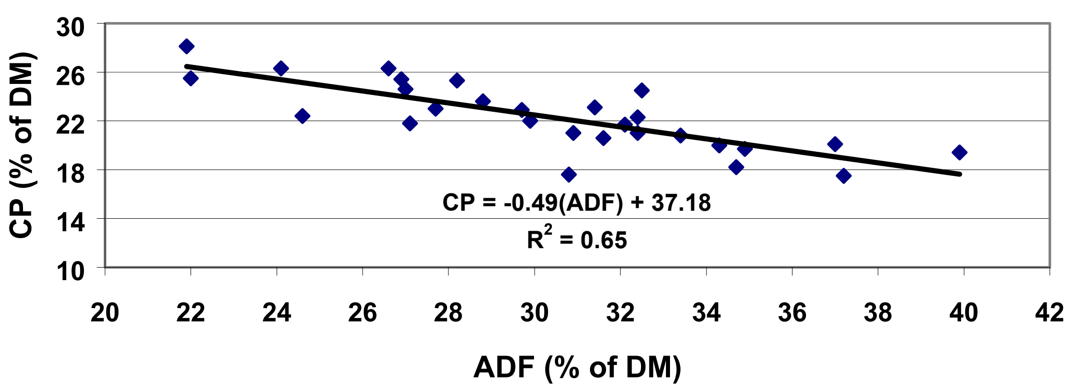
Figure 2. Relationship of NDF and digestible NDF (dNDF) in California Alfalfa Hays.



The relationship of NDF and dNDF (Figure 2) is certainly not as strong as that between ADF and NDF, reflecting the biological reality that there a numerous agronomic factors that impact the resistance of NDF to digestion by cows, but the relationship is clear.

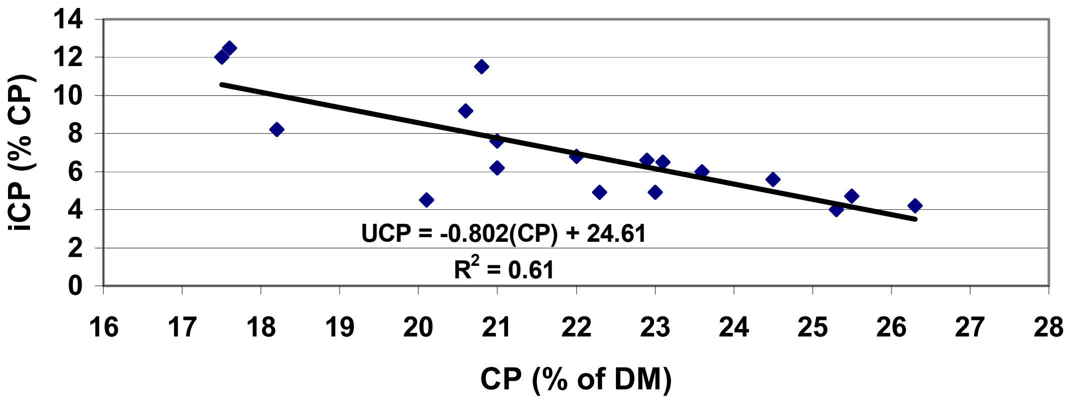
Another negative associated with increasing ADF levels in alfalfa hay is that the crude protein (CP) level of the hays declines. CP is required in relatively high quantities by dairy cows and, if not supplied in hay, it must be purchased in high cost protein meals such as soybean or canola. This strong relationship, also noted by others, is in Figure 3.

Figure 3. Relationship of ADF and CP in California Alfalfa Hays.



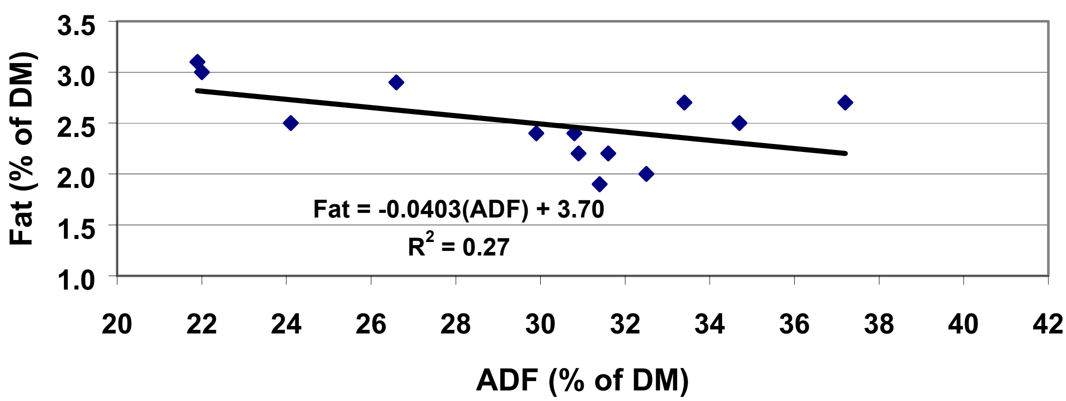
However, as with NDF, it is not just that CP is declining as ADF increases, but that the indigestibility of the CP is increasing as well (Figure 4), which means that on a unit CP basis, there is less digestible CP in the CP that is actually in the hay.

Figure 4. Relationship of CP and iCP in California Alfalfa Hays.



Finally, the fat level of alfalfa hay also declines as the level of ADF increases. Although fat levels of alfalfa hay are rather low, generally in the range of 2 to 3% of DM, fat is an energy dense component packing, on a weight basis, about twice as much energy as digested protein or carbohydrate. So even small declines (Figure 5) can be important.

Figure 5. Relationship of ADF and fat as ether extract (EE) in California Alfalfa Hays.



Overall it is clear that as the ADF level of hay increases, a number of other components change and that all of these changes will depress the energy (i.e., TDN) level of the hay. Clearly this is one of the major strengths of the Western States Equation, as it is not only increasing ADF per se which drives down the TDN of hay, but that ADF levels are tightly related to a number of other hay components that impact the energy level of the hay. But doesn't this merely underline that the dollar value of hay should increase as its ADF level decreases ? Maybe, but it depends on what is limiting the feed intake of the cows fed the ration in which the hay, after all, makes up only a portion.

WHAT DRIVES INTAKE OF FEED BY DAIRY COWS ?

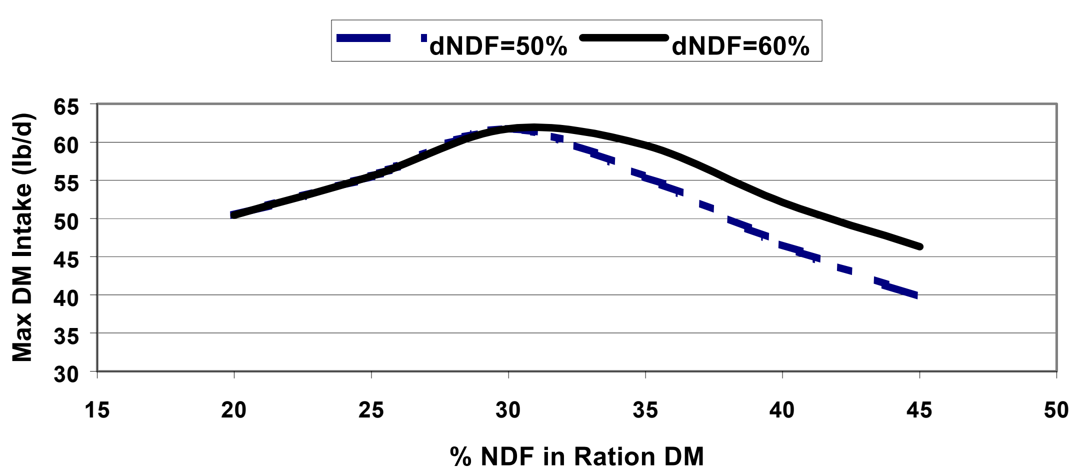
Hay only makes up a portion of the rations fed to lactating dairy cows falling, typically in California, in the range of 15 to 35% of the dry matter (DM) of the ration. So it is not just the hay that impacts ration intake, but all the other ingredients in the ration as well. Dry matter intake of dairy cows fed any particular ration can be influenced by numerous factors, only some of which can be described mathematically and only some of which are truly understood. However the two key factors that will impact the intake of any ration by dairy cows are its level of total structural fiber (i.e., NDF) and its level of total non-structural carbohydrates (NSC; i.e., starches, sugars and pectins).

NDF limits intake by increasing the bulk of the ration, thereby requiring the cow to spend more time eating and ruminating (i.e., cud chewing), per unit of ration consumed. Since there is a limit to how much time that cows will do this in a day (about 14 hours or 35,000 chews), as the NDF level of the ration gets too high (and/or its digestibility declines) potential intake of the ration is increasingly limited.

In contrast, NSC provides no bulk to the ration, but it does provide carbohydrates that are very rapidly fermented in the rumen. If the amount, and rate of fermentation, of these carbohydrates create intermediate digestion products faster than bacteria in the rumen can use them up, then they tend to accumulate in the rumen and drive down the pH. Low rumen pH (i.e., acidosis) is a common problem in cows fed rations high in NSC but, perhaps more importantly, acidosis depresses appetite and so total feed intake is reduced.

Thus intake of any ration tends to be depressed if the level of NDF gets too high or if it gets too low (i.e., NSC gets too high, since as NDF goes up the NSC goes down). This is illustrated, for a particular ration situation, in Figure 6. This general form will hold for all situations, although absolute values will change as other factors in the ration change.

Figure 6. Relationship between NDF level of the ration and Maximum DM intake.



But how does the ADF (and NDF) level of the alfalfa hay, that is a part of the ration fed to the cows, impact the intake of the ration ?? For example, if the intake of the ration is limited by high NDF (move to the right on Figure 6) then reducing the ADF (i.e., reducing the NDF and increasing the dNDF) will both reduce the NDF level of the ration (and increase its dNDF content) thereby increasing the intake of the ration leading to increased energy intake and increased milk yield. Bottom line: the value of the alfalfa hay with a *lower* ADF increases to the cow, the dairy producer and the grower.

However if the intake of the ration is limited by high NSC (i.e., low NDF; moving to the left on Figure 6) then increasing the ADF (and NDF) will reduce the level of NSC in the ration thereby increasing the intake of the ration leading to increased energy intake and increased milk yield. Bottom line: the value of the alfalfa hay with a *higher* ADF increases to the cow, the dairy producer and the grower.

But is this just theory, or can it happen in real feeding situations on real dairies in California? To evaluate this question, three actual high group dairy rations were evaluated to determine if there was a level of ADF below which no further increases in intake, and milk production, occurred. Outlined in Table 1, these are real rations that were fed to commercial high group cows on three dairies in California.

EVALUATION OF SOME REAL CALIFORNIA DAIRY RATIONS

For the evaluation, the actual level of alfalfa in the ration was not changed, but the TDN (and ADF and all of the correlated components discussed above) were changed from 49 to 63% TDN. The conditions of the cows were kept constant (i.e., 1430 lbs with no body weight change producing milk with 3.5% fat and 3.2% protein), and so all changes in feed and energy intake were expressed by changes in the milk yield.

Ration 1

For Ration 1, which had the lowest NDF level in the total ration (28.3% of DM) and highest NSC level (40.3%) in the ration actually fed to the cows, the relationship between the TDN level of the hay and the predicted DM intake and milk yield are in Figure 7. There is a clear break point between 58 and 59 TDN hay that maximizes both DM intake and milk yield. As the TDN of the hay goes lower than 58, intake is limited by increasing levels of NDF in the ration, whereas as the TDN of the hay goes higher than 59, intake is limited by increasing levels of NSC in the ration.

Ration 2

For Ration 2, which had the intermediate NDF level in the total ration (32.7% of DM) and intermediate NSC level (36.7%) in the ration actually fed to the cows, the relationship between the TDN level of the hay and the predicted DM intake and milk yield are in Figure 8. Here there is a clear break point, in this case between 60 and 61 TDN, that maximizes both DM intake and milk yield. As the TDN of the hay goes lower than 60, intake is limited by increasing levels of NDF in the ration, whereas as the TDN of the hay goes higher than 61, intake is limited by increasing levels of NSC in the ration.

Figure 7. Relationship of alfalfa hay TDN and predicted dry matter intake (DMI) and Milk yield on dairy 1 in Table 1.

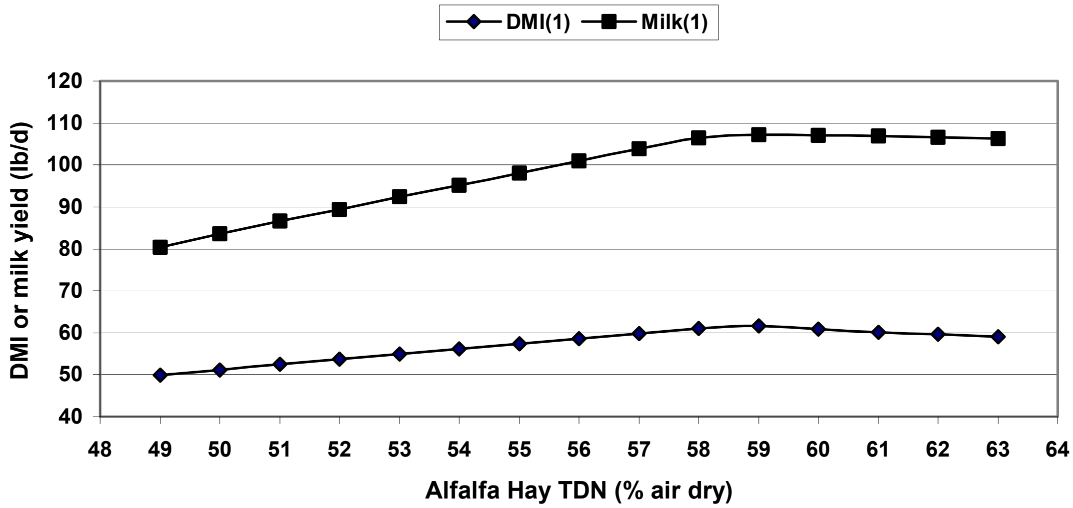
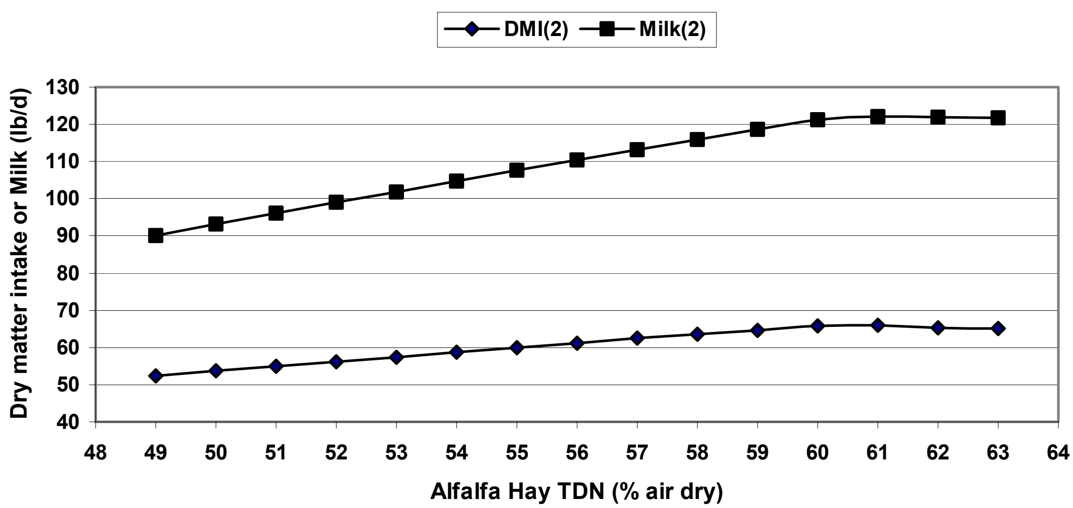


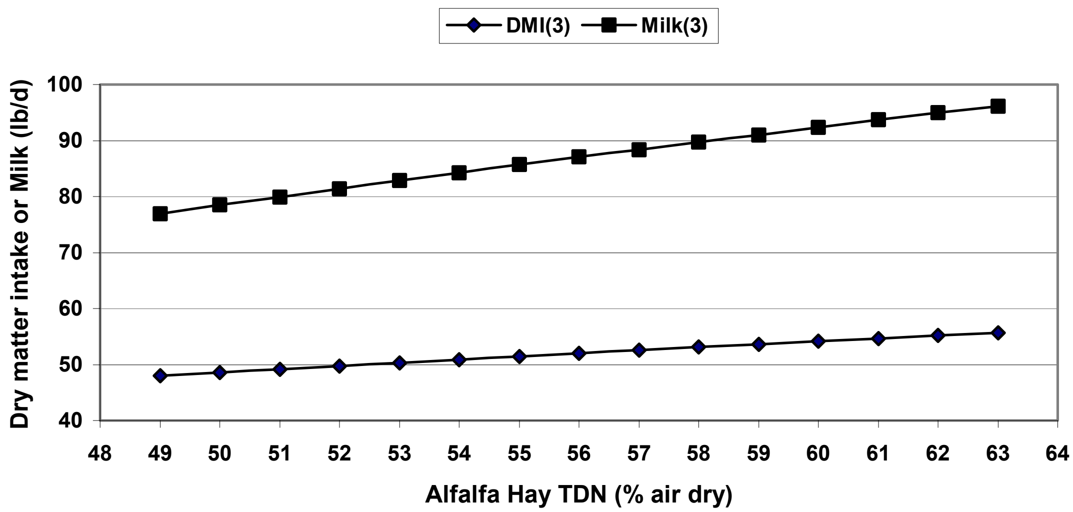
Figure 8. Relationship of alfalfa hay TDN and predicted dry matter intake (DMI) and Milk yield on dairy 2 in Table 1.



Ration 3

For Ration 3, which had the highest NDF level in the total ration (33.6% of DM) and lowest NSC level (33.9%) of these rations actually fed to cows, the relationship between the TDN level of the hay and the predicted DM intake and milk yield are in Figure 9. Here there is no break point and both DM intake and milk yield continue to increase as the TDN of the hay increases. While part of the reason for this is due to the high NDF level of the base ration, a part is also due to the relatively low inclusion level of hay in the ration, meaning that there is an insufficient amount of hay in the ration to impact the ration composition and so create a break point.

Figure 9. Relationship of alfalfa hay TDN and predicted dry matter intake (DMI) and Milk yield on dairy 3 in Table 1.



Ration 2 - Modified

Ration 2, which had the intermediate NDF level in the total ration (32.7% of DM) and intermediate NSC level (36.7%) in the ration actually fed to the cows, contained 9.9% of ration DM as beet pulp (which contains about 46% NDF (DM basis) with a very high dNDF proportion - about 75%). To illustrate how changes in the NDF and NSC level of the ration can change the break point, a fictitious ration was created by simply removing the beet pulp and replacing it with low NDF (and high NSC) corn grain. The original and modified ration 2 are in Figure 10. For the modified ration 2, there is a clear break point that is well to the left (i.e., lower hay TDN) than in the original ration, reflecting the now much higher NSC level of the ration that results in depressed DM intake at a much lower TDN of the hay than in the original ration.

Figure 10. Relationship of alfalfa hay TDN and predicted dry matter intake (DMI) and milk yield on dairy 2 in Table 1 as well as a modified ration.

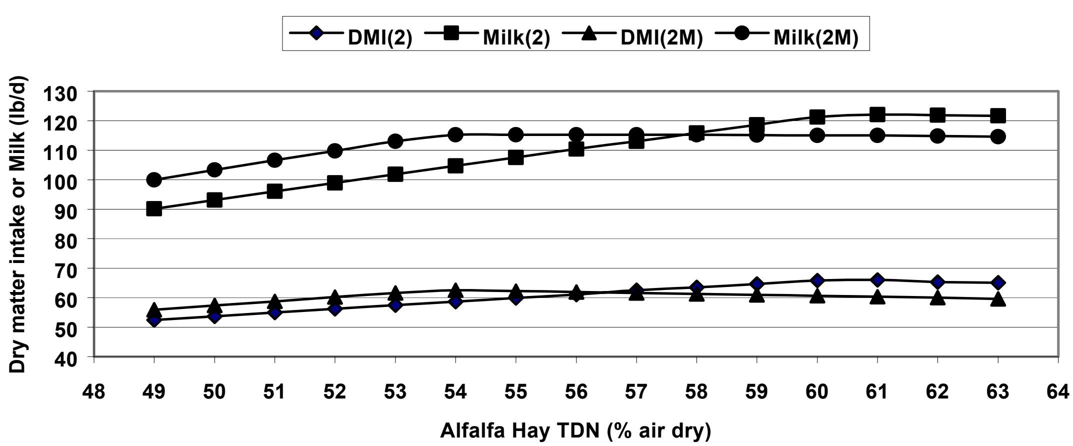


Table 1. Characteristics of the California high group dairy rations evaluated

	Ration			
	1 (as fed)[1]	2 (as fed)[1]	2 (modified)[2]	3 (as fed)[1]
Ingredient composition (% of DM):				
Alfalfa hay	35.1	27.7	27.7	18.7
Corn silage (30-40% grain)	-	9.3	9.3	-
Wheat silage	-	-	-	13.5
Oat hay	-	-	-	2.7
Almond hulls	7.5	-	-	8.8
Beet pulp (dehy)	-	9.9	-	7.2
Brewers grains (dehy)	0.3	-	-	-
Citrus pulp (HM)	-	-	-	3.2
Distillers grains (dehy)	0.3	9.8	9.8	7.9
Wheat (millrun)	1.2	-	-	-
Barley (rolled)	17.0	-	-	-
Corn (rolled)	22.4	26.2	36.1	15.0
Canola meal (solv)	-	5.0	5.0	4.5
Corn gluten meal	0.3	-	-	-
Cottonseed meal (solv)	1.3	-	-	-
Soymeal (48% solv)	1.5	-	-	2.7
Blood meal (ring dried)	0.3	-	-	-
Feather meal	0.3	-	-	-
Whole cottonseed	12.6	7.7	7.7	8.3
Methionine (RP, 40%)	0.1	-	-	-
Water	0.1	-	-	-
Fat	-	0.7	0.7	0.8
Molassses (liquid)	-	1.5	1.5	4.4
Yeast culture	-	0.1	0.1	0.2
Vitamin/mineral premix	2.1	2.0	2.0	2.4
Nutrient composition:				
Dry matter	52.8	69.7	69.4	64.1
Fat (% DM)	5.2	5.2	5.5	5.2
Crude protein (% DM)	18.5	17.6	17.7	17.8
Soluble CP (% CP)	33.5	28.0	30.9	32.7
Indigestible CP (% CP)	4.5	4.3	4.2	5.0
NDF (% DM)	28.3	32.7	29.3	33.6
NSC (% DM)	40.3	36.7	40.7	33.9

[1] - as fed on the commercial dairies
[2] - modified in theory by replacing the beet pulp with corn grain

BUT WHAT HAPPENS IF THE BASE RATIONS CHANGE ?

All well and good. But the situations outlined in the previous section merely reflect the changes in ration intake and milk production of cows due to changing the ADF (and TDN) level of the hay in the fixed (for the purposes of the examples) rations. What, one might ask, will occur if feed ingredient prices change the grain to forage formulation ratio of the base ration ?

Rations for dairy cows are commonly formulated to meet minimum and maximum levels of both NDF and NSC. As a result of research, and practical experience, consulting nutritionists know that the most effective high group dairy rations contain between about 27 and 32% of DM as NDF and 36 and 42% of DM as NSC. Rations outside of these ranges will depress feed intake and animal performance for the reasons discussed above. However these ranges, while not large, do give nutritionists formulation latitude to exploit changes in the relative costs of feedstuffs to reduce ration costs and, nutritional consultants being savvy folks, they do exploit them. If, for example, the price of grains (i.e., high NSC, low NDF feeds) becomes less expensive relative to the costs of forages (i.e., high NDF, low NSC feeds) then nutritionists tend to push the NSC level of the rations up to allow more of the lower priced grains into the rations. If the opposite occurs, then nutritionists tend to push up the NDF level of the ration to reduce levels of the relatively higher priced grains in the rations. This formulation process happens every day in California since most dairy rations are formulated on a least cost basis, within defined nutritional bounds, and the relative costs of grains and forages are constantly changing.

How do these decisions impact potential hay price break points ? As forage levels are restricted, and NSC levels of the rations increase, then price break points will move down the TDN scale as it is the NDF of the hay that is more required in the ration. Thus dairy producers may tend to cap hay prices at relatively lower TDN values. However if forage levels are increased in rations, and their NDF levels are allowed to increase, then the hay price break points will move up the TDN scale, as it is the NSC in the hay that is more needed and dairy producers may tend to cap prices at relatively higher TDN levels.

It seems clear that the relative prices of grains and forages will impact hay price break points. Thus savvy hay producers should keep one eye on the corn grain futures markets when making decisions on the quality of hay they strive to produce.

CONCLUSIONS

Alfalfa hay is a premier forage for dairy cows in California and research conducted at UC Davis, that resulted in publication of the Western States Equation, has had an enormously beneficial impact on increasing the quality of alfalfa that is grown, marketed and fed in California. However, as with many things in life, there can be too much of a good thing.

Based upon the rations commonly formulated and fed to high producing dairy cows in California, break points beyond which further increases in the TDN content (air dry basis) of alfalfa will have no further value in rations appears to be in the range of 55 to 58% (i.e., 28 to 24% ADF on a DM basis), although individual poorly formulated rations may have break points well outside this range.

Thus the alfalfa hay pricing break points that are seen in practice are a rational economic response to a known biological response of dairy cows to changes in the NDF and NSC level of the rations that they are fed. While most well formulated rations will have break points for their added alfalfa hay in the range of 55 to 58% TDN, the actual break point will differ for each ration. In general, the break point price of the alfalfa hay will move to TDN values higher than this range as the NDF level of the ration goes above about 32% of DM and will move to TDN values lower than this range as the NDF level of the ration goes below 29% of DM. The level of inclusion of alfalfa hay in the ration will have no impact on these trends in the alfalfa price break point, although as the inclusion level of alfalfa decreases it will become much more variable. However as grain prices decline relative to forages, hay price break points will tend to move to lower TDN values, and the reverse will occur as grain prices increase relative to forages.

Since alfalfa hay inclusion levels in alfalfa hay are slowly declining in California, because cow numbers are increasing faster than available alfalfa hay, we can expect to see more variation in alfalfa hay break points among, and within, dairy producers in the future.

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