

ANALYZING SILAGE CROPS FOR QUALITY: WHAT IS MOST IMPORTANT?

Ralph Ward¹

ABSTRACT

Animal productivity depends on the nutrient composition of the ration presented to the animal as well as on the quality of feed ingredients. In assessing animal productivity the nutritionist must determine if ration composition is the factor limiting productive potential. In order to do this one must have an accurate assessment of feed quality and delivery. Having as complete a set of information as possible on the feeds and delivered ration will assist the nutritionist in making this determination and allow for the identification of limiting factors.

With advances in the use of Near Infrared Reflectance Spectroscopy (NIRS) thirty or more items of nutrient information can be provided with minimal cost. Various evaluations beyond the scope of NIR are available as well. This volume of information can often overwhelm the nutritional diagnostician and make it more difficult to focus on critical indexes of forage quality. With so many analyses available which characterize different aspects of feed quality, where does one start in order to critically assess feed quality in silages?

Defining Objectives

Obviously, the first step in determining what analytical approach to use in forage evaluation is to define the objectives of testing which dictates what evaluations should be performed. Testing objectives can be summarized within the following four categories:

- Diagnostic Evaluation
- Providing nutritional inputs for ration balancing
- Marketing
- Process control

It is the author's observation that often these objectives are not used in defining the scope of testing and as a result either more is spent on testing than necessary, or sufficient data is not generated to meet the objective. It is granted that there is significant overlap in what is potentially tested to meet goals of each of these objectives.

Traditionally, emphasis has been placed on nutritional forage evaluation for meeting the objectives of each of these categories. These values are *quantitative* in nature and are more easily defined and measured than items that are more *qualitative* evaluations. However, the qualitative evaluations often relate more significantly to animal performance. These evaluations comment more significantly on forage management, harvesting, and storage than nutritional measures. This paper will spend much time discussing the use of qualitative evaluations in meeting the above objectives.

¹ Ward, R. T. (rward@foragelab.com), President, Cumberland Valley Analytical Services. 14515 Industry Drive, Hagerstown, MD 21783; **In:** Proceedings, 2011 Western Alfalfa and Forage Conference, Las Vegas, NV, 11 – 13 December, 2011. UC Cooperative Extension, Plant Sciences Department, University of California, Davis, CA 95616. (See <http://alfalfa.ucdavis.edu> for this and other alfalfa conference Proceedings.)

Qualitative versus Quantitative Evaluation of Feeds

It is easy to become overly focused on key quantitative evaluations such as the amount of protein or NDF in a feed material. While these nutrients are important for balancing rations, they often are not the most important when initially assessing forage or feed quality factors related to conservation or acceptability by the animal.

Animal productivity is significantly dependent on animal acceptance of the feed and resulting dry matter intake. Those factors of forage quality associated with high and consistent dry matter intake should be some of the first factors to evaluate. These same factors are often associated with higher levels of dry matter conservation during the storage and feed-out processes. Losses of dry matter from field to feed bunk run 10% to 15% under optimum conditions and can be 20% to 40% where management is poor (Table 1). This represents serious economic loss of feed nutrients apart from impaired animal performance.

Those qualitative factors that are important to consider are dry matter, fermentation acid levels, ammonia, ADF-CP (bound protein), fiber digestibility, molds, yeasts, ash, forage particle size and corn silage starch processing. This paper will focus briefly on the listed items related to qualitative evaluation. Each of these evaluative criteria of themselves would provide opportunity for lengthy discussions. Forage laboratories should be able to provide most of these qualitative evaluation services for their clients along with traditional quantitative evaluations.

Requirement for Reference Statistics

In order for forage or feed evaluation to have value, the data or index generated from the analysis must be compared against some standard or distribution of results consistent with the feed class that is being evaluated. It does little good for us to know that the 30 hour in vitro NDF digestibility of corn silage is 55.3% unless we know how that relates to the population of analyses for corn silage.

Table 2 provides an example of averages and standard deviations for various forage classes. Figure 7 provides more extensive information about the distribution of 30 hour in vitro NDF digestibility in corn silages specific to a given laboratory.

It is important to refer to reference statistics from the laboratory that is generating the analyses for a given forage sample. Procedures can be different among various commercial and research laboratories with widely varying averages and distributions for some nutrients. Measures such as in vitro starch and NDF digestibility would be a good example where significant lab differences may exist.

This paper provides a number of examples of reference statistics (Figures and Tables) generated from commercial laboratory data of Cumberland Valley Analytical Services (CVAS) that can be used to interpret specific laboratory values. Table 4 provides an example of “goal” values for fermentation profiles.

Qualitative Evaluation of Forage - Use of Fermentation Analysis

Some argue that while the fermentation analysis is interesting, it is of little value, because it provides no information that can be used directly in the ration balancing process. However, this

challenge avoids the true value of fermentation evaluation that is meant to provide a comparative evaluation that allows the user to better characterize the silage, and to lend insight into possible dry matter intake and performance problems. A silage at 30% DM that has 1.5% butyric acid and 18% ammonia nitrogen as a percentage of total nitrogen will be utilized differently than a silage at the same DM level that has no butyric acid and 9% ammonia nitrogen. The extent of an adverse fermentation can be determined better by the fermentation analysis than by visual and olfactory observation, or by the use of a simple pH measurement.

A second and perhaps more important application of the fermentation report is as a “report card” on the management of the silage making process. Fermentation end-products the result of all conditions that affected the silage making process, including plant maturity, plant moisture, sugar content, epiphytic (indigenous) bacteria activity, additive use, ambient temperature, packing, and face management (Kung and Shaver, 2001). Significant breakdowns in the management of the silage making process will show up as silage with less desirable fermentation characteristics. The farm adviser can use the information gained from the fermentation analysis to document the quality of the silage and to challenge a farmer to improve silage making practices. Quality forage is the basis of profitable animal production. The type and degree of fermentation will significantly affect the amount of DM recovery from the silage making process.

Significance of Moisture to Fermentation Outcome

Forage that is ensiled properly exhibits rapid pH drop where homo-fermentative bacteria predominate. Lactic acid should be a significant end-product of these fermentations. Fermentations that yield more lactic acid typically result in the lowest dry matter losses. Silages that have high levels of acetic, propionic, butyric or iso-butyric indicate conditions where DM recovery from the silage making process may be poor. Generally, in well-preserved silage, 60% -70% of the total acid will be lactic acid or 4-7% lactic acid (%DM). Acceptable silages generally contain <3% acetic acid, <0.1% butyric acid, and <0.5% propionic acid. Table 4 provides an example of goals for fermentation profiles of corn silage and high moisture corn.

The significance of level of moisture in providing opportune conditions for various epiphytic organisms that are active during ensiling cannot be overstated. Fermentation end products are significantly related to moisture level because of the epiphytes favored at those moisture levels. Figure 1 shows fermentation data for legume silage broken out by dry matter range across thousands of samples evaluated at CVAS (2008 – 2011). Most evaluations vary significantly by DM of the plant material.

Highly Fermented High Moisture Silages

High levels of silage acids indicate that an extensive fermentation occurred in the silo. Many feeding situations utilize silages with high acid content with no apparent problems. Although higher lactic acid levels are usually considered to be better for silage preservation, lactic acid may be a problem in silages where it exceeds ten percent of DM. This rarely happens in North America but is more common in Europe. When wet grasses (<30% DM) with a high amount of sugar are ensiled, perhaps as direct-cut silage, they can undergo an extensive silo fermentation and can contain high levels of lactic acid. In one study with direct-cut ryegrass silage, it had a pH of 3.8 and 17.5% lactic acid (McDonald, 1991 as cited by Harrison et al., 1994).

Wet silages that have undergone a long fermentation often contain higher levels of acetic acid (>3% DM) (Figure 1). Ammoniated silages also often have higher levels of acetic acid because of their longer fermentation (Kung and Shaver, 2001). Very high levels of acetic acid (>5% DM) have been suggested to cause intake problems, however research has not consistently found this to be true and the mechanism by which acetic acid might compromise intake is not understood (Seglar and Mahanna, 2001). The acetic acid itself may not be a problem, but may be an indicator of less desirable fermentation.

Poorly Fermented High-Moisture Silages - Clostridial Fermentations

Forages ensiled at less than 32% DM have a greater risk for clostridial growth. Clostridia bacteria are one of the most common undesirable bacteria that may persist in unstable silage that has no oxygen. They produce butyric acid and break down protein. Clostridia usually are associated with hay-crop silage that has a pH of 5.0-5.5. With a clostridial fermentation, there will be higher silage dry matter losses, poor silage palatability, and a higher level of ammonia nitrogen. It is suspected that the protein breakdown products, such as ammonia, amines, and amides, may be responsible for limiting intake. Butyric acid itself may not significantly impact intake, but may be a marker for protein degradation products.

Soluble protein has been used to evaluate retention of protein quality in fermented silage. Forage evaluation data compiled by CVAS indicates that there is significant variation in the quality of protein in the soluble fraction. In Figure 2, one can observe a very strong relationship between moisture level of legume forage and the ammonia nitrogen as a percentage of total nitrogen. This would be expected as there are more clostridial and proteolytic organisms active at higher moisture levels. However, there is little correlation between soluble protein and moisture level (Figure 2) indicating that the soluble protein test is not sensitive to the quality of the protein in the soluble fraction. It would not be a good predictor of ammonia or proteolytic activity during the forage wilting and fermentation process.

Unavailable Protein (ADF-CP)

The ADF-CP is measured by boiling feed or forage in an acid detergent solution and determining the protein content of the residue. This protein fraction is assumed to be of little use to the cow. Excessive heating of forages leads to what is known as the Maillard reaction where sugars are condensed with amino acids and become insoluble like the lignin complex. Van Soest (1982) makes the statement concerning the evaluation of heat damage: "Its assay as a guide to quality of processed feeds cannot be underestimated nor overlooked." This process of heat damage may severely reduce the availability of protein and digestible carbohydrate in a feed. ADF bound protein (%DM) values above 2% (Figure 3) in legume silage indicate a potential problem with excessive heating. Ensiling at higher dry matter levels and poor bunk face management which exposes more silage surface area to air can increase ADF bound protein in silage (Ruppell et al., 1995). Fiber digestibility in hay-crop forages as determined by a 30 hour invitro NDF assay is negatively impacted by heating and creation of ADF-Protein (Figure 5, CVAS 2011).

Ash

The ash content of a feed or forage is a measure of the total amount of all minerals. Higher ash content indicates that soil born yeasts and clostridial organisms may have been incorporated into the silage material compromising the fermentation and aerobic stability of the silage. Elevated ash levels are due primarily to soil contamination. This is often accompanied by high iron levels. Causes of high ash content include mowers set too low, splash on windrows from rain, raking with tines set to low, flooding of standing crops, and incorporation of soil during bunker filling or feed-out. Ash values in corn silage analyzed at CVAS average 4.4% and often will range over ten percent due to contamination. The mean of legume silage ash values is 11.8% with many samples over 15% (Figure 9, CVAS 2011). Organic ash levels for legumes average only about 10%, leaving the balance of determined ash to be from contamination, or potentially higher silica levels depending on soil type.

Fiber Digestibility

A key criterion of forage quality is the digestibility of the forage fiber. Increasing fiber digestibility is related strongly to increased dry matter intake and increased milk production. Across a number of studies, increasing forage NDF digestibility by 1% increased dry matter intake by milk production by .15 kg. (Figure 6) In studies utilizing brown mid-rib corn silage, increased milk yields of 2 to 3 kg more milk are often realized. Rumen fill and rate of passage are impacted by NDF digestibility.

Table 2 is a summary of CVAS data for NDF digestibility by forage class. Two significant observations from this data are that there is significant variation in fiber digestibility across forage class and significant variation within forage class. This provides the basis for NDF digestibility to be a significant qualitative tool for differentiating between forages. Figure 7 shows the wide range of 30 hour NDF digestibility in corn silage impacted by hybrid and growing and storage conditions.

Starch Digestibility

Starch provides a high proportion of the total digestible nutrients (TDN) in a ration. The chemical characteristics and particle size properties of the starch have great influence on the rate of starch degradation in the rumen, the amount that degrades in the rumen versus the small intestine or hind gut, and total tract digestibility.

Use of in vitro systems to evaluate rumen starch digestibility allows the characterization of starch degradation into categories of high, medium, or low. This allows nutritionists to formulate rations with complementary starch sources that provide differing degradation characteristics, as well as, providing a better understanding of the total starch that can be fed without creating potential acidosis.

Table 3 provides reference information on 7 hour in vitro starch digestibility of corn silage and corn grain samples. Digestibility will be influenced by moisture at ensiling, particle size, and length of time in storage.

Starch Particle Size Evaluation

Evaluation of corn silage presents unique challenges because it contains variable portions of both grain and stover that differ in chemical and physical characteristics. Most corn silage contains 40% to 50% corn grain. The availability of starch in the corn silage grain is variable and influenced by chemical composition of the grain, moisture, length of fermentation, corn particle size and fragility. The particle size and fragility of the corn grain have significant impact on the amount of corn that is digested in the rumen, the rate of starch degradation in the rumen, and the total tract digestibility.

Dr. David Mertens developed the corn silage fragmentation index (corn silage processing score or CSPA) as a diagnostic tool to determine the adequacy of processing of grain in corn silage. In this evaluation approximately 600 ml of dried corn silage is shaken through a set of sieves. The proportion of starch passing through the 4.75 mm sieve is known as the “processing score” or “fragmentation” index.

Figure 8 shows the distribution of processing scores from 1131 samples ran at CVAS from 2009 to 2011. Notice that there is a significant range with values as low as 10% to 15% and as high as >90%. By this index over 40% of the samples evaluated were not adequately processed, potentially impacting rumen function, total tract starch digestibility, and milk production.

Forage Particle Size Evaluation

The Penn State Forage Particle Separator is one of a number of available tools for evaluating forage particle size in forages and total mixed rations. While not unique, this tool allows for easy particle size characterization by field or laboratory personnel. Wet samples of silage are manually shaken through a set of either two or three sieves and the resulting fractions are weighed back and described as a percentage of the total.

Forage samples that are processed too finely will not stimulate the cow to chew adequately thereby creating buffering action for the rumen, neither will they promote the development of an adequate rumen mat for retaining fibrous feed material in the rumen. Forage samples that are too coarse will lead to potential sorting of the ration in the feed bunk. Coarse chopped materials will not pack as well in the silo and will lead to potentially less efficient fermentations and poor dry matter conservation.

Yeast and Molds

Simple plating techniques allow for enumeration of yeast and molds in silages and feeds and for identification of major mold types. This evaluation allows the nutritionist to see if there have been particular contamination problems that might lead to forage conservation and animal production problems. Yeasts are particularly prevalent in starch based silages and high moisture grains. Figure 10 shows the distribution of yeast counts in corn silage samples tested at CVAS. Over 50% of samples yielded counts of over 1,000,000 cfu/gram. Even allowing for elevation of counts during transport of samples from the field to the lab, a significant number of samples have levels that can impact animal productivity. These organisms multiply rapidly leading to degradation of nutrients and heating of rations in the bunk. Recent research by Dr. L. Kung at the University of Delaware (personal communication) shows a significant decline in in vitro fiber digestibility of corn silage samples inoculated with increasing levels of *C. valida* yeast.

High levels of mold indicate potential field or storage problems. By plating and identifying key mold organisms, one can determine if species generating certain toxins are present at levels to warrant concern. During the fall of 2009 and winter of 2010, following particularly problematic crop growing conditions, CVAS identified fusarium molds in >50% of the TMR evaluated, 15.7% incidence of aspergillus, and 34% incidence of penicillium. Evaluation of TMR and forage and feed ingredients during that crop year determined a high incidence of related mycotoxins.

Laboratory Evaluations for Marketing of Alfalfa

There has been interest in advancing the analytical evaluation of alfalfa hay and silage for marketing purposes. While current approaches provide information that may be adequate for marketing purposes, this information is not as powerful a predictive tool for nutritionists as would be desired. Traditional approaches that rely on laboratory evaluations have used primarily ADF, NDF, or a combination of those nutrients to define hay quality. The argument for use of ADF and an associated calculated TDN value (the California TDN) is that this value is most closely related to indigestible fiber in alfalfa. The lower the ADF value, the higher the digestibility of fiber and the higher the level of non-fiber carbohydrates. As ADF was the earliest development in fiber analysis beyond crude fiber, it received earlier acceptance as a means of defining alfalfa hay quality.

The use of NDF, the total fiber complex, is highly related to alfalfa quality and potential intake potential. The RFV index which uses both ADF and NDF was derived as a means of combining the elements of digestibility potential and intake potential into one index. This has been the predominant analytical approach to ranking alfalfa quality for marketing purposes. The use of ADF still enjoys widespread acceptance as there is argument that there is a high correlation of ADF to NDF and RFV in alfalfa hay.

The calculation of RFV is as follows:

$$\begin{aligned} \text{DMI, \% of BW} &= 120 / (\text{NDF, \% of DM}) \\ \text{DDM, \% of DM} &= 88.9 - .779 * (\text{ADF, \% of DM}) \\ \text{RFV} &= \text{DMI} * \text{DDM} / 1.29 \end{aligned}$$

Evaluation of 1520 alfalfa hay samples from Western States would demonstrate a high correlation between ADF and RFV and NDF and RFV. Thus, there is little advantage in using the RFV index over ADF or NDF in defining alfalfa hay quality. Putnam in looking at a USDA dataset for Western States determined a correlation of .85 between ADF and RFV and .97 between NDF and RFV. Figure 11 shows the relationship between ADF and RFV in 1520 alfalfa samples run at CVAS with a correlation of .94. Figure 12 describes the relationship between RFV and NDF in the same group of samples. The correlation is .99. Little additional information is gained from the use of the RFV as an index.

In recent years the concept of a more elaborate index to evaluate haycrop quality has been introduced. The Relative Forage Quality index (RFQ) is an attempt to be more refined in ranking forages based on potential TDN and dry matter intake. For legumes the calculation would be as follows (2):

$$\text{RFQ} = (\text{DMI}_{\text{leg}}, \% \text{ of BW}) * (\text{TDN}_{\text{leg}}, \% \text{ of DM}) / 1.23$$

$$\text{DMI}_{\text{Legume}} = 120/\text{NDF} + (\text{NDFD} - 45) * .374 / 1350 * 100$$

(Mertens, 1987 with NDFD adjustment proposed by Oba and Allen (1999). 45 is an average value for fiber digestibility of alfalfa and alfalfa/grass mixtures.)

$$\text{TDN}_{\text{legume}} = (\text{NFC} * .98) + (\text{CP} * .93) + (\text{FA} * .97 * 2.25) + (\text{NDFn} * (\text{NDFD}/100)) - 7$$

where:

CP = crude protein (% of DM)

EE = ether extract (% of DM)

FA = fatty acids (% of DM) = ether extract - 1

NDF = neutral detergent fiber (% of DM)

NDFCP = neutral detergent fiber crude protein

NDFn = nitrogen free NDF = NDF - NDFCP, else estimated as NDFn = NDF * .93

NDFD = 48-hour in vitro NDF digestibility (% of NDF)

NFC = non fibrous carbohydrate (% of DM) = 100 - (NDFn + CP + EE + ash)

In the approximately seven years since introduction, this index has not received widespread adoption. The perceived benefit of increased precision has not been outweighed by a lack of understanding of this more complicated system. As this index requires a number of inputs, it is only cost effectively run by NIR. It requires a number of analytical measures that are not routinely run by forage laboratories requiring the use of third party NIR equations that may not be properly validated or standardized to local NIR instruments.

Lab Analysis in Haycrop Marketing

Analytical information for haycrop marketing purposes would conform to the following needs:

- Must be able to be generated rapidly
- Must be reliable and utilize recognized methods
- Must be repeatable across laboratories
- Must be repeatable across time
- Must be easily understood
- Must relate significantly to animal productivity

While much of the above deals with the protocol of executing analysis, the author would suggest the following as the basis of an analytical approach that is simple yet relates more directly to animal productivity. Much of the alfalfa haycrop marketed in the U.S. is for use in the rations of high producing dairy cattle. In these rations one of the key objectives is to maximize the intake

and digestibility of forage organic matter. In general, lower fiber forages promote dry matter intake as do forages with higher fiber digestibility. A review of invitro NDF digestibility at 30 hours in 1520 samples (chemistry methods) at CVAS shows a wide range of digestibility as shown in Figure 13.

The use of this information (actually the indigestible NDF fraction at 30 hours) can be used along with ash content of the forage material to generate a measure of organic matter digestibility. Ash content is significantly variable in alfalfa hay and more significantly in alfalfa silage. A summary of the same data set referenced above is provided in Figure 14.

Combining the invitro indigestible NDF (ash free) fraction at 30 hours along with the ash content of the hay allows us to generate an estimate of organic matter digestibility. An index can be created from organic matter digestibility to relate it in tangible terms as “Pounds of Digestible Organic Matter” per ton of hay. The distribution of this index is shown below in Figure 15.

The Digestible Organic Matter Index (DOMI) while related to NDF, has an R2 of .77, indicating that it has the potential to provide more information related to digestibility than can be determined by NDF alone. The relationship of DOMI to NDF is shown in Figure 16.

Regressing DOMI on RFV provides an R2 of .78, about the same as the regression of DOMI on ADF. This would indicate that the use of NDF or an index of ADF and NDF does not explain all of the variation in invitro digestible organic matter in alfalfa hay. The relationship of DOMI to RFV is shown in Figure 17.

Advantages to the Use of a Digestible Organic Matter Index

There are opportunities to improve the evaluation of alfalfa hay for marketing purposes using a digestible organic matter index. It requires only the use of two analytical values: ash and invitro indigestible NDF (ash free). This makes it much simpler than the Relative Forage Quality Index. Relating it in terms of pounds of digestible organic matter per ton of hay or silage is a concrete concept that is easy to for producers and purchasers of forage to understand. It has the potential to describe potential organic matter digestibility of forage much better than ADF, NDF, or RFV. There is significant range to the index allowing for differentiation of quality.

It may be argued that not all laboratories can run invitro digestibility evaluations, that there is no standard protocol for this assay and no standardization across laboratories. As well, invitro evaluations can't be accomplished quickly enough to meet marketing needs. These points are quite valid. However, much of evaluation of hay for marketing purposes by virtue of cost and time constraints needs to be accomplished by NIR. I would contend that an entity that certifies laboratories for hay marketing evaluations would contract for the development of an NIR equation utilizing this information and then provide it to certified labs as a uniform measure of hay and silage quality. This approach would provide an analytical evaluation tool of biological significance and standardization across laboratories. It would not preclude the continued use of

ADF, NDF, and RFV measures but could be adopted over time as confidence was gained by the marketplace in the value of this new approach.

Conclusion

While the evaluation of forages and feeds quantitatively for nutrients used in the ration balancing process or for marketing is important, the qualitative characterization of a forage or feed is the critical first step in the process of evaluating forage quality. Understanding characteristics such as forage fermentation, potential heat damage, fiber digestibility, starch particle size and digestibility, forage particle size, ash contamination, and the potential presence of yeasts and molds will allow the nutritionist to have a better handle on forage production and management as well as animal productivity. These evaluations place value on silage for marketing beyond the traditional evaluations for protein and fiber. RFV provides little value beyond either ADF or NDF evaluation in the evaluation of alfalfa haycrop. An index that takes into account organic matter digestibility could provide differentiation in quality beyond traditional fiber evaluations.

References

- Heinrichs, J. and Kononoff, P. 2002. Evaluating particle size of forages and TMRs using the New Penn State Forage Particle Separator, DAS 02-42. Department of Dairy and Animal Science. The Pennsylvania State University. University Park, PA.
- Kung, L. and R. Shaver. 2001. Interpretation and use of silage fermentation analysis reports. Focus on Forage, Vol. 3, No. 13, University of Wisconsin Extension.
- Mahanna, W.C. 1993. Troubleshooting Silage Problems. 4-State Applied Nutrition Conference, June 29-30. LaCrosse, WI.
- Mahanna, W.C. and L.E. Chase. 2003. Practical applications and solutions to silage problems. Pages 855-895 in Silage Science and Technology.
- Mertens, D. R. 2003. Particle Size, Fragmentation Index, and Effective Fiber: Tools for evaluating the physical attributes of corn silages. Proceedings of 4 – State Dairy Nutrition and Management Conference, Dubuque, IA. Midwest Plan Service, Iowa State, University, Ames
- Muck, R.E. 1998. Factors Influencing Silage Quality and Their Implications For Management. J. Dairy Sci. 71: 2992-3002.
- Ruppel, K.A., R.E. Pitt, L.E. Chase, and D.M. Galton. 1995. Bunker silo management and its relationship to forage preservation on dairy farms. J. Dairy Sci. 78:141-153.
- Putnam, D.H. 2004. Forage Quality Testing and Markets: Where are we Going? 34th California Alfalfa & Forage Conference.
- Seglar, B. 2003. Fermentation analysis and silage quality testing. *In:* Proc. Minnesota Dairy Health Conference, University of Minnesota, May 2003.

Undersander, D. and Moore, J. E. Relative Forge Quality. In: Focus on Forage.
<http://www.uwex.edu/ces/crops/uwforage/RFQvsRFV.pdf>

Van Soest, P.J. 1982. *Nutritional Ecology of the Ruminant*. O & B Books, Inc. Corvallis, OR.

Ward, R. 2001. Analysis and Quality Assessments of Corn and Other Silages. Pp. 95-110 in 62nd Minnesota Nutrition Conference & Minnesota Corn Growers Association Technical Symposium. Bloomington, MN.

Figure 1. Fermentation Acids by Dry Matter Range in Legume Silage Analyzed at CVAS

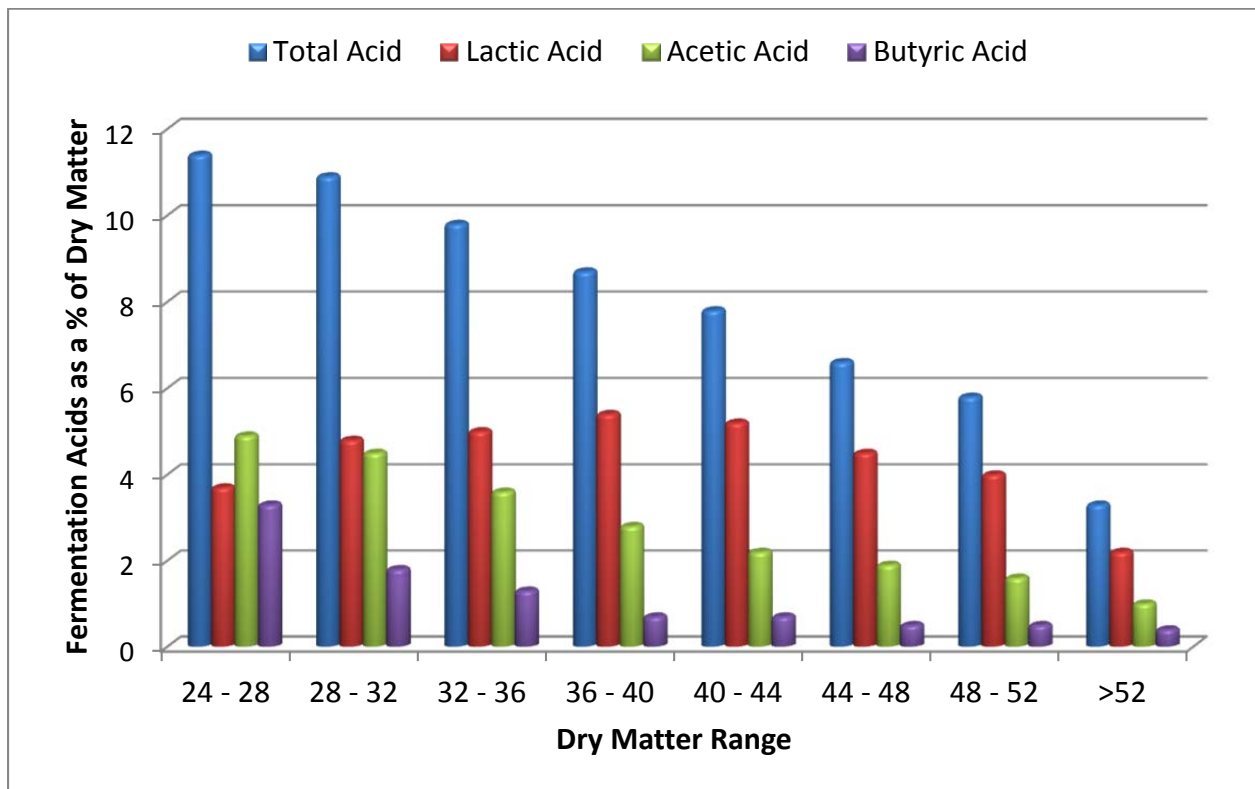


Figure 2. Ammonia Protein and Soluble Protein by Dry Matter Range in Legume Silage Analyzed at CVAS in 2008-2011

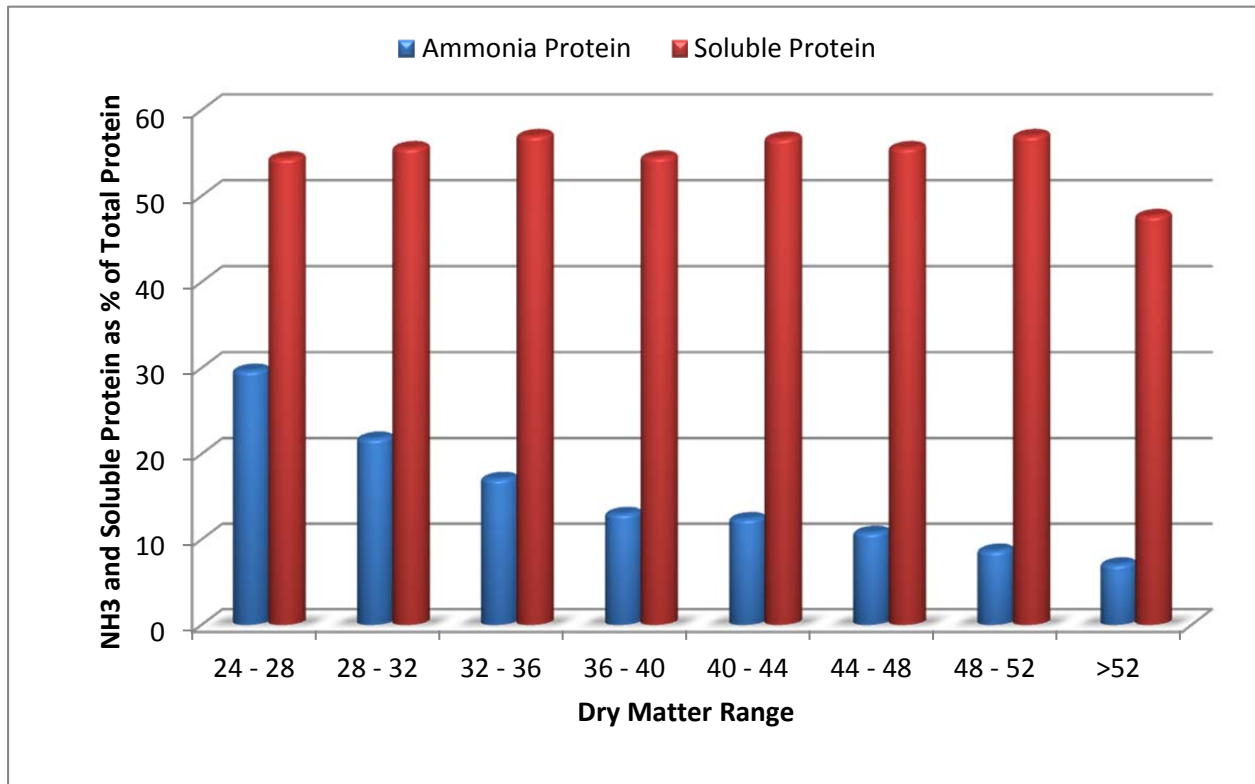


Figure 3. Distribution of ADF Protein as a Percent of Crude Protein, CVAS 2011

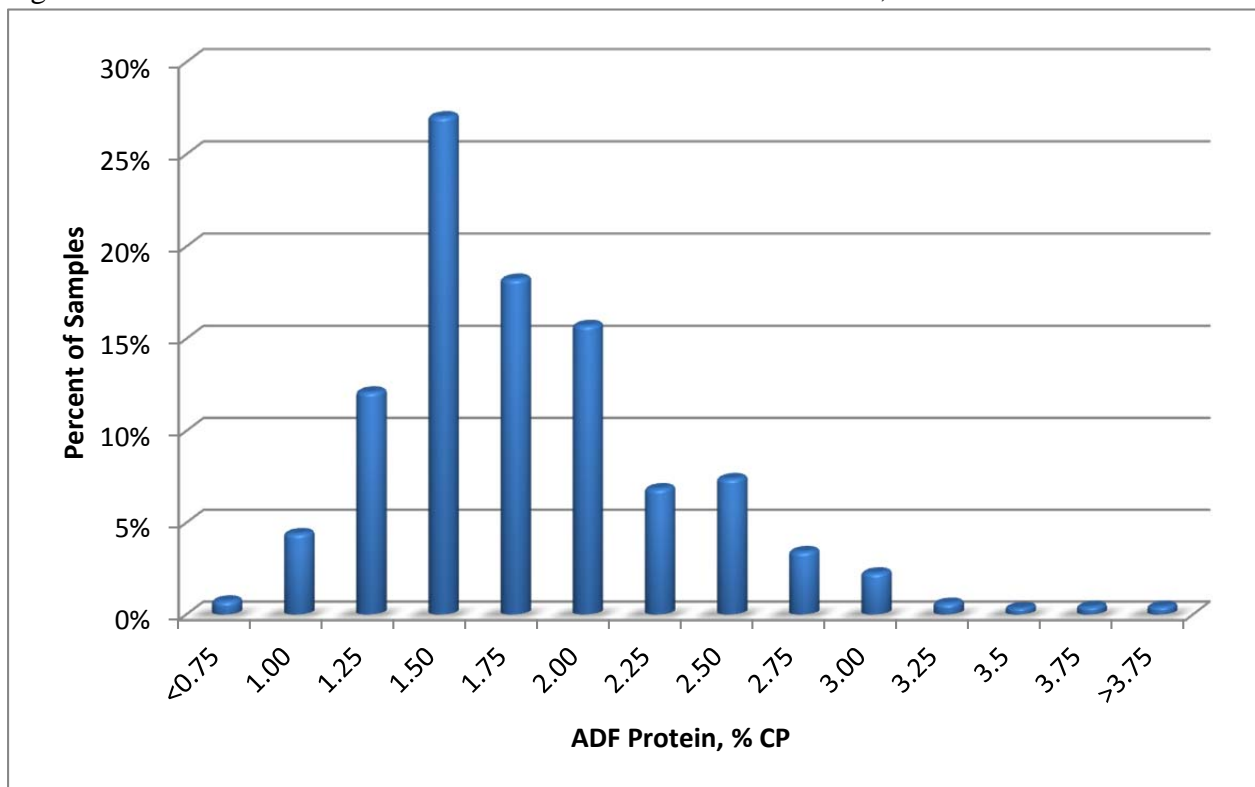


Figure 4. ADF Protein by Dry Matter Range in Legume Silage Analyzed at CVAS in 2008-2011

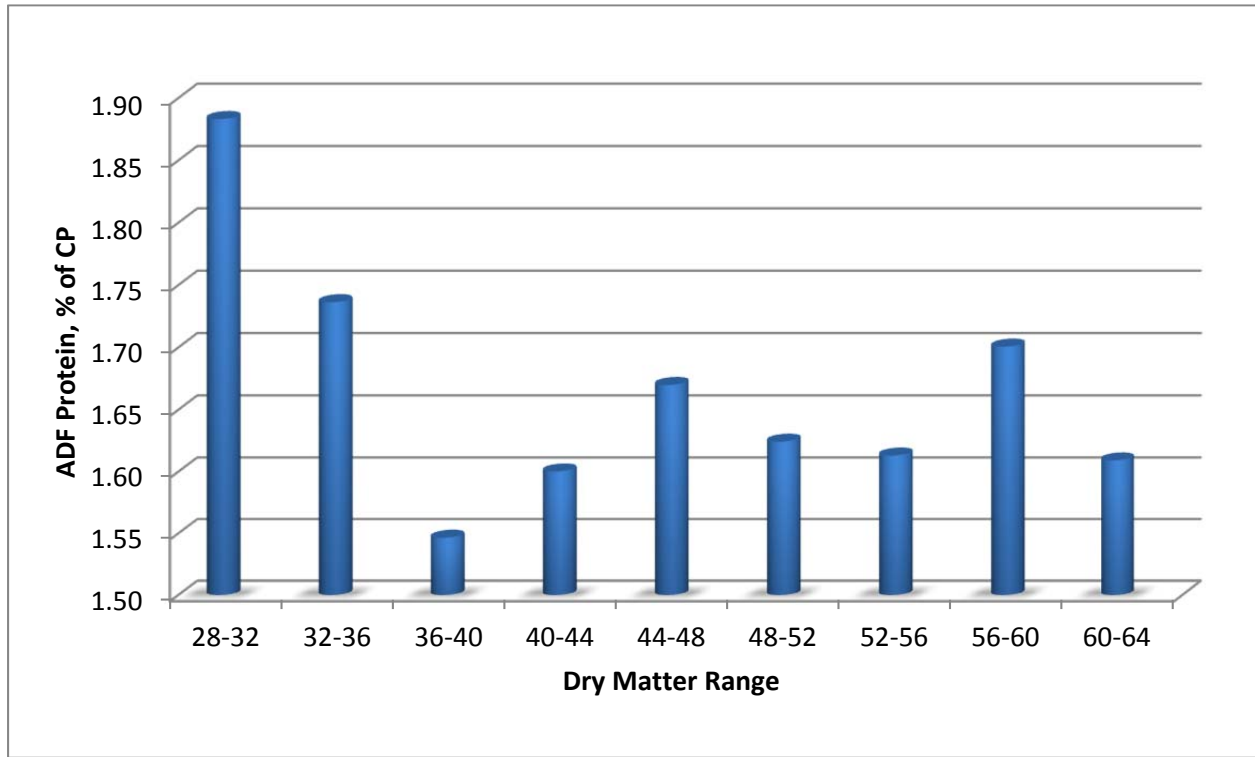


Figure 5. Relationship of ADF Protein to 30h In Vitro NDF Digestibility in Legume Silage (CVAS, 2011)

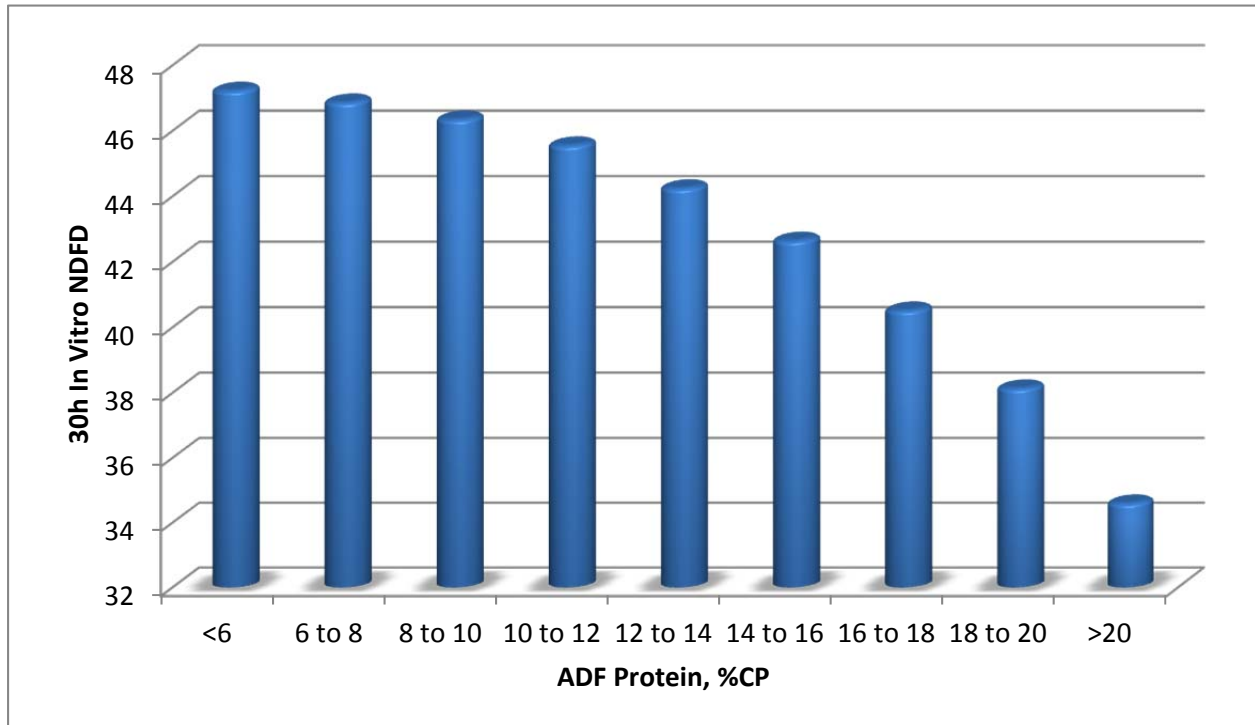


Figure 6. Impact of Increasing Forage NDFD by 1%

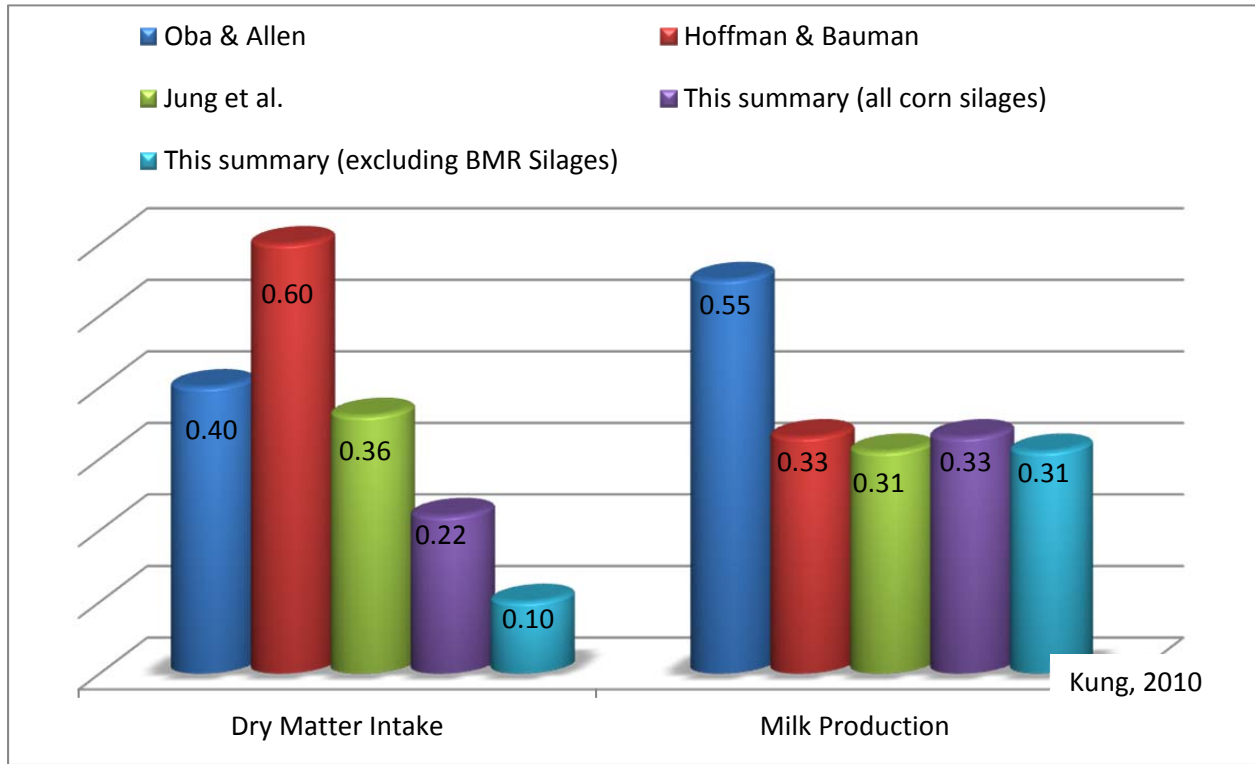


Figure 7. Distribution of 30h In Vitro Digestibility in Corn Silage, CVAS 2011

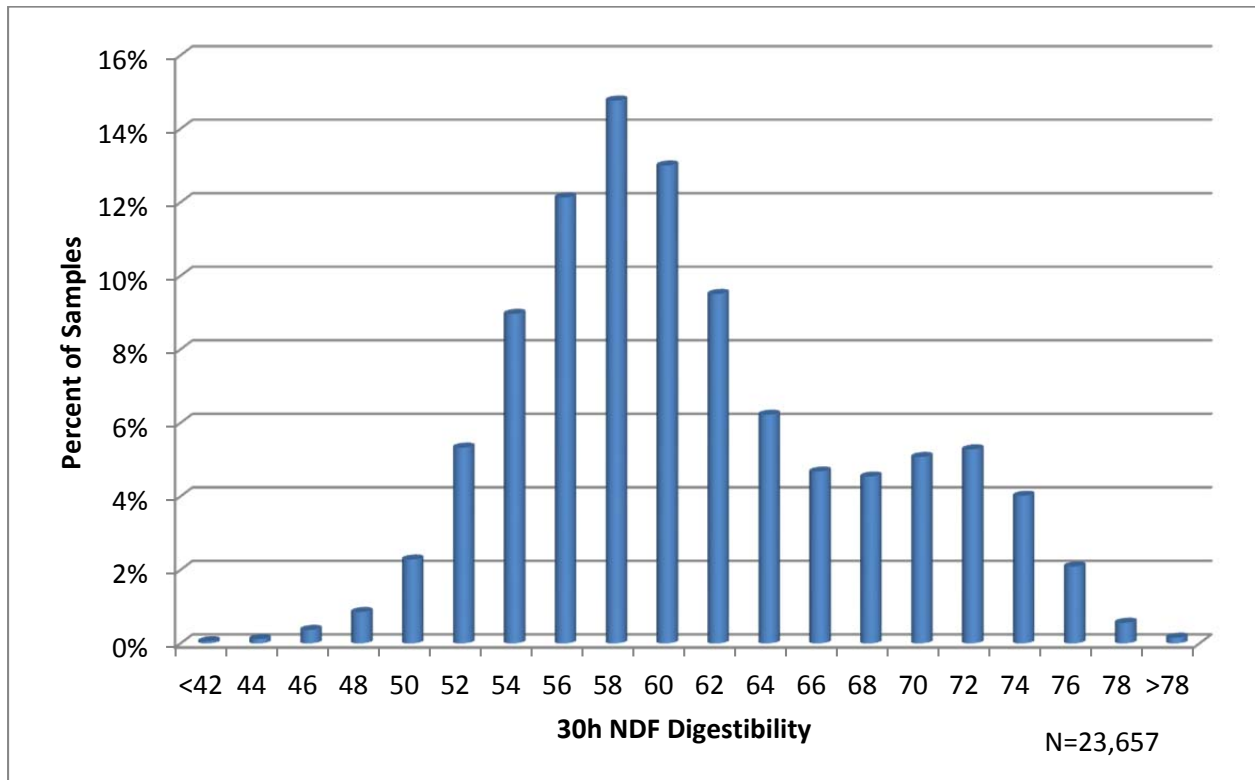


Figure 8. Corn Silage Processing Score, 1131 Samples, CVAS 2009 – 2011

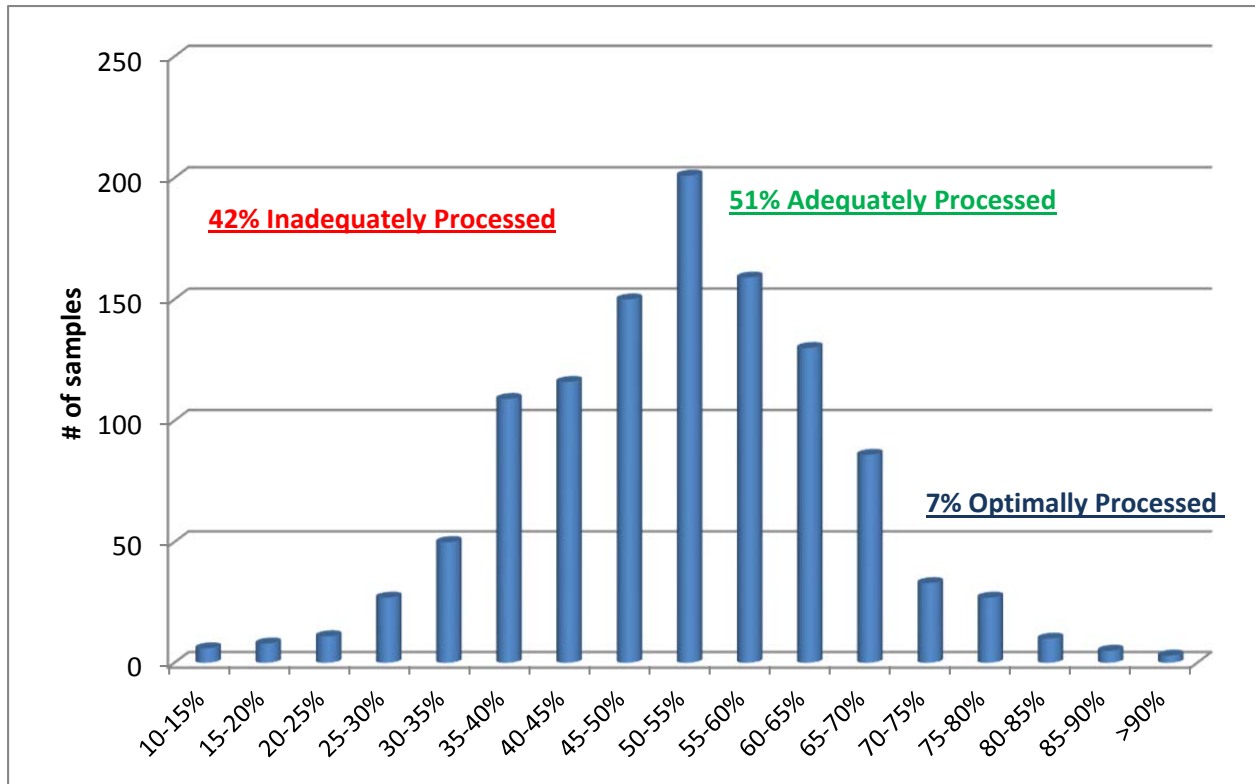


Figure 9. Distribution of Ash (%DM) in Legume Forages

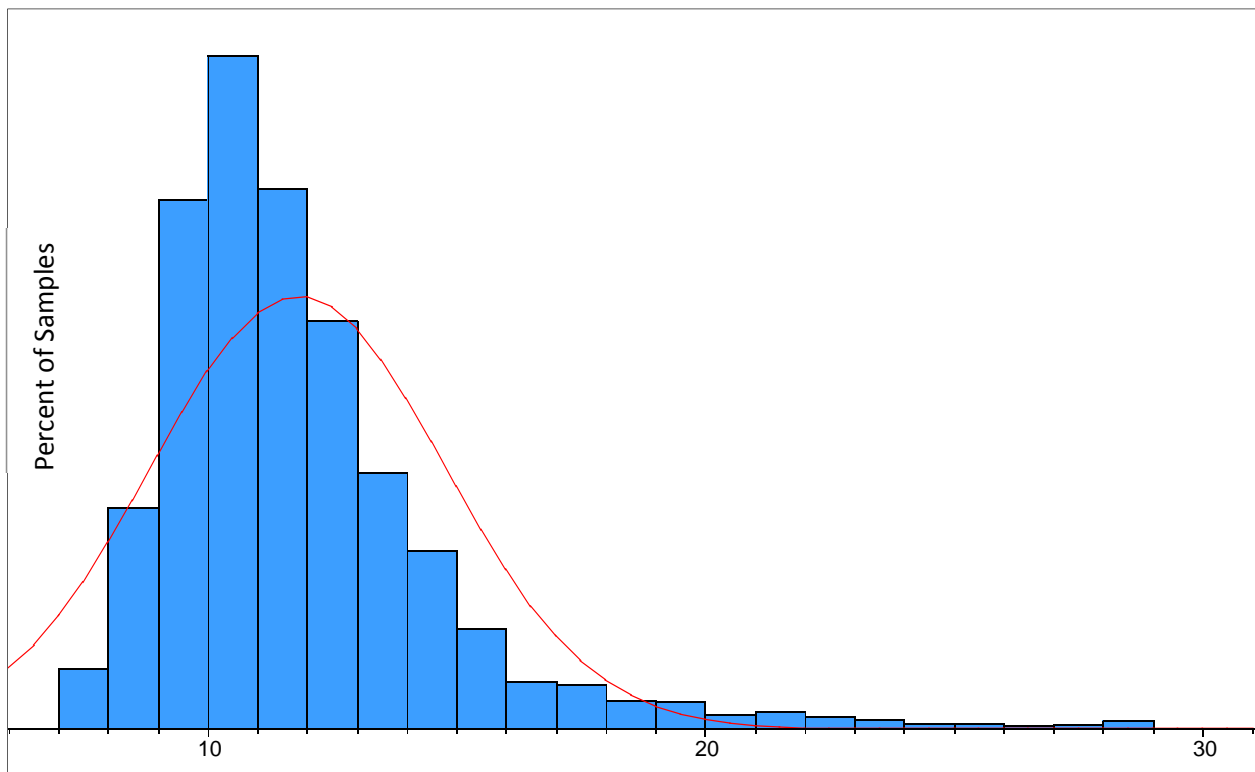


Figure 10. Distribution of Yeast Counts in Corn Silage Samples, CVAS, 2010-2011

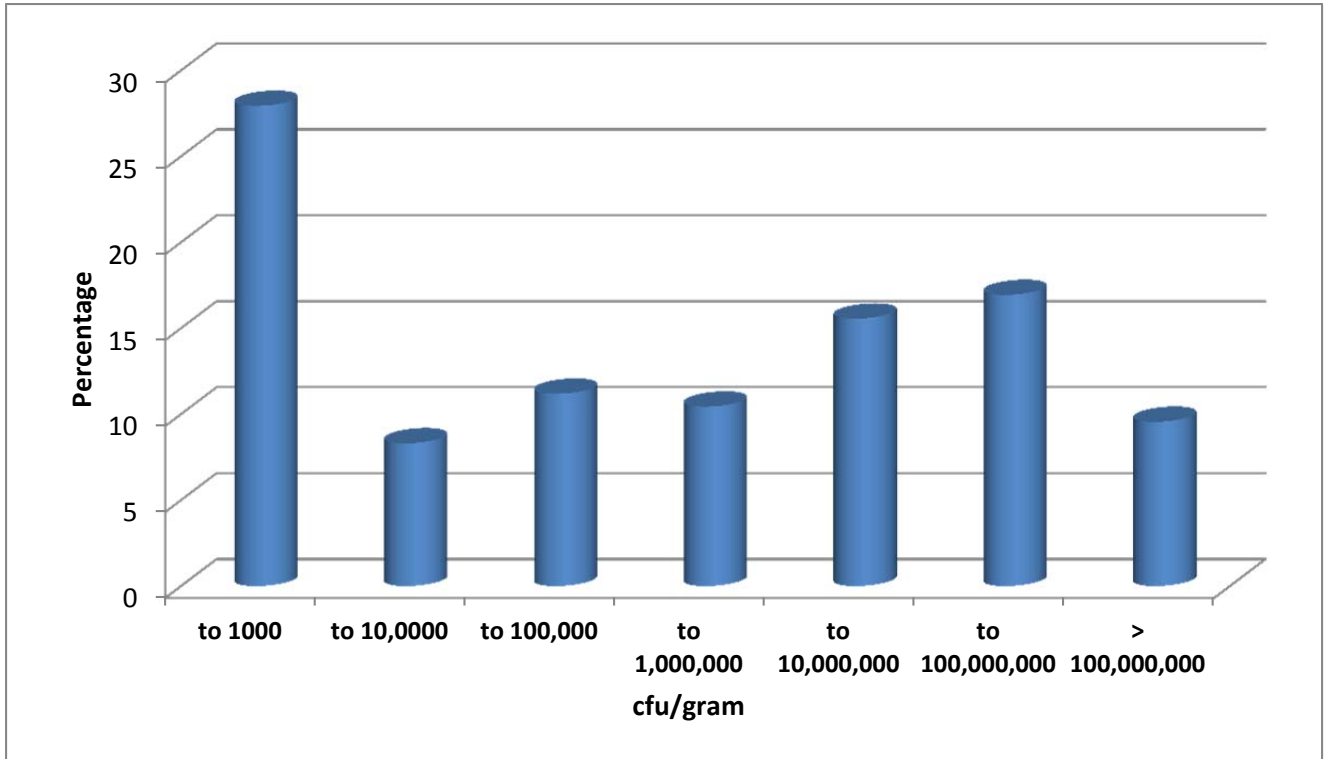


Figure 11. Regression of Relative Feed Value on ADF (CVAS, 2011)

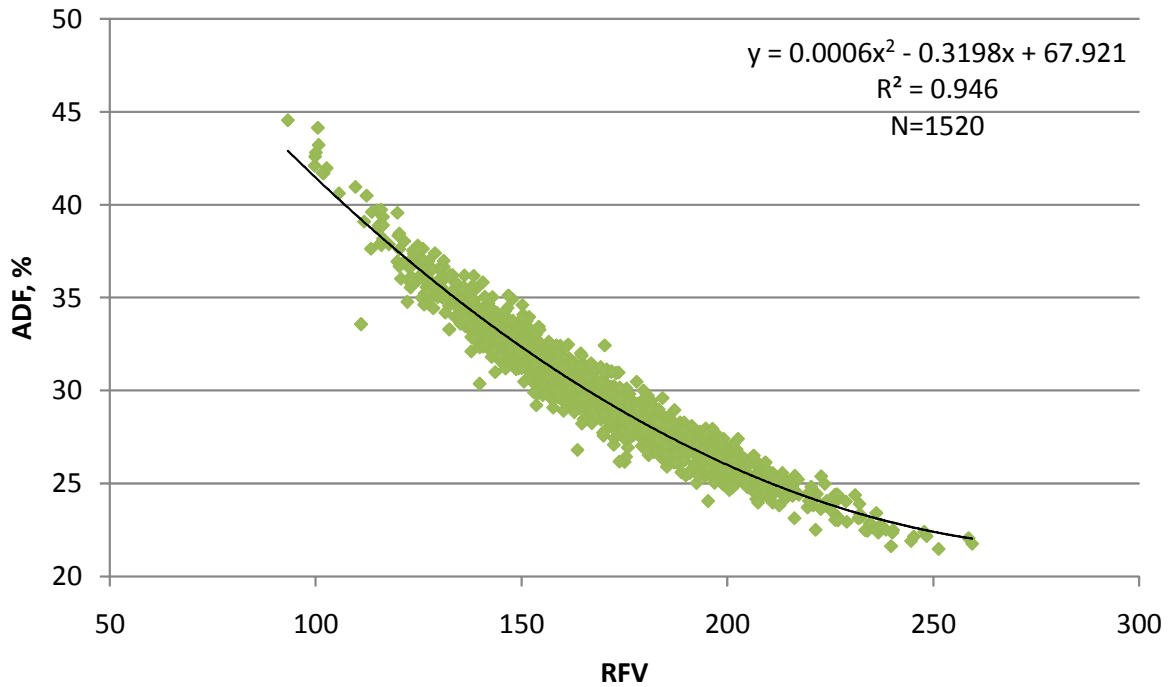


Figure 12. Regression of Relative Feed Value on NDF (CVAS, 2011)

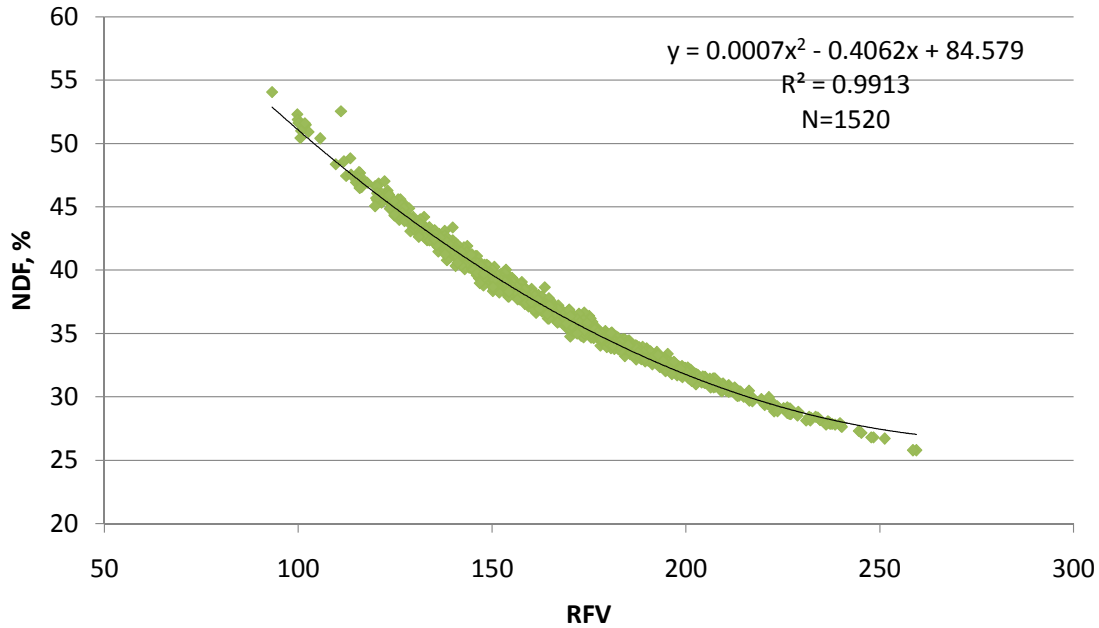


Figure 13. Distribution of NDF30, Western States Alfalfa Hay (Chemistry, CVAS 2011)

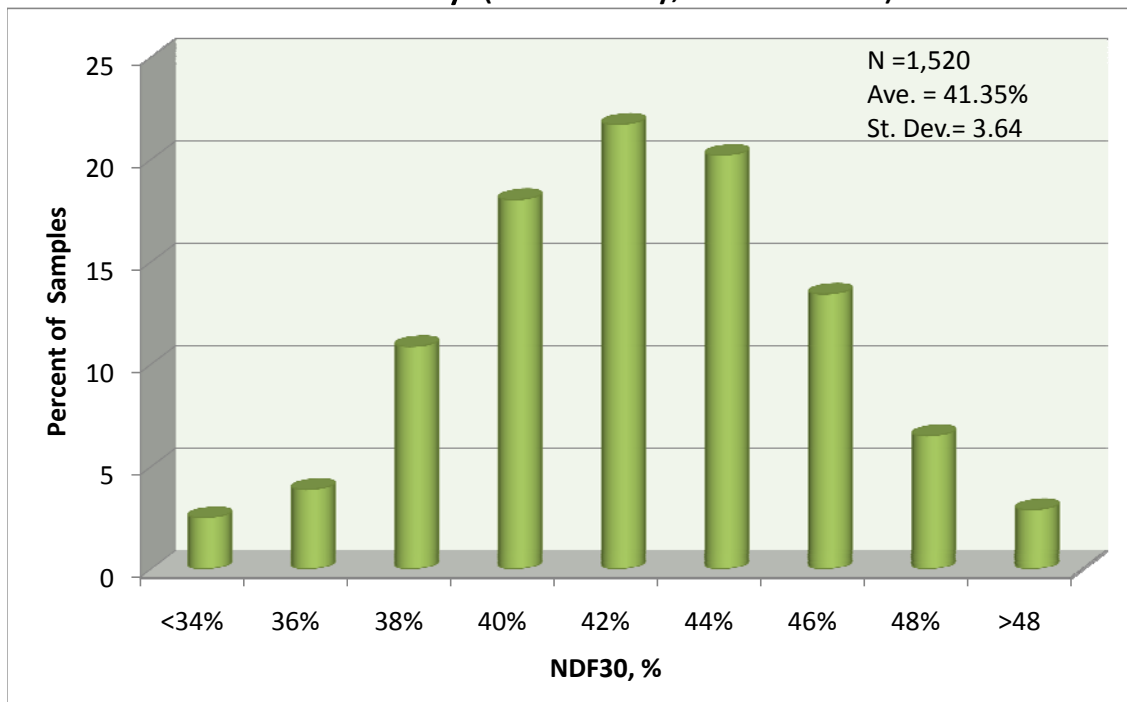


Figure 14. Distribution of Ash, Western States Alfalfa Hay (Chemistry, CVAS 2011)

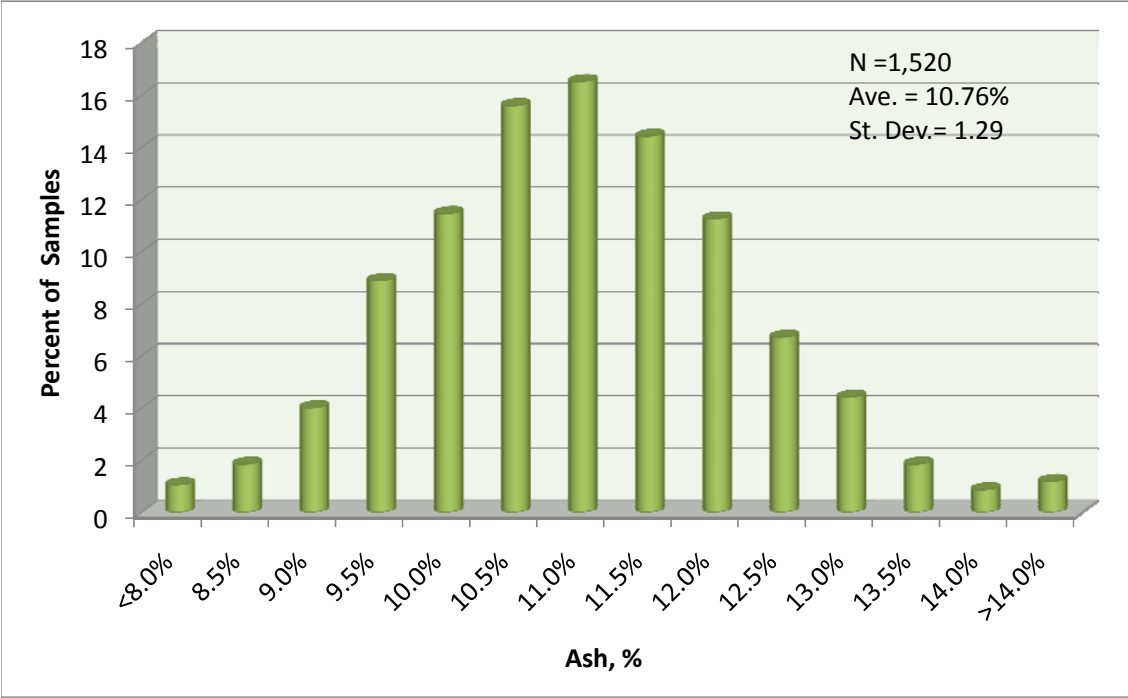


Figure 15. Distribution of Digestible Organic Matter Index, Western States Alfalfa Hay (Chemistry, CVAS 2011)

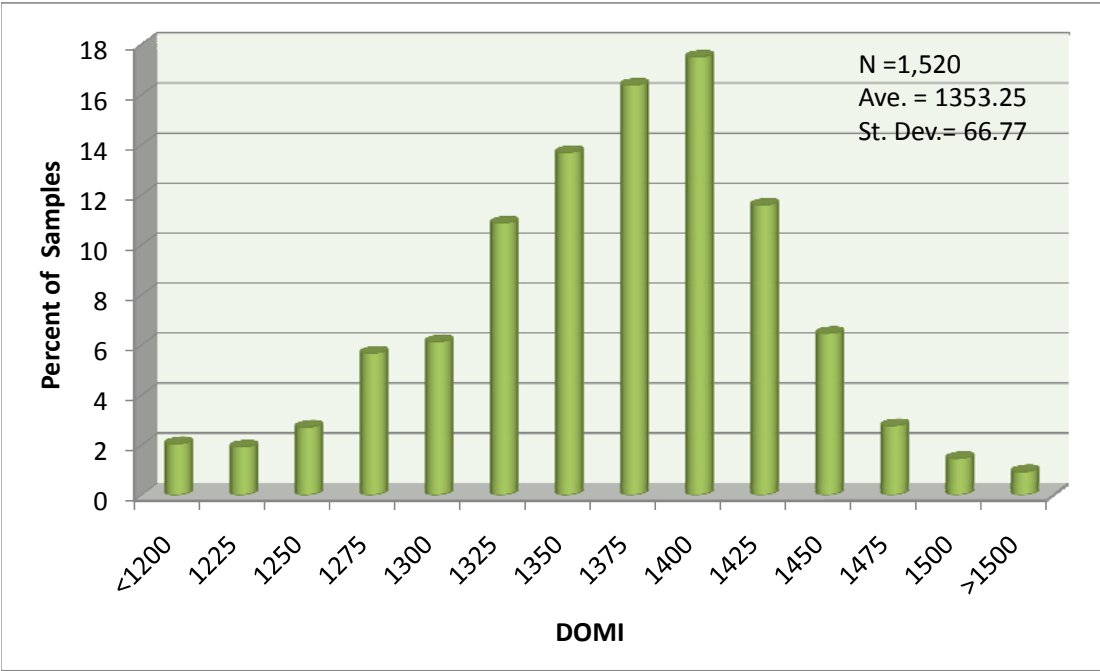


Figure 16. Regression of Digestible Organic Matter Index on NDF (CVAS, 2011)

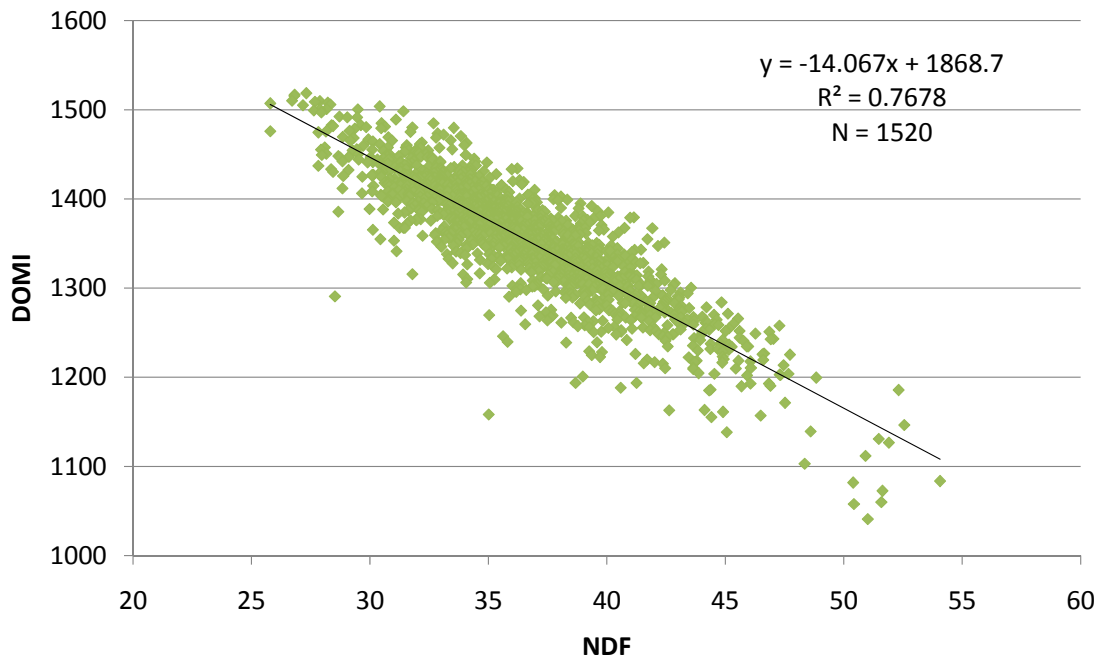


Figure 17. Regression of Digestible Organic Matter Index on Relative Feed Value (CVAS, 2011)

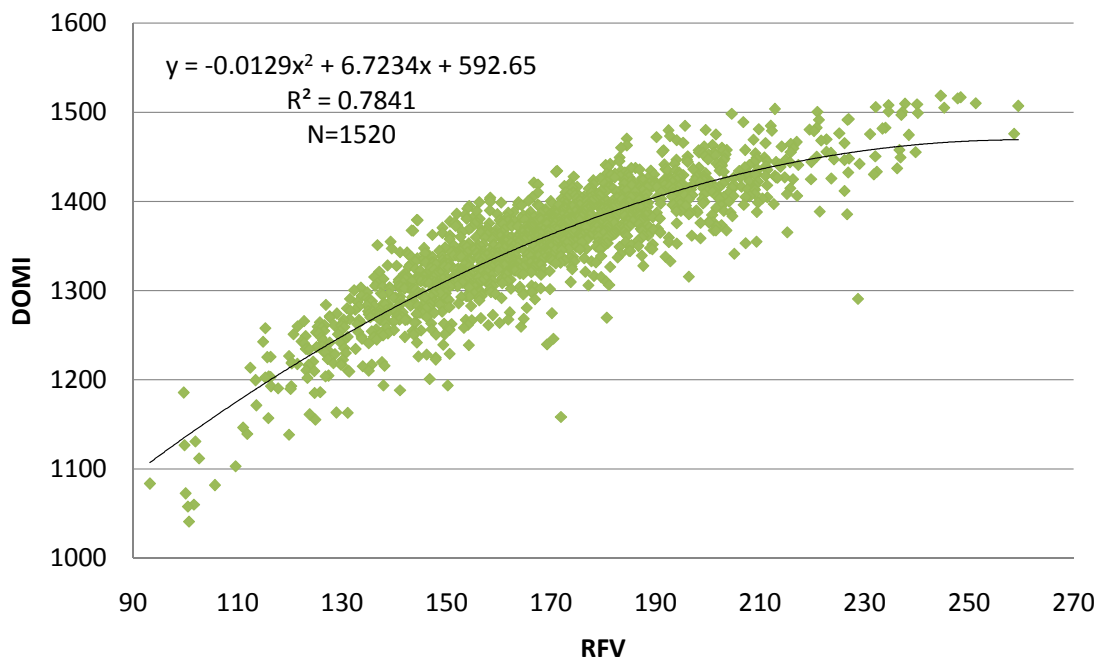


Table 1. Dry Matter Losses from Good vs. Poor Silo Management

	Good Management	Poor Management
Respiration	0-4%	10-15%
Fermentation	4-6%	10-15%
Seepage	0%	5-10%
Storage (Aerobic)	5-7%	10-20%
TOTAL LOSSES	9-15%	20-40%

Table 2. 30-Hour NDF Digestibility of Forage Samples (CVAS, 2011)

	Mean	SD
Legume	45.6	9.38
Mixed Mostly Legume	50.9	9.36
Mixed Legume/Grass	57.8	9.89
Mixed Mostly Grass	55.1	9.89
Grass	51.6	11.4
Small Grain	56.0	9.86
Corn Silage	58.7	6.13
BMR Corn Silage	69.8	4.62
Sorghum	52.7	9.92
TMR	55.1	5.56

Table 3. 7-Hour In Vitro Starch Digestibility of Corn Samples (CVAS, 2010)

Feedstuff	No. of Samples	DM	7 h IV Starch Digestibility	SD
Corn Grain	123	87.5	60.9	8.1
HM Corn	103	72.9	64.1	8.9
HM Ear Corn	20	58	73.9	8.5
Corn Silage	107	< 28	80.1	7.5
Corn Silage	204	28 to 32	79.7	8.7
Corn Silage	224	32 to 36	77.5	9.5
Corn Silage	102	36 to 40	73.3	10.2

Table 4. % of Samples with Identified Mold Type (CVAS, Fall 2009 –Winter 2010)

	No. Samples	Fusarium	Aspergillus	Penicillium	Mucor	Rhizopus
TMR	70	51.4	15.7	34.3	40.0	1.4
Haylage	89	13.5	6.7	14.6	13.5	0
Distillers	22	27.3	0	22.7	36.4	4.5
Corn Silage	352	17.3	9.7	23.9	19.9	0.6
Corn Grain	247	36.8	8.9	25.1	42.5	0.8