Fermentation of Silage

Ralph T. Ward [4]
Cumberland Valley Analytical Services, Inc.

Introduction

Animal productivity is significantly dependant on the quality of feed ingredients and the composition of the ration presented to the animal. In assessing animal productivity the nutritionist must determine if the ration is the limiting factor in 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 on the feeds and delivered ration as possible (given analysis cost restraints) will assist the nutritionist in making this determination and allow for the identification of limiting factors. Often the nutritionist or consultant is challenged to push animal performance beyond what may be an undetermined performance barrier established by feed quality and delivery issues.

This paper will review the evaluation of forage fermentation that is one key aspect of forage quality. Specific information provided on averages and ranges for various feed nutrients and quality assessments will be those determined by Cumberland Valley Analytical Services, Inc. (CVAS). Reported data is by wet-chemistry and is representative of feeds from across the country.

Qualitative versus Quantitative Evaluation of Forages

Forage evaluation is best accomplished as one de-emphasizes the aspect of quantitative evaluation. How much "protein" and how much "energy" in a given forage is of secondary importance to those qualitative aspects that promote animal acceptance and high dry matter intake. One might argue that quantitatively, the energy assessment of a forage is critical as it is the limiting nutrient in most rations. The energy value of a feed is dynamic and is the result of many factors. Rate of passage and rumen efficiency are two significant factors. The energy value of a feed is more the result of a given feeding situation than an input to it. The National Research Council's *2001 Nutrient Requirements of Dairy Cattle* addresses this issue in part emphasizing a variable energy discount system based on intake at various levels of maintenance. If we *qualitatively* evaluate a hay-crop forage by saying that is has a "low" neutral detergent fiber level, then we can predict that we should support good dry matter intakes, and have potentially higher digestible fiber and higher non-fiber carbohydrate contribution to the ration. These conditions allow for construction of a ration that has a greater opportunity to promote optimum animal performance.

If we *qualitatively* evaluate an ensiled forage and determine that its fermentation characteristics should promote good dry matter intakes we have said more about the production potential of a forage than perhaps an attempt at "fine-tuning" our assessment of energy. As an example, consider the following set of forages:

[4] Cumberland Valley Analytical Services Inc., 14515 Industry Drive, Hagerstown, MD 21742, (301) 790-1980, email rward@foragelab.com.

	Silage #1	Silage #2
Dry Matter (DM)	31.4%	33.4%
Crude Protein (CP)	22.7%	21.2%
Acid Detergent Fiber (ADF)	32.4%	34.4%
Neutral Detergent Fiber (NDF)	36.9%	40.8%
Net Energy of Lactation (NE_L)	.63 mcal/lb	.59 mcal/lb

Which forage would you choose to purchase based on the *quantitative* data? Based on the above information, you might choose Silage #1. Your decision might change if you had more information about the *qualitative* aspects of the Silage #1. The fact that Silage #1 underwent a clostridial fermentation and had 2% butyric acid, 22% crude protein equivalent (as % of CP) from ammonia, 16% ash, and a fiber digestibility that was seven points lower than Silage #2.

Considerations in Using Laboratory Evaluations

Critical in making use of laboratory information for diagnostic purposes is having an understanding of the expected levels for the item that is evaluated, and what levels are considered to be a problem. If we are provided with a crude protein equivalent from ammonia in an alfalfa silage at nine percent, we gain little value from that information unless we know that nine percent falls within a typical range that is non-problematic. The laboratory should be able to provide you information on the average and range for a nutrient that is tested. This paper provides as reference the average and distribution for a number of nutrients.

Variation between laboratories in procedures may lead to differences in interpretation of results. It is important again to know the average and range for a given nutrient from the laboratory that produced the results. When comparing numbers over time try to stay with the same laboratory and focus more on differences than on absolute numbers.

Use of Fermentation Analysis

There are those that argue that while the fermentation analysis is interesting, it is of little value, providing no information that can be used directly in the ration balancing process. While it is generally true that the fermentation data have little direct application, this challenge avoids the true value of the analysis. The fermentation report is meant to provide a comparative evaluation that allows the user to better characterize the silage, and to lend insight into possible DM 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 degree or extent of an adverse fermentation can be better determined by the fermentation analysis than by visual and olfactory observation alone.

A second and perhaps more important application of the fermentation report is as a "report card" on the management of the silage making process. The fermentation end-

products are a summary of all conditions that affected the silage making process, including plant maturity, moisture, epiphytic bacteria activity, additive use, ambient temperature, packing, and face management. 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 on a third party basis the quality of the silage and to challenge a farmer to better 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. Herbage that is ensiled properly exhibits a fermentation where pH drops rapidly, and homo-fermentative bacteria predominate. Lactic acid should be a significant end-product of these fermentations. Silages that have high levels of acetic, propionic, butyric or iso-butyric imply conditions where DM recovery from the silage making process may be poor.

Fermentation Acids

Dry matter intake may be limited due to fermentation characteristics. It is well known that clostridial fermentations resulting in the creation of butyric and elevated levels of ammonia are characteristic of silages with poor animal acceptance. 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.

Less certain are the effect of high levels of lactic or acetic acids on animal intake. Research has proven that the addition of acids, such as lactic, acetic, and propionic acid to silages prior to feeding will reduce intake. Intake of whole frozen (then thawed) corn plants is significantly higher than the same material fed as silage. The addition of acids to either fresh or frozen whole plant corn silage significantly reduced intakes (Erdman, 1993). Richard Erdman of the University of Maryland in a review of silage pH and intake studies developed a regression for adjusting DM intake based on pH of a silage: DM intakes as a percent of bodyweight =
$(-.18+0.88pH - 0.077pH^2)$. The degree to which intake is limited by particularly high levels of acids is however open to question.

Personal communications from individuals in the field suggest that there may be significant intake problems associated with some silages that have acetic acid levels above five percent, but the mechanism is not understood. The acetic acid itself may not be a problem, but may be a marker. It is recognized that those fermentations that produce excessive levels of acetic acid are more prolonged, and are less conserving of silage DM. There are differences in the utilization of fermentation acids by the rumen. Acetic acid is not fermented in the rumen, whereas one form of lactic acid is fermented by rumen bacteria under normal conditions (Muck, 1998). Lactic acid may be a problem in silages where it exceeds ten percent of DM, although that occurs only in rare fermentations in North America. Many feeding situations utilize silages with high acid content with no apparent problems. Feed bunk management, ration parameters, and associative effects of feedstuff may determine whether high silage acid levels may be a problem in any given feeding situation.

It must be noted that silages that are higher in lactic acid with minimal acetic and propionic acid, or what we consider "better" fermentations, may actually be more aerobically unstable. Lactic acid is not a good anti-mycotic. A certain amount of acetic acid is desirable in order to minimize possible growth of yeast and mold organisms. Poor fermentations with elevated butyric acid levels are actually much more aerobically stable.

Yeast end products, such as methyl- and ethyl-acetates, are compounds that may be present and limit DM intake (Seglar, 1999). Ethanol is a primary yeast end product that may be intake limiting. Yeasts are responsible for much of the secondary heating of silages exposed to air and associated DM losses.

Ammonia

While there is no current effort to look at ammonia or non-protein nitrogen (NPN) as independent variables in most ration balancing programs, there may be justification to give more consideration to evaluating ammonia in forages. Ammonia is often categorized along with smaller proteins such as amino acids and peptides. These components are buffer soluble, as well as true protein such as albumins and globulins (Asplund, 1994). Ammonia is utilized differently than peptides and true proteins. Ammonia has value as a nitrogen source for bacteria, but there is an energy and metabolic cost to the animal with excessive ammonia intakes.

Traditionally nutritionists have looked at soluble protein as the most cost effective means of estimating a functional pool of ruminally degraded protein. Soluble protein has also 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 6, 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 6) 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. The r^2 on the correlation between soluble protein and ammonia is less that 0.01% for data from CVAS (Ward, 2001).

Significance of Moisture to Fermentation Outcome

The significance of level of moisture in providing conditions opportune to various epiphytic organisms cannot be overstated. Fermentation end products are significantly related to moisture level because of the epiphytes supported at those moisture levels. Figures 4 and 5 show fermentation data for corn silage and legume silage broken out by dry matter range. Most evaluations vary significantly by DM of the plant material, with the exception of pH and ammonia in corn silage. In evaluating any given fermentation analysis, it is important to compare the analysis to sample averages for similar dry matter levels. What would be an expected fermentation outcome at 38% DM in a legume silage would not be the same if the material were ensiled at 30% DM. It is important to note

that forage fermentation is a dynamic process and the outcome is influenced by the interaction of many different factors. Fermentations may vary considerably from "average" values, but still be reasonably efficient and provide for excellent stability.

The pH as an Index of Fermentation Quality

The pH has traditionally been used to evaluate the quality of fermentation. It is a fast and inexpensive test to run and can easily be run at the farm. While pH in a broad sense can aid in differentiating between a good and poor fermentation, it is limited in the information that it can provide. In Figure 2, average pH and total fermentation acids are graphed by DM range in corn silage. Average pH levels by dry matter range do not vary by more than 0.14 pH units from <26% to 38% DM. In that same range total acids range from 10.5% to 6.4%. pH is somewhat more descriptive in legume forages, but only varies by 0.47 pH units between 24% and 52% DM. In that same range, total fermentation acids varied from 11% to 4.5% (Figure 3). pH, as an evaluative tool, is also limited in that it cannot tell us about the rate of change to arrive at a terminal pH (Mahanna, 1993). The faster the drop in pH, the more DM that is conserved in the fermentation process.

The Importance of Evaluating Ash Content of Forages

Ash is often overlooked as it is not a nutrient that is used directly in balancing rations. Elevated ash levels are due primarily to soil contamination (this often accompanied by high iron levels). Causes of this include haybines 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 provides no digestible organic matter and higher levels in a ration will reduce energy levels. An ash level that is higher by five percent due to contamination will be five units lower in TDN (Mooney, 2002). It also indicates that soil born yeast and clostridial organisms may have been incorporated into the silage material compromising the fermentation and aerobic stability of the silage.

Soil and climate will affect mineral uptake and ash levels; ash values in Western crops tend to run higher, primarily due to higher silica levels. Silica has a compensatory association with lignin and digestibility is reduced in the presence of higher silica levels. Van Soest states that the sum of silica and lignin is probably more closely related to digestibility than either one alone.

Ash values in corn silage run at CVAS average 4.4% and often will range over ten percent due to contamination (Figure 16). The mean of legume silage ash values is 10.9% with many samples over 15% ash (Figure 7).

Iron levels may vary considerably in forage. High levels are usually associated with incorporation of soil into the forage material. Figure 9 shows the distribution of iron in legume silage samples determined at CVAS. Again, the significant number of samples with soil contamination (as determined by high iron levels) would indicate that there is much progress to be made in the harvest and storage management of forage materials.

Using ADF Bound Protein as a Quality Index

Basic silage making practices include requirements to fill the storage structure quickly with silage at the correct moisture and to pack the silage well in the case of trench storage. Cutting corners when ensiling forages may lead to conditions where oxygen is not quickly eliminated from the silage mass resulting in excessive heating.

The excessive heating of forages or processed feeds leads to what is known as the Maillard reaction where sugars are condensed with amino acids and become part of the lignin complex. Van Soest 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 (as a % of dry matter) values in legume silage are summarized in Figure 1. A high percentage of these forages have values above 2% indicating a problem with excessive heating. Evaluating lab data for the impact of heating during ensiling of legumes showed a trend toward lower digestibility as the amount of heating increased as measured by acid detergent insoluble nitrogen (ADIN). Legumes with NDF 30 hour invitro digestibility values were summarized by ADIN levels ranging from .5% to >5% as a percent of total nitrogen. Average NDF30 digestibility was 53% at .5% to 1.0% ADIN and dropped to 39% for ADIN levels of 4.5% to 5.0% (Figure 8). This decrease in NDF digestibility significantly impacts the potential digestibility of forage materials.

Summary

Fermentation analysis is a diagnostic tool that will allow the nutritionist to better characterize problem forages and their possible contribution to dry matter intake problems. Fermentation analysis can be used as a management "report card" on the silage making process. It allows the advisor and producer to focus on potential weaknesses in management that may need to be corrected. Evaluation of fermentation end-products is a common research tool, but the field person needs to be careful in using fermentation analysis to draw conclusions about treatments and practices. The outcome of a forage fermentation is significantly related to dry matter level at ensiling due to the epiphytic organisms that are supported. Total acids, as well as types of acids present, are significantly correlated to dry matter level. Not following good silage making practices may lead to excessive heating during fermentation which may degrade significantly protein and carbohydrate quality. Incorporation of soil into the forage material should be avoided as it may lead to poorer fermentations and forage of generally lower quality.

References

Asplund, J.M. 1994. *Principles of Protein Nutrition of Ruminants.* CRC press, Boca Ration, FL.

Erdman, R. 1993. Silage Fermentation Characteristics Affecting Feed Intake. Pp. 210-219 in Proc. National Silage Production Conference. Syracuse, New York.

Hall, M.B. 2001. How Should We Formulate For Non-NDF Carbohydrates? Pp. 44-49 in 12th Annual Florida Ruminant Nutrition Symposium. Gainsville, FL.

Kung, L., Shaver, R. "Interpretation and Use of Silage Fermentation Analysis Reports", Sept. *Focus on Forage*, vol. 3, no.13. Available from http://www.uwex.edu/ces/crops/uwforage/fermentaion.html; Internet.

Mahanna, WC. 1993. Troubleshooting Silage Problems. 4-State Applied Nutrition Conference, June 29-30. LaCrosse, WI.

McDonald, P., A.R. Henderson and S.J.E. Heron. 1991. *The Biochemistry of Silage*, 2nd Ed. Marlow, Bucks, U.K.: Chalcombe Publications.

Mooney, R. "Kick Some Ash". *Hay & Forage Grower*, Sept. 1, 2002. Available from http://www.keepmedia.com:/jsp/article_detail_print.jsp; Internet.

Muck, R.E. 1998. Factors Influencing Silage Quality and Their Implications For Management. J. Dairy Sci. 71: 2992-3002.

National Research Council, 2001. Nutrient Requirements of Dairy Cattle, 7th Revised Ed. National Academy Press; Washington, D.C.

Seglar, B. Coping with Catastrophic Ensiled Forage Losses and Case Studies. 1999. *Nutitional Insights*, Vol. 2, No. 2. Pioneer Hi-Bred International, Inc., Johnston, IA.

Undersander, D., D.R. Mertens, and N. Thiex. 1993. Forage Analyses Procedures. National Forage Testing Association, Omaha, NE, pp. 95-103.

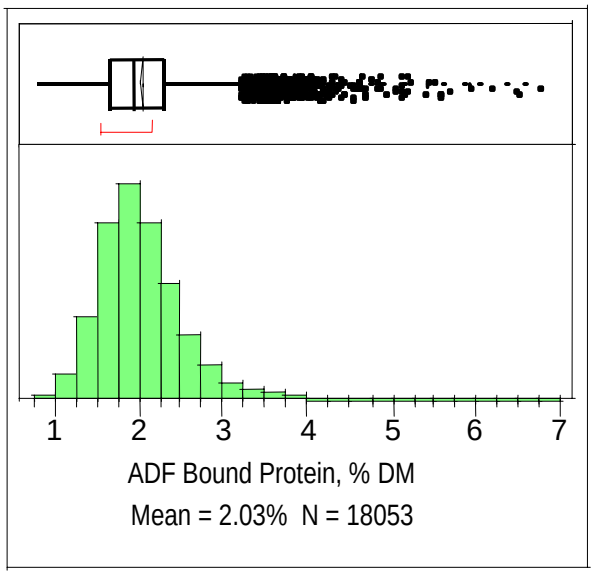
Van Soest, P.J. 1982. *Nutritional Ecology of the Ruminant*. O & B Books, Inc. Corvallis, OR.

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.

Figures

The following figures represent forage testing data generated by Cumberland Valley Analytical Services, Inc. All values are from wet-chemistry analysis. Figures were generated primarily from 2003 data except Figures 2 through 6, which were compiled from 1999 and 2000 data.

Figure 1. ADF Bound Protein in Legumes



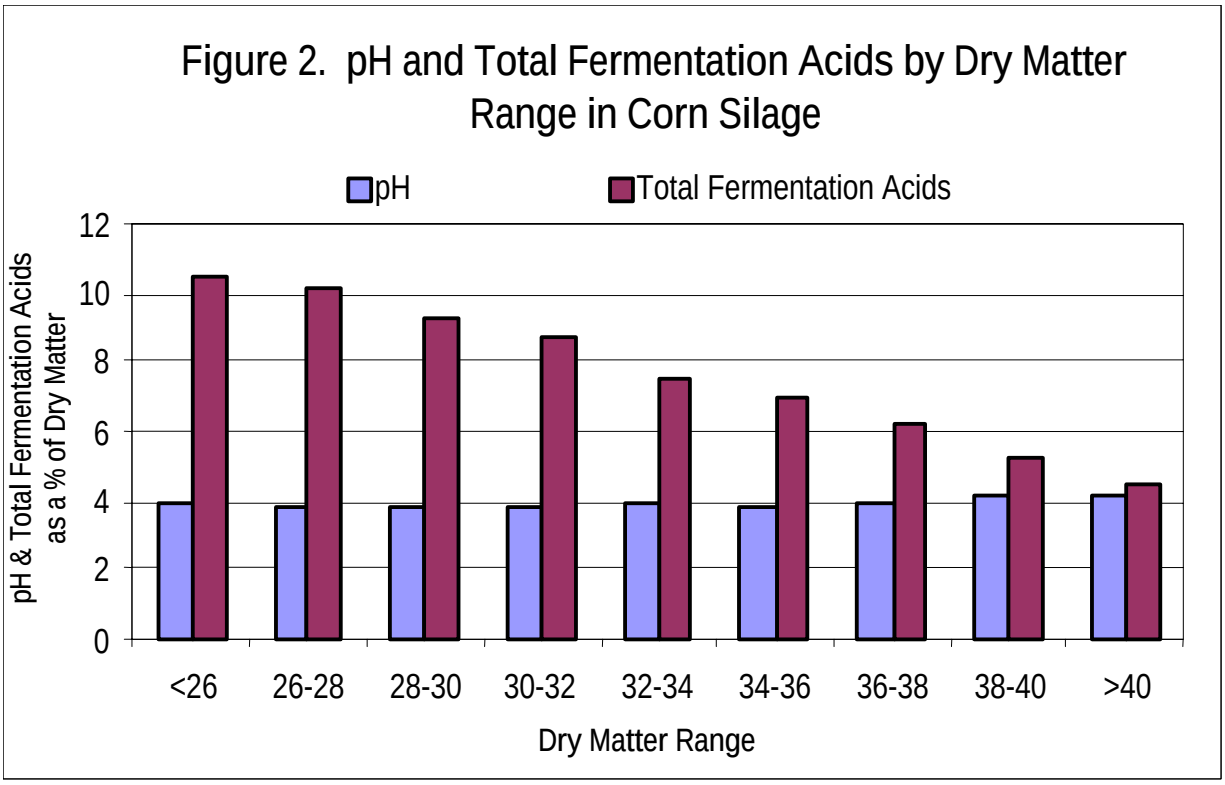


Figure 2. pH and Total Fermentation Acids by Dry Matter Range in Corn Silage
pH
Total Fermentation Acids
pH & Total Fermentation Acids as a % of Dry Matter
12
10
8
6
4
2
0
<26
26-28
28-30
30-32
32-34
34-36
36-38
38-40
>40
Dry Matter Range

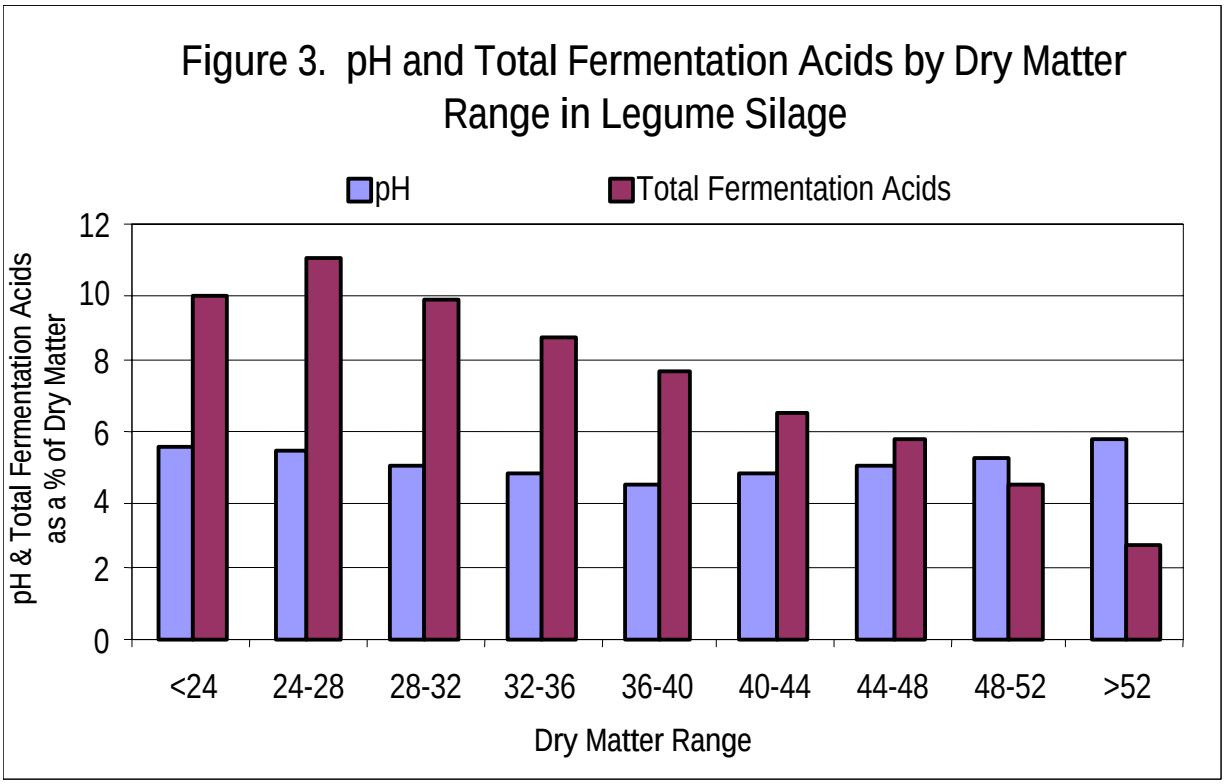


Figure 3. pH and Total Fermentation Acids by Dry Matter Range in Legume Silage
pH
Total Fermentation Acids
pH & Total Fermentation Acids as a % of Dry Matter
12
10
8
6
4
2
0
<24
24-28
28-32
32-36
36-40
40-44
44-48
48-52
>52
Dry Matter Range

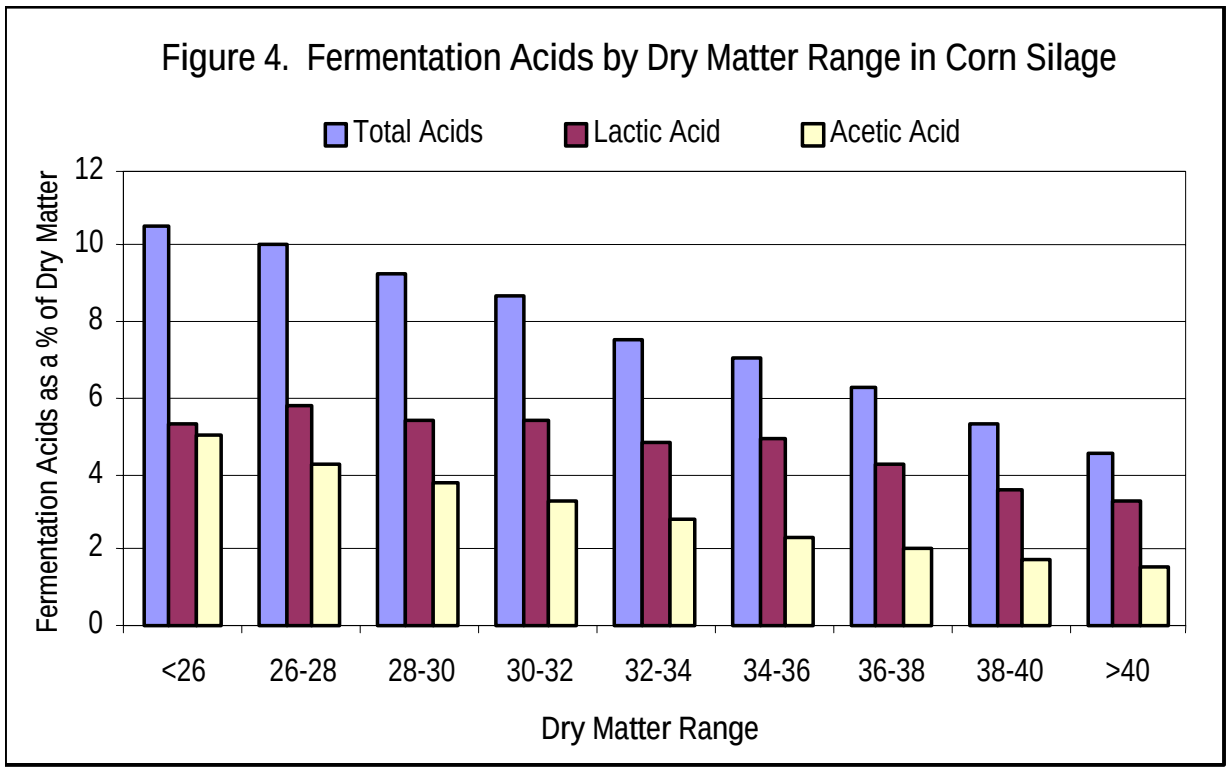


Figure 4. Fermentation Acids by Dry Matter Range in Corn Silage
Total Acids
Lactic Acid
Acetic Acid
Fermentation Acids as a % of Dry Matter
12
10
8
6
4
2
0
<26
26-28
28-30
30-32
32-34
34-36
36-38
38-40
>40
Dry Matter Range

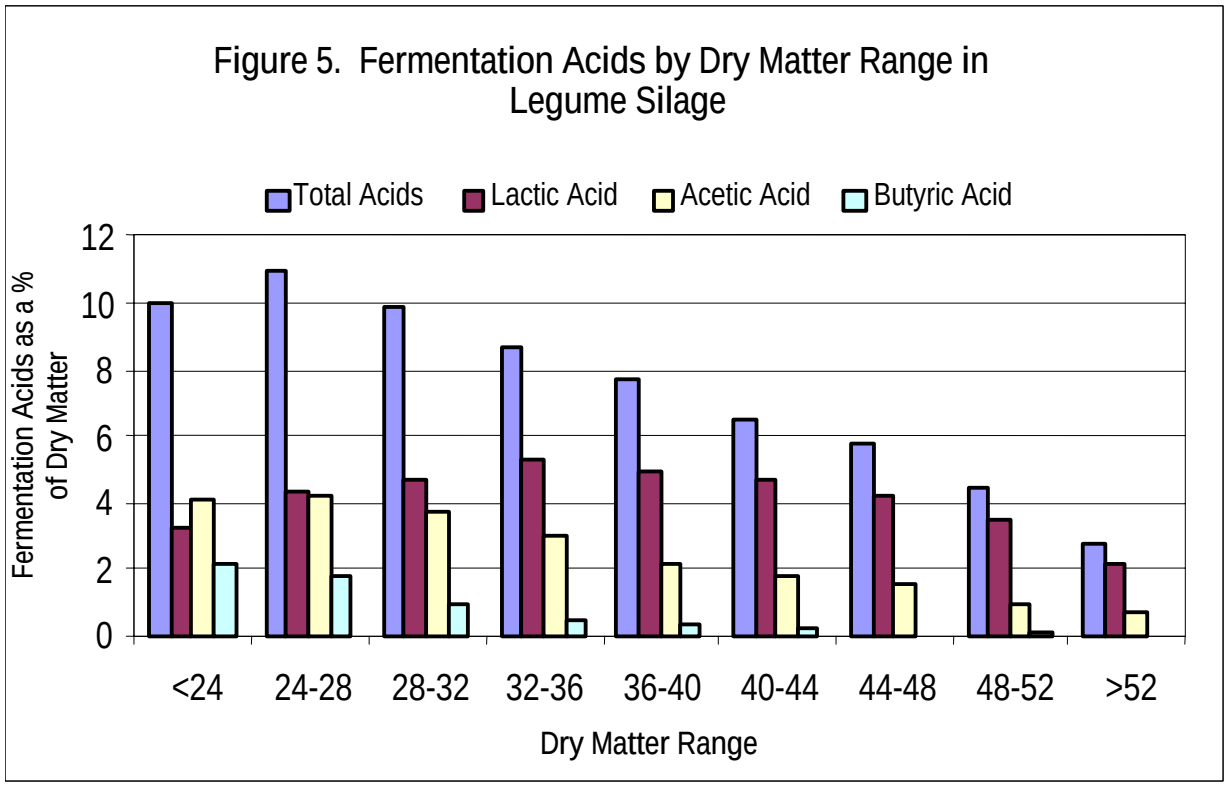


Figure 5. Fermentation Acids by Dry Matter Range in Legume Silage
Total Acids
Lactic Acid
Acetic Acid
Butyric Acid
Fermentation Acids as a % of Dry Matter
12
10
8
6
4
2
0
<24
24-28
28-32
32-36
36-40
40-44
44-48
48-52
>52
Dry Matter Range

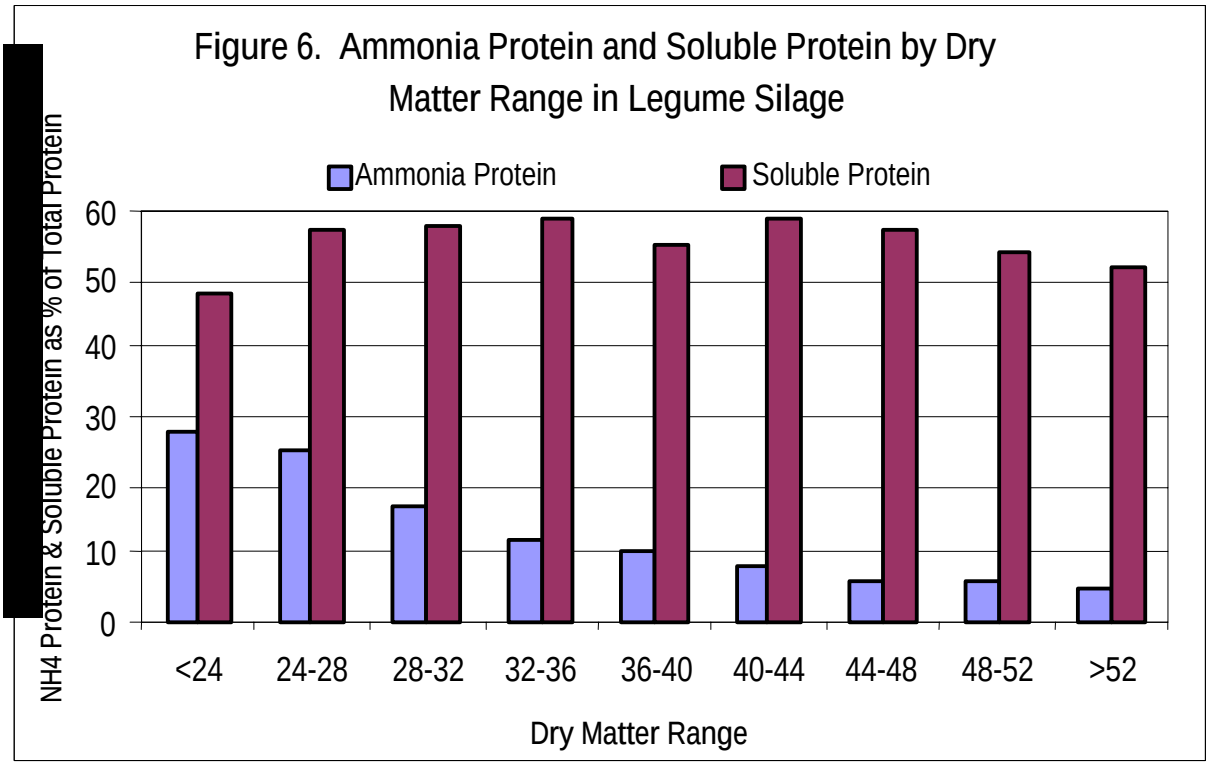


Figure 7. Legume Silage Ash Distribution

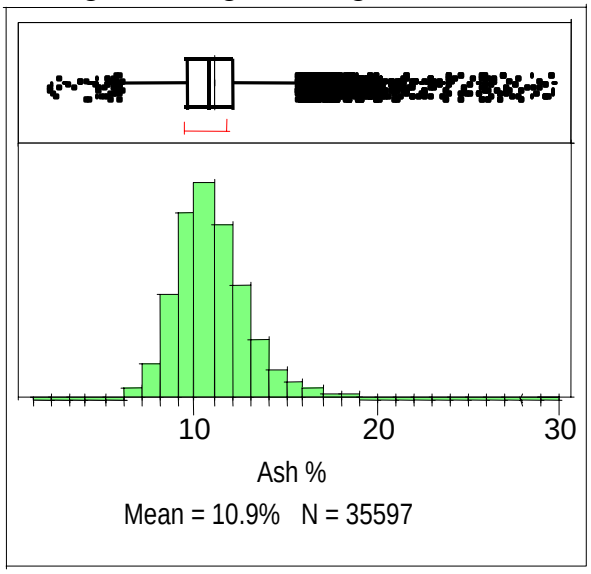


Figure 8. Impact of Heating During Fermentation on 30 hr NDF Digestibility in Legumes as Indicated by Acid Detergent Insoluble Nitrogen

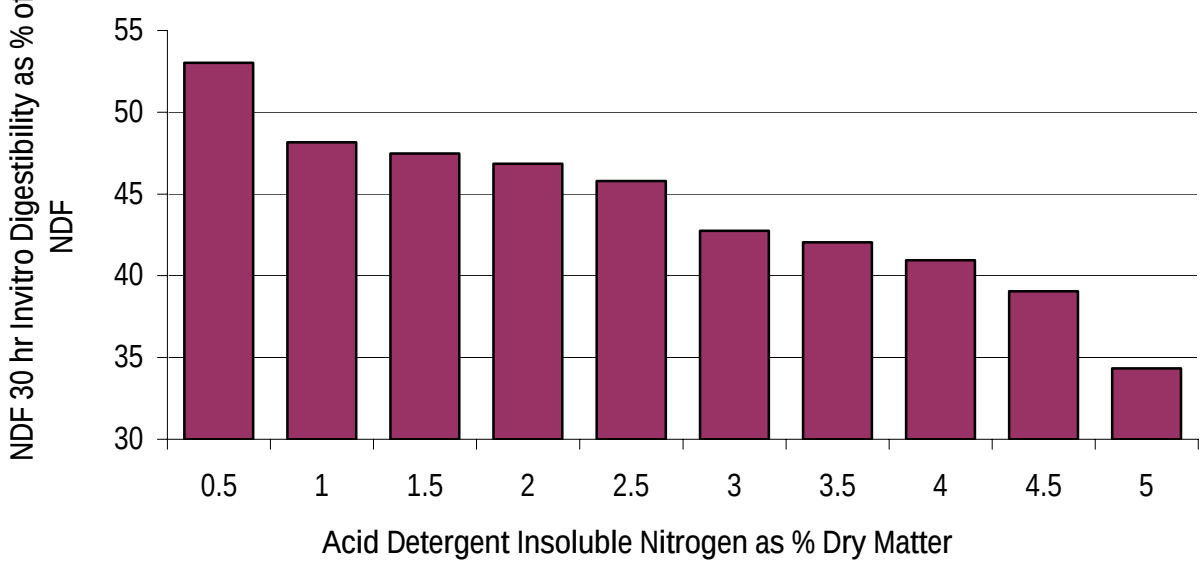
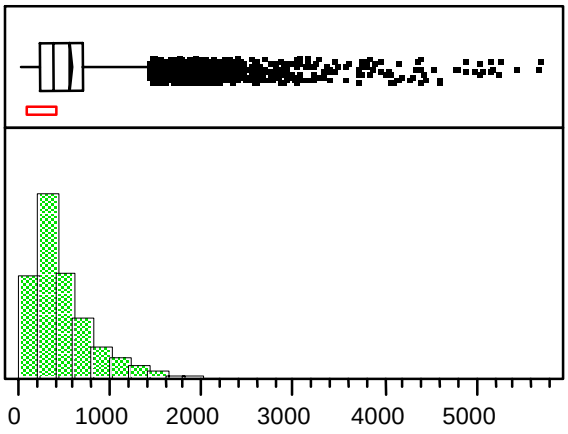


Figure 9. Legume Silage Iron Distribution



Iron ppm

Mean = 585 ppm N =10375

Figure 16. Corn Silage Ash Distribution