Forage quality testing Consistency....
DEVELOPMENT OF THE CALIFORNIA HAY TESTING CONSORTIUM

Dan Putnam[1] and Ed DePeters[2]

ABSTRACT

An ad hoc committee of hay testing laboratories, dairy nutritionists, hay producers and University scientists was formed in 1995 with the intent to address a range of issues surrounding consistency of hay testing in California, primarily alfalfa. These issues include hay sampling, uniformity in calculation and presentation of results, standardization of lab methods, and public education on the appropriate use of hay testing results. A series of recommendations have been made, most of which have been relatively rapidly adapted by laboratories in California. This consortium represents an ongoing effort directed towards improving precision and consistency of results using wet chemistry and NIRS methods for hay quality testing in California.

INTRODUCTION

It has been estimated that the value of premium hay (greater than 54 TDN[3]) is about $30/ton greater than fair hay (less than 52% TDN), averaged over 5 years across all California markets (Putnam, 1994). This indicates that a large price is placed upon a relatively small change (as little as 2 % points TDN) in forage quality. Due to the high stakes, and the often contentious price issues which arise between hay growers and dairy producers, there has been a considerable interest in the reliability of alfalfa hay testing in California.

Although many are satisfied with the quality of individual lab performance, discussions with hay brokers, dairy producers, dairy nutritionists, hay growers, university scientists and the commercial analytical labs themselves, revealed that concerns about consistency of hay test results from lab to lab were almost universally held. Part of this concern may have originated from a lack of knowledge of many of the other sources of variation in hay test results which have nothing to do with lab methods. Most notably, methods of hay sampling and subsampling hay core composites are not often acknowledged as a significant factor in differences in results from a single hay lot. But it was also recognized that there were few forums for discussion of these issues between labs and representatives of the alfalfa and dairy industries, and brokers and nutritionists, who individually are competitors.

THE HAY TESTING PROBLEM - VARIATION IS PART OF THE GAME

Although most buyers and sellers and users of alfalfa hay recognize the value of hay test results for ADF and CP, we have found that there is often an unrealistic expectation of the potential accuracy and precision of the process. The current hay testing process usually does a good job of ranking hays

---

[1]Extension Agronomist, Forages, Department of Agronomy and Range Science. Presented in the 25th CA Alfalfa Symposium, Modesto, CA December 7-8, 1995.

[2]Professor, Animal Nutrition, Department of Animal Science, University of California, Davis 95616.

[3]ABBREVIATIONS: TDN = Total Digestible Nutrients, ADF = Acid Detergent Fiber, NDF = Neutral Detergent Fiber, CP = Crude Protein, DM = Dry Matter, CHTC = California Hay Testing Consortium.

according to quality. However, some hay purchases have rested on as little as 1/10 percentage point difference in TDN value. Let's be realistic: we cannot currently, nor do we expect in the near future, to be able to test alfalfa hay to this degree of precision. A minimum of 0.6 percentage points +/- range in the testing process for ADF should be expected, and in practice, this range is likely much higher.

Hay test results do accurately represent the potential feeding value of hay, as many studies have shown. But each hay testing values should be associated with an "error term" or a +/- value which shows a realistic range surrounding this value. **Figure 1** indicates the sources of variation which are inherent in the measurement of feeding value or forage quality of alfalfa.

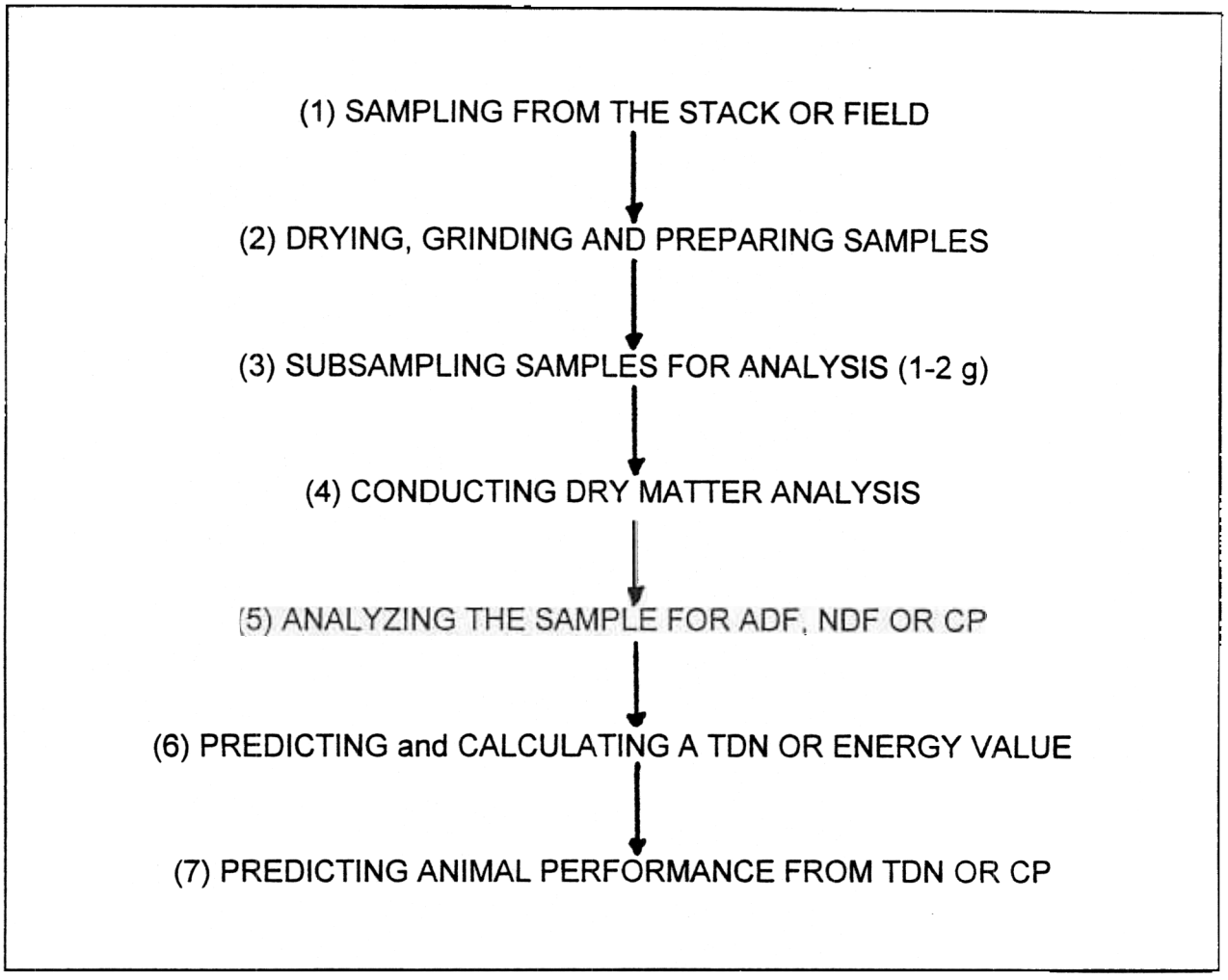

Figure 1. Sources of Variation in the Hay Testing Process. Most forage quality researchers agree that the sampling step (1) often accounts for the largest source of error in a hay testing program. This is due to the difficulty of obtaining a sample that is representative of the stack or field of hay. Lab-to-Lab variation is represented by all the variation in steps 2-6.

It is clear from this chart **(Fig. 1)** that steps 2-6 are under the control of the laboratories, but one important step, the hay sampling process, is only under control of the sampler. Many forage quality researchers believe that this step (1) is probably the most important source of variation in

representing the feeding value of a stack of hay. Step 7, which is the degree to which a TDN or CP value for hay actually results in a change in animal performance, contains much in the way of animal-to-animal variation, in addition to plant variation, and is to a great degree beyond the scope of the testing process itself. Part of the goal of the California Hay Testing Consortium is to promote an understanding of these sources of variation, and encourage a realistic expectation of the degree of variation which will be "naturally" be a part of the hay testing process. (see "Interpreting your Hay Test Report" attached to this article).

THE CALIFORNIA HAY TESTING CONSORTIUM (CHTC)

Several multiple split-sample comparison of laboratories were performed in 1994, both by the American Registry of Professional Animal Scientists (ARPAS), and the University of California, Davis (Putnam, 1994). These results indicated a sometimes disturbing range of reported values for a split sample. It was felt that there were several sources of variation which could, perhaps easily, be address through cooperative efforts.

These concerns about lab-to-lab variation led to the establishment, in the spring of 1995, of the California Hay Testing Consortium, an ad hoc committee of interested volunteers who are vitally interested in improving the hay testing process in California. The committee consists of most of the laboratories who test hay in California, representatives of hay marketing organizations, dairy nutritionists, alfalfa growers and dairy producers, and University of California scientists and UC Cooperative Extension staff. The committe welcomes further participation in this ongoing effort.

CHTC RECOMMENDATIONS

In the spring of 1995, the Consortium made a series of recommendations, with the aim of standardizing several aspects of the hay testing process. These recommendations are summarized in Table 1. Readers should keep in mind that this consortium consists of individual labs that are often competitors in the marketplace. Similarly representatives of both the dairy and alfalfa industries attended Consortium meetings. The degree to which all participants have pitched in to wrestle with these important issues in a truly cooperative fashion has been inspiring, and we all hope this cooperative relationship will continue in the future.

Many of the recommendations listed on Table 1 have been implemented in the 1995 hay testing season. In particular, several labs have made a switch from MCF measurements (as a routine testing method) to ADF measurements. They report that this has been accomplished with minimal disruption. MCF should give similar results in the prediction of TDN on the average. However, since it is a different method, any individual sample will be more likely to vary in its TDN value if calculated from MCF vs. ADF in different labs, or even in the same lab. Similarly, there is no good reason why all hay testing labs in California should not use the exact same equation to predict the TDN content of hay, thereby eliminating an important source of variation. Members of the consortium have been pleased that these recommendations have been followed across the majority of labs who test hay in California.

EDUCATIONAL EFFORTS

Members of the Consortium also felt that significant efforts were also required to educate the users of hay test results in California. There have been misconceptions about the degree of "natural" variation to expect in lab test reports, the importance of sampling, about how to interpret the results, about the differences between calculated values (such as TDN) compared with measured values (ADF), and other issues. It is also recognized that perception, interpretation, and use of hay testing results are a significant part of the utility of such results. Therefore, the consortium initiated and approved the development of an educational "pamphlet" which could be used by laboratories to send to clientele for educational purposes. This pamphlet, entitled "Interpreting Your Hay Test Report" by D. Putnam, S. Mueller, E. DePeters, and Barbara Reed is attached to this paper and available by contacting the authors or your UC Cooperative Extension office.

SPLIT-SAMPLE COMPARISON OF LABORATORIES

Members of the Consortium felt that it was important to continually check consistency between labs. Therefore, the Consortium initiated a split-sample evaluation in the summer of 1995. Two large hay samples were uniformly ground using a 1 mm hammer mill, mixed thoroughly, and split into more than twenty equal parts per sample. These samples were sent out to all participating labs with instructions to conduct analysis for ADF, CP, DM, and NDF on three separate days, and the results are provided in Table 2.

INTERPRETATION OF SPLIT SAMPLE COMPARISONS

Most of the laboratories who test hay in California participated in this split-sample comparison. Remember that this test takes into account only the sources of variation in laboratory testing after the samples are ground, dried and prepared. Therefore, it includes only source of variation of 3-6 (Figure 1). During the summer of 1995, members of the consortium identified significant sources of variation at one laboratory which were due primarily to sample grinding and subsampling problems (subsampling prior to grinding). In our view, hay samples should never be subsampled prior to grinding for quality analysis. In this particular case differences of at least 10 percentage points ADF were caused by subsampling problems. Issues such as these, or variation due to hay sampling, are not addressed with such multiple-sample tests.

Results. All laboratories in California were successful at identifying the higher and lower quality hay sample (**Table 2**-sample 2 was generally lower in fiber, but also lower in crude protein, than sample 1). However, the absolute values for ADF, TDN, and CP differed somewhat between labs. Table 2 represents the total amount of variation of all reported values (including duplicates per lab), and including both NIR and wet chemistry values. The lab-to-lab variation (comparing reported mean values per lab), generally showed less variation. For example, 12 labs reported a range of 24.2-26.5% ADF and a St. Dev. of 0.66 for wet chemistry evaluation of sample 1 (mean 25.2%). The difference in variation is accounted for by within-lab variation. Thus, for these alfalfa hay samples, clientele might see about a 4 percentage point difference in ADF, depending upon to which lab the sample was sent (worse case scenario, highest vs. lowest).

Standard Deviation. The Standard Deviation is an indication of dispersion of values. In a normal distribution, about 68% of the values should fall into the area around the mean plus and minus 1 standard deviation, and 95% of the values should fall into an area of +/- about 2 Standard Deviations from the mean. Thus for Sample 1, 95% of the results from California would range from 23.6-28.0, and 68% of the results returned might range from 24.7-26.9, with a mean of 25.8.

TDN Values. Members of the Consortium were pleased that of the labs which calculated TDN content of alfalfa hay from ADF, all used the same recommended equation, a significant change from a year ago. All labs but one used ADF to calculate TDN.

NIRS vs. Wet Chemistry. It is often asked how wet chemistry differs from NIR in results. Four labs in California reported values from NIR analysis, and at least 12 reported wet chemistry values. Therefore, direct comparison of the methods with this type of test is difficult. However, there were no indications from this test that NIRS was any more or less variable than wet chemistry, or showed any bias in results.

Limitations of this Test. This test was a part of an ongoing program at quality management for California labs, is completely voluntary, and does not constitute a certification program, but is rather an internal fact-finding exercise. An excellent certification program is currently run by the National Forage Testing Association, and we would highly recommend participation in this program as an integral part of a quality control program, where appropriate. Most laboraties have shown a keen interest in this program. We will likely continue efforts in California as a part of the Consortium to try to identify sources of difficulties, and to improve the quality of hay testing process in the state.

WHY ADF IS BETTER THAN TDN FOR BUYING AND SELLING HAY

Total Digestible Nutrients is a term useful in calculating the digestible energy in a quantity of hay, and is used by nutritionists to balance dairy rations. It is calculated directly from ADF or MCF values and is not independently measured. The equations used to calculate TDN come from animal performance studies conducted over the years which estimates the quantity of digestible energy value per unit of fiber in a given forage sample. However, TDN does not measure the rate of digestion, or forage intake, which is very important aspect of forage quality. Forage intake has been more highly correlated with NDF, and many nutritionists have move towards the greater use of NDF in balancing dairy rations. There are many forage sources which are superior to alfalfa in TDN, but have a much lower forage intake potential. The utilization of digestible energy per unit time is one of the key aspects of the feeding value of alfalfa hay (Van Soest, 1995). Therefore, NDF may become more important than ADF or TDN in balancing rations in the future.

Reporting Consistency. However, the reason that it would be better to use simply ADF rather than TDN to buy and sell alfalfa hay is more mathematical and practical than conceptual. First of all, there will probably remain some confusion between buyers and sellers as to whether the

Table 1. Recommendations made by the California Hay Testing Consortium (Spring, 1995).

RECOMMENDATIONS

1. That all labs routinely use Acid Detergent Fiber (ADF) to predict Total Digestible Nutrients (TDN).

Comments: TDN is the most commonly used parameter to estimate forage quality in California. However, TDN can be calculated from Modified Crude Fiber (MCF) or ADF. California labs were split on the method used, therefore adding significantly to overall lab-to-lab variation. Due to the fact that ADF is 1) used nationally, 2)an easier, more repeatable method, and 3) used with NDF in an overall conceptual scientific system for fiber analysis, the Consortium recommend a uniform use of ADF. As of fall of 1995, all labs but one have switched to routine use of ADF for fiber analysis.

2. That all labs utilize a single equation to predict TDN from ADF.

Comments: It was found that even among labs which were using ADF to predict TDN, there were some labs using different equations to predict TDN. A uniform equation, published by the University of California in 1989, was recommended to be used as a standard equation [TDN (% of dm) = 82.38 - (0.7515 x ADF%].

3. That all labs utilize either the Association of Official Analytical Chemists (AOAC) or National Forage Testing Association approved methodology for wet chemistry, ADF or Near Infrared Spectroscopy (NIRS) analysis.

Comments: It is recognized that lab methods are difficult to standardize because so many steps are involved. However, there are widely recognized and published methods which the consortium recognized as standard methods. The two methods listed here differ only slightly in technique. The National Forage Testing Association has published a collection of approved methods for forage analysis (Undersander et al., 1993)

4. The all analytical data be reported on a 100% dm basis at a minimum. Reporting all analyses on an "as received", 90% dm", and "100% dm" basis is recommended.

Comments: There is often confusion in the reporting of hay testing results, due to the difference in "as received" (or "as fed") results, compared with results standardized at 90% dm or 100% dm. Current practice is to report ADF at 100% dm and TDN at 90% dm. It would simplify the interpretation of results if, at a minimum, all data were reported standardized at 100% dm. "As received" dm estimations may be useful to calculate the amount of water being purchased in a hay load, but not as useful for comparing lots for feeding value.

5. All calculated values (TDN, NEL, etc.), should be differentiated in the report as calculated (not measured) values, and referenced by appropriate notation as to source of calculation.

Comments: This recommendation follows that of #2, and seeks to educate clientele about what values are measured vs. those which are calculated, and to reduce confusion about where the values originate.

Table 2. Results of a split sample analysis of California Labs, conducted Summer, 1995 (represents all observations, including about 3 observations/lab).

Parameter/Sample	N	Mean	Range	St. Dev.	Median
ADF (Acid Detergent Fiber)					
Sample	49	25.8	23.7-28.3	11	25.7
Sample 2	48	22.7	20.3-25.7	.36	22
NDF (Neutral Detergent Fiber)					
Sample	33	33.2	30.9-36.3	.49	33.6
Sample 2	33	29.5	26.3-33.4	.68	29.3
CP (Crude Protein)					
Sample	49	25.4	24.1-26.6	0.78	25.4
Sample 2	47	20.9	19.8-22.	0.58	20.9
TDN (Total Digestible Nutrients, calculated from ADF)					
Sample	51	56.7	55.0-58	0.74	56.8
Sample 2	51	58.8	56.8-60.4	0.9	59

TDN value is reported at 90% dm, 100%dm, or "as received" or "as fed" basis. This difference could easily cause values to differ by 3-5 percentage points. Secondly, though most labs are currently using a single mathematical equation to calculate TDN content of alfalfa hay from ADF, someone could easily substitute a different published equation (there are several), either by mistake or deliberately, thereby modifying TDN values.

Mathematical Anomaly. But the third and perhaps most significant problem with using TDN beyond these is illustrated in Table 2. All of these TDN values for samples 1 and 2 were calculated directly from the ADF values reported in the same table. However, you may have noticed that the range of values and the Standard Deviation is far less for TDN (range of about 3 percentage points) than it is for ADF (range of about 4 points). How can this be, especially if TDN is simply calculated from ADF?

The answer lies in the method of calculation. The TDN equation (see Fig. 1) includes a constant, plus a multiplier times the ADF value. Therefore the ADF value represents only a (small) portion of the TDN value, mathematically. For example a 4 percentage point difference in ADF results in only a 2.7 percentage point change in TDN value! This can only be compared to using a ruler with many 1/16 " gradations and whiting them out in favor of the 1/4' gradations!

Rounding Error Differences in Quality Designation. This mathematical disadvantage in using TDN to compare hays is reflected in the California Hay Standards currently in use in California (Table 3).

These standards have been in effect at least since 1985, and were likely arrived at through considerable discussion between the dairy and alfalfa industries. However, the designations are somewhat inconsistent, in that the
TDN values arrived at through calculation from the designated ADF differ by more than .5 percentage points in "good" and "premium" hay from the TDN standard values for these hays (Table 3). Since (as was observed earlier), buyers and sellers are trading hay based upon less difference than this, this constitutes an additional source of error and confusion in the use of TDN for buying and selling hay. A given hay lot with an ADF value of 29.5, for example, would be designated as premium if using the TDN standard (54.2% TDN), but this same lot would receive a "good" designation if using the ADF standard (29.5- see Table 3). Some rounding is probably necessary, but this degree of rounding creates additional problems.

Table 3. Hay Standards for TDN Published by the Federal State Market News, Compared with Actual TDN values calculated from ADF standard values. Note that the published designations for the standard TDN contains rounding differences from the actual TDN values as calculated from ADF.

	Published By Hay Market News*		Calculated Directly from ADF
Hay Designation	ADF (100% dm)	TDN (90% dm)	TDN (90% dm)
Premium	29 or Less	54 (or greater)	54.53 (or greater)
Good	32	52	52.50
Fair	37	49	49.12

*Hay Market News, October 13, 1995 (Vol. 45, No. 41) Federal-State Market News, Sacramento, CA.

The designation of TDN or ADF values for premium, good, or fair hay are arbitrary, and it would likely be difficult to reach a consensus between dairy producers and alfalfa growers on this issue. Bath and Marble (1989) published a method of pricing hay by assigning a dollar value to each increment in ADF value. Their method appears to make better sense than having such discrete "cut off" points for hay designations.

All of the previously stated concerns support the recommendation that ADF alone, on a 100% dry matter basis, is currently the best method to compare various lots of hay for quality. NDF is very interesting nutritionally, but consistent NDF determination is somewhat more problematic (see Standard Deviations, Table 2), and it is not clear that NDF would improve upon ADF in differentiating quality differences between hay lots. Since most of the industry is currently using TDN (90% dm basis), it will remain to be seen whether the industry will also see the utility and the simplicity of using ADF instead of TDN in the marketing of alfalfa hay.

SUMMARY

The California Hay Testing Consortium was formed in 1995 and has made important progress towards improving the consistency of hay test results in California. A number of recommendations made in early 1995 have been largely followed by the analytical labs which service the hay testing industry. Split sample comparisons demonstrated that labs are generally successful at designating higher versus lower quality samples, but the absolute values for ADF, CP, and TDN are still somewhat variable. The factors contributing to this variability may be addressed through future or continuing cooperative efforts

at quality control and methods standardization. The ad hoc committee is continuing to meet and initiate measures which would help standardize laboratory methods, and educate the public on the use and interpretation of hay test results. Although some degree of variation is to be expected in the hay testing process, the committee beleives that greater consistency of hay testing results in California is possible in the future.

REFERENCES

Bath, D.L., and V.L. Marble, 1989. Testing Alfalfa for its Feeding Value. Cooperative Extension Leaflet 21457. University of California Division of Agriculture and Natural Resources.

Undersander, D., D.R. Mertens, and N. Thiex. 1993. forage Analysis Procedures. National Forage Testing Association, PO Box 371115, Omaha, NB 68137. (402-333-7485).

Putnam, D.H. 1994. Alfalfa Hay Testing: What do the results really mean? In 24th California Alfalfa Symposium Proceedings. Department of Agronomy and Range Science, University of California, Davis 95616.

Van Soest, P.J. 1995. What Constitutes Alfalfa Quality: New Considerations. pp. 1-15 In Proceedings 25th National Alfalfa Symposium. Feb. 27-28, 1995, Syacuse, NY. Certified Alfalfa Seed Council, Davis, CA.