FORAGE QUALITY TESTING AND MARKETS; WHERE ARE WE GOING?

By Dan Putnam[1]

ABSTRACT

Forage quality has a large impact on market price and profitability. Nationwide, the marketing systems of Total Digestible Nutrients (TDN) and Relative Feed Value (RFV) are primarily 'fiber-based' marketing systems, since they depend upon Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) lab measurements. Average change in California markets over 8 years of market reports in California was slightly over $7.00 per unit ADF (over $10.50/unit TDN), with somewhat lower values per unit of quality in the Intermountain, desert regions, and the Pacific Northwest. Marketing systems based upon ADF or NDF have the advantage of simplicity, and can successfully differentiate major differences between hay lots. However, they may fail to differentiate important differences in forage quality within a critical range of interest where changes in price are dramatic. Greater use of NDF digestibility, Ash, or other more measurements may assist in differentiating these hay products and improve prediction of the feeding value, if those measurements can be shown to be rapid and repeatable. There are limitations to the use of calculated values (including TDN); therefore it is important to primarily use measured, not calculated values in the marketplace. More sophisticated methods to incorporate additional measurements into the marketplace are needed.

Key Words: lab testing, ADF, NDF, TDN, forage quality, economics

INTRODUCTION

While 50 years ago, most alfalfa hay was evaluated on the basis of color (a minor predictor of quality), today, most alfalfa hay entering commerce for the dairy industry are evaluated via lab testing. A 1972 California Agriculture article estimated that about 15% of the California's hay was tested, but today this figure is likely over 60%.

In recent years, growers have had to cut at ever-more shorter schedules to meet dairy quality expectations (Figure 1). As late as the 1950s, the highest quality hay category

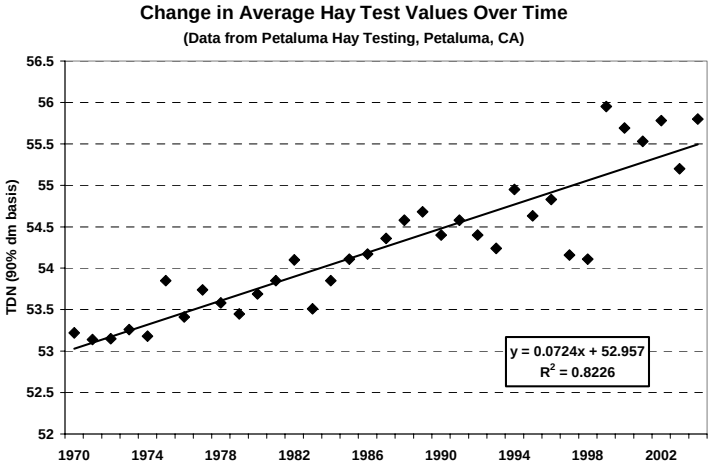

Figure 1. Change in average forage quality measurements over years (>1,000 samples/year), Petaluma Hay Testing, Petaluma, CA.

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described by USDA could contain significant bloom and even up to 49% seed pods—today, most high quality dairy hay is harvested at pre-bud to bud stages, and little bloom is seen, much less seed pods. In 1972, 52% TDN hay (below 33% ADF, 100% DM basis—see box for abbreviations) was considered excellent quality dairy hay. Today, many nutritionists consider 'high quality dairy hay' to be above about 55-57 % TDN (below 27-29% ADF). Data over time from a single lab has shown a dramatic increase in the average TDN values of the samples tested over a 30-year period (Figure 1). Midwestern markets have similarly seen a rise in the use of forage testing, and greater use of the 'RFV' index and other measures for evaluating quality. The average dairy cow of 2004 produces >60% more milk than a dairy cow in 1974. Given the dynamics and improvements in the genetics and feeding of dairy cows, the importance of forage quality and lab testing is likely to intensify, not diminish in the future.

Abbreviations:
ADF = Acid Detergent Fiber
NDF = Neutral Detergent Fiber
NDFd = NDF digestibility
CP = Crude Protein
TDN = Total Digestible Nutrients
RFV = Relative Feed Value Index
RFQ = Relative Forage Quality Index
CF = Crude Fiber
NEL = Net Energy for Lactation
NFTA = National Forage Testing Association

However, the greater use of forage testing has not always been associated with greater rationality in the use of hay testing results in the market. Sometimes hay testing results are misunderstood and are abused in the market place. This article discusses the current system of hay testing in the marketplace, and likely avenues of change in hay testing in the future.

QUALITY IMPACTS ON PRICE

Alfalfa is now the third most important crop in the US. The dairy-forage sector combined with the beef-forage sector is without a doubt the most important agricultural enterprises in the United States. In 2002, Beef/Calf enterprises were worth $72 billion, dairy $20 billion, and all hay $12 billion, while the largest crop in the US (corn) was worth $21 billion (USDA data). The primary language for translating animal productivity and economic worth between animal industries and forages is laboratory testing.

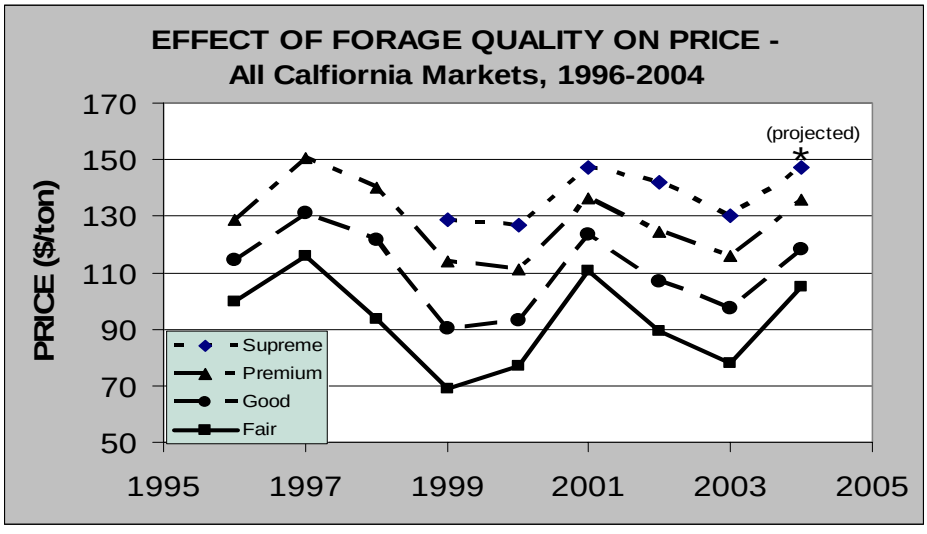


Figure 2. Average hay prices over the past 9 years in California markets (USDA-Market News Service) based upon quality category (2004 projected). Categories are described in Table 1.

Quality and Price. Market price depends both upon supply-demand factors and upon forage quality factors (Figure 2). It should be noted that over 95% of hay in California and other western states is sold on the market, whereas in many midwestern and eastern regions, the majority is fed on-farm, complicating the price and value estimations across the US. The average dollar value over 14 reporting markets and 9 reporting years in California is a little over $7.00 per unit of ADF, and varies from about $5.00 to over $8.00 on an annual basis (Figure 3). Fluctuations within a year are greater. **Note:** we had to make some simplifying assumptions to estimate these values. Hay quality categories are only partly described by forage quality measurement, but are also determined by subjective factors as determined by buyers and sellers (see box page 5).

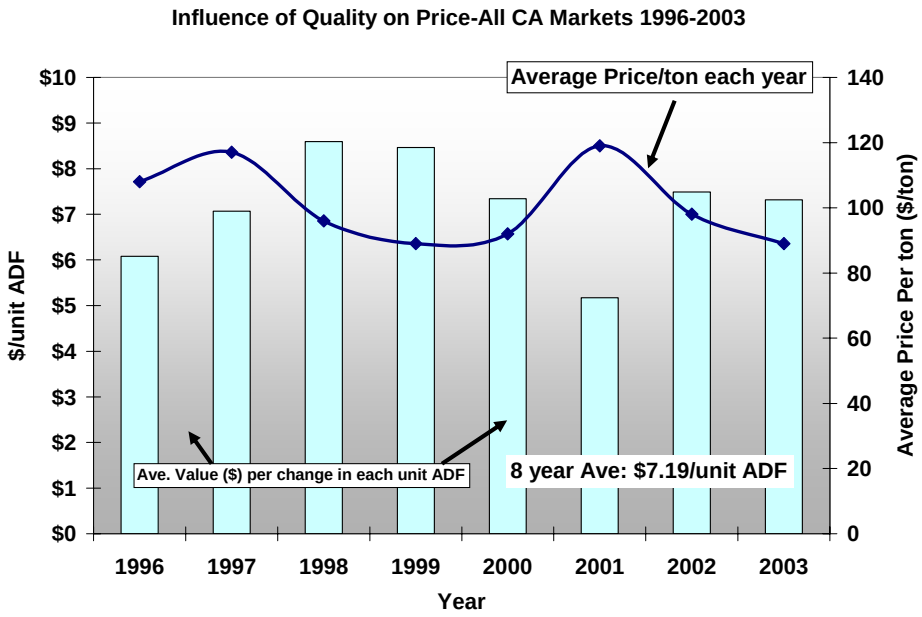


Figure 3. Value of each unit of ADF, average of all California Markets, 1996-2003 (USDA Market News, 2004a).

Forage Quality-More Important in a 'Down' Year. Generally, forage quality has a larger impact in a lower priced year and less of an impact in a high priced year (Figure 3). This is primarily due to changes in behavior, when the hay markets move from a 'seller' market to a 'buyer' market, and due to the relative abundance of hay in the different hay quality categories.

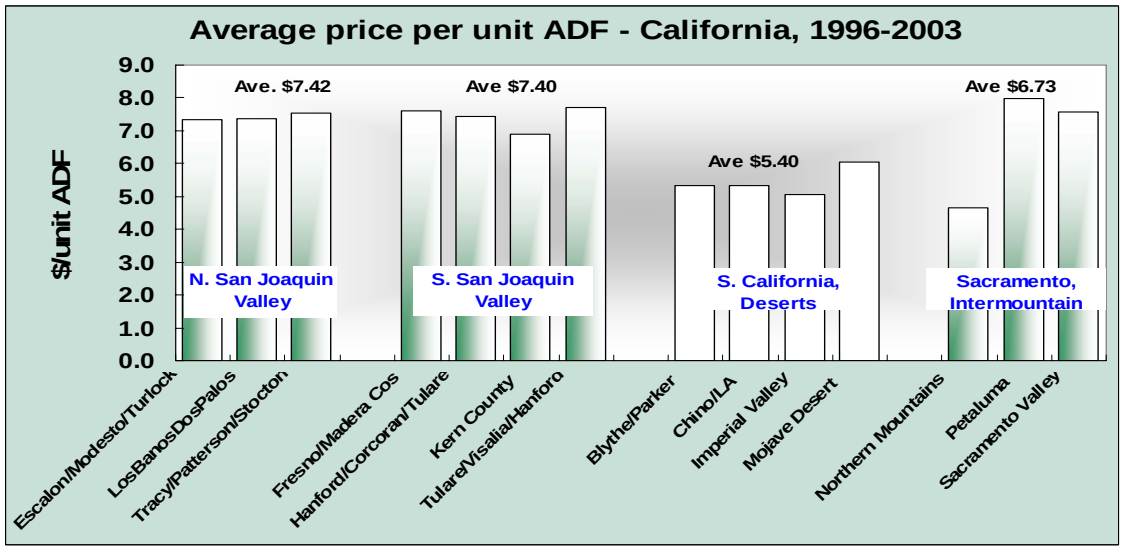


Figure 4. Differences between regions in the dollar value per unit of ADF (USDA Market News, 2004a).

Buyers have fewer options when supplies are relatively scarce, and must accept lower quality hay, whereas when supplies are abundant, they can demand higher quality. One clear message: growers have more of an incentive to produce high quality hay in a 'down' year than in a high-priced year, and probably should change their management practices to respond to these market signals.

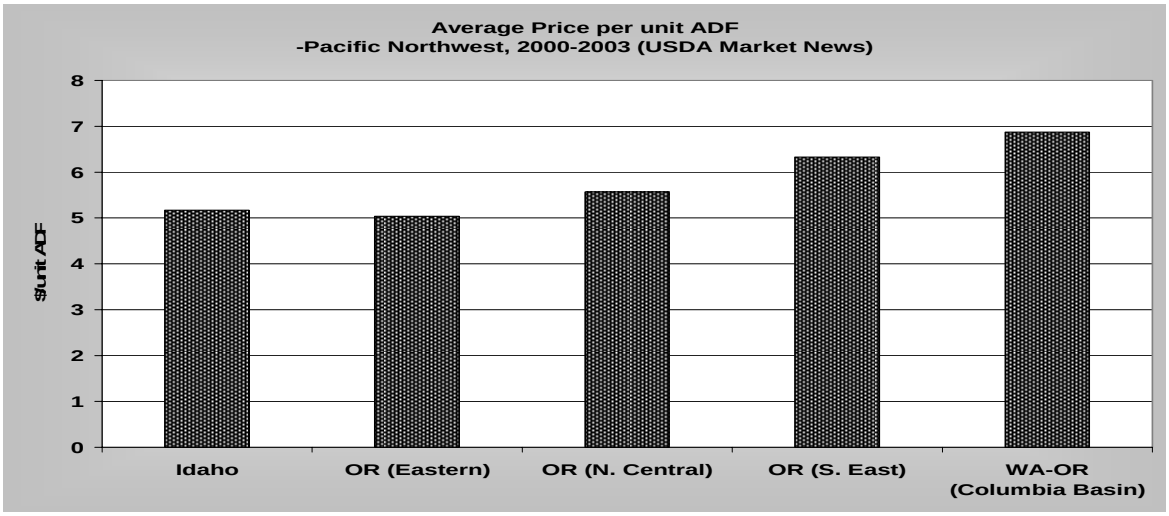


Figure 5. Differences between regions within the Pacific Northwest in change per unit of ADF, average of 4 years (USDA Market News, 2004b).

Regional Differences. There are regional differences in the importance of quality as well. Whereas differences in California's Central Valley (San Joaquin and Sacramento Valleys) appear to be relatively similar, differences between hay quality categories are less in the Intermountain region and the southern California desert regions (Figure 4). Similar differences exist in the Pacific Northwest between regions (Figure 5). Generally it appears that the regions further from the highest concentration of dairy cows exhibit fewer market differences due to quality compared with those areas with closer proximity to dairy regions.

How is Quality Described in the Marketplace? The methods of describing forage quality in the marketplace differ to some degree across the nation. The two most dominant methods currently are RFV, which has been commonly used in the Midwest, and TDN, which is more common in California and some other western states. (RFQ has been proposed-see Undersander article, these proceedings). However, RFV and TDN are not as different as would first seem. Both are based upon either ADF (TDN as a simple calculation from ADF), or a combination of ADF and NDF (RFV is calculated from these measurements). Since TDN is a linear function of ADF the 'western' system is essentially an 'ADF' marketing system, since that's what is measured. The RFV system is similar, though incorporates NDF. In practice, RFV is essentially equal to NDF, since over 99% of the variation in RFV is explained by NDF alone.

Table 1. *USDA Quality Guidelines for alfalfa hay (not more than 10% grass). Guidelines used for reporting economic data across the United States, and adapted in 2002 (2003 USDA Livestock, Hay & Grain Market News, Moses Lake, WA). Guidelines are used along with visual appearance to determine quality. All figures are expressed on 100% DM except as noted.*

Category	ADF	NDF	*RFV	*TDN	*TDN(90% DM)	CP
	----------%----------					
Supreme	<27	<34	>180	>62	>55.9	>22
Premium	27-29	34-36	150-180	60.5-62	54.9-55.9	20-22
Good	29-32	36-40	125-150	58-60	52.5-54.5	18.20
Fair	32-35	40-44	100-125	56-58	50.5-52.5	16-18
Utility	>35	>44	< 100	<56	<50.5	<16

TDN based upon calculation from ADF using the 'Western' Equation: TDN = {82.38 – (0.7515 x ADF)} according to Bath & Marble, 1989. 90% DM is TDN x 0.9. RFV is calculated from ADF and NDF: *RFV = (88.9-(.779x%ADF)) x ((120/%NDF)/1.29)*

Hay Marketing Categories. In 2002, the USDA Market News developed a set of guidelines for hay quality designation into 5 categories, and attempted to 'harmonize' the various styles of marketing across the US (Table 1). Grass hay guidelines were also developed. These were based upon work conducted by USDA scientist Dr. Dave Mertens, who examined the behavior of hay testing data from many states. These guidelines have the advantage that the numbers were arrived at through measured relationships between real hay samples from commercial labs. This

<u>Physical Descriptions of Hay Quality</u> to be used in combination with lab tests for alfalfa hay quality categories (USDA-Market News):

Supreme: Very early maturity, pre bloom, soft fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay is excellent color and free of damage.
Premium: Early maturity, i.e., pre-bloom in legumes and pre head in grass hays, extra leafy and fine stemmed-factors indicative of a high nutritive content. Hay is green and free of damage.
Good: Early to average maturity, i.e., early to mid-bloom in legumes and early head in grass hays, leafy, fine to medium stemmed, free of damage other than slight discoloration.
Fair: Late maturity, i.e., mid to late-bloom in legumes, head-in grass hays, moderate or below leaf content, and generally coarse stemmed. Hay may show light damage.
Utility: Hay in very late maturity, such as mature seed pods in legumes or mature head in grass hays, coarse stemmed. This category could include hay discounted due to excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category.

was a real improvement in hay quality-price reporting, since previously, genuinely different quality hays were assigned to different hay quality categories across the United States (e.g. a 'good' hay in Iowa was not the same as a 'good' hay in Arizona). This should assist in those trying to make sense of the US marketing methods. Additionally, subjective hay quality

attributes are included in the hay quality guidelines, since lab measurements do not predict all of the attributes of quality (see text box).

These new guidelines have some disadvantages, though. The primary one is that individual hay lots may be categorized in one category by one measurement, but not by another. For example, how to designate a hay lot with 28% ADF, 35% NDF but 17.5% CP? Additionally, the categories themselves create a problem with those hay lots which are right in between two categories—causing arguments over a few tenths of a percent ADF or TDN, or a few points RFV. While hay test values are 'continuous', the categories imply that forages are 'discrete'. A continuous variable is needed to allow differentiation across a wide range of qualities.

WHERE ARE WE NOW?

The current system of hay testing and marketing is essentially a 'fiber-based' system, with either TDN or RFV used as calculations from fiber lab values. TDN (as used in markets) is 100% equivalent to ADF (Figure 6). RFV is derived from both ADF and NDF, but examination of the behavior of laboratory data reveals that it is almost purely a function of NDF (Figure 7). ADF is not as influential in the calculation of RFV, but is also highly correlated (Figure 7). This USDA dataset from 15 states show the close relationships of RFV to NDF (97% of the variation in RFV explained by NDF using an exponential equation), but in more regional datasets, we have found that NDF explains even more of the variation in RFV in western states (over 99%). Hence, regardless of the value of the concepts of Total Digestible Nutrients (TDN) or Relative Feed Value Index (RFV), as a practical matter it should be clear that these marketing methods are equivalent to the use of ADF or NDF measurements alone.

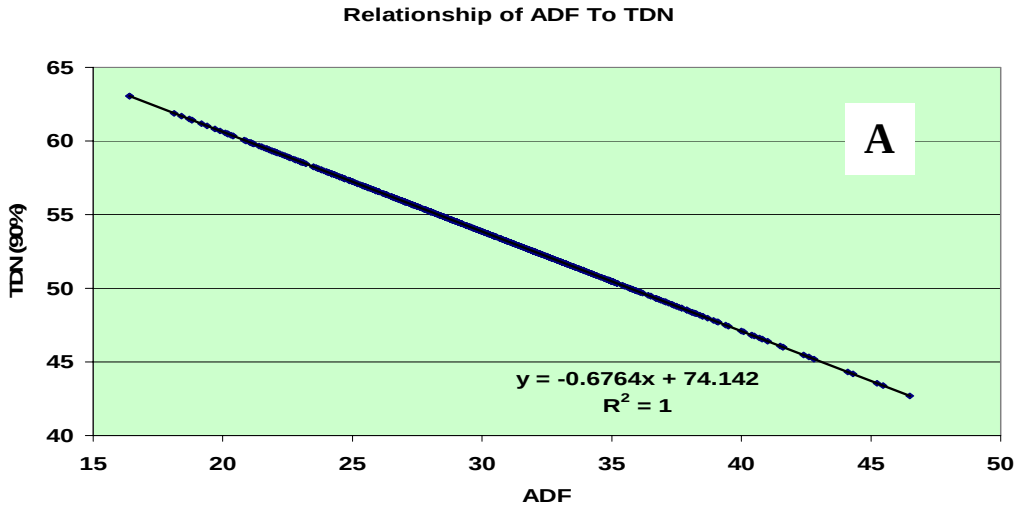


Figure 6. Relationship between ADF and TDN. In terms of hay marketing, there is absolutely no difference between TDN and ADF (A).

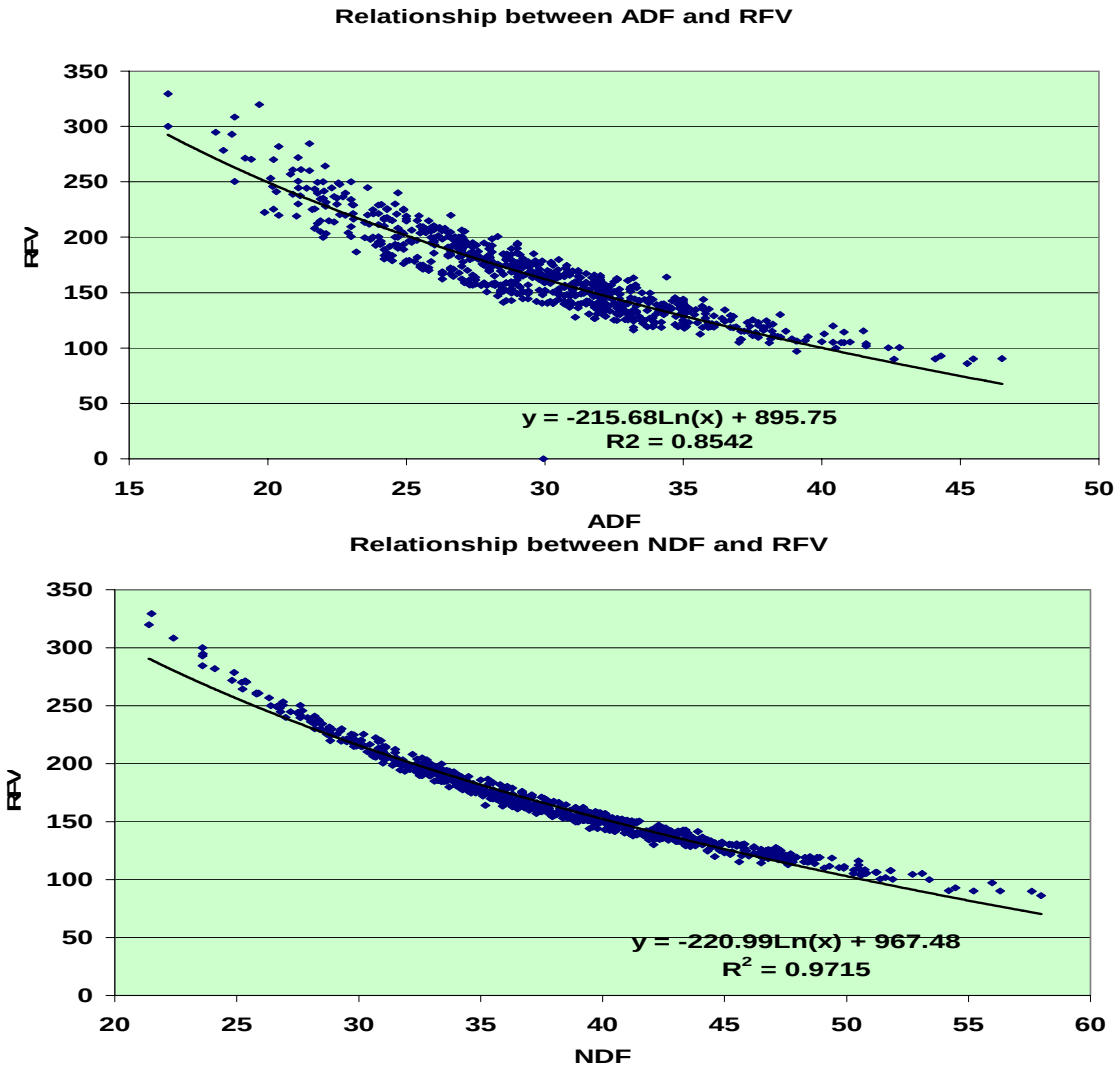


Figure 7. ADF and RFV index (top graph), and NDF and RFV (bottom graph). RFV values can be virtually entirely predicted using NDF alone (bottom graph).

The Problems with TDN in Markets. Total Digestible Nutrients is an estimate of the energy available to the animal from a feedstuff, and a valuable concept to nutritionists. Nutritionists use TDN for calculating NEL and other energy estimates. However, it can be troublesome in markets. It is a predicted (calculated) value, not a measured value, and subject to interpretation. Historically, most TDN estimates were linear measurements derived from ADF (see figure 6), and there have been a range of TDN equations available. The NFTA website lists dozens of ADF-TDN equations (see www.foragetesting.org). Figure 8 illustrates the problems with TDN in marketing—in this example, even though measured ADF values were equivalent, TDNs ranging from 45.4 to 57.4 were predicted, depending upon equation. Additionally, in California, we use a 90% DM TDN, based mostly on tradition, but this further confuses the issue (this is obtained by multiplying the TDN x 0.9). This assumes that the dry matter content of hay equilibrates to 90% after storage. However, to avoid confusion it makes more sense to consider the nutritional value of hay on a 100% dry matter basis rather than 90% for TDN and 100% for CP. California has standardized the TDN calculation about 8 years ago (to solve the problem illustrated in Figure 8), but it still occasionally presents problems. The use of ADF directly

would be a more rational approach to hay marketing than the use of TDN, since ADF is the value actually measured by the lab.

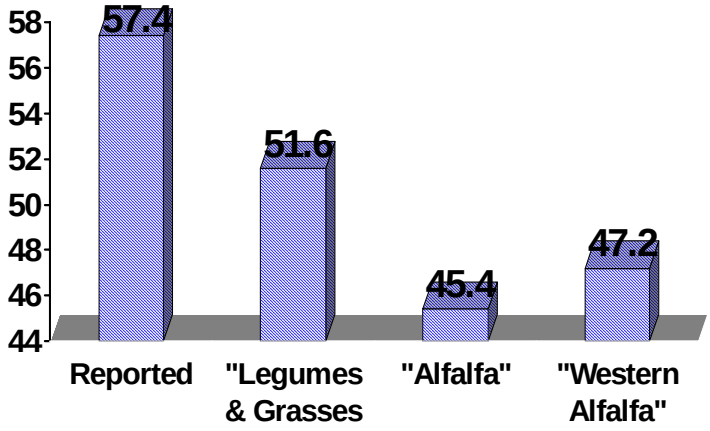


Figure 8. Influence of Equation choice on the TDN value of alfalfa hay based upon a single measured ADF value. In this case, the TDN was taken from a single lab report, and compared with 3 other published TDN equations from the same ADF value. There is no real difference in quality, since the measured value is exactly the same, only the calculated TDN values change.

Energy estimates such as TDN, although important, are essentially interpretations of data, rather than data itself. They are (and should be) subject to modification over time according to scientific advances and schools of thought. As new research information is gathered, predictions of energy from lab values should change! Many nutritionist currently derive TDN (and NEL and other energy estimates) using 'summative equations' which use other measured values (NDF, NDFd, Ash, EE, etc.), not just a fiber value. They may ignore the 'TDN' as presented by the lab report and calculate their own. These 'summative equations' are widely considered to be improvements in energy predictions. In the 2001 NRC Requirements of Dairy Cattle summative equations predominate, and it is noteworthy that the ADF-TDN approach is completely absent.

The use of a TDN calculation in the marketplace requires a high degree of standardization of TDN calculation (as we've done in California with the 'Western States' equation in Table 1), since widely varying TDN calculations create problems (Figure 8). Improvements in energy prediction (ether by additional measurements or by conceptual improvements in predictive equations), cannot be easily incorporated in marketing systems, given the strong need for standardization of lab testing for marketing purposes.

The Problems with RFV in Markets. Relative Feed Value Index was developed to incorporate 'intake' considerations along with 'digestibility', and to index the relative values based upon a numerical scale. In this respect, it is conceptually an advance over earlier methods which just considered 'digestibility'. However, RFV appears to have some of the same limitations as does TDN when used for marketing. RFV is also a calculated not measured value, which places an added dimension of complexity onto a marketing system. Use of two analyses may compound errors of the two analyses in lab testing, causing more variation in some cases. Additionally, as stated above, RFV is mostly a function of NDF (see Figure 6). Consequently, it is questionable as to whether the calculation of RFV accomplishes anything more than using NDF directly. Thirdly, RFV has little direct nutritional meaning. There is no direct requirement for RFV, and nutritionist do not use the RFV value to balance rations, and usually need to refer back to the analyzed ADF or NDF values to help balance rations. Lastly (and probably most importantly) the RFV Index curve has probably the wrong shape, if it used to place a value on hay (see figure

7 for a description of the shape of the NDF-RFV curve). RFV shows that the 'value' of hay increases at an increasing rate as the fiber value becomes lower and lower. It is doubtful as to whether this represents either a) the real behavior of markets, or b) a rational approach to the economic value of forages as considered by most nutritionists. For example, the RFV curve places a higher value on the change from 26 to 27 ADF than from, say, 32 to 31% ADF.

Nevertheless, Valuable Tools. Having described these limitations of the TDN and the RFV based marketing systems, it must be said that these methods have served as valuable tools to help describe forage quality over the past decades. The fiber-based marketing systems will continue to serve as valuable tools to aid in the identification of hay quality in the marketplace, as long as the limitations of these systems are understood. But there are important questions as to 'where we go from here?' Are there important aspects of forage testing that are missed with a fiber based system?

How does the market behave? Observations on behavior of Markets and preferences of nutritionists for hays of differing quality have shown definite trends in the relationship between quality and price (Figure 9). Figure 9 was generated partially from actual market data, but 'idealized' by frequent discussions with hay brokers, growers, and buyers about the way the market actually functions in California. This curve reflects the following observed behavior of the markets: a) the relationship between fiber and 'feeding value' as defined by the market is negative (lower fiber, higher $ value), b) The market recognizes 'cutoffs between 'dairy quality' and non-dairy quality hay, and prices are steeply discounted below this level, c) Extremely low fiber (high quality) hays are not rewarded very much in the market beyond a certain level (below approximately 26% ADF), d)The penalty for each unit change in fiber at low quality (high fiber)

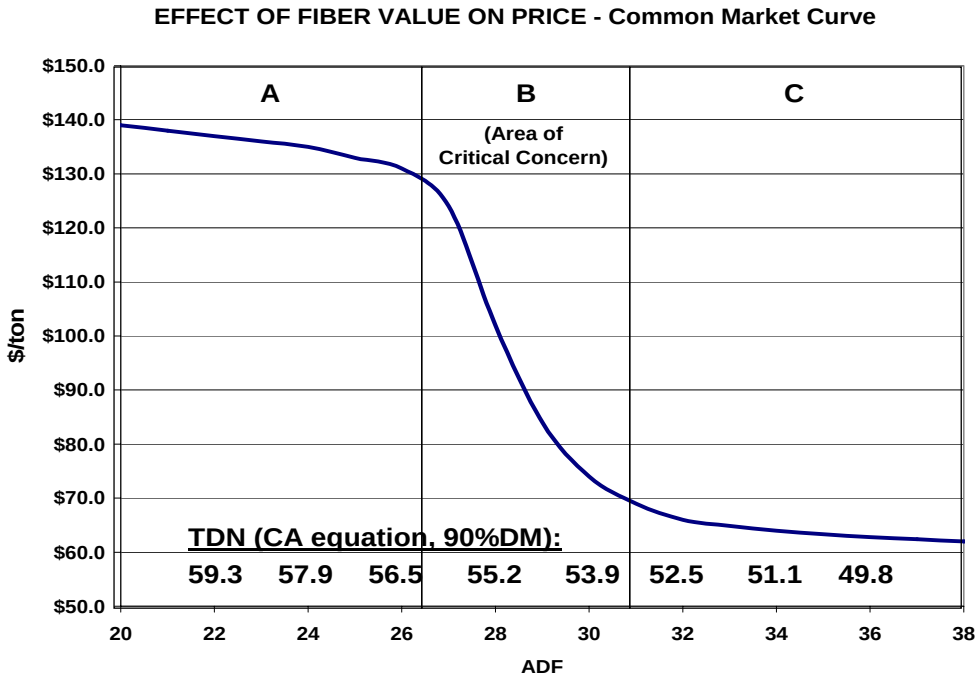


Figure 9. Idealized relationship between ADF value and price, using real data, but informed by discussions with hay brokers, buyers and sellers.

levels are not very great beyond a certain level ADF (approximately 32-33% ADF). Forage quality measurements do not have as strong an influence with higher fiber hay, in fact this lower quality hay (e.g. above about 35% ADF) is rarely tested in the California market.

Frequent discussions with experienced marketers reveal that although the absolute values may be higher or lower, and the cutoff (inflection points) may change based upon markets or specific buyers, this basic relationship reflects generally the way the market functions. As represented in Figures 3-5, the relative influence of forage quality on price fluctuates according to location, year, and other factors. This market behavior has implications for the issue how we should evaluate forages.

What is the correct Fiber-Price Curve? I should point out that the fiber-price relationship represented by Figure 9 is not a statement about the way the market should function, only an observation on how it does function. However, in discussions with nutritionists, there is a certain logic to this curve (at least the shape, if not the absolute values). Higher fiber hays (high ADF or NDF hays) are not often fed to high producing dairy cows, but instead fed to dry cows, or other animals with a lower energy requirement. Thus, a change in one or two points of ADF or NDF is not likely to make a large difference in feeding value for that class of animals. On the other end of the spectrum, very low fiber hays (low ADF or NDF) are commonly fed to much higher performance animals. However, ruminants require fiber from forages for healthy rumen function, and if alfalfa is too low in fiber this characteristic is lost. Dairy managers report health problems with animals fed too much of this 'rabbit hay'. Some have suggested that very low fiber alfalfa (e.g. very high TDNs) should be discounted as a result. Some feel it is true that alfalfa can be 'too good'.

It is important to note that this curve (Figure 9) does not resemble either the ADF-TDN curve (Figure 6) or the NDF or ADF–RFV marketing curve (Figure 7). Both of the currently used marketing techniques (RFV and TDN) imply that the highest feeding value would be at the very lowest fiber value possible. Both TDN and RFV marketing methods reward lowering the fiber levels as low as possible. However, we know very clearly this is not correct, either in the way the markets really function, nor does it really make sense nutritionally. If we follow the TDN and RFV marketing methods to their logical conclusions, perhaps we should give up on alfalfa and consider algae or duckweed?

The Need for Added Dimensions. The most critical portion of Figure 9 is the middle portion. The fiber-based marketing methods do a pretty good job of defining the 'high quality' portion of the curve, and the 'low quality' portion of the curves, and it is not clear whether additional measurements would improve our ability to recognize those hay types (in terms of market identification). However, the 'Area of Critical Concern' is in the middle, or linear portion of the curve—this is the point at which a small change in fiber level results in a large change in price. This is where most of the action is in terms of arguments between buyers and sellers over price and quality.

The fact that a small change in ADF or NDF may result in a large price change reveals two limitations to the fiber method of marketing 1) Market differences in price in this linear portion of the curve can be explained by natural sampling variation or differences between labs alone,

and 2) ADF or NDF alone is inadequate to predict the full dimensions of feeding quality sufficient to have such a dramatic influence on price as evidenced by this linear drop in price for each change in ADF or NDF. Although the 'fiber method' is simple and relatively repeatable, the California market, is too focused on the fiber level at the expense of other dimensions of quality, especially in this critical 'linear portion' of the fiber-price curve. This is the area where, in my view, we should look for added dimensions which would help further differentiate qualities of hay in the marketplace.

Forage Testing for Marketing. Generally, nutritionists will require a larger set of analyses to balance rations than what might be required to identify the quality of hay in the marketplace. Many nutritionists are interested in a wide range of analyses, from basic fiber and crude protein to minerals, protein digestion estimates, ether extract (fat), ash, and sometimes detailed carbohydrate analyses. However, analyses of hay for marketing purposes may only be a subset of these, and should have the following characteristics:

- Must be rapid (within a day or two or hours)
- Must be reliable and utilize recognized methods
- Must be repeatable across labs and across time
- Must not change significantly over time or be subject to different interpretations
- Must be a relatively powerful predictive tool for nutritionists

An ADF or NDF system satisfies most of these requirements, with the possible exception of the last. There is sufficient anecdotal and experimental evidence to show that ADF or NDF alone, though useful, cannot suffice to predict the feeding value, particularly to differentiate some important differences in intake and digestibility.

Are there added measurements that could assist? ADF, NDF, CP, and DM are the current measurements considered the 'standard hay test' in the US. The relationship between ADF and NDF appears to be fairly close, at least for western-grown hays (Figure 10). That is: if one knows the ADF level, you can predict with fair confidence what the NDF level is. Over 97% of the variation in NDF in the California dataset, and over 91% in the 'western hay' dataset can be explained by ADF. This is not surprising; ADF is always smaller than NDF—it is a subset of NDF. ADF represents the lignin and cellulose portions of the cell wall, whereas NDF represents the lignin, cellulose, and hemicellulose, or most of the cell wall. Thus, it is questionable as to whether both ADF and NDF are required to judge hay quality in western alfalfa hays. The use of both ADF and NDF may be more useful in markets which see a significant amount of mixed grass-alfalfa forages. But for pure alfalfa hays, since there is a emphasis on simplicity of hay analysis for marketing, it makes sense to choose one or the other, not both for marketing purposes.

Protein. The relationship between fiber (either ADF or NDF) and CP is relatively weak (data not shown). Although fiber and protein are correlated (higher fiber indicates generally lower protein), they are not so highly correlated that measurement of one could adequately predict the other. Therefore, both a fiber and a protein measurement appear necessary.

Fiber digestibility (more precisely, NDF digestibility) is the fraction of the NDF content which breaks down in rumen fluid in 30 hours (or other prescribed period). The relationship between fiber digestibility and the ADF or NDF measurement itself is weak (Figure 11). At a given ADF

level, fiber digestibility percentage of alfalfa ranges from the low 30s to upper 50s in some of these datasets (Figure 10). This indicates that NDFd may provide more information than is provided by the simple NDF or ADF measurement. From a nutritional perspective, NDF digestibility are thought to aid in prediction of the 'residence time' and intake factors for forage crops, and this can be used in ration balancing programs. Rapid NDF digestibility in rumen fluid at 30 hours may indicate the potential for a forage to either limit intake (with low NDFd) or to enhance rate of passage and feed intake (high NDFd).

Gas Production Method. When samples are placed in rumen fluid, gas is evolved from fermentation. Measurement of gasses (timing and volumes) may enable more dynamic measurements of forage quality, since timing of digestion is nearly as important as extent of digestion for many classes of animals (Robinson et al., 2004). This has an advantage over the NDFd method, in that multiple times of digestion can be estimated on a single sample.

Ash. Measurements of the non-organic, mineral component of hay identifies hay lots which have a significant soil contamination, or hays which have an above-normal mineral concentration due to salt accumulation or another factor. Figure 12 shows the range of ash values at different ADF levels for western hays. ADF and NDF do not predict ash value. Since ash has zero energy content, it is normally subtracted from an energy calculation, such as TDN. Hay lots with several points greater ash content than other hay lots may genuinely be lower in feeding value.

One has to wonder why buyers and sellers argue over 0.5 or even 0.1 of a point TDN or ADF, when, at a given ADF and TDN level, a hay could vary as much as 20 percentage points in the digestibility of the fiber fraction, and 10 points in the ash content. There are other analyses other than these which may also be worth considering (e.g. more detailed protein analyses, more detailed carbohydrate analyses), but this group is striking as candidates for consideration.

Cautions. While there are strong conceptual arguments in favor of considering added measurements to be incorporated into marketing methods, particularly for the 'critical range' of alfalfa hays transitioning between the low and high quality categories, several cautions are necessary. Such measurements must be demonstrated to provide significantly greater nutritional predictive value than the fiber-based marketing system currently used. In addition, such measurements must be highly repeatable both from run-to-run and between labs. Furthermore, to be effective marketing tools, such measurements must be adapted to rapid reporting, or rapid lab turnaround. Markets will judge whether such analyses are useful, or they will not pay the additional costs for additional analyses. Tradition also plays a role—it is difficult to change habits.

FUTURE TRENDS

A casual conversation with 10 ruminant nutritionists will likely reveal at least 11 philosophies of ruminant nutrition, ration balancing, and forage testing. This fact is frustrating to those interested in standardizing forage testing and understanding the use of forage testing in markets, but also reveals a dynamic and changing field. The seemingly confusing array of equations and approaches to forage testing is a reflection of the true complexity of ruminant systems and forages quality. There are genuine conceptual problems in providing a comprehensive approach

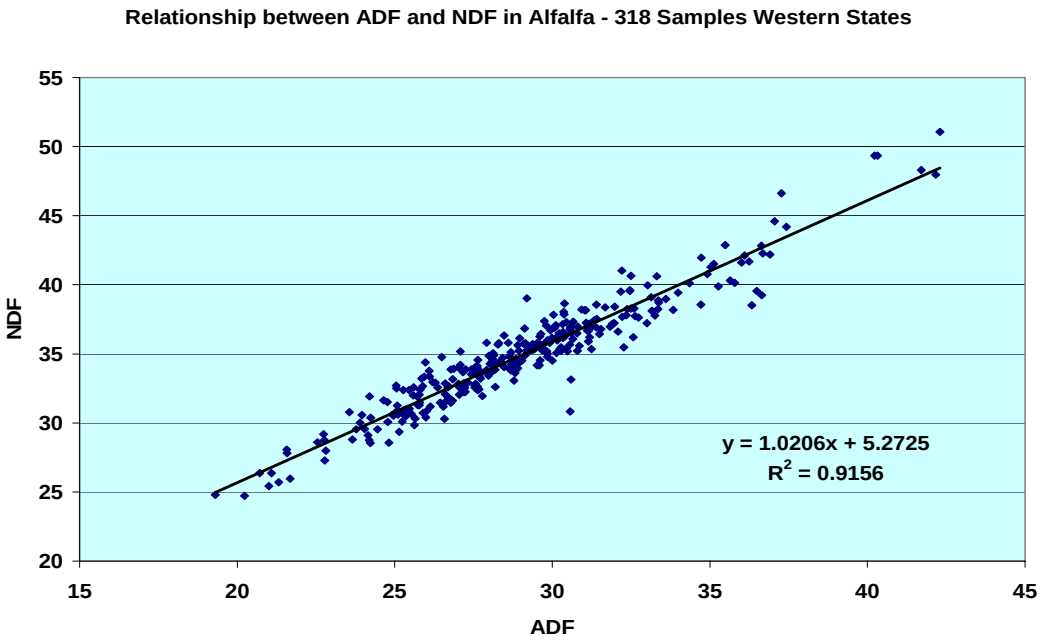
to forage testing that can handle all forages from all regions for all classes of animals. Over time, a system of 'fiber-based' marketing methods have evolved, and these standard techniques (ADF, NDF, CP, and DM) are now fairly well adapted across the US. However, there is a need to seek ways of improving this system. A series of recommendations are suggested for the future of forage testing as it relates to marketing of alfalfa hay for dairy production in Western States:

- **Use of a single fiber value** for marketing as a simplification of the TDN and RFV system. The TDN and RFV systems in reality consist of a 'fiber-based' system anyway, so such a move would articulate this in the marketplace and remove some of the confusion and negative aspects of calculating TDN and RFV. Furthermore, standardization on a measured value would enable more consistent reporting across marketing regions.
- **Gradual move from ADF to NDF** as a primary tool for a fiber-based marketing system, since NDF is of stronger interest to nutritionists. ADF and NDF are highly correlated in pure alfalfa hay and it doesn't always make sense to measure both (at least for pure alfalfa hay). The NRC 2001 recommendations for dairy cows did not mention ADF at all as a tool for ration balancing, but focuses on the use of NDF in summative equations. Although some labs are unfamiliar with NDF, NFTA labs have shown that NDF can be standardized to minimize lab-lab variation.
- **Expression of lab values on 100% DM basis** (including ADF, NDF, CP as well as TDN). The expression of TDN on 90% DM in California is simply a bad habit (it is harmless if calculated correctly, but creates confusion in the marketplace). In reality, labs calculate TDN on a 100% DM basis (from ADF) anyway and simply multiply by 0.9. It should be understood that forage quality measurements in the marketplace should be compared at a 100% DM basis.
- **Gradual incorporation of NDFd, Ash,** and potentially other methods of forage quality estimation into marketing if 1) they can be demonstrated to reveal significantly greater predictability for animal performance, 2) they are repeatable, 3) the analysis can be delivered rapidly for marketing purposes. These conditions can only be satisfied through further research and experience in the marketplace. These analyses have the potential to improve differentiation between hays which are genuinely different in feeding value but have the same fiber value.
- **Clear separation between analyzed and calculated values** on lab tests to reduce confusion in the marketplace. Prediction equations such as TDN, indexes such as RFV and RFQ, and calculations of various types are interpretations of data, and are not lab data themselves. Since these are essentially conceptual models which have a framework which depends upon both a school of thought, and limitations of research data, they are subject to change and modification as further research is conducted and ideas improve. This is as it should be. It makes no sense to stick with the same TDN that has been calculated for 40 years, if evidence clearly points to an improved prediction equation. Furthermore, predictions of energy and single 'feeding value' predictions are highly dependent upon class of animal chosen as well as feed type. This makes such calculations more risky as marketing tools than the use of measured values directly for pricing of forages. The choice of a single calculated value freezes that conceptual model as being the most appropriate for all markets and all feeding philosophies, which we know is not the case in practice. Such calculations may be useful for predictive purposes,

however, and may be demanded by those viewing lab reports, so if included, should be clearly differentiated and footnoted as to source. As the utility of these types of calculations must be tested over time, it is important to assure that they are distinctly separated on lab reports as calculated, not analyzed values.

- **There is a need for improved methods for economic analysis of multiple analyses** (e.g. NDF, NDFd, CP, Ash) for marketing purposes to account for the differences between animal groups, economics of ration balancing, and other factors. For example, the protein content in alfalfa hay will likely be worth more when protein supplements are expensive and far less when they are cheap. The fiber (NDF) content of alfalfa hay may be more valuable than the energy or protein content when the rate of inclusion of forages in the ration is low. Low potassium hay is important for 'close up' pregnant cows nearing calving, and therefore has 'value'. The rate of NDF degradation in the rumen may be more important for high producing dairy cows than for dry cows or beef cows. These considerations provide a challenge when pricing forages, one that is resistant to simplification. It is clear, however, that nutritionists often use a 'hierarchical' method of ranking hay, depending upon class of animal and feed market factors. For example, for one situation, 60% of the value of hay might be determined by the NDF value, 25% by the CP value, and 15% by NDF digestibility value, but this might differ for other situations. More sophisticated methods of determining prices based upon multiple quality characteristics are needed, especially if those anlyses are major considerations for animal performance, and as a result, should be translated to value in the marketplace.
- **Continued attention to the importance of hay sampling and lab standardization,** and choosing labs Certified by the National Forage Testing Association (see www.foragetesting.org for listing of certified labs and for sampling certification). It is impossible to overemphasize the influence of sampling on hay testing, as well as the importance of lab standardization. None of these analyses are worth their while if widely-accepted protocols for sampling and lab analyses are not followed.

Alfalfa growers, in particular, should be interested in addressing these issues. They perceive (and rightly so) that forage quality requirements are forced upon them by the dairies and the nutritionists. However, it is clear that forage quality is increasingly important to animal production and economic incentives for understanding and producing high quality forages are likely to intensify in the future. Although forage testing is a subject mostly concerning animal nutrition, is in the interest of alfalfa producers to assist in determining the definitions and measurements of quality, since they are the ones who have to produce for the market demand.



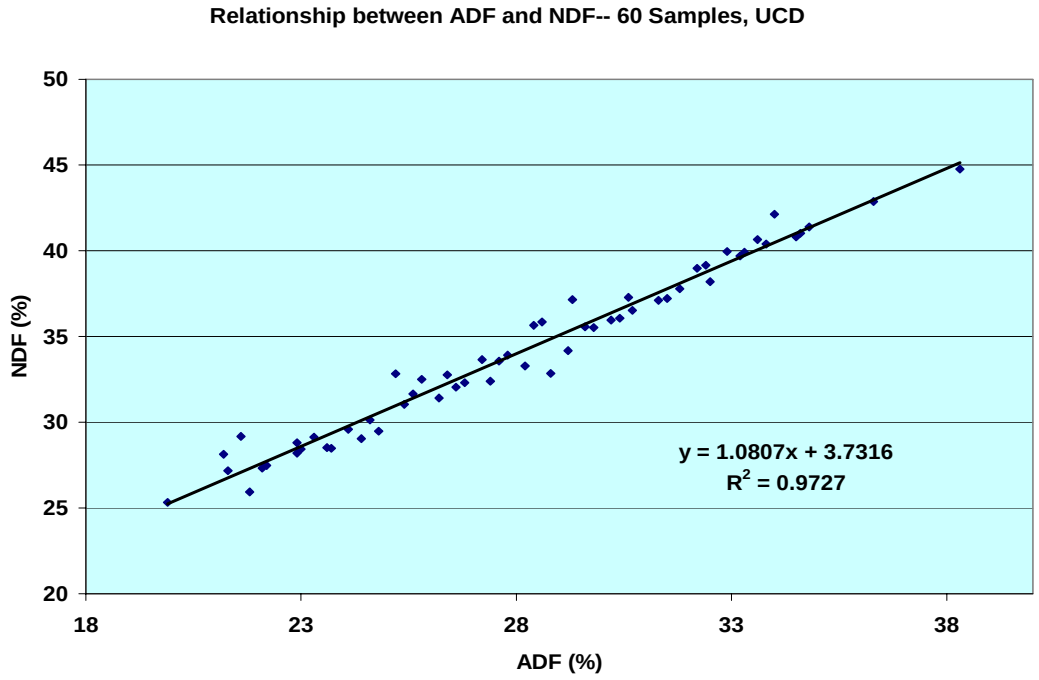
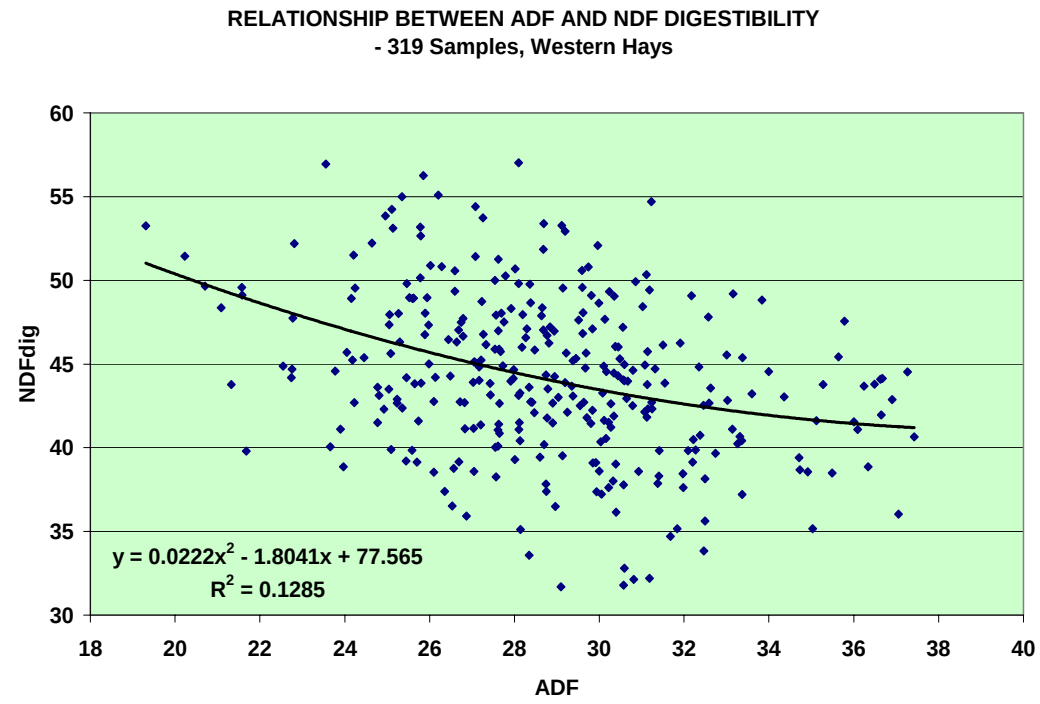


Figure 10. Relationship between ADF and NDF in two samples sets: top from many western states (CO, ID, TX, NM, CA, UT, NV), and the bottom from a commercial lab in Northern California representing a wide range of samples received by that lab.



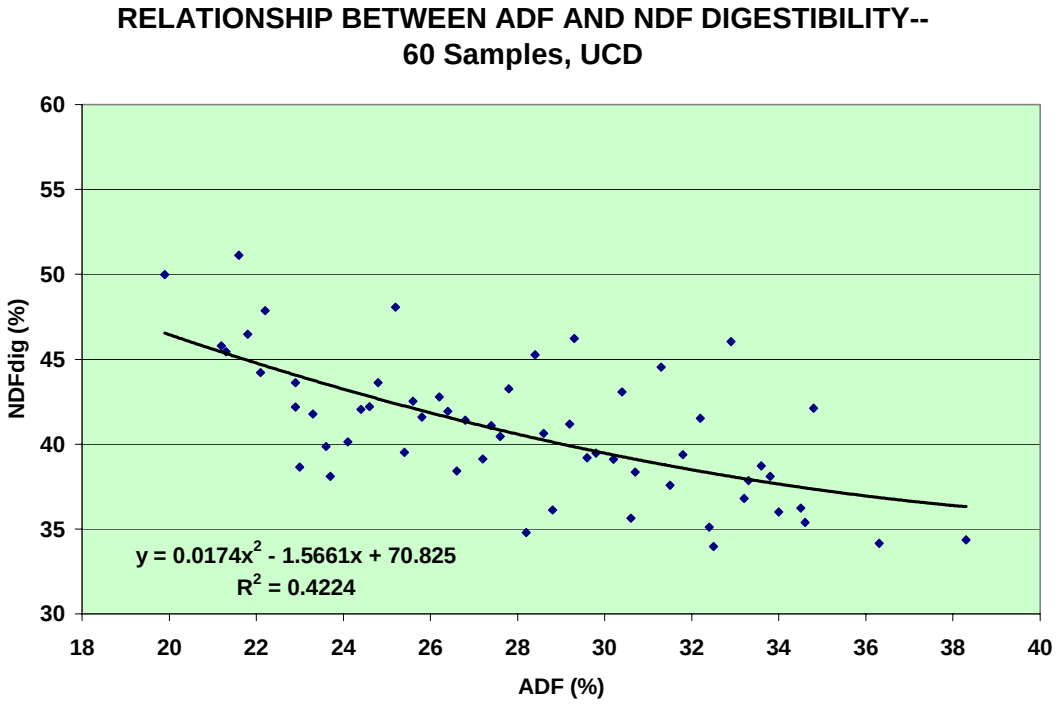


Figure 11. Relationship between ADF and NDF digestibility. NDF digestibility (30 hr) is the percentage of the NDF fiber fraction which digested in rumen fluid in 30 hours, expressed as a percentage of NDF.

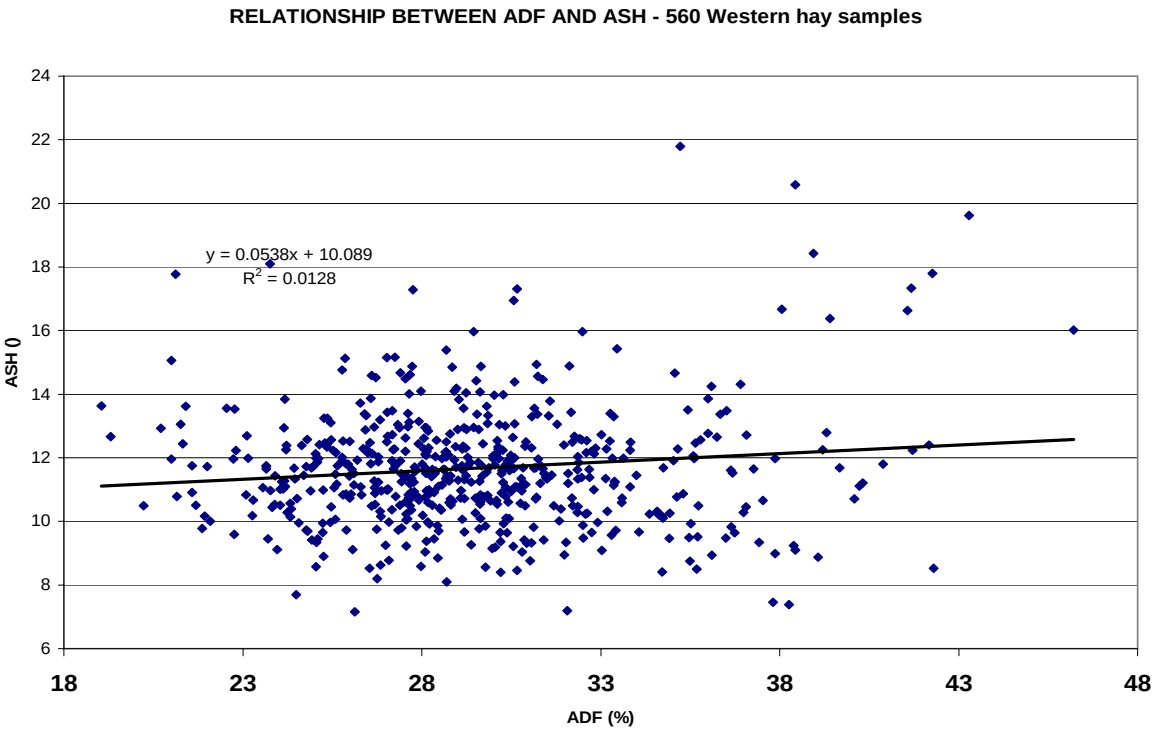


Figure 12. Relationship between ADF and Ash Percentage, Western Hays.

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