Adjusting Rations To Forage Quality, And Suggested Criteria To Use In Buying Forages

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The sharp increase in the milk fat differential during 1996 reminded dairy producers of the direct economic importance of ample fiber to maintain milk fat test. From 5.4¢ per point in March, to 15.9¢ per point in August, the penalty as well as the reward, came into clear focus. And quickly comes the question of how much effective fiber is needed to maintain fat test? And can forage quality be expressed with a single value or number? Historically, as forage quality has changed, we've adjusted the forage to concentrate ratio (F:C), but the limits to that adjustment are reached quickly and the definition of minimum forage becomes an involved exercise which includes the total ration fiber, its particle size, digestibility, etc. More recently it has been recommended (Mertens, 1996) that we should adjust rations to a constant neutral detergent fiber (NDF), but effective fiber again requires definition.

Another dimension relates to the need to substitute other forages and/or high fiber concentrate ingredients to increase the energy of the ration or in some cases, to reduce energy. Is alfalfa and/or corn silage required for high milk production? And when purchasing forages, what specifications are essential but reasonable? My objectives here are to define some expressions of forage quality, to recommend some specifications to use in purchasing forages, and to suggest some steps to use with forage substitutions in formulating rations.

Expressions Of Forage Quality

With respect to alfalfa hay, Marble (1986) notes that visual examination does not accurately reflect the maturity at harvest which has such a direct effect on both acceptability and digestibility. But chemical analysis does not usually show the presence of mold or reflect how much foreign material is present in hay. So both visual inspection and chemical analysis are needed for a more complete evaluation. In Table 1 are several expressions of forage quality, based on nutrients and calculations from those nutrients. Different systems are used across the U.S. and each has merit. The American Forage and Grasslands Council (AFGC) has defined 6 forage grades, prime and 1 through 5, based on relative feed value. The Relative Feed Value (RFV) is an index system for ranking forages within classes, was developed in Wisconsin and is based on acid detergent fiber (ADF) and neutral detergent fiber (NDF). It uses ADF to predict digestible dry matter (DDM), and NDF to predict intake as a percentage of body weight. It then combines these 2 to give an index of quality, but comparisons are appropriate only within forage classes. A unit of RFV can be assigned a value in pricing hays. If an alfalfa hay with an RFV of 130 is sold for $95 per ton, the value of a point of RFV is $.73 and hays above and below this RFV can be priced based on an agreed upon standard RFV hay and its value.

California and some other western states (Bath and

Table 1: Some Expressions Of Forage Quality

	by Analysis			by Calculation			
Standard[a]	CP	ADF	NDF	TDN[b]	DDM	DMI	RFV
	(% of DM)						(% BW)
Prime	>19	<31	<40	60	>65	3.0	>151
1	17-19	31-35	40-46	59-56	62-65	3.0-2.6	151-125
2	14-16	36-40	47-53	55-52	58-61	2.5-2.3	124-103
3	11-13	41-42	54-60	52-51	56-57	2.2-2.0	102-87
4	8-10	43-45	61-65	50-49	53-55	1.9-1.8	86-75
5	<8	>45	>65	48	<53	<1.8	<75

[a]: Standard assigned by Hay Market Task Force of AFGC.
[b]: California System, Bath and Marble, 1989, based on ADF.

Marble, 1989) use an equation (TDN = 82.38-(.7515 X ADF%)) to predict TDN from ADF and DDM also is calculated from ADF. The price of hay is then calculated based on a standard hay and the percentage of ADF or Modified Crude Fiber (MCF) (dry basis) in the test hay.

Hutjens (1995) has suggested that because protein also has considerable value, it should be incorporated into the RFV system to more completely reflect the nutritive value of the forage. He uses a term Total Forage Index (TFI) to describe an index which builds on RFV, but adds a protein value and a physical value. In the above example for RFV, if the hay had a protein content of 18% and protein was relatively expensive, multiply 18 by 3 (54) and add this to the RFV to get 184 (130 + 54), the TFI. Then divide the cost of this hay $95 by 184 to get $.52, the value of one point of TFI. This addition to the RFV brings a more complete expression of the nutritive value of the forage. It is important to recognize which nutritive values are analyzed by forage testing laboratories and which expressions are calculated from analyzed nutritive values. Most laboratories now give protein, ADF and NDF even for the minimal package. Nearly all other expressions are calculated, including TDN, NEl, RFV and TFI. An expression which combines the 3 measured values should have an advantage and I believe that it does.

Purchasing Guidelines For Forages

We can gain some insights on this subject from two associations who trade cotton and cottonseed products. They have established "Trading Rules" for their members which are shown in Table 2. I don't know whether dairy producers use these rules when they buy cottonseed, but with a small range for each rule, they would be very helpful. For forages, certainly a maximum on foreign matter and moisture are good starting points. Then either, ADF, NDF (or both), RFV, and CP could also be included. Or a sum of ADF and NDF might simplify the expression. And a statement with regard to freedom from mold by sight or smell, should be included. I realize that much hay has and is being sold on the basis of trust established from years of purchasing, but today, hay is being transported over long distances, through brokers, handlers or truckers and the final purchaser may not know or be able to determine its original source. By establishing and specifying guidelines in the purchase order, the buyer is in a much stronger position to request an adjustment in price, when a forage is not of the standard or quality that the purchase order requires.

Corn silage is a unique forage with its variable proportions of grain and stover. Soderlund (1996) states that a fair price for corn to be harvested and stored as silage should consider: 1) corn grain price, 2) predicted grain yield, 3) plant DM content, 4) NEl of grain and stover, 5) DM recovery, and 6) handling, storage and inoculation costs. He has shown an example of these 6 considerations at 2 grain/stover concentrations. The cost involved makes a comprehensive analysis worthwhile. Such an exercise is much more likely to ensure fairness to both the corn grower and the dairy producer.

Forage Concentrate Substitution

Historically when the goal was to increase the energy consumption of the ration or when a poorer quality forage had to be fed, the practice was to simply feed more concentrate. This approach was effective until a forage: concentrate ratio of about 35:65 was reached, because both the energy density of the total diet and voluntary DM increased to this point (Kawas et al. 1983). However, when this approximate ratio was reached, DM intake no longer increased and may have decreased slightly, fat test depressions often resulted and acidosis was a near or resultant problem. But fortunately there are better ways to describe minimum forage or better yet, minimum effective fiber. Because of the increasing genetic trend and the continually rising production capability of dairy cows, it will be necessary to be on the edge of ample dietary fiber in order to present a diet as rich in energy as it is possible to formulate with good consumption.

Table 2: Trading Rules for Whole Linted Cottonseed

	NCPA[a] Prime	ACA[b] Prime	Premium
Foreign Matter (max) %	2	2	1
Moisture (max) %	13	13	11
Free Fatty Acids (% of the oil, max)	3	3	3
Crude Protein + Crude Fat (min) %	34	34	38

[a]: National Cottonseed Products Association.
[b]: American Cottonseed Association.

The serious downside to insufficient effective fiber and/or excessively fermentable DM is the occurrence of acidosis and depressed milk fat percentage. Acidosis is the direct result of greater ruminal acid production than can be absorbed or neutralized. An excellent review of the causes, detection and prevention of acidosis in dairy cattle was given by Allen and Beede (1996). They note the consequences of ruminal acidosis to be decreased energy intake and microbial protein production, but more severe acidosis can lead to ruminal ulcers, liver abscesses and laminitis. Acidosis can be an insidious problem, because its effects may be hidden for some time and then disastrous consequences may appear. Many of us may have thought that milk fat percentage is a good barometer of fiber adequacy, and it is has merit, but it is not perfect. As emphasized by Allen and Beede (1996), there are several reasons that milk fat percentage may not reflect well ruminal acidosis: 1) Cows in early lactation are especially sensitive to ruminal acidosis, but because they are mobilizing body fat, their milk fat percentage may be maintained at a near normal concentration; 2) dietary fat may elevate milk fat percentage; 3) and if bulk tank tests are used, these may not be sensitive enough to reflect problems in early lactation cows because of the dilution effect.

Table 3: Effective Fiber Varies Greatly Among Feedstuffs

Feedstuff[a]	Percentage of NDF Which is Effective	X Total NDF (%)	= Effective NDF (%)
Alfalfa Hay	92	45	41.4
Alfalfa Haylage (3/8")	82	45	36.9
Alfalfa Haylage (1/4")	67	45	30.2
Grass Hay	98	55	53.9
Corn Silage (50% grain, (1/4")	71	50	35.5
Corn, Ground	48	9	4.3
Soybean Meal	23	16	3.7
Brewers' Grains	18	42	7.6
Whole Cottonseed	100	44	44.0
Beet Pulp	33	54	17.8
Soy Hulls	2	67	1.3

[a]: After Hutjens, 1993.

Effective Fiber (EF)

The most effective and direct way to control acidosis is to maintain ample effective fiber in the diet. Neither NDF, ADF, or any other chemical or nutritive fraction characterizes the EF or roughage value because feed samples must be ground before sampling for analyses. Effective fiber is the feed's property to stimulate initial chewing, subsequent regurgitation and rumination, and it reflects the particle size, the fibrous nature, and the fiber content of the feed. Chewing or rumination is especially important because it is directly related to the amount of saliva production and saliva contains 2 buffer systems, the primary one being sodium bicarbonate which provides most of the buffering action in the rumen. So the greater the fiber concentration (designated by NDF), the larger the particle sizes of the feed, the degree of coarseness and the more chewing that is required, the greater is the EF of the feedstuff. Therefore, several workers (Hutjens, 1993, Mertens, 1992) have calculated EF values for an array of feedstuffs and some of these are in Table 3. An important variable is particle size; Mertens (1992) has assumed that only particles retained on a sieve of 1.8 mm contributes to chewing activity and therefore this fraction was used to calculate the roughage value or EF. However, until recently, most dairy producers would had no way of easily determining the particle size of their forages or of the totally mixed ration (TMR) which would prevent acidosis. Recently, Heinrichs (1996) constructed a particle separator with 3 screens which allows one to screen a sample of forage, but especially a TMR, to determine whether a significant fraction of the particles are large enough to cause enough chewing to prevent acidosis. Guidelines for this screening method are in Table 4.

Several of the commodities or byproducts have a significant concentration of EF and this fact can increase their value when EF is especially needed. For example, Wisconsin workers (Swain and Armentano (1993) and Depies and Armentano (1995) showed that NDF from oat hulls, corn gluten feed, beet pulp, corn cobs and wheat middlings was about one-half as effective as NDF from alfalfa with respect to returning a depressed fat test to near normal from a low fiber-alfalfa based forage diet. Earlier it was found that NDF from linted whole cotton-

Table 4: The Penn State Forage Separator Has Three Sieves[a]

	Recommended Particle Size	
		TMR
Upper Sieve[b]	> 0.75 inch	6 - 10%
Middle Sieve[b]	0.75-0.31 inch	30-50%
Bottom Pan[b]	< 0.31 inch	40-60%

[a]: Heinrichs, 1996
[b]: Portion remaining on the screen

seed and dried distillers grains was equal to NDF from alfalfa NDF for maintaining milk fat yield. Just how the EF of these byproducts would be measured by the Heinrichs (1996) screen separator, especially imbedded in a TMR is not clear yet. But a number of the byproducts have NDF which despite a modest particle size, are very effective at maintaining milk fat test. Firkins (1995) summarized the EF of a number of feed ingredients that he designated as nonforage fiber sources. He noted that whole cottonseed and cottonseed hulls are the best forage substitutes among the many byproducts available to dairy producers.

Forage-To-Forage Substitution

Many dairy producers feel that some alfalfa in the ration is a necessity if top production is to achieved. You may recall an article published last year with the title: "24,000 pounds of milk... no corn silage, no alfalfa" (Merrill, 1996). The forages used were a combination of grasses, mostly stored, rather than pastured. Yes, high production can be achieved without alfalfa, but it is much easier with alfalfa. However, in some areas of the U. S., especially in much of Texas, the freight makes alfalfa hay very expensive. My advice to a number of clients has been this: grow the very best forage which you can grow on your farm, and you know better than anyone what that forage is, and we will build the ration on that forage. But what is it about alfalfa that makes it so special? Van Soest (1987) described 5 features of alfalfa which make it superior to grasses: 1) It incurs a small depression in digestibility with intake; 2) It has a moderate NDF content; 3) Its high cell wall density leads to higher intakes; 4) It has a high buffering capacity; and 5) It has a moderately fast rate of fermentation. If it were possible to more nearly define the "mystic" of alfalfa, then those of us for whom it is very expensive might be able to construct a ration which would equal or very closely approach the performance of rations based on alfalfa. And if that "mystic" is contained in 4 lbs of alfalfa, then under most conditions, we would not feed 6 or 8 lbs of it.

Another reason alfalfa may be superior to grasses is that it contains a higher concentration of pectin. Although a component of cell walls, pectin has some very desirable nutritional characteristics. Hall (1994) noted that: a) it is a highly digestible, fermentable carbohydrate energy source; b) during its fermentations it appears not to produce lactic acid; c) it tends not to depress ruminal pH, and d) it ferments little during silage fermentation.

Many years ago, Ward et al. (1957) confirmed earlier studies which showed that alfalfa ash stimulated the digestibility of low quality roughages by sheep. Compared to grasses, alfalfa has a rich mineral profile. In addition to the 14 mineral elements for which requirements are defined by NRC (1989), there are at least 12 more which have been shown to be required by some animal (McDowell, 1992). My hypothesis is that alfalfa is a rich source of these exotic 12 compared to grasses. A comparison of 7 of these in alfalfa, corn silage, and bromegrass hay shows this to be so.

A direct comparison of alfalfa with orchardgrass (Weiss, 1995) shows that under some conditions grasses produce results both with respect to DM intake and milk production comparable to alfalfa. Other work (West et al., 1996) shows that improved varieties of bermuda grass (Tifton 85) compared to alfalfa in corn silage based diets, can give similar results. Although NDF in grasses is usually higher and may be more digestible, it is more slowly digested which is a disadvantage in high yielding cows (Glenn, 1994).

Another forage which under some conditions has special properties is cottonseed hulls (CSH). This is an ideal diluent for an alfalfa hay that is too rich in protein and low in EF. These hulls are also an excellent diluent for corn silage which is too rich for late lactation cows, dry cows or heifers. Its relatively low potassium (1.13%) makes it ideal for transition cows. At concentrations in the order of 7 to 10% of the ration, its value often far exceeds its book value which categorizes it in the low quality forage class.

Among forages, corn silage is a special case because it is a combination of forage and corn grain. The best time to harvest corn for silage has traditionally been defined as a total plant DM of about 35%. For field application, it is easier to examine the kernel and describe its features in order to know when to begin harvesting. A recent Wisconsin study (Bal et al., 1996) showed that a kernel described as 1/4 to 2/3 milkline gave the greatest lactation performance compared to earlier and later maturities, and this coincides with a DM content of about 32 to 35%. However, based on the recent work of Johnson et al. (1996) this current ideal maturity range may be expanded or at least extended to drier more mature plants. This work suggests that processing whole plant corn by a roller mill prior to ensiling may improve nutritive value by crushing the kernels and increasing starch digestibility by reducing whole kernel passage through the cow. This study used corn of 31.5% DM, so it did not address the question of whether the feeding value would be increased even more if more mature corn had been used to achieve greater DM yield per acre. But with harder kernels, greater benefit might have been seen. Field results suggest that such processing allows one to use a coarser chop and thereby obtain the value of a higher EF in the resulting silage. Much research is needed here, but the prospects are very encouraging.

One consideration in crop production is the lbs of water transpired by a plant per lb of above-ground DM produced. Values reported include 858 for alfalfa, 635 for oats, 372 for corn and 271 for sorghum (Peters, 1964).

Summary And Conclusions

Yes, forage quality can be expressed as a single number, but an index based on the 3 nutrients usually measured, CP, ADF, and NDF, gives the best indicator to date. It can be used to price forage given agreement on the value of a standard forage.

Purchasing guidelines or specifications for buying forages should begin with an acceptable range for moisture and foreign matter. There should be a statement to exclude visible mold and mustiness. Then reasonable ranges should be defined for nutrient content or an index based on measured nutrient values. This is an insurance policy which costs very little, and one which will pay back when delivery of a forage is made which is well outside the ranges specified and an adjustment in price is in order.

To formulate rations which ensure high intakes of energy requires being near the canyon's edge of acidosis, where only careful inclusion of ample effective fiber will prevent a disaster. Many nonforage byproducts contain EF which should be included in the calculation for EF. The two best forage substitutes are whole cottonseed and cottonseed hulls, both with EF equal to their NDF. Fortunately, particle size separators are now available which give strong indications when particle sizes of the TMR are not sufficient to prevent acidosis.

No doubt alfalfa is a very special forage, but in some areas, its cost is difficult to justify. If the reasons for its special nutritive value can be more clearly defined, then rations can be formulated without alfalfa which will more nearly result in equal production to those with alfalfa. In turn some minimum amount of alfalfa which results in high production may be evident.

Corn silage is also special and its real nutritive value is much more difficult to assess because not only does it have a variable ratio of forage to grain, but the grain can become so hard that some of it passes through the cow undigested. New equipment which allows processing to crush the grain before or after ensiling offers much promise to make corn silage an even richer feed with more EF and a greater range of acceptable harvest dates.

Unlike feedlot rations for beef cattle where forage is optional, for dairy cattle, ample effective fiber is a physiological imperative, an absolute necessity for good health and longevity.

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