The Blue Mountain Alfalfa Guide

Why is Alfalfa Important for Ostrich Production?
What is Quality Alfalfa?
How to take Accurate Samples
How to understand lab test
and lots more

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Note:

Alfalfa and Lucerne are the same plant. There are many different varieties to suit many different climatic and growing conditions.

Introduction

Alfalfa is a critical ingredient in feed for commercial ostrich production,[1] as it is for many other commercial livestock. It is the third most valuable crop produced in the United States behind Maize and Soyabean.

Today there is a wealth of information now available to understand the productive value of alfalfa and the important role it plays in many different commercial livestock rations. Quality Alfalfa not only supplies an excellent source of digestible fibre, it also supplies high quality protein, energy and many micro nutrients such as vitamins and minerals.

This document is a consolidation of some articles that discuss identifying quality, the economics of production, assessing the value, how to take accurate samples and how to understand the analysis. There is also a paper that covers the significant positive impact Alfalfa contributes to the environment.

Alfalfa Quality:
What is it? What can we do about it? and Will it pay?

By Garry D. Lacefield [2]

Abstract
Alfalfa is a premier forage legume with potential for high yields, quality and stand persistence. Alfalfa quality is defined in many ways, but is usually more meaningful to producers when associated with animal performance. Alfalfa quality is influenced by many factors, but stage of maturity at harvest offers the best opportunity for improvement. Managing for quality will usually result in positive rewards. Animal feeding programs are more efficient and economical when alfalfa quality is known and matched to animal nutritional needs.

Key Words: alfalfa, quality, palatability, digestibility, management

Introduction
Profitable livestock production almost always requires a forage program that will supply large quantities of adequate quality, homegrown feed. A major percentage of the feed units for beef (83%) and dairy cattle (61%) come from forages. In addition, forages supply an estimated 91%, 72%, 15% and 99% of the nutrients consumed by sheep and goats, horses, swine, and wildlife, respectively.

Although both alfalfa quantity and quality are important, it is easier for livestock producers to recognize problems associated with alfalfa quantity than with alfalfa quality because quantity can be readily assessed visually; whereas, a laboratory analysis of a sample is required to determine quality. Fiber, which is less digestible than other components of alfalfa, increases with age, so it is not possible to simultaneously maximize alfalfa quantity and quality from a given alfalfa stand.

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[1] "The Importance Of Quality Alfalfa In Ostrich Feed Formulas!", Daryl Holle, Blue Mountain Feeds Inc. http://www.blue-mountain.net/bulletin/bull77.htm and Page 8
[2] Garry D. Lacefield, Extension Forage Specialist, University of Kentucky Research & Education Center, Princeton, KY 42445; Email: glacefie@uky.edu. In: Proceedings, National Alfalfa Symposium, 13-15 December, 2004, San Diego, CA, UC Cooperative Extension, University of California, Davis 95616. (See http://alfalfa.ucdavis.edu for this and other proceedings).

What is Alfalfa Quality?

Alfalfa quality has been defined in many ways, including protein, fiber, lignin content, relative feed value, color, smell, leafiness, fineness of stems, total digestible nutrients, and other physical and/or chemical components. Each of these has merit, but all fall short of clearly defining forage quality. Factors such as average daily gains, conception rates, milk production, wool production, etc. are reliable indicators of alfalfa quality.

Perhaps the best concise definition of alfalfa quality is: the extent to which alfalfa (pasture, hay, or silage) has the potential to produce a desired animal response. This definition acknowledges the necessity of considering the animal. As an example, a high producing dairy cow needs higher quality feed than a dry, pregnant beef cow. Animal performance is influenced by a number of factors, including:

Palatability - Will the animals eat it? Animal selection of one forage species over another depends on smell, touch, and taste. Therefore, palatability may be affected by texture, leafiness, fertilization, dung or urine patches, moisture content, pest infestation, or compounds that cause a forage to be sweet, sour, or salty. In general, high quality alfalfa is highly palatable and vice versa.

Intake - How much will they eat? Alfalfa must be consumed in adequate quantities to enable animals to perform well. In general, the higher the palatability and forage quality, the more that will be consumed. The poorer forage quality is, the longer it remains in a ruminant animal's digestive system, resulting in lower animal performance.

Digestibility - Of the alfalfa consumed, how much will be digested? Digestibility (the portion of the forage consumed as it passes through an animal's body) varies greatly. Immature, leafy alfalfa may be 80 to 90 percent digested, while mature, stemmy material often has a digestibility below 50 percent.

Nutrient content - Once digested, does the alfalfa provide an adequate level of nutrients? Leafy, growing forage plants usually contain 70 to 90 percent water. Because of this range in water content, for most purposes, it is best to express forage yield and nutrient content on a dry matter basis. Forage dry matter can be divided into two main categories: (1) cell contents (the non-structural part of the plant tissue such as protein, sugar, and starch); and (2) structural components of the cell wall (cellulose, hemicellulose, and lignin).

Anti-quality factors - Depending on the plant species, time of year, environmental conditions, and animal sensitivity, various compounds may be present in forage that can result in reduced animal performance, sickness, or even death. Such compounds include tannins, nitrates, alkaloids, cyanoglycosides, estrogens, and mycotoxins. High quality forages must not contain harmful levels of anti-quality components.

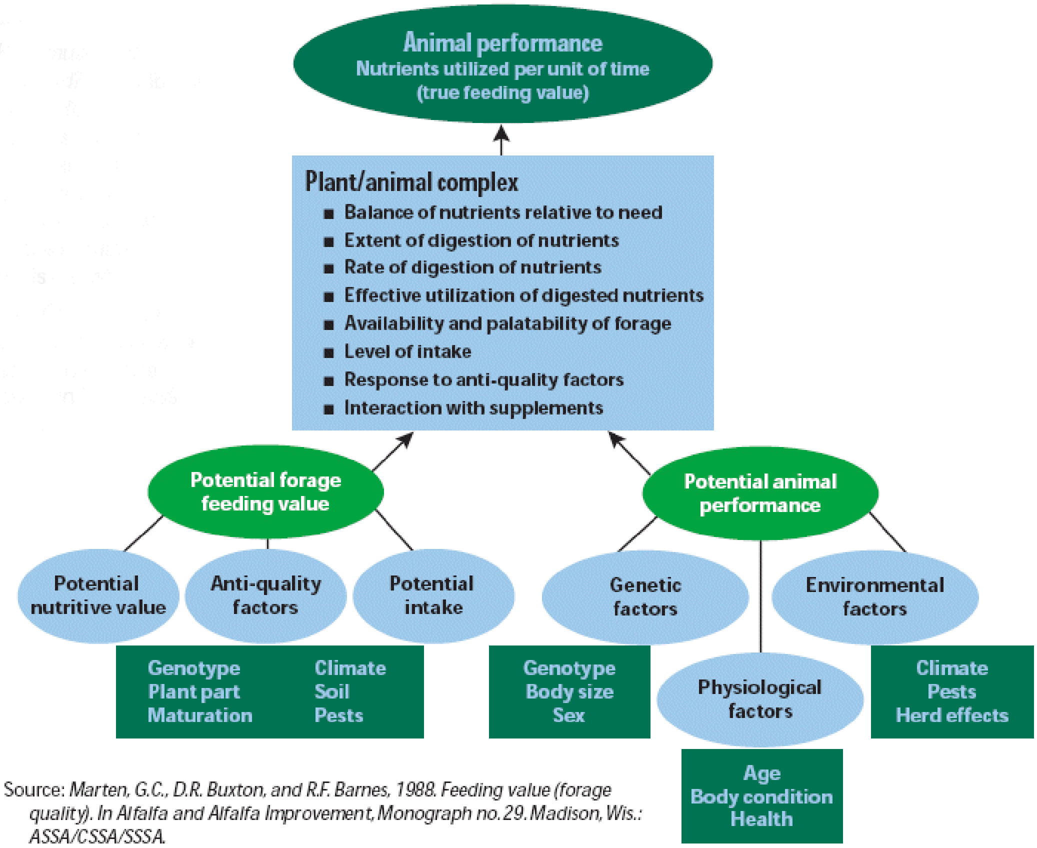

Figure 1. Factors associated with true forage feeding value (Marten et al.)

Animal Performance: The ultimate test of alfalfa quality is animal performance. Alfalfa quality encompasses its "nutritive quality" (its potential for supplying nutrients), the intake that results when it is made available to animals, and any anti-quality factors present. We cannot separate alfalfa quality from animals because their performance can be influenced by any of a number of factors associated with plants and forage-consuming animals (Figure 1). A failure to give proper consideration to any of these factors may result in a level of performance less than is desired.

What can we do about Alfalfa Quality?

Alfalfa has high quality potential. Our ability to manage all the factors impacting quality will determine how much of this "potential" we can capture and have available for use by our animals or for sale.

Alfalfa quality is influenced by soils and fertility, varieties, other species, pests, growing conditions, season of the year, time of day, stage of maturity, harvesting, handling and storage, and of course weather. All of these factors can have an impact on alfalfa quality regardless of whether we are using it as pasture, hay, or silage.

Although all of the above are important, in general, the most important and the one that will have the greatest impact on alfalfa quality is the "stage of maturity" when harvested. As alfalfa plants advance form the vegetative to reproductive (seed) stage, they become higher in fiber and lignin content, lower in protein, digestibility and acceptability to livestock (Figure 2 and Tables 1 & 2). Delaying harvest from late bud to full bloom (early seed stage) can result in over 45 percent loss in protein. Digestibility can drop by up to 0.5 percent per day and RFV by 5 points per day.

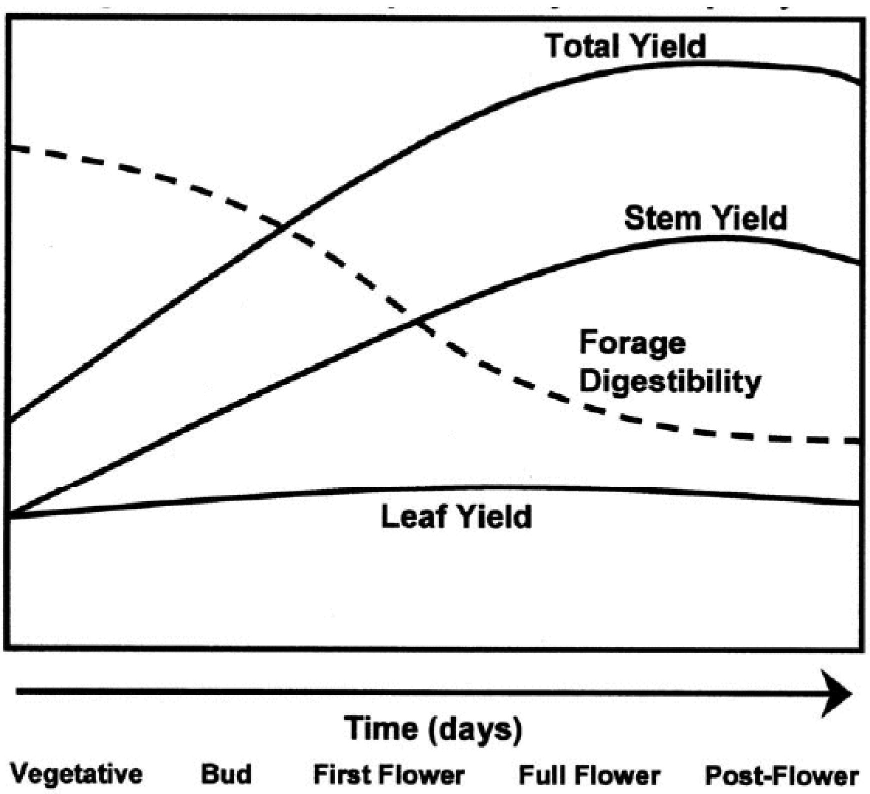

Figure 2. Relationship between yield and quality

Table 1. Effects of Alfalfa Hay Quality on Animal Performance

Alfalfa Hay	Quality		
	Good	Fair	Poor
Crude Protein	18.7	15.9	13.7
Crude Fiber	29.4	35.4	46.7
Animal Performance*			
Hay consumed/day	17.1	16.5	13.8
ADG	1.85	1.49	0.06

*550 lb. beef steers - Tennessee

Table 2. Estimated Grade, Average Concentration of Crude Protein (CP), Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF) and Milk Yield in Wisconsin Forage Council Green Gold Project.

Estimated Grade	Number of Cuts	CP%	ADF %	NDF%	Milk lbs/A
Prime to 1	5	22	31	43	10,688
No. 1	4	21	32	44	9,120
No. 1 to 2	3	19	35	46	7,022
No. 2	2	17	36	48	4,259

SOURCE: Adapted from D.A. Rohweder, et al., University of Wisconsin.

Will it pay to produce higher quality?
This is an excellent question and one that I would like to say a resounding YES to; however, it's not always that easy and true. To say "it depends" may seem like a very weak answer, but in this case I think it is true. For example, if you are selling by the ton or bale and quality is not a factor, then it will likely not pay you to go the extra mile to achieve the highest quality if overall yield is reduced in the process or stand persistence is compromised. There are some markets where this is the case, but things are changing. In general, most people are able to market their highest quality alfalfa even during surplus production years. The biggest challenge during these years is how to market the medium and low quality. With advances in testing and marketing, and with greater awareness of the relationship between quality and animal performance, and with a greater database showing the relationship between quality and price (Table 3), it appears the answer to the question "Will it pay?" is appearing more positive all the time.

Table 3. Forage Quality Values as Alfalfa Advances in Maturity.

Stage of maturity	Crude protein	Acid detergent fiber	Neutral detergent fiber	Digestible dry matter	Relative feed value	Market value[1] average
	---------------- % of dry weight			------------------	index	$/T
Vegetative	>22	<25	<34	>69	>189	144
Bud	22-20	25-31	34-41	69-65	189-147	126
Early Bloom	19-18	32-36	42-46	64-61	146-123	96
Late Bloom	17-16	37-40	47-50	60-58	122-107	78
Seed pod	<16	>41	>50	<58	<107	72

[1]Market value based Y = .88X - 22.3 where, Y = $/T and X = RFV index.
SOURCE: Dr. Neal Martin, Director, Dairy Forage Research Center, Madison, WI, personal communications.

Summary
Alfalfa is a premier forage legume with potential for high yield, quality and stand persistence. Our challenge is: to establish to get good stands, produce for high yields, harvest for highest quality and market for profit.

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Bulletin of the Month

The Importance of Quality Alfalfa In Ostrich Feed Formulas

By: Daryl Holle
Blue Mountain Feeds, Inc.

Alfalfa, What is it?

Alfalfa is generally known as a most valuable forage crop ideally suited for use in high production livestock feed formulas. It belongs to the **Legume** family of plants and is of the Genus **Medicago.** Alfalfa combines the excellent virtues of high dry matter yield and high protein content, minerals (especially calcium), vitamins, and highly digestible Fiber along with good palatability unsurpassed by most other forages.

Alfalfa is also known as **Lucerne** in many countries throughout the world. Lucerne is the same crop as Alfalfa, just another name that is used. For this writing, we will refer to Alfalfa/Lucerne as **Alfalfa**.

There are many different types and qualities of Alfalfa, the same as most any feed ingredient. The Quality of Alfalfa depends totally on how it is grown in the field and how it is harvested—and WHEN it is harvested.

Figure 3 - High Quality Field of Alfalfa

Quality Alfalfa is raised by crop farmers just like Quality Ostrich is raised by Ostrich farmers. The nutrients in the soil of the Alfalfa field must be correct and have enough nutrient reserves so the Alfalfa plant can thrive and produce a fully nutrient crop. Then, that Alfalfa crop must be properly harvested and stored in order to retain those high quality nutrient levels for use in Ostrich feed formulas. Figure 3 shows a high quality field of Alfalfa and it is easy to see that the Alfalfa plants in this picture are very healthy and full of quality nutrients. An Alfalfa field like this will produce a quality Alfalfa product that will result in a high "productive performance" for Ostrich feed formulas in the most cost effective manner.

Figure 4 shows a very low quality field of Alfalfa. As you can clearly see, the crop in Figure 4 is unhealthy, shows lots of variance is color indicating very poor soil nutrition factors, and the plants are very mature indicated by the purple flowers beginning to bloom. This field is way past the proper harvesting stage for a quality Alfalfa product and will result in a Forage ingredient that is poor quality for Ostrich feed formulas.

Figure 4 - Low Quality Field of Alfalfa

There is a lingering thought within the Ostrich Industry that "Alfalfa is Alfalfa" which is so misleading and UNTRUE! The differences between Alfalfa purchased from one farmer can be as different as night and day when purchased from another farmer. Sometimes, even Alfalfa purchased from the SAME farmer can vary greatly as it totally depends on what field the crop came from and when it was harvested. Even some unknowledgeable Nutritionists from feed companies only specify ALFALFA in their Ostrich feed formulations without specifying any type of grade, nutrient content and so on. This mistake by Nutritionists leads to UNPRODUCTIVE feed formulas being mixed and used by many Ostrich farmers and many bird problems result because of that error.

As shown in Figure 5, Alfalfa can vary greatly depending on when it was harvested. The harvest stage has a significant and direct effect on the nutrient content of Alfalfa. Figure 5 also proves that "all Alfalfa is NOT the same" and can have a positive or negative effect on an Ostrich feed formula depending on the QUALITY of the Alfalfa itself.

Figure 5 - Changes In Nutrient Values verses Alfalfa Maturity

Item	Protein	Fiber	Calcium	Phosphorus
13% Very Mature Alfalfa	13.0%	38%	1.18%	0.19%
15% Mature Alfalfa	15.0%	34%	1.30%	0.21%
18% Average Alfalfa	18.0%	29%	1.40%	0.24%
20% Good Alfalfa	20.0%	26%	1.60%	0.29%
22% Premium Alfalfa	22.0%	23%	1.80%	0.32%

To best demonstrate why it is so important to KNOW the exact quality of Alfalfa being used in an Ostrich feed formula, we can use a couple charts to simply explain that need. Figure 6 is a chart that shows a few nutrient values for a good Ostrich Breeder feed. Please remember that in a good Ostrich Breeder feed, there are nearly 60 important nutrients to be considered, but for simplicity purposes of this discussion, we will only use Protein, Fiber, Calcium and Phosphorus to demonstrate the effects of Alfalfa quality on Ostrich Breeder feed formulas

Figure 6 – Typical Ostrich Breeder Feed Nutrient Values

Ostrich Feed Formula	Protein	Fiber	Calcium	Phosphorus
Total Feed Formula Nutrients	**21.0%**	**12.00%**	**2.00%**	**1.00%**

For purposes of this demonstration, let's assume for a moment that within the Total Feed Formula, 38% of the total weight of the formula is coming from Alfalfa as the main Forage ingredient and the other 62% of the Total Feed Formula is grains, protein feeds, minerals, vitamins & additives for a complete feed formula. Figure 7 shows the result of using Alfalfa of GOOD quality that carries an average protein content of 20% which indicates it was from a well managed field of Alfalfa and was harvested at the correct stage.

The amount of the individual nutrient contribution by this Alfalfa ingredient to the Total Feed Formula can be calculated by multiplying the "% of Total" column times each of the nutrient values shown for "20% Good Alfalfa" in Figure 3 above (Protein, Fiber, Calcium, Phosphorus). The "Rest of Formula Ingredients" obviously provides the remainder of the nutrients so that the "Total Feed Formula Nutrients" equal Figure 6.

Figure 7 - Ostrich Breeder Feed Using 20% Protein Alfalfa

Ostrich Feed Formula	% of Total	Protein	Fiber	Calcium	Phosphorus
20% Good Alfafa	38%	7.6%	9.88%	0.61%	0.11%
Rest of Formula Ingredients	62%	13.4%	2.12%	1.39%	0.89%
Total Feed Formula Nutrients	**100%**	**21.0%**	**12.00%**	**2.00%**	**1.00%**

Using Figure 7 table as a reference, we can now see what happens when a farmer, or the people formulating and mixing the Ostrich feed formula, substitutes a LOW QUALITY Alfalfa for the GOOD QUALITY Alfalfa as shown in Figure 8.

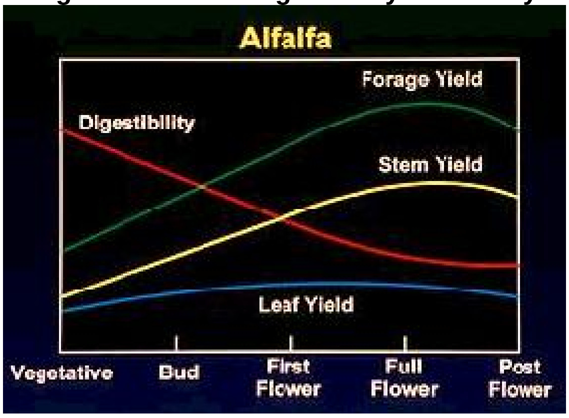
Figure 8 - Ostrich Breeder Feed Using 13% Protein Alfalfa

Ostrich Feed Formula	% of Total	Protein	Fiber	Calcium	Phosphorus
13% Very Mature Alfalfa	38%	2.9%	14.44%	0.45%	0.07%
Rest of Formula Ingredients	62%	13.4%	2.12%	1.39%	0.89%
Total Feed Formula Nutrients	**100%**	**16.3%**	**16.56%**	**1.84%**	**0.96%**

Figure 8 clearly demonstrates that substituting poor Alfalfa for good Alfalfa without reformulating the feed formula makes a significant difference in the Protein, Fiber, Calcium and Phosphorus levels in the total feed. In fact, that simple mistake of substitution of Alfalfa quality brought the total feed formula from a very good productive feed formula in Figure 7 to a non-productive feed formula for Ostrich in Figure 8. The new formula in Figure 8 with the incorrect Alfalfa quality is seriously lacking of Protein, far too much Fiber which will interrupt utilization of other nutrients, and also caused a slight deficiency of Calcium and Phosphorus.

"All Alfalfa is NOT alike"--The Grade and Quality of Alfalfa used in Ostrich rations must always be specified, identified, and KNOWN in order to develop a productive Ostrich feed formula that is properly balanced.

Figure 9 - Alfalfa Digestibility & Maturity



Another important factor to consider when discussing Alfalfa quality to be used in Ostrich feed formulas is the Fiber DIGESTIBILITY. Since Alfalfa is providing a major percentage of the digestible fiber in the total formula, it is crucial that this Fiber be as digestible as possible to allow for a good productive performance feed formula.

Figure 9 shows why the stage of harvest is so crucial to good Alfalfa quality and high digestibility. As the Alfalfa plant begins to gradually mature, it forms a bud that will begin to open into a flower. In a short time the flower will fade and a seed pod will form. The entire process from "Bud" stage to "Post Flower" stage is only a matter of a few days. Figure 9 shows how quickly the characteristics of Alfalfa CHANGE during this period of maturity. It is a proven scientific fact that when Alfalfa is in the "Bud" stage, the Fiber Digestibility is HIGH while at the same time the total expected yield of the Alfalfa is rather low and not to its peak. As the Alfalfa matures into the "First Flower" stage and on through the "Full Flower" and "Post Flower" stage, the expected yield increases rapidly along with the Stem Yield while the Leaf Yield remains rather steady throughout the stages of maturity.

To put Figure 9 in Layman's language, the reason the expected yield is increasing as the Alfalfa matures is the Stems of the plant are getting much larger. The reason the digestibility is going down is because the Stems is the most undigestible part of the Alfalfa plant. The leaves of the Alfalfa plant are highly digestible.

If you study Figure 9 carefully, you will now understand WHY many unknowledgeable farmers raising alfalfa always want to "Go for High Yield" as that means more tonnage per acre for them and more dollars of revenue per acre of Alfalfa. But, going for High Yield always results in poor quality alfalfa with low protein and high undigestibility. That is why there is so much poor quality Alfalfa in the world.

The proper answer to this dilemma is a COMPROMISE! The proper time to harvest Alfalfa for reasonably good quality AND yield is when the Alfalfa field is around "10% flower". That means when one plant in ten is beginning to open its flower, that field needs to be cut TODAY! That will generate a quality Alfalfa ingredient for use in productive Ostrich feed formulas with a reasonably good protein level and high digestibility—while at the same time provide a reasonable yield for the farmer.

In return for the Alfalfa farmer raising this quality crop, the Livestock feed industry should always be prepared to pay a small premium for this quality Alfalfa based on a verified lab test analysis of the Alfalfa after harvest. In the United States, this reward payment for quality has become quite sophisticated between buyers and sellers with several dollars increased premium per ton of Alfalfa for each percentage of increased Alfalfa protein content over 18% protein. Higher quality Alfalfa containing higher protein, high digestibility factors is very cost effective in Ostrich feed formulas as it reduces the need for extra protein from other feed ingredient sources that is always MOST expensive. Using high quality Alfalfa also makes it possible to develop HIGH PERFORMANCE Ostrich feed formulas which is not possible using low quality Alfalfa.

Summary:

1. If it is possible, check out the Alfalfa fields of the farmer you intend to buy from. View the quality of the Alfalfa field and watch when the farmer harvests that field to assure that the harvest was of quality and that the Alfalfa was of good field quality.

2. Make sure that the Alfalfa field has a minimum amount of weeds and grass growing in the field. Large amounts of weeds and grass will change the nutrient values of the Alfalfa---they also severely affect the fiber digestibility and can cause low protein and calcium contents in the Alfalfa when fed to livestock. If it is Alfalfa you are buying, buy 100% Alfalfa and insist on it as that is what your Ostrich feed formula is requiring for productive feed formulas.

3. Never substitute a low quality Alfalfa for a high quality Alfalfa without first getting the feed formula re-calculated. Never substitute a high quality Alfalfa for a low quality Alfalfa for the same reason.

4. Always know exactly what quality of Alfalfa you are feeding with routine sampling and lab testing to ascertain that quality level. As with any agricultural industry, the Alfalfa industry constantly has some individuals “playing tricks” on the unsuspecting people so never trust a farmer handing you a sheet of paper showing a test analysis that is supposed to be a sampling from the Alfalfa you are buying—TEST IT YOURSELF and buy it accordingly.

5. Never mix poor quality Alfalfa with good quality alfalfa in hopes of attaining an average quality Alfalfa. It doesn’t work that way as part of your Alfalfa mix is still POOR with low fiber digestion factors and low calcium, phosphorus, and other nutrients. Remember, you cannot change a paint color from black to white by added more white - it only gets gray!

6. For productive Ostrich feed formulas, always use the higher quality Alfalfa of a minimum 17% protein content. NEVER use the lower quality Alfalfa of less than 17% protein content as it will not result in a productive Ostrich feed diet for your birds.

Sampling Alfalfa

As can be seen, it is essential to sample the crop and obtain an accurate analysis to ensure it is of the right quality for the design of ration being made. To achieve an accurate forage test of a sample it is imperative that the sample is taken correctly. A lab test can only be as accurate as the sample provided and here lies the problem. Hundreds of thousands of kilos of highly variable plant material must be represented by a very tiny sample actually analysed by the lab – often represented by as little a ½ gram! This minute sample must not only represent the leaf/stem ratio of the Alfalfa but must also include the presence of any contaminants such as grass or weeds in their respective ratios.

Sampling variation is a significant problem in hay testing and causes millions of dollars in lost revenue each year, either in costs to the buyer or seller or in animal performance. In practice hay sampling causes much greater variation that does lab error but if sampling protocol is carefully followed the variation can be reduced to an acceptable level and the potential forage quality successfully predicted. The following sampling steps have been compiled from various recommendations that have been refined over the years and are widely considered to be the key elements of a standardised sampling protocol.

Steps for Proper Hay Sampling:

- ❖ Identify a single 'lot' of hay
- ❖ Choose a sharp coring device
- ❖ Sample at random
- ❖ Take enough cores
- ❖ Use proper technique
- ❖ Not too big, not too small
- ❖ Handle samples correctly
- ❖ Never split samples without grinding
- ❖ Choose a Lab that is reliable

Each of these points is discussed in detail below.

Sampling Alfalfa Cubes

A procedure has been developed by the University of California in conjunction with the California Department of Food and Agriculture. Just select 40 cubes at random from the lot to be graded, and place these cubes in one container for submission to the laboratory for grinding and analyses.

Standardized Protocol to assure a representative sample of hay[3]

1. **Identify a single 'lot' of hay.** This is a key first step to proper hay sampling, and one frequently ignored. A hay lot should be identified which is a single cutting, a single field and variety, and generally be less than 200 tons. Combinations of different lots of hay cannot be represented adequately by a forage sampling

[3] Recommended Principles for Proper Hay Sampling - D. H. Putnam, University of California, Davis.
http://alfalfa.ucdavis.edu/+producing/forage_quality/hay_sampling/HAYSAMPLINGSTEPS.htm#_ftn1

method; different lots should be sampled separately. Don't mix cuttings, fields, or hay types.

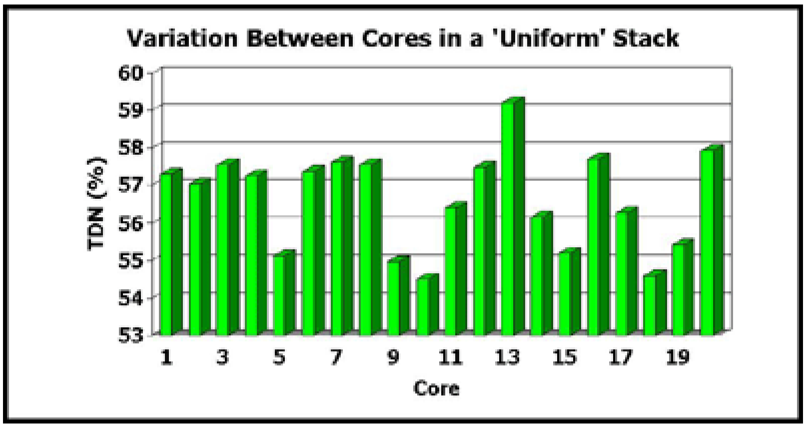
2. **When to Sample?** It is important to sample the hay either as close to feeding, or as close to point of sale as possible. Dry matter measurements are especially subject to changes after harvest and during storage, but other measurements may also change. Hay immediately after harvest normally goes through a process of further moisture lost known as a 'sweat'. During this period, hay may heat up due to the activities of microorganisms, driving residual moisture from the hay. Thus, moisture content is likely to be reduced in the days and weeks after harvest. If the hay has been baled at excess moisture, further biological activity may result in molding, or even (under very high moisture conditions) spontaneous combustion of hay. However, after hay has equilibrated to the range of 90% DM (10% moisture, depending upon humidity), it is typically quite stable. 'As received' dry matter measurements should be used to adjust quantity (tonnage, yield), not quality parameters, which should be compared on 100% DM basis.

3. **Choose a sharp, well-designed coring device.** Use a sharp coring device 3/8-3/4" diameter. Never send in flakes or grab samples, it is nearly impossible for these samples to represent a hay lot. "Hand-grab' samples have been shown to be significantly lower in quality than correctly sampled forage. The corer should have a tip 90o to shaft, not angled—studies have shown that angled shafts push aside some components of hay, providing a non-representative sample of the entire mix. Very small diameter tips (<3/8") do not adequately represent the leaf-stem ratio of the hay. Too-large diameter or too-long probes (e.g. > 24") provide good samples, but give too much forage in a 20 probe composite sample—thus the sampler may stop before 20 cores are completed or the lab may not grind the whole sample (see below). The length of probe should allow probing to a depth of 12"-24". Studies have shown this depth to successfully characterize the variation in hay, even in large (1 ton) bales, and no significant differences were seen between a 32" and 12" probe. A range of probe tip designs have been used successfully, from serrated to non-serrated tips—it is probably most important that the tip be sharp (and maintained sharp), and not create 'fines' during the cutting action, but cleanly cut across a cross-section of hay. Some probes are power, hand-brace, or auger driven, whereas others are push-type, both of which may work well. Many (not all) probes can be used to successfully represent a hay lot as long as they follow these principles: they easily penetrate the bale, fairly represent the leaf-stem ratio, can be easily sharpened, and produce approximately ½ lb (200 g) of sample in about 20 cores to a depth of 12"-24". A list of probes can be found at the NFTA (National Forage Testing Association) website.[4]

4. **Sample at random.** The sampler should walk around the stack as much as possible, and sample bales at random. Both ends of bales should be sampled by walking around the stack. This is sometimes difficult since all of the bales are not available to the sampler (they may be against walls of a barn or up too high for practical sampling). However, the sampler should make every attempt to sample in a random fashion—this means not to bias either for or against any bales in the stack. For example, the sampler may walk 15 steps, sample, walk 20 steps, sample, walk 5 steps, sample, while walking around stack—trying to represent all areas of the stack. Don't avoid or choose bales because they look especially bad or good--If 20 cores are taken, they won't make much difference anyway. Avoiding or choosing bales introduces bias.

[4] National Forage Testing Association: http://www.foragetesting.org/.

5. **Take enough cores.** We recommend a minimum of 20 cores for a composite sample to represent a hay lot. This is the same for large (e.g. 1 ton bales), or small 2-tie or 3-tie bales. This is because core-core (and bale-bale) variation in forage quality is tremendous (e.g. 5-7 % points ADF or CP). Sampling a large number of locations and bales throughout the stack to create a composite sample is a key aspect of representing the full variation contained in a hay lot. It is recommended to take more than 20 cores (e.g. up to 35) with very large lots (100-200 tons), or with highly variable lots (e.g. lots that may have non-attached leaves or are from very weedy fields). With small bales, sample 1 core per bale, >20 bales; with larger (e.g. 1 ton) bales, take 2-3 cores per bale in the center of the ends, sampling >10-12 bales. A larger number of core samples is generally better at characterizing variation in hay in more variable hay lots.



6. **Use proper technique.** Sample butt ends of hay bale, between strings or wires, not near the edge. Probe should be inserted at 90o angle, 12”-18” deep. Do not sample in the same exact spot twice. Do not use any technique which is likely to misrepresent the leaf-stem ratio. The sides or the top of the bale should not be sampled, since these cores will only represent one flake from a single area of the field, and additionally misrepresent the leaf-stem ratio. With round bales, sample towards middle of bale on an angle directly towards the center of the bale.

7. **Sample amount: “not too big, not too small”.** Sampling should be done so that about ½ lb of sample is produced. Too-small samples don’t fairly represent the full range of variation in the hay lot. Very big samples (common with large length or diameter probes) are excellent at representing the hay but have practical disadvantages. Large samples cannot be easily ground by the labs—many labs will simply sub-sample such large samples before grinding, defeating the entire purpose of good sampling technique! The sampler should ensure that the entire sample is ground by the lab—this is important to check. If your lab is not grinding the whole sample, ask why—it could be that your sample is too large. Only work with labs that are willing to grind the entire sample (after a DM sample for field DM is taken). But you should also assure that you are providing a reasonable ½ lb sample, so that it can be practically handled by the lab. If a probe is too big or small to produce about ½ pound in 20 cores—get a different one! (see list of probes on NFTA website)

8. **Handle samples correctly.** Seal Composite 20-core sample in a well-sealed plastic bag and protect from heat. Double bagging is beneficial, especially for DM measurements. Deliver to lab as soon as possible. Do not allow samples to be exposed to excess sun (e.g. in the cab of a pickup truck). Refrigeration of hay

samples is helpful, however, dry hay samples (about 90% DM) are considered fairly stable.

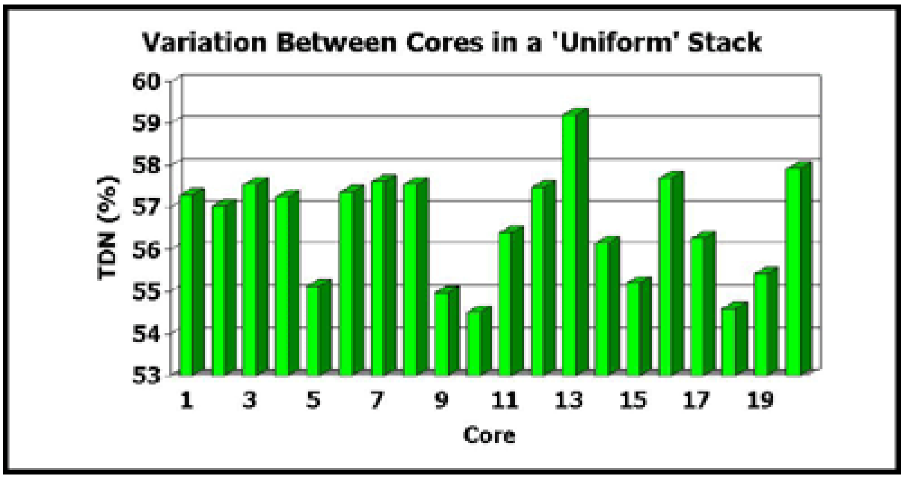
9. **Never split samples without grinding.** It is important to occasionally double check the performance of your lab by comparing with another (or several other) labs. However, never split un-ground samples and send them to two different labs—the samples are likely to be genuinely different! To test two labs, either grind and carefully split the sample, or better yet, ask for your ground sample back to send to another lab. Use several samples to test average potential bias between labs. Don't work with labs that are unwilling to do this—good labs should be wiling to test their performance and answer questions with regards to consistency of lab results. Ask for their NFTA results!

10. **Choose a Quality Lab**.

Questions and Answers[5]

Question: Why is Hay Sampling Important
Answer:
Proper sampling of hay and forage is of tremendous importance to assure an accurate forage test. Here's the dilemma: Hundreds of thousands of kilos of highly variable plant material must be represented in a single, tiny, thumbnail-sized sample!! This sample must not only represent the proper leaf-stem ratio and the legume/grass mix, but also reflect the spotty presence of weeds. Sampling variation is a common problem in hay testing, and causes millions of dollars in lost revenue each year. In practice, hay sampling produces more variation in results than does lab error. A lab test is only as good as the sample provided to the lab. If sampling protocol is carefully followed (see below), sampling variation can be reduced to an acceptable level, and the potential forage quality successfully predicted.

Question: How much variation is there in hay?
Answer:
LOTS!
These graphs show the amount of core to core variation within a single lot of seemingly uniform hay. Each point is data from a single probe sample in the lot.



[5] http://alfalfa.ucdavis.edu/sampling/hayprobe.html

Question: Can't I just take a grab sample?
Answer:
NO!
In a test of 7 hay lots, comparing 'grab' samples with 20 properly-cored combined samples, the grab sample was always lower quality than the proper sample. There was an AVERAGE difference of 16 points RFV (about 2.4% CP, 3.1% ADF, and 3.2%NDF). Never submit a 'grab' or 'flake' sample to a lab.

Question: What is RFV
Answer: Relative Feed Value - See "Understanding Relative Feed Value (RFV) and Relative Forage Quality (RFQ) on Page 19.

Question: Do I need a long hay probe for big bales?
Answer:
PROBABLY NOT!
Comparing a long (32") probed sample to a short (12") corer in proper 20-core samples of two hay lots showed no difference in results. Some people like long corers for large bales, since they show potential problems in the interior. However, it's usually not necessary, since 12-18" has been show to characterize hay variation successfully. Long probes may be a problem since 20 cores typically produce samples that are too large for labs to grind economically. The number of cores taken is probably more important than the depth.

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COLLEGE OF AGRICULTURE & BIOLOGICAL SCIENCES / SOUTH DAKOTA STATE UNIVERSITY / USDA

Understanding Relative Feed Value (RFV) and Relative Forage Quality (RFQ)

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Alvaro D. Garcia, Dairy Science Department

Feed quality of alfalfa harvested as haylage or hay depends, to a great extent, on the maturity of the stand. With increasing maturity, plant structural carbohydrates, as measured by the ADF and NDF fractions, increase. These fiber fractions represent the more indigestible parts of the plant. As a result, digestibility and energy obtained through fermentation decrease with maturity.

Relative feed value (RFV) has been used for years to compare the quality of legume and legume/grass hays and silages. Having one index to price hay and predict animal performance has been very useful for livestock producers and hay farmers.

Relative Feed Value (RFV)

The Relative Feed Value index estimates digestible dry matter (DDM) of the alfalfa from ADF, and calculates the DM intake potential (as a percent of body weight, BW) from NDF. The index is then calculated as DDM multiplied by dry matter intake (DMI as a % of BW) and divided by 1.29.

The index ranks forages relative to the digestible DMI of full bloom alfalfa, assuming 41% ADF and 53% NDF. The RFV index is 100 at this growth stage.

DDM = Digestible Dry Matter = 88.9 - (0.779 x % ADF)
DMI = Dry Matter Intake (% of BW) = 120 / (% NDF)
RFV = (DDM x DMI) / 1.29

where the numerator, **120**, in the DMI calculation indicates maximum feed intake in alfalfa-based dairy rations when NDF is 1.2 lb per 100 lb of body weight; the divisor, **1.29** in the RFV calculation was chosen so that the RFV of full bloom alfalfa has a value of 100.

Example: Alfalfa hay or haylage with 32% ADF and 40% NDF
(Plug in values for ADF and NDF on a dry matter basis)

DDM = 88.9 - (0.779 x 32) = 63.97
DMI = 120 / 40 = 3
RFV = (63.97 x 3) / 1.29 = 149

Relative Feed Value reflects both digestibility (from % ADF) and intake potential (from % NDF) of alfalfa.

Limitations of the RFV method include:
1. DDM and DMI are assumed constants for all forages.
2. ADF and NDF are the only laboratory values used in the calculation.
3. Crude protein concentration of forage is not used.
4. RFV cannot be used in ration formulation or evaluation.

Forage quality parameters including RFV ranking for each type of forage are in Table 1.

Higher RFV values indicate higher forage quality. Since the RFV system was developed using legume forages and intake responses of lactating dairy cows, it works best when applied to that situation.

Relative Forage Quality (RFQ)

Relative feed value is calculated by estimating the digestibility of the forage dry matter, and how much the cow can eat based on its “filling” capacity. However, cows sometimes perform differently even when fed forages of identical RFV. Variations in the digestibility of the NDF fraction can probably account for these differences.

Table 1. Forage quality values of some forages at different growth stages.

Forage type	CP	ADF	NDF	RFV
		%		
Alfalfa-prebud	22	28	38	164
Alfalfa-bud	20	30	40	152
Alfalfa-early bloom	18	33	43	138
Alfalfa-full bloom	16	41	53	100
Alfalfa-seed pod	14	43	56	92
Alfalfa + grass	13	39	54	101
Bromegrass, late vegetative	10	35	63	91
Bromegrass-late bloom	7	49	81	58
Corn silage-well eared	10	28	48	133
Corn silage-few ears	8	30	83	115
Sorghum silage	8	32	52	114

Source: Dunham (1998)

Fiber from grass and legumes naturally differs in digestibility, as it also does when grown under different ambient temperatures. RFV of first-cutting alfalfa will be similar to that of second and third cuttings harvested at similar stages of maturity. However, fiber fraction digestibility from each cutting will be different, as this is influenced by ambient temperatures at the time of growth and development. Therefore, differences in fiber digestibility are not taken into account in the RFV calcucation and cows may perform differently when fed forages from different cuttings.

Researchers at the University of Wisconsin have designed the relative forage quality (RFQ) index that uses fiber digestibility to estimate intake as well as the total digestible nutrients (energy) of the forage.

The RFQ index is an improvement over the RFV index for those that buy and sell forages, and it better reflects the performance that can be expected from cattle fed those forages.

One other advantage of the RFQ prediction is that it differentiates legumes from grasses.

The higher neutral detergent fiber in grasses will make RFQ a better predictor of quality than RFV. The RFQ emphasizes fiber digestibility while RFV uses digestible dry matter intake. Although grasses have

higher fiber fractions (ADF and NDF), they also have lower lignin content (Table 2).

A comparison of data generated by the Olson Biochemistry Laboratory, SDSU shows that RFQ is slightly higher than RFV for the same sample. A relationship between RFV and RFQ has been derived from this limited data set and is presented in Figure 1.

The RFV generally penalizes grasses because of the higher fiber fraction compared with alfalfa. The RFQ credits grasses because the grass fiber tends to be more digestible than alfalfa fiber. Table 2 shows higher cell wall digestibility for timothy than alfalfa when incubated for 72 hr in rumen fluid-buffer solution.

Relative Forage Quality Calculation

In the RFQ calculation total digestible nutrients (TDN) substitutes for DDM. Intake and TDN are calculated from fiber digestibility obtained in the laboratory.

For RFQ:

RFQ = (DMI, % of BW) * (TDN, % of DM) / 1.23

The value 1.23 ensures the equation has a mean and range similar to that of RFV.

Calculations to estimate TDN and DMI for alfalfa, clovers, and legume/grass mixes are as follows:

For TDN:

TDN = (NFC*.98) + (CP*.93) + (FA*.97*2.25) + (NDFn * (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).

Table 2. Nutrient composition of selected forages.

Forage type	CP	NDF	ADF	Lignin	Cell wall digestibility*
			%		
Alfalfa	16	49	34	7	46
Corn silage	10	51	28	4	68
Timothy	10	66	34	4	57

* The % of NDF lost in 72 hr of incubation.

Source: Collins (1988)

For DMI:

DMI = 120/NDF + (NDFD – 45) * .374 / 1350 * 100

Where: DMI is expressed as % of body weight (BW)
NDF as % of DM
NDFD as % of NDF
45 = average value for fiber digestibility of alfalfa and alfalfa/grass mixtures.

Conclusion

Relative feed value continues to be widely used as an index to assess quality, compare forage varieties, and price forages. However, differences in the digestibility of the fiber fraction can result in a difference in animal performance when forages with a similar RFV index are fed.

The RFQ index has been developed to overcome this difference. This index takes into consideration the differences in digestibility of the fiber fraction and can be used to more accurately predict animal performance and match animal needs.

Although hay base prices vary with supply and demand, the market premium for quality forage is fairly constant. Long-term auction data indicate that the premium for quality forage is worth $0.90/ton as RFQ changes from one value to another; therefore improving RFQ of harvested forage can improve profitability.

Table 3. Forage quality needs of cattle by relative forage quality.

Relative Forage Quality	Suggested Cattle Type
100-200	Heifer, 18-24 mo Dry cow
115-130	Heifer, 12-18 mo Beef cow and calf
125-150	Dairy, last 200 days Heifer, 3-12 mo Stocker cattle
140-160	Dairy, 1st three months of lactation Dairy calf

Source: Undersander (2003)

References

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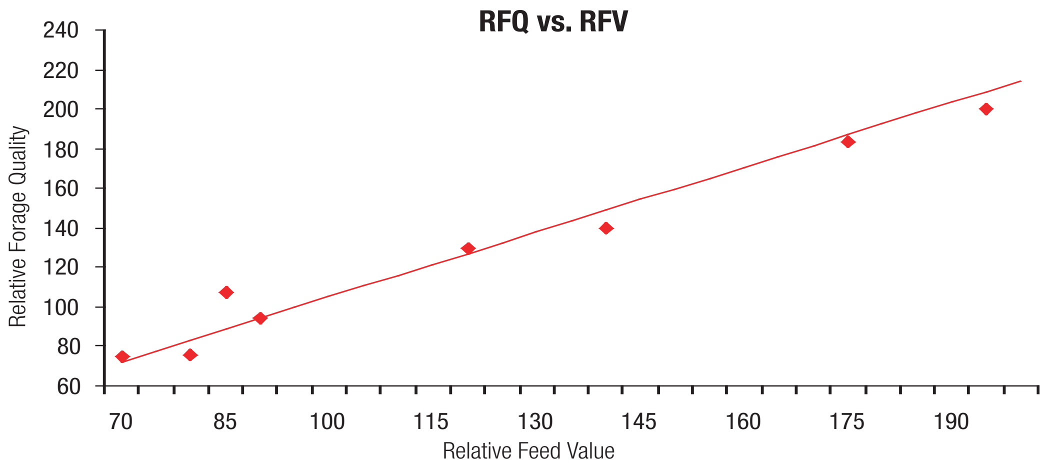
Undersander, D. 2003. The new Relative Forage Quality Index-concept and use. World's Forage Superbowl Contest, UWEX.

Fig 1. Relative Forage Quality versus Relative Feed Value.



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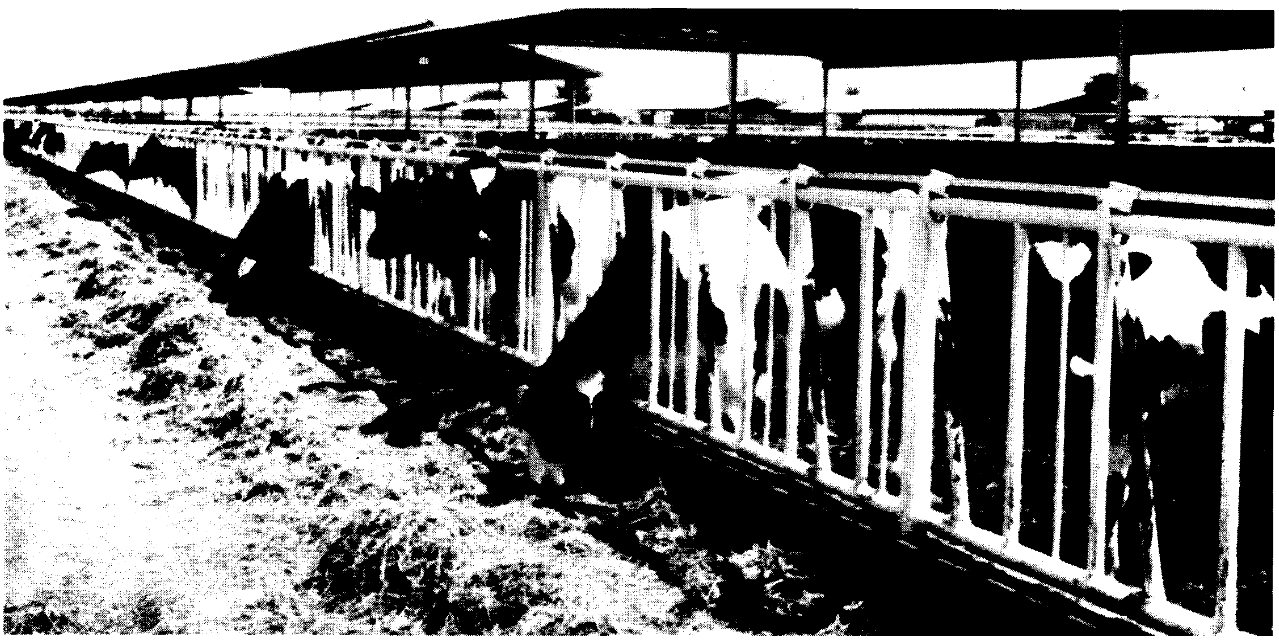
Testing Alfalfa for its Feeding Value



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Abbreviations
The following abbreviations are used extensively in this publication:

ADF = acid detergent fiber
CF = crude fiber
CP = crude protein
DDM = digestible dry matter
DM = dry matter
kg = kilogram
lb = pound
Mcal = megacalories
MCF = modified crude fiber
NDF = neutral detergent fiber
NEL = net energy for lactation
NIRS = near-infrared reflectance spectroscopy
SNF = solids-not-fat
TDN = total digestible nutrients

Testing Alfalfa for Its Feeding Value

Alfalfa Quality

Alfalfa is the most widely grown forage in the western United States, providing over $2 billion of cash income to its producers. The purchase of alfalfa accounts for the largest cash expenditure for many dairy and livestock enterprises. The producer's ability to influence quality by improving production techniques and the buyer's ability to recognize quality interact to determine economic value.

High-quality alfalfa must be nutritious and palatable and must be preserved in a manner that will retain these characteristics, whether it is fed as hay, green chop, or silage. Digestibility alone cannot characterize alfalfa quality. To be of greatest value, alfalfa must also be consumed at the highest level possible. High-quality alfalfa will be consumed in greater quantities than low-quality alfalfa, thus magnifying its benefit.

Producers and buyers have estimated alfalfa quality visually for centuries. The visual factors that have been used to estimate alfalfa digestibility and palatability are

- stage of maturity
- leafiness
- foreign material
- condition and odor
- green color

Stage of Maturity

Producers, estimate quality and determine when to harvest the alfalfa based on stage of maturity. Maturity is, by far, the most important controllable factor in the hay making process. As maturity increases, yield also increases, but at the same time, quality decreases, mostly because the proportion of fibrous stems to leaves goes up. Since leaves are high in protein and low in fiber, the highest-quality alfalfa is cut early in the pre-bud or bud stage. The immature plants have a high proportion of leaves, and the stems have not yet become highly lignified, hard, and unpalatable. However, by Cutting alfalfa at the immature bud stage for more than 1 year, you deplete the root of carbohydrate reserves and reduce plant vigor. Lower yields result, along with more weeds and a reduced stand life. The relationships are shown in table 1.

Buyers usually do not see the crop standing in the field. They depend on the other four visual factors to estimate quality, because maturity is very difficult to estimate after alfalfa has been harvested and baled.

Leafiness

Leaves make up the most digestible part of the alfalfa plant, containing two-thirds to three-fourths of the protein and other nutrients. Alfalfa leaves at the 10 percent bloom stage contain approximately 2-4 percent crude protein (CP), while the stems contain only about 12 percent. Alfalfa harvested in the spring and fall has a higher leaf and protein content than summer-cut alfalfa at the same stage of maturity (table 2). In order to maintain a high degree of leafiness, growers should harvest at the bud stage in midsummer.

Table 1. Effects of different alfalfa cutting frequencies on 3-year yield and quality, weeds, and stand life at the end of the third year.

Maturity at harvest	Harvest interval	Harvest per year	Yield	TDN*	Crude protein	Leaves	Weeds	Stand
	days		---	---	---	%	---	---
Pre-bud	21	9-10	7.5	62.6	29.1	58	48	29
Mid-bud	25	8-9	8.8	60.2	25.2	56	54	38
10% bloom	29	7	9.9	58.2	21.3	53	8	45
50% bloom	33	6-7	11.4	57.8	18.0	50	0	56
100% bloom	37	5-6	11.6	55.7	16.9	47	0	50

SOURCES: V.L. Marble, 1974. How cutting schedules and varieties affect yield quality, and stand life. In *Proceedings. Fourth California* Alfalfa *Symposium* December 4 & 5, 1974, Fresno, California: Univ. Calif. Cooperative Extension; and V.L. Marble unpublished.
*Total digestible nutrients (TDN) at too percent dry matter

Table 2. Protein percentage and leaf content expressed as a percentage of the total weight of the alfalfa plant for different seasonal periods and harvest schedules

	March-May		***June-August***		***September-November***	
Maturity at harvest	**Leaf content**	**Protein content**	**Leaf content**	**Protein content**	**Leaf content**	**Protein content**
	---	---	---	%	---	---
Pre-bud	60	27.5	59	25.5	65	28.5
Mid-bud	53	23.5	51	22.0	61	26.0
10% bloom	51	21.0	47	19.0	55	24.0
50% bloom	49	20.0	46	17.5	51	21.0

SOURCE: W.C. Weir, L. C. Jones, and J. H. Meyer. 1960 Effect of cutting interval and stage of maturity on the digestibility and yield of alfalfa. *J. Anim. Sci.* 19:5-19.

Foreign Material

Foreign material in hay can be weeds, straw, old hay stubble, rocks, dirt clods, baling wire or twine, sticks, or any other material that has little or no value as a feed. Weeds are the most common foreign material. Certain weeds are toxic to livestock; others are stemmy and fibrous and may irritate the months of animals; most are of poor quality. Weeds occur in alfalfa when stands are thin, or when frequent harvests decrease plant vigor.

Condition and Odor

Soundness in alfalfa hay is its condition after packaging. Unsoundness is usually caused either by excessive leaf shatter, a consequence of raking and/or baling when the hay is too dry (table 3), or by the hay being baled when it is too wet. To be of high quality, alfalfa must be free from objectionable odors, mold, dust, and excessive leaf shatter, and must be dry, but with no evidence of excessive heating. Heating above 125°F will reduce the digestibility of protein, fiber, and carbohydrate compounds. Alfalfa dry matter disappears in the heating process, reducing yield as well as digestibility. Moldiness and odors that decrease palatability are usually associated with alfalfa that has been baled too wet and that subsequently heated to 115° to 125°F. Hay that has heated to 130° to 140°F may be brown, and hay that has heated to more than 150°F may turn black. With the high-density bales now produced, alfalfa hay should not be baled at a moisture content of more than 17 percent.

Table 3. influences of hay-making practices on quality and yield of alfalfa grown on 1 acre

Measurement*	Harvested correctly	Raked dry	Baled dry	Raked and baled dry
Yield (tons/acre)	1.45	1.08	1.38	0.94
Lamb gain (lb)	224	154	218	114
Crude protein (%)	22.4	20.4	21.8	19.4
Modified crude fiber (%)	26.7	28.7	26.8	30.6
Total digestible nutrients (%)	58.3	56.4	58.1	54.6

SOURCE: J. H. Meyer and L. C. Jones, 1962. Controlling alfalfa quality. *Calif. Ag Exp. Stn. Bull*. 784.
*Crude protein, modified crude fiber, and total digestible nutrients (TDN) values are on a 100 percent dry matter basis.

Green Color

To many, a bright green color is an indicator of the feeding value of alfalfa hay. Green color does indicate that hay was rapidly and properly cured, with no damage from rain or overheating during storage, but color is not a good indicator of digestibility. Even bright green hay can lose up to 80 percent of its carotene during the curing process due to oxidation.

Visual versus Chemical

The relative reliabilities of visual inspection and chemical analysis for evaluating the five quality factors are presented below.

Quality Factor	Judgment by visual inspection	Judgment by chemical analysis
Stage of maturity	Poor	Excellent
Leafiness	Fair	Excellent
Foreign material	Excellent	Poor
Condition	Excellent	Poor
Green color	Excellent	Poor

Clearly, visual analysis cannot accurately or consistently describe the feeding value of alfalfa. Chemical analysis to predict alfalfa quality combines with a visual estimate to give the most reliable evaluations. Alfalfa cut at the right stage of maturity can be made into low-quality hay by poor hay-making practices and conditions that can only be detected by visual inspection. Complete dependence on the chemical methods presented in this publication can be misleading. The tables relating nutritive value to chemical components were developed from hays in which alfalfa was the only forage present. Significant proportions of grasses or other weeds (more than 10 percent) in the hay would destroy the validity of the chemical tests. Some immature weeds are high in feed value but may be unpalatable, and the effects of mold, rain damage, and brittleness cannot be detected by chemical analysis. Visual inspection must supplement chemical analyses to predict alfalfa quality accurately.

Sampling Procedures and Equipment

Taking an Adequate Sample

The validity of the testing program rests on obtaining a sample that accurately reflects the quality of a particular amount *(lot)* of hay. A *minimum* of 20 core samples taken at random, one core per bale, should he drawn and composited to develop one sample per lot. A *lot* consists of hay from the same cutting; variety; field; stage of maturity; and harvested within a 48-hour period.

Bales should be probed near the center of one end, with the probe entering at right angles to the surface and not slanting up, down, or sideways. Bales must be sampled at random. Randomness can be insured by sampling at various heights on the stack periodically around the entire bale stack, truck load, or row of bales in the field. Variability between bales can be greater than you would expect. It is thus imperative that a 20-bale sample be combined into a single sample if the tests are to give an accurate estimate of the chemical composition of a lot of hay.

Coring Devices

Many core samplers have been developed. The inside diameter of the coring device must be no less than 3/8 inch and no more than 3/4 inch. The cutting edge must be sharp and must not separate stems from leaves. The shaft on the coring device should be long enough to take a core of at least 12 inches from the bale. Some of the most commonly used core sampling devices:

- *Penn State Forage Sampler* an 18-inch probe with an internal diameter of 3/4 inch, available for use with a hand brace or an electric drill (Nasco Farm and Ranch Catalog, Nasco West, 1524 Princeton Avenue, Modesto, CA 95354, [2091 529-6957)

- *Techni-Serv E-Z Probe,* a 12-inch probe with an internal diameter of 1/2 inch and equipped with a sample collection box, for use with a hand brace or electric drill (Techni-Serv, Inc., P.O. Box 848, Madras, OR 97-41, [5031 475-2209)

- *Oakfield Hay Sampler* (Oakfield Apparatus, Inc., P.O. Box 65, Oakfield, WI 53065, [414] 583-4114)

- Thirteen- to fifteen-inch golf Club shaft with an internal diameter of 3/8 inch or more (homemade)

- *Utah Hay Sampler,* a 20-inch probe with an internal diameter of 1/2 inch and a sample collection box for use with a hand brace or electric drill (Utah Hay Sampler, P.O. Box 1141, Delta, UT 84624, [801] 864-5380)

- *Hay Chec Hay Sampler* a 12-inch hand probe with an internal diameter of 7/16 inch and sample collection jar (A.M. Hodge Products, P.O. Box 202005, San Diego, CA 92120 [6191 444-3147)

- *Forageurs Hay Sampler* a 24-inch probe with an internal diameter of 5/8 inch and a sample collection box (Forageurs Corp., 8500 210th Street, W., Lakeview, MN 54044, [6121 469-2596)

Sample Handling

A 20-core sample provides a large amount of sample material, particularly if the sampling device has a 3/4 inch internal diameter. *No sample should ever be divided before it has been ground and mixed at the laboratory* After coring, place the whole sample in a polyethylene freezer bag and identify it with a sample number and the sampler's name and address. The bag should be sealed tightly so the laboratory report of dry matter "as received" will approximate the dry matter content of the lot when it was sampled. Store the samples in a cool place where plastic bags are safe from puncture until they can be shipped to the laboratory. After grinding, samples may be thoroughly mixed and subsamples taken for analysis.

Unacceptable Samples

Alfalfa "flakes," samples obtained by using a “hay hook,”' very small core samples, and hand-mixed samples are not representative and should not be submitted for chemical analysis. Most problems involving chemical analysis of "duplicate" samples sent to different laboratories have been traced to hand mixing and subsampling of the cored sample prior to grinding. The sifting of fine leaves and stem parts cannot be avoided, and no two samples can really be considered to be duplicates when divided in this way.

Sampling Alfalfa Cubes

Properly sampling alfalfa cubes is like sampling baled alfalfa hay. The following procedure has been developed by the University of California in conjunction with the California Department of Food and Agriculture. Just select 40 cubes at random from the lot to be graded, and place these cubes in one container for submission to the laboratory for grinding and analyses.

Sampling Limits

A lot of baled alfalfa hay or alfalfa cubes should not exceed 200 tons. Remember that the smaller the lot, the more likely the sample will represent the actual feeding value of the lot.

Sampling devices with a dull edge or with a diameter of less than 3/8 inch may not cut through tough or wet stems, and so should not be used.

Very small samples consisting of a few cores cannot represent the true quality of the lot and should not be submitted. A 20-core sample should weigh no less than 1/2 pound; an even better weight is 3/4 Pound (225 to 350 g).

Laboratory Certification

Different analytical procedures are used in different states and regions to predict alfalfa forage quality. Methods and terms of reporting also vary. The **National Alfalfa Hay Testing**

Association has developed a national program of alfalfa forage quality evaluation to eliminate these two problems. However, some variation in the individual chemical analyses of different laboratories still exists and must be resolved. At the re- of the National Alfalfa Hay Testing Association, the American Forage and Grasslands Council (AFGC) and the National Hay Association (NHA) have volunteered to serve as umbrella organizations to sponsor the certification of laboratories throughout the United States.

The voluntary laboratory certification program has these objectives:

- to provide a voluntary mechanism for laboratories and hay testing facilities that evaluate alfalfa hay quality to certify the accuracy of their procedures for acid detergent fiber (ADF) and crude protein (CP)

- to use the certification of laboratories to improve quality control for test result,, and thereby increase grower confidence in the laboratory information

- to publish an annual list of certified participating laboratories in national, regional, state, and local hay association publications

Voluntary laboratory certification will be conducted as follows (a manual of instruction describing the program and procedures has been prepared by the National Alfalfa Hay Testing Association). Homogenous alfalfa hay samples obtained from various regions of the country have been prepared by grinding and mixing an entire bale of hay. Subsamples for laboratory analysis have been drawn from the large samples using a sample splitter. Subsamples weigh at least 200 g to ensure sufficient material for triplicate analyses of crude protein (CP), acid detergent fiber (ADF), and dry matter (DM). Subsamples will be stored in moisture-tight containers.

A copy of the manual and a set of subsamples will be sent to each requesting laboratory four times a year. All subsamples sent out at a given time will come from the same sample. The laboratories will be required to submit the results of triplicate CP ADF, and DM analyses and a calculation of digestible dry matter (DDM). The National Alfalfa Hay Testing Association, Inc., (PO Box 1059, Jackson, MI 49204) will ship and receive all subsamples and data. The association will also collect fees and serve as the statistical analysis resource office for calculating outlier information.

Compiled statistics will include the mean and standard deviation (SD) for each laboratory, and a grand mean for the entire population of laboratories. A statistical outlier test will determine which values fall outside of an acceptable range.

If a laboratory's data fall within an acceptable range for three out of the four annual samples, the laboratory will be certified. The association will report program results, including tables and graphs, to the participating laboratories. The results will also be published where they are sure to reach farmers and others to whom the information will be useful. Twice a year the supporting organizations, AFGC and NHA, will publish an updated list of certified laboratories.

Each laboratory location will pay an annual fee of $100 for certification. The association will have the right to publish the compiled data and a list of certified laboratories.

There has been a great response from laboratories interested in being certified to run the ADF prediction analysis and the supplemental CP and DM analyses. This voluntary program of self-improvement will increase the users' confidence in alfalfa hay testing. Over 90 laboratories from different regions of the United States were certified in 1987.

Testing Methods

Energy and protein are the most valuable components of alfalfa. The crude protein content of alfalfa can be determined directly in a laboratory, but there is no direct chemical test to determine its energy value. The energy value of alfalfa hay is closely related to its fiber content - as the alfalfa plant matures, its fiber content increases and its energy value decreases. Several fiber tests are used in the U.S. to estimate the energy value of alfalfa hay.

Modified Crude Fiber

Research at the University of California in the 1950s established relationships that reliably predict the energy value of alfalfa from its modified crude fiber (MCF) content. A detailed description of the laboratory procedure for determining MCF is contained in the Appendix, under *Determining Modified Crude Fiber* The difference between MCF and crude fiber (CF) is that MCF includes the silica (dirt) present in a sample. As crude fiber and dirt in a sample increase, energy and protein contents decrease. The standard CF analysis does not include silica, so it is not as accurate as MCF analysis in predicting the nutritional value of alfalfa.

The equations for predicting the energy value of alfalfa, measured as total digestible nutrients (TDN) or net energy for lactation (NEL), follow.

TDN (% of DM) = 81.07 - (0.8558 x MCF %) [Equation 1]

NEL (Mcal/lb DM) = 0.8465 - (10,0095 x MCF %) [Equation 2]

NEL (Mcal/kg DM) = 1.8662 - (0.02097 x MCF %) [Equation 3]

These equations give values on a 100 percent dry matter (DM) basis. In the past, the MCF test commonly has been used on a 90 percent DM basis because most hay is near to 90 percent DM when it is fed, regardless of how much moisture it contained when it was packaged. However, comparing nutrient values among various lots of hay, and among various feed ingredients, is more convenient if all are expressed on a 100 percent DM basis. This is particularly true when comparing values of such wet feeds as silage and haylage with values of drier feeds, such as hay and grain. If values on a basis other than a 100 percent DM are required, they can be calculated by multiplying the values obtained from equations 1, 2, and 3 by the desired DM percentage.

Example: What is the total digestible nutrient percentage (TDN%) at 90 percent DM of an alfalfa hay sample with 24 percent at 100 percent DM?

TDN (% of DM) = 81.07 - (0.8558 x MCF%)

= 81.07 - (0.8558 x 2 4)

= 60.5%

TDN% at 90% = TDN (% of DM x 90%,

= 60.5 x .90

= 54.5%

The MCF test has been used extensively in California for more than 30 years, and has served the industry well. The main disadvantage of MCF is that it is accurate only for pure alfalfa samples. The test is not appropriate for mixtures of alfalfa and grasses, nor for alfalfa samples that are contaminated with weeds. This is a serious drawback in areas where alfalfa-grass mixtures are more common than pure stands of alfalfa. However, in western states where pure alfalfa stands are the rule rather than the exception, the MCF test is as accurate as the other, more recently developed tests.

Neutral Detergent Fiber and Acid Detergent Fiber

Research conducted by USDA scientists at Beltsville, Maryland resulted in chemical procedures to identify various plant components by using detergents and mixtures of acid and detergent. When a forage sample is ground and mixed with a neutral detergent (sodium lauryl sulfate), the cellular contents (lipids, soluble protein, nonprotein nitrogen, starch, and pectins) go into solution. All of these fractions are highly digestible. The remainder of the sample is called neutral detergent fiber (NDF) and contains hemicellulose, cellulose, lignin, insoluble protein, and insoluble minerals. Neutral detergent fiber consists of the structural components of a plant cell that are bulkier and less digestible than the components that go into solution in neutral detergent. The NDF content has been shown to correlate with voluntary intake of forages by ruminant animals.

If a sample is mixed with acid (1 normal sulfuric acid) and detergent (cetyl trimethyl-ammonium bromide), the hemicellulose of the NDF fraction also goes into solution. The remainder of the sample (cellulose, lignin, insoluble protein, and insoluble minerals) is called acid detergent fiber (ADF). The constituents of ADF are the least digestible portions of plant materials. As was the case for MCF, ADF is inversely related to the digestibility of forages. The ADF analysis is increasing in popularity relative to the MCF test because it is easier and faster to conduct, is more discrete and more scientifically based, and more accurately measures the digestibility of alfalfa-grass mixtures and forages other than alfalfa. Furthermore, limited research has shown it to be as accurate as MCF for predicting the energy values of pure alfalfa samples. Equations for predicting the TDN and NEL values of alfalfa grown in the western states, based on limited research conducted to date, are

TDN (% of DM) = 82 38 - (0.7515 x ADF%) [Equation 4]

NEL (Mcal/lb DM) = 0.8611 - (0-00835 x ADF%) [Equation 5]

NEL (Mcal/kg DM) = 1.8983 - (0.0184 x ADF%) [Equation 6]

Again, all constitutents are expressed on a 100 percent DM basis. Energy prediction equations for forages based on their ADF content are in use in many states. The statistical analysis of alfalfa digestibility data from many areas resulted in the development of a *National Equation* for predicting digestible dry matter (DDM) from ADF. That equation is

DDM (% of DM) = 88.9 - (0.779 x ADF%) [Equation 7]

The National Equation is useful for comparing the DDM content of alfalfa from various areas. However, equations 1 through 6 are more accurate for estimating alfalfa energy values, since those equations were developed from digestibility trials using alfalfa grown in the western states. A detailed description of the laboratory procedure for determining ADF is contained in the Appendix.

Crude Protein

Modified crude fiber has been used to predict the digestible protein content as well as the energy content of alfalfa, but direct laboratory determination of protein gives a more accurate measure. Crude protein (CP) can be determined accurately by the Kjeldahl method. The CP should be determined directly by this laboratory procedure rather than estimated from MCF. A detailed description of the laboratory procedure for determining CP is contained in the Appendix.

Dry Matter

The dry matter (DM) content of a sample is important for calculating nutrient values to a 100 percent DM basis, and for establishing relative economic values of hay lots offered for sale. Although alfalfa hay usually stabilizes at about 90 percent DM (10 percent moisture) during storage, it may contain 14 to 17 percent moisture or more at baling. The extra moisture reduces the dollar value of the hay because there is less dry matter, and thus less energy and protein, per ton of hay bought or sold. Determining the DM content of a lot of hay at the time of sale allows the buyer and seller to adjust the price to a standardized DM content and compare the lot with other hay lots on the same moisture basis. The laboratory procedure for determining DM is described in the Appendix.

Near-Infrared Reflectance Spectroscopy

Research at the USDA experiment station in Beltsville, Maryland resulted in the development of a machine that measures the reflectance of a band of light shining on a finely ground sample, and correlates the measurements with the composition of the sample as determined in a chemical laboratory. Speed of analysis is the major advantage of near-infrared reflectance spectroscopy (NIRS). Chemical analysis of a forage sample may take a day or more, but similar information can be obtained by NIRS in only 10 to 15 minutes. The accuracy of NIRS analysis is as high as that of chemical analysis if the NIRS instrument is properly calibrated for the specific forages. Considerable research has been conducted to determine how to obtain the best calibrations. Calibrations must be different for alfalfa grown in the western states than for that grown in other parts of the United States. Differences probably result from irrigation practices in the west and the prevalence of alfalfa-grass mixtures outside of the western states. Limited research with alfalfa grown in California and Nevada has resulted in improved calibrations for NIRS machines used in the west. Their popularity and use probably will increase in the future because of their speed of analysis and the repeatability of their results.

Estimated Nutrient Content of Alfalfa

There are five major classes of nutrients needed by cattle: energy, protein, minerals, vitamins, and water. Energy is most often the limiting factor for milk production, so the energy value of alfalfa deserves the greatest emphasis. High-energy alfalfa also is high in protein, a very important nutrient.

Total digestible nutrients (TDN) and net energy for lactation (NEL) are two of the most common measures of the energy value of feeds. Though TDN has been used extensively in the past, NEL has the advantage of greater accuracy when comparing the energy values of different types of dairy cattle feed. Using TDN, you can over-evaluate forages in comparison with grains and other concentrate feeds. More energy is lost as heat from forages, leaving less of the digestible energy available for productive purposes such as growth and milk production. This heat loss, plus the losses of energy in the expelled gases and urine, are subtracted from digestible energy when determining the NEL value of a feed.

Although NEL is more accurate when comparing the energy values of different types of feed and for ration balancing for dairy cattle, there is little difference in the accuracy of NEL and TDN when comparing relative energy values of different lots of alfalfa hay. Both the NEL and TDN values of alfalfa predicted from either MCF or ADF are included in tables 4 and 5, since both are used extensively in the field. Digestible dry matter (DDM) predicted from ADF also is included in table 4 for use in comparing values nationwide.

Table 4. Net energy for lactation (NEL), total digestible nutrients (TDN), and digestible dry matter (DDM) of alfalfa estimated from its acid detergent fiber (ADF) content (100 percent dry matter basis)

ADF	TDN	NEL	DDM
%	%	Mcal/lb DM	%
20	67.4	0.694	73.3
21	66.6	0.686	72.5
22	65.8	0.677	71.8
23	65.1	0.669	71.0
24	64.3	0.661	70.2
25	63.6	0.652	69.4
26	62.8	0.644	68.6
27	62.1	0.636	67.9
28	61.3	0.627	67.1
29	60.6	0.619	66.3
30	59.8	0.611	65.5
31	59.1	0.602	64.8
32	58.3	0.594	64.0
33	57.6	0.585	63.2
34	56.8	0.577	62.4
35	56.1	0.569	61.6
36	55.3	0.560	60.9

37	54.6	0.552	60.1
38	53.8	0.544	59.3
39	53.1	0.535	58.5
40	52.3	0.527	57.7
41	51.6	0.519	57.0
42	50.8	0.510	56.2
43	50.1	0.502	55.4
44	49.3	0.494	54.6
45	48.6	0.485	53.8

Table 5. Net energy for lactation (NEL) and total digestible nutrients (TDN) of alfalfa estimated from its modified crude fiber (MCF) content (100 percent dry matter basis)

MCF	**TDN**	**NEL**
%	%	Mcal/lb DM
16	67.4	0.694
17	66.5	0.685
18	65.7	0.676
19	64.8	0.666
20	64.0	0.656
21	63.1	0.647
22	62.2	0.638
23	61.4	0.628
24	60.5	0.618
25	59.7	0.609
26	58.8	0.600
27	58.0	0.590
28	57.1	0.580
29	56.2	0.571
30	55.4	0.562
31	54.5	0.552
32	53.7	0.542
33	52.8	0.533
34	52.0	0.524
35	51.1	0.514
36	50.3	0.504
37	49.4	0.495
38	48.5	0.486

Laboratory Reports

Laboratory test data for alfalfa samples are reported in various formats by different laboratories, often causing confusion among hay growers, purchasers, and others using the test data. Some laboratories report results on a 100 percent DM basis, some at 90 percent DM, and some on an "as received" DM basis. For the sake of utility and clarity, laboratories should report data on all three of the above mentioned DM bases, as shown in figure 2.

Values for TDN, NEL, and DDM at 100 percent DM can be calculated from equations 4, 5, and 7, or estimated from values in table 4. In figure 2, the sample contained 30 percent ADF. From table 4, a sample with 30 percent ADF contains 59.8 percent TDN and 0.611 Mcal NEL/lb DM. To convert to "as received" and 90 percent DM basis, multiply the values by the corresponding DM percentages, in this case 87 percent and 90 percent. Thus, the sample with 30 percent ADF has 59.8 percent TDN and 0.611 Mcal NEL/lb at 100 percent DM, 53.8 percent TDN and 0.550 Mcal NEL/lb at 90 percent DM, and 52.0 percent TDN and 0.532 percent Mcal NEL/lb at 87 percent DM.

The bottom portion of the suggested form contains boxes to indicate the relative nutritional value of the sample. Four categories are listed (Premium, Good, Fair, and Low) which correspond to ratings listed in the *California Hay Market News* published by the California Department of Food and Agriculture, and in the *Nevada Hay Market News* published by the University of Nevada. The states of Colorado, Montana, Oregon, Utah, Washington, and Wyoming also use these four categories to report market sales. A sample must contain not more than 29 percent ADF to qualify for the "Premium" category, 29.1 to 32 percent ADF for "Good," and 32.1 to 37 percent ADF for "Fair." Samples with more than 37 percent ADF are in the "Low" category. The sample in figure 2 contains 30 percent ADF at 100 percent DM, so it is in the "Good" category.

For laboratories using the MCF test procedure, values for TDN and NEL can be calculated from equations 1 and 2 or estimated from values in table 5. For the MCF percentages that define the four hay quality rating categories, see figure 2.

Lab. Number: ______________________
Date received: ______________________
Date sampled: ______________________
Date reported: ______________________

Name: ______________________
Address: ______________________
____

Number of bales sampled: ______________________
Total bales or tons in lot: ______________________
Cutting number: ______________________

Laboratory Analysis:	Dry Matter Basis As Received	90% DM	100% DM
Dry matter (DM), %	87.0	90.0	100.0
Acid Detergent fiber (ADF), %	26.1	27.0	30.0
Modified crude fiber (MCF), %	21.6	22.3	24.8
Crude protein (CP), %	17.4	18.0	20.0

= =

Estimated Energy Values (Calculated from ADF or MCF)			
Total Digestible Nutrients (TDN), %	52.1	53.9	59.8
Net Energy for Lactation (NEL), Mcal/lb	0.531	0.550	0.611
Digestible Dry Matter (DDM), %	57.0	59.0	65.5

= =

Hay Quality Rating for this Sample
(ADF and MCF values on a 100% DM basis)

☐	Premium	(29% ADF or less)	or	(24% MCF or less)
✓	Good	(29.1 to 32% ADF)	or	(24.1 to 27% MCF)
☐	Fair	(32.1 to 37% ADF)	or	(27.1 to 31% MCF)
☐	Low	(more than 37% ADF)	or	(more than 31% MCF)

Fig. 2. A sample laboratory form for reporting the chemical and nutrient values of alfalfa.

Relative Economic Values

One of the main uses of alfalfa test information is in formulating rations. Alfalfa is the predominant forage grown in the western states and so often makes up a major portion of the rations fed to livestock. Therefore, it is important to know the nutrient content of alfalfa in order to ensure that it is supplemented with the right type and amount of other feedstuffs for a properly balanced ration.

Another use of the data is economic worth of different alfalfa lots. The energy value and DM content of the sample are important for estimating its economic value. When hay is selling for $80 per ton, 1 percent moisture costs the buyer $.80 per ton. Most hay will standardize at about 90 percent DM (10 percent moisture) after being stored for a month or so in warm, dry weather. When hay is bought soon after baling, moisture levels of 15 to 17 percent are common, especially in the spring and fall. Hay grown in high mountain desert areas frequently contains 1 or 2 percent less moisture than hay grown in lower valley areas. The buyer should consider the decreased value of high-moisture hay as well as its energy value when negotiating the price. Tables 6, 7, and 8 can be used to estimate the relative dollar values of alfalfa lots at varying ADF, MCF, and DM percentages. The tables are based on a standard hay sample arbitrarily set at 90 percent DM, and either 31 percent ADF (table 6) or 26 percent MCF (table 7) (both on a 100 percent DM basis). This corresponds to the middle of the "Good" category in the "Hay Quality Rating" section of figure 2.

After the chemical composition of the sample is determined, use tables 6, 7, and 8 as follows. From the left column, find the row with ADF percentage (table 6), or the MCF percentage (table 7) of the alfalfa sample. Read across that row to the column headed with the dollar value closest to the price of standard hay (90 percent DM, and 31 percent ADF or 26 percent MCF). Where the row and the column intersect you will find the corrected value of the tested hay. From the left column of table 8, find the DM percent of the tested hay. Read across to the right column for the DM correction factor. Multiplying the ADF or MCF corrected value from table 6 or 7 by the DM correction factor from table 8 will give you the value of the tested hay relative to the standard hay.

Table 6. Relative Alfalfa Hay Values at Various ADF Percentages[1]

ADF % of DM	Price of Standard Hay ($/ton) 50.00	52.00	54.00	56.00	58.00	60.00	62.00	64.00	66.00	68.00	70.00	72.00	74.00	76.00	78.00	80.00	82.00	84.00	86.00	88.00	90.00	92.00	94.00	96.00	98.00	100.00
20.0	57.64	59.95	62.25	64.56	66.86	69.17	71.48	73.78	76.09	78.39	80.70	83.00	85.31	87.61	89.92	92.23	94.53	96.84	99.14	101.45	103.75	106.06	108.37	110.67	112.98	115.28
21.0	56.98	59.26	61.53	63.81	66.09	68.37	70.65	72.93	75.21	77.49	79.77	82.05	84.33	56.60	88.88	91.16	93.44	95.72	98.00	100.28	102.56	104.84	107.12	109.40	111.67	113.95
22.0	56.23	58.48	60.73	62.98	65.23	67.48	69.72	71.97	74.22	76.47	78.72	80.97	83.22	85.47	87.72	89.97	92.22	94.47	96.71	98.96	101.21	103.46	105.71	107.96	110.21	112.46
23.0	55.56	57.79	60.01	62.23	64.46	66.68	68.90	71.12	73.35	75.57	77.79	80.01	82.24	84.46	86.68	88.90	91.13	93.35	95.57	97.79	100.02	102.24	104.46	106.68	108.91	111.13
24.0	54.90	57.10	59.29	61.49	63.68	65.88	68.08	70.27	72.47	74.66	76.86	79.06	81.25	83.45	85.64	87.84	90.04	92.23	94343	96.62	98.82	101.02	103.21	105.41	107.60	109.80
25.0	54.15	56.32	58.49	60.65	62.82	64.98	67.15	69.32	71.48	73.65	75.81	77.98	80.15	82.31	84.48	86.64	88.81	90.98	93.14	95.31	97.48	99.64	101.81	103.97	106.14	108.31
26.0	53.49	55.63	57.77	59.51	62.05	64.19	66.33	68.47	70.60	72.74	74.88	77.02	79.16	81.30	83.44	85.58	87.72	89.86	92.00	94.14	96.28	98.42	100.56	102.70	104.84	106.98
27.0	52.85	54.94	57.05	59.16	61.28	63.39	65.50	67.61	69.73	71.84	73.95	76.07	78.18	80.29	82.41	64.52	86.63	88.74	90.86	92.97	95.08	97.20	99.31	101.42	103.53	105.65
28.0	52.08	54.16	56.24	58.33	60.41	62.49	64.57	66.66	68.74	70.82	72.91	74.99	77.07	79.16	81.24	83.32	85.41	87.49	89.57	91.65	93.74	95.82	97.90	99.99	102.07	104.15
29.0	51.41	53.47	55.52	57.58	59.64	61.69	63.75	65.81	67.86	69.92	71.98	74.03	76.09	78.15	80.20	82.26	84.32	86.37	88.43	90.49	92.54	94.60	96.65	98.71	100.77	102.82
30.0	50.75	52.78	54.81	56.84	58.87	60.90	62.93	64.96	66.99	69.02	71.05	73.08	75.11	77.14	79.17	81.20	83.23	85.26	87.29	89.32	91.35	93.38	95.41	97.44	99.47	101.50
31.0	50.00	52.00	54.00	56.00	58.00	60.00	62.00	64.00	66.00	68.00	70.00	72.00	74.00	76.00	78.00	80.00	82.00	84.00	86.00	88.00	90.00	92.00	94.00	96.00	98.00	100.00
32.0	49.34	51.31	53.28	55.26	57.23	59.20	61.18	63.15	65.12	67.10	69.07	71.04	73.02	74.99	76.96	78.94	80.91	82.88	84.86	86.83	88.80	90.78	92.75	94.72	96.70	98.67
33.0	48.59	50.53	52.48	54.42	56.36	58.31	60.25	62.19	64.14	66.08	68.02	69.97	71.91	73.85	75.80	77.74	79.68	81.63	83.57	85.51	97.46	89.40	91.35	73.29	95.23	97.18
34.0	47.92	49.84	51.76	43.67	55.59	57.51	59.43	61.34	63.26	65.18	67.09	69.01	70.93	72.84	74.76	76.68	78.59	80.51	82.43	84.35	86.26	88.18	90.10	92.01	93.93	95.85
35.0	47.26	49.15	51.04	52.93	54.82	56.71	58.60	60.49	63.38	64.27	66.16	68.05	69.94	71.83	73.72	75.61	77.50	79.40	81.29	93.18	85.07	86.96	88.85	90.74	92.63	94.52
36.0	46.51	48.37	50.23	52.09	53.95	55.81	57.67	59.53	61.40	63.26	65.12	66.98	98.84	70.70	72.56	74.42	46.28	78.14	80.00	91.86	83.72	85.58	87.44	89.30	91.16	93.02
37.0	45.85	47.68	49.51	51.35	53.18	55.02	56.85	58.68	60.52	62.35	64.19	66.02	97.85	69.69	71.52	73.36	75.19	77.02	78.86	90.69	82.52	84.36	86.19	88.03	89.86	91.69
38.0	45.18	46.99	48.80	50.60	52.41	54.22	56.03	57.83	59.64	61.45	63.26	65.06	66.87	68.68	70.49	72.29	74.10	75.91	77.71	79.52	81.33	83.14	84.94	86.75	88.56	90.37
39.0	44.44	46.21	47.99	49.77	51.54	53.32	55.10	56.88	58.65	60.43	62.21	63.99	65.76	67.54	69.32	71.10	72.87	74.65	76.46	78.21	79.98	81.76	93.54	85.32	87.09	88.87
40.0	43.77	45.52	47.24	79.02	50.77	52.52	54.28	56.03	57.75	59.53	61.28	63.03	64.78	66.53	68.28	70.03	71.78	73.53	75.29	77.04	78.79	80.54	82.29	84.04	85.79	87.54
41.0	43.11	44.83	46.55	48.28	50.00	51.73	53.45	55.18	56.90	58.62	60.35	62.07	63.80	65.52	67.25	68.97	70.69	72.42	74.14	75.87	77.59	79.32	81.04	82.76	84.49	86.21
42.0	42.36	44.05	45.75	47.44	49.14	50.83	52.52	54.22	55.91	57.61	59.30	61.00	62.69	64.39	66.08	67.77	69.47	71.16	72.86	74.55	76.25	77.94	79.63	81.33	83.02	84.72
43.0	41.69	43.36	45.03	46.70	48.37	50.03	51.70	53.37	55.04	56.70	58.37	60.04	61.71	63.38	65.04	66.71	68.38	70.05	71.71	73.38	75.05	76.72	78.39	80.05	91.72	83.39
44.0	41.03	42.67	44.31	45.95	47.59	49.24	50.88	52.52	54.16	55.80	57.44	59.08	60.72	62.37	64.01	65.65	67.29	68.93	70.57	72.21	73.85	75.50	77.14	78.78	80.42	82.06
45.0	40.28	41.89	43.50	45.12	46.73	48.34	49.95	51.56	53.14	54.78	56.50	58.01	59.62	61.23	62.84	64.45	66.06	67.67	69.29	70.90	72.51	74.12	75.73	77.34	78.98	80.56

[1]For hay above $100/ton, multiply the values in the $100 column by the corresponding factor (e.g., for $130/ton, multiply the $100/ton values by 1.3).

Table 7. Relative Alfalfa Hay Values at Various MCF Percentages[1]

ADF % of DM	Price of Standard Hay ($/ton)																									
	50.00	52.00	54.00	56.00	58.00	60.00	62.00	64.00	66.00	68.00	70.00	72.00	74.00	76.00	78.00	80.00	82.00	84.00	86.00	88.00	90.00	92.00	94.00	96.00	98.00	100.00
18.0	56.33	58.59	60.84	63.09	63.35	67.70	69.85	72.11	74.36	76.61	78.87	81.12	83.37	85.63	87.88	90.13	92.39	94.64	96.89	99.15	101.40	103.65	105.91	108.16	110.41	112.67
19.0	55.50	57.72	59.94	62.16	64.38	66.60	68.82	71.04	73.26	75.48	77.70	79.92	82.14	84.36	86.58	88.80	91.02	93.24	95.46	97.68	99.90	102.12	104.34	106.56	408.78	111.00
20.0	54.67	56.85	59.04	61.23	63.41	65.60	67.79	69.97	72.16	74.35	76.53	78.72	90.91	83.09	85.28	87.47	89.65	91.84	94.03	96.21	98.40	100.59	102.77	104.96	107.15	109.33
21.0	53.92	56.07	58.23	60.39	62.54	64.70	66.86	69.01	71.17	73.33	75.48	77.64	79.80	81.95	84.11	86.27	88.42	90.58	92.74	94.86	97.05	99.21	101.36	103.52	105.68	107.83
22.0	53.17	55.29	57.42	59.55	61.67	63.80	65.93	68.05	70.18	72.31	74.43	76.56	78.69	80.81	82.94	85.07	87.19	89.32	91.45	93.57	95.70	97.83	99.95	102.08	104.21	106.33
23.0	52.33	54.43	56.52	58.61	60.71	62.80	64.89	66.99	69.08	71.17	73.27	75.36	77.45	79.55	81.64	83.73	85.83	87.92	90.01	92.11	94.20	96.29	98.39	100.48	102.57	104.67
24.0	51.50	53.56	55.62	57.68	59.74	61.80	63.86	65.92	67.98	70.04	72.10	74.16	76.22	78.28	80.34	82.40	84.46	86.52	88.58	90.64	92.70	94.76	96.82	98.88	100.94	103.00
25.0	50.75	52.78	54.81	56.84	58.87	60.90	62.93	64.96	66.99	69.02	71.05	73.08	75.11	77.14	79.17	81.20	83.23	85.26	87.29	89.32	91.35	93.38	95.41	97.44	99.47	101.50
26.0	50.00	52.00	54.00	56.00	58.00	60.00	62.00	64.00	66.00	68.00	70.00	72.00	74.00	76.00	78.00	80.00	82.00	84.00	86.00	88.00	90.00	92.00	94.00	96.00	98.00	100.00
27.0	49.17	51.13	53.10	55.07	57.03	59.00	60.97	62.93	64.90	66.87	68.83	70.80	72.77	74.73	76.70	78.67	80.63	82.60	84.57	86.53	88.50	90.47	92.43	94.40	96.37	98.33
28.0	48.33	50.27	52.20	54.13	56.07	58.00	59.93	61.87	63.80	65.73	67.67	69.60	71.53	73.47	75.40	77.33	79.27	81.20	83.13	85.07	87.00	88.93	90.87	92.80	94.73	96.67
29.0	47.58	49.49	51.39	53.29	55.20	57.10	59.00	60.91	62.81	64.71	66.62	68.52	70.42	72.33	74.23	76.13	78.04	79.94	81.84	83.75	85.65	87.55	89.46	91.36	93.26	95.17
30.0	46.83	48.71	50.58	52.45	54.33	56.20	58.07	59.95	61.82	63.69	65.57	67.44	69.31	71.19	73.06	74.93	76.81	78.68	80.55	82.43	84.30	86.17	88.05	89.92	91.79	93.67
31.0	46.00	47.84	49.68	51.52	53.36	55.20	57.04	58.88	60.72	62.56	64.40	66.24	68.08	69.92	71.76	73.60	75.44	77.28	79.12	80.96	82.80	84.64	56.48	88.32	90.16	92.00
32.0	45.17	46.97	48.78	50.59	52.39	54.20	56.01	57.81	59.62	61.43	63.23	65.04	66.85	68.65	70.46	72.27	74.07	75.88	77.69	79.49	81.30	83.11	84.91	86.72	88.53	90.33
33.0	44.42	46.19	47.97	49.75	51.52	53.30	55.08	56.85	58.63	60.41	62.18	63.96	65.74	67.51	69.29	71.07	72.84	74.62	76.40	78.17	79.95	81.73	83.50	85.28	87.06	88.83
34.0	43.67	45.41	47.16	48.91	50.65	52.40	54.15	55.89	57.64	59.39	61.13	62.88	64.63	66.37	68.12	69.87	71.61	73.36	75.11	76.85	78.60	80.35	82.09	83.84	85.59	87.33
35.0	42.83	44.55	46.26	47.97	49.69	51.40	53.11	54.83	56.54	58.25	59.97	61.68	63.39	65.11	66.82	68.53	70.25	71.96	73.67	75.39	77.10	78.81	80.53	82.24	83.95	85.67
36.0	42.00	43.68	45.36	47.04	48.72	50.40	52.08	53.76	55.44	57.12	58.80	60.48	62.16	63.84	65.52	67.20	68.88	70.56	72.24	73.92	75.60	77.28	78.96	80.64	82.32	84.00
37.0	41.25	42.90	44.55	46.20	47.85	49.50	21.15	52.80	54.45	56.10	57.75	59.40	61.05	62.70	64.35	66.00	67.65	69.30	70.95	72.60	74.25	75.90	77.55	79.20	80.85	82.50
38.0	40.50	42.12	43.74	45.36	46.98	48.60	50.22	51.84	53.46	55.08	56.70	58.32	59.94	61.56	63.18	64.80	66.42	68.04	69.66	71.28	72.90	74.52	76.14	77.76	79.38	81.00

[1]For hay above $100/ton, multiply the values in the $100 column by the corresponding factor (e.g., for $130/ton, multiply the $100/ton values by 1.3).

Example

What is the relative value of alfalfa hay with 28 percent ADF (100 percent DM basis) and 85 percent DM (as received) when standard hay is selling for $87.50 per ton? In the left column of table 6, find the row for 28 percent ADF. Read across that row to the column heading nearest to the standard hay price: in this case, $88. The value where the row and column intersect is $91.65.

In the left column of table 8, find the row for 85 percent DM. Read across to the right column for the DM correction value: in this case, 0.9444. Multiply the MCF corrected value ($91.65) by the DM correction factor (0.9444), to get the approximate value of the tested hay, $86.55.

This method is not intended as a guide for pricing hay. Prices are established by supply and demand. Rather, it is intended as a way to compare the values of different hay lots whose sale prices have been stated.

For example, a dairy operator is offered two lots of hay, each at $79 per ton. Good quality hay is selling for $80 per ton on the open market. Lot A has 32 percent ADF (100 percent DM basis) and has 88 percent DM as received at the laboratory. Lot B has 28 percent ADF (100 percent DM basis) and has 86 percent DM. Which is the better buy? Using tables 6 and 8, the following comparison determines the relative value of the two lots.

	Lot A	**Lot B**
Standard hay price per ton	$80.00	$80.00
ADF-corrected value (table 6)	78.94 (32%)	83.32 (28%)
DM correction (table 8)	x 0.9778 (88%)	x 0.9556 (86%)
DM- and ADF-corrected value	$77 1-9	$79.62

The above calculations indicate that Lot B is worth more per ton than Lot A by $2.43 ($79.62-$77.19= $2.43). The dairy operator would do better to purchase Lot B if both were priced at $79 per ton.

High-Quality Alfalfa Costs More to Produce

Since maturity is a major determinant of quality, and high-quality alfalfa is less mature, it costs more to produce than does low-quality alfalfa. This is because high-quality alfalfa requires one or more extra cuttings during the growing season. Harvesting costs increase and yield decreases with more frequent cutting. Also, a grower incurs greater costs in maintaining weed control (table 1). If there is no economic incentive to produce more palatable, more nutritious alfalfa, the grower profits more by producing forage of a lesser quality. Buyers must be willing to pay a premium for high-quality alfalfa if enough is to be produced to fulfill their needs.

High-Quality Alfalfa Returns More to the Feeder

High-quality alfalfa is worth more to livestock producers because of the greater milk flow it produces in dairy cows, and the faster weight gains in growing animals. Though the value of the extra nutrients can be estimated with reasonable accuracy, livestock producers are not likely to want to pay the full value of the extra nutrients. By doing so, they would merely be trading dollars. The area of negotiation between the alfalfa grower and the buyer lies between the extra cost of producing high-quality alfalfa and the value of the extra nutrients it contains. Prices will shift with supply and demand, as always. Chemical analyses can help identify the supply, and also strengthen the tone of demand, in both directions.

Very Low Fiber Rations and Milk Composition

Feeding extremely low-fiber alfalfa to lactating dairy cattle can result in a depressed milk fat percentage. Milk flow and solids-not-fat (SNF) usually increase at the same time. In most cases, the increased amount of milk compensates for the drop in fat, resulting in approximately the same amount of milk fat per cow.

However, minimum standards must be maintained by milk processors, and low-fat milk must be standardized with milk fat from other sources. Therefore, milk that is low in fat may not be acceptable to some milk processors.

Factors other than fiber are involved in the production of low-fat milk, but feeding rations with less than either 17 percent crude fiber or 21 percent acid detergent fiber in the dietary DM may result in lowered milk fat percentages. Maintaining the appropriate level of fiber in the total ration of a cow that is fed a high level of concentrates requires alfalfa with 22 percent or more crude fiber, or 27 percent or more acid detergent fiber (100 percent DM basis). If cows eating high levels of grain (20 or more pounds per day) do not voluntarily eat at least 1.5 percent of their body weight in forages per day, even higher-fiber hay may not prevent a drop in milk fat. Many times, however, the advantages of the greater milk flow, the higher SNF test values, and the better body condition of cows eating low-fiber alfalfa with higher energy levels overshadow the disadvantages of lower fat tests.

Table 8. Dry matter (DM) correction factors for determining comparative values of alfalfa -at various dry matter percentages

DM of tested hay	Correction factor for table 6 or 7
80	0.8889
81	0.9000
82	0.9111
83	0.9222
84	0.9333
85	0.9444
86	0.9556
87	0.9667
88	0.9778
89	0.9889
90	1.0000
91	1.0111
92	1.0222
93	1.0333
94	1.0444
95	1.0556
96	1.0667
97	1.0778

98	1.0889
99	1.1000
100	1.1111

Other Advantages of High-Quality Alfalfa

Besides the higher energy value of low-fiber alfalfa, secondary benefits substantially increase its worth to livestock producers.

Since low-fiber alfalfa contains more protein, the protein level of the concentrate mix can be lowered accordingly. Protein supplements are expensive in a concentrate mix, so a lower protein level means a lower-cost concentrate mix.

Alfalfa with a higher energy value can either replace an equal amount of additional energy in the concentrate mix or provide additional energy if the same quantity of concentrates are fed. Either procedure will benefit the livestock producer.

Low-fiber alfalfa usually is more palatable than high-fiber alfalfa, resulting in higher forage intake and less wastage. Since low-fiber alfalfa is usually less mature, the stems are not very hard and are seldom rejected by livestock.

Appendix
Laboratory Procedures

Determining Modified Crude Fiber Content

Sample collection. A sample representative of the entire lot of the alfalfa being tested (at least 20 bale probes per lot) is collected directly into a polyethylene bag, sealed, and stored in a cool place out of direct sunlight.

Dry matter percent as received. If the as-received dry matter percentage is of interest, the sample is mixed by hand in the polyethylene bag, without milling, and two representative aliquots[1] are weighed into tared aluminum pans for drying. Samples should be dried for 15 hours at 100º C in a forced-draft oven and then weighed within 5 minutes after removal from the oven.

Sample milling. A representative aliquot of the sample, carefully selected to avoid classification, is milled[2] to pass totally through a sieve with an opening diameter of 1 mm, and then mixed and stored for analysis.

Aliquots for analysis. The milled sample is mixed well just before the aliquots are weighed for analysis. Two 4.000 g aliquots are weighed into previously tared aluminum cups for determination of dry matter. Two 2.000 g aliquots are folded into filter paper[3] envelopes that are then secured with paper clips.

Dry matter fraction determination. The 4 g milled samples are dried for 15 hours at 100º C in a forced-draft oven, and then cooled in a desiccator and weighed. The *dry matter fraction* is calculated by dividing the dry sample weight by 4.

Extraction of crude fiber samples. The samples in the filter paper packages are extracted[4] for at least 4 hours, but preferably overnight, on a rapidly refluxing Goldfisch extractor using ethyl ether or 1.9:1 (v/v) 95 percent ethyl alcohol-benzene mixture as the solvent.

[1] Preferably not less than 25 g, which allows an accuracy of 1 percent or better when weighing to the nearest 0.2 g on an ordinary triple beam balance. Take care that no classification occurs when mixing coarse samples.

[2] Use a Wiley Mill or equivalent with a screen or plate with 1 mm perforations.

[3] Use Whatman No. 1, 18.5-cm circles.

[4] It is convenient to extract a number of samples (40 to 50 packages) together in a large Soxhlet. Extracting for three or four 8-hour periods with alcohol-benzene is adequate, Groups of two to eight packages may be extracted in 3 or 4 hours in a Soxhlet extractor of minimum size, using a very rapid cycling rate. Samples previously used for ether-extract determination can be used without additional treatment.

Acid treatment. Using a stiff brush[5], the dry solvent extracted samples are transferred from the filter paper packages to 600 ml Berzelius beakers. Treating beakers in pairs[6], 200 ml of boiling 1.25 percent sulfuric acid is added slowly to each along with 10 to 20 drops of 2-ethyl hexanol as a defoamer. The beakers are at once placed on the preheated crude fiber apparatus. Boiling should begin in about 3 minutes.

Boiling under reflux is continued for exactly 30 minutes, and material collecting on the sides of the beakers is washed down with a stream of hot acid, if necessary. The beakers are lowered and the condensers rinsed into the beakers with acid.

At once, the acidic suspensions are vacuum filtered through linen cloth[7] on 3-inch Hirsch funnels. The beakers are rinsed into the funnels with water, and the filter cake washed free of acid with four distilled water washes. The cloth and filter cake may be removed from the funnel and draped across the top of the original empty beaker until the basic extraction is started.

Base treatment. The filter cake is rinsed completely from the cloth into the original beaker with a stream of hot 1.25 percent sodium hydroxide. Boiling 1.25 percent sodium hydroxide is added to bring the volume to about 200 ml, more 2-ethyl hexanol is added, and again the suspension is refluxed[8] for 30 minutes as with the acid. At the end of the heating period, the beakers are lowered and the condensers rinsed with Sodium hydroxide solution.

At once, the suspensions are vacuum filtered through previously tared 50 ml Pyrex filter crucibles with coarse frit plates. The beakers are rinsed and policed to complete transfer of the residue to the crucibles. Each filter cake is washed four or five times with distilled water.

Drying and ashing. The crucibles and contents are dried for 15 hours (overnight) at 100º C in a forced draft oven and then cooled in a desiccator and weighed. The weighed crucibles are now muffled for 3 hours at 550º C[9]. They are muffled only to remove organic matter before future use of the crucibles. To prevent crucible breakage, do not remove them from the muffle until their temperature has dropped below 200º C.

Calculations of results. The modified crude fiber percentage (MCF percentage) for alfalfa hay quality evaluation is expressed on a 100 percent DM basis as indicated in the equations below Duplicate determinations should not vary by more than 5 mg.

$$\text{MCF\%} = \frac{\text{(weight of crucible + fiber) - (tare weight of crucible)}}{\text{(sample weight) x (dry matter fraction)}} \times 100$$

$$\text{DM\%} = \frac{\text{(weight of pan + dry sample) - (weight of pan)}}{\text{(weight of sample)}} \times 100$$

Reagents.

- Sulfuric acid, 1.25 percent (w/v) or 0.255 *N*
  Dilute 127 ml of 96 percent reagent-grade sulfuric acid to 18.00 liters with distilled water.

- Sodium hydroxide, 1.25 percent (w/v) or 0.313 *N*
  Dissolve 225 g of reagent-grade sodium hydroxide in distilled water to make 18.00 L. Protect from carbon dioxide.

- Extraction solvent
  Mix 1.9 L 95 percent ethanol with 1 L of benzene.

- Defoamer
  Technical-grade octyl alcohol, or 2-ethyl hexanol.

Equipment.

- Six-place Labconco crude fiber apparatus
- Muffle with temperature controls
- Drying oven
- Pyrex or metal desiccators
- Pyrex fritted-glass filter crucibles. Pyrex catalog number 32940, high form, 50C
- Six 1,000 ml filter flasks
- Six 100 mm Hirsch funnels with 45 mm diameter perforated area
- Berzelius beakers, 600 ml
- Vacuum manifold with valving arrangement to apply vacuum to filter flasks
- Neoprene filter cones to fit crucibles to filter flasks
- Water aspirator of large capacity or house vacuum

[5] Use a 1/2-inch paintbrush with bristles shortened to 3/4 inch.

[6] Allowing about 5 minutes between treating pairs of beakers usually enables one to maintain the 30-minute heating schedule The filtering characteristics of the samples determine the interval used. One person can treat about 40 samples per 8-hour day starting at the point of brushing samples into beakers.

[7] See Association of Official Analytical Chemists (AOAC). Linen drawing cloth cut into 5-inch squares and washed free of starch is suitable

[8] In instances of violent "bumping" the addition of heat-stable boiling chips (Hengar Granules is required. They must be removed before the crucibles and residues are dried.

[9] After muffling the crucible and fiber, the crucible is readied for re-use by washing with water and a stiff brush, rinsing with distilled water and drying. Crucibles may be tared for future use in the modified crude fiber determination after heating at 100º C or higher for about 1 hour and then cooling in a desiccator and weighing.

Crucible cleaning. After continued use, the fritted glass bottom of a crucible may become obstructed with minerals, causing poor filtering performance. If crucibles do not exhibit normal filtering properties, place previously ashed crucibles in a shallow enamel pan and add approximately 25 ml of hot cleaning solution.

The crucible cleaning solution is prepared by dissolving 200 g of potassium hydroxide, 50 g of laboratory-grade trisodium phosphate, and 5 g of reagentgrade disodium ethylenedia-minetetra-acetate (EDTA) dihydrate crystal in 1.0 L of distilled water.

Allow the solution to filter through each crucible, and then apply vacuum to the top of each crucible, using a No. 9 1/2 rubber stopper (with a tube through the middle connected to a vacuum source), until the crucible is half-filled with cleaning solution.

Wait for the cleaning solution to filter through each crucible again, and then remove and wash with tap water. Force distilled water upward through the bottom of the crucible, using a No. 7 rubber stopper with a tube through the middle connected to a source of distilled water. Rinse the outside of the crucible with distilled water and proceed with normal preparation.

Exercise caution when immersing crucibles in this cleaning solution. Subjecting a crucible to long (5 minutes or more) or repeated cleanings may damage its fritted glass bottom and actually change its porosity.

Alternatively, crucibles may be placed in an ultrasonic water bath and sonicated for approximately 30 minutes to dislodge minerals from the fritted bottom. The crucibles are then removed and distilled water is forced upward through the bottom.

Determining Acid Detergent Fiber Content

When determining the acid detergent fiber (ADF) content of alfalfa, sample collection, dry matter percentage as received, and sample milling remain as outlined for modified crude fiber determination.

Aliquots for analysis. Just before weighing aliquots for analysis, the milled sample is mixed well. Two 4.000 g aliquots are weighed into previously tared aluminum cups, and the dry matter fraction determination is completed as for MCF determination. Two 1.000 g aliquots are weighed directly into 600 ml Berzelius beakers (sample weight).

Fiber determination. Add 100 ml of cold (room temperature) acid detergent solution[10] and place the beakers on a preheated fiber digestion apparatus. Boiling should begin within 5 to 10 minutes. A slow, even boil under reflux is continued for exactly 60 minutes. Material collecting on the sides of the beaker is washed down with acid detergent solution, if necessary.

At the end of the 60-minute heating period, the beakers are lowered and the condensers are rinsed with acid detergent solution. The suspension is filtered through a previously prepared[11] and weighed (tare weight) Gooch crucible (50 ml Pyrex coarse frit plate) that is set on the filter manifold, using light suction. The beakers then are rinsed with hot distilled water and policed to complete the sample transfer to the crucible.

Each filter cake is washed 4 or 5 times with hot (90º to 100º C) distilled water. Break up the filter mat with a glass rod between washes to promote thorough rinsing. Rinse down the inside of the crucible with a stream of hot water from a squeeze bottle.

Repeat washing with several small rinses of acetone until no more color is removed from the sample. Again, break up the filter mat with a glass rod to ensure that all particles come into contact with the solvent.

Drying and ashing. The crucible and contents are dried for 8 hours, or overnight, at 100º C in a forced draft oven and then cooled in a desiccator and weighed (weight of crucible + fiber). The weighed crucibles arc now muffled for 3 hours at 500º to 550º C. This step is necessary, only to remove organic matter from the crucibles before future use. To prevent crucible breakage, do not remove them from the Muffle until their temperature has dropped below 200º C.

[10] Acid detergent solution is prepared by slowly adding 882.72 g of reagent-grade, concentrated (93 to 99 percent) sulfuric acid to approximately 10 L of distilled water. Once the solution has cooled (20º C), make up to a volume of 18 L with distilled water and then standardize the acid to 1.0 *N* by titration. Add 360 g of technical-grade cetyl trimethylammonium bromide (CTAB) and stir until dissolved.

[11] Both new and previously used crucibles (containing acid detergent fiber residue) should be washed with distilled water and then muffled for 3 hours at 500º to 550º C. Once the muffle furnace has cooled to a temperature of less than 200º C, the crucibles may be removed. Place approximately 1 g of filter aid (enough to form a thin filtering bed over the bottom of the crucible) into the bottom of the crucible and add 6 *N* hydrochloric acid to fill the crucible half full. To prepare the filtering aid, see below.

Using a low vacuum, suck off all hydrochloric acid (this acid may be re-used several times for crucible preparation, and need not be discarded after one use). Wash and vacuum the crucible five or six times with cool (25º C) distilled water, disturbing the filter bed with a stream of water during each wash, Rinse down the sides and bottom of the crucible and place it in a 100º C oven overnight. Remove the crucible from the oven place it into a desiccator, and allow it to cool to room temperature. Then weigh it and record the crucible tare weight.

To prepare the filtering aid, place approximately 100 g of Johns Manville Celite 545 into a 3 L flask containing 850 ml of distilled water. Slowly add 1.4 L of technical grade sulfuric acid, mix, and cool to room temperature. Filter on a large Buchner funnel and wash with distilled water. Resuspend and agitate the mat several times to remove acid. Ash the celite filter aid overnight in a 600º C muffle furnace, allow to cool, and store until needed.

Repeatability and calculations. Duplicate determinations of acid detergent fiber should not vary by more than 5 mg. Calculation of acid detergent fiber percentage (ADF %) is expressed on a 100 percent dry matter basis as follows:

$$ADF\% = \frac{\text{(weight of crucible + fiber) - (tare weight of crucible)}}{\text{(sample weight) x (dry matter fraction)}} \times 100$$

$$DM\% = \frac{\text{(weight of pan + dry sample) - (weight of pan)}}{\text{(weight of sample)}} \times 100$$

Equipment. The ADF procedure can be conducted with the same equipment as that listed for the MCF procedure. Similarly, clean the crucibles as in the MCF procedure.

Determining Crude Protein Content

Apparatus. To determine the crude protein content (CP) of alfalfa, use a Labconco (or equivalent) 12-place Kjeldahl combination digestion-distillation apparatus, with Kjeldahl flasks of hard, moderately thick, well-annealed glass having a total capacity of 800 ml, as well as 500 ml Erlenmeyer flasks calibrated in 100 ml increments.

Sample preparation. Sample collection, dry matter percentage as received, sample milling, aliquots for analysis, and dry matter fraction determination remain as outlined for MCF determination.

Digestion. Remove the paper clip from the folded filter paper containing a previously weighed 2.000 g sample aliquot (sample weight), and place the packet into a Kjeldahl flask. Blank nitrogen values should be determined simultaneously by placing one piece of filter paper in a Kjeldahl flask along with all reagents used during digestion and distillation processes. Add 15 g of anhydrous sodium sulfate or potassium sulfate and either 0.65 g of metallic mercury or 0.05 g of anhydrous copper sulfate. If copper sulfate is used, it may be mixed with the sodium or potassium sulfate in large quantities. Add 50 ml of concentrated sulfuric acid to each flask, place on the Kjeldahl digestion apparatus, and begin digestion over a low heat.

Continue over a low heat until white fumes appear and most of the black digestion material has been refluxed from the sides of the flask. At this time the heat may be increased until the solution and flask clear. Then continue digestion at a high heat for 45 minutes.

Turn off the heat, and allow the flasks to cool nearly to room temperature and until no more white fumes are visible. Remove the flasks from the digestion rack and carefully add approximately 400 ml of distilled water while swirling. Again, let the flasks cool to room temperature before proceeding to the distillation step.

Distillation. Add approximately 100 ml of 3 percent boric acid to each 500 ml Erlenmeyer flask. Place the flasks under the condenser on the receiving shelf, making sure the tip of the condenser tube is immersed in the boric acid.

If metallic mercury was used as the digestion catalyst, add approximately 5 g of zinc dust to each Kjeldahl flask to precipitate the mercury and help prevent bumping during distillation. If copper Sulfate was the catalyst during digestion, add 5 to 10 boiling chips (Hengar Granules) to each Kjeldahl flask.

Tilt each Kjeldahl flask and carefully add 100 ml of 50 percent sodium hydroxide solution, making sure the sodium hydroxide flows down the neck of the flask and forms a layer on the bottom. Do not agitate the Kjeldahl flask. Immediately connect the flask to the distillation bulb on the condenser, and rotate the flask to mix the contents thoroughly. Adjust the heaters on the distillation rack to produce a rapid, even boil.

Continue distillation until 200 ml of condensate has been collected in the 500 ml Erlenmeyer receiving flask, making a total volume of 300 ml. Lower the Erlenmeyer flask from the receiving shelf so that the tip of the condenser tube is above the surface of the distillate. Shut off the heaters and allow the final few drops of distillate to collect in the receiving flask. Wash down the tip of the condenser with distilled water, and remove the flask.

Add 5 to 10 drops of indicating solution to each flask, and titrate to the light purple endpoint with 0.1 *N* standardized acid. Record the ml of standardized acid used during titration for unknowns (“sample nil of acid'”) as well as blanks (“'blank rut of acid'”).

Calculation. The amount of nitrogen (N%) in the sample is expressed on a 100% dry basis as follows.

$$N\% = \frac{\left(\begin{array}{c}\text{molecular weight}\\ \text{of N}\\ \text{14.01 g/mole}\end{array}\right) \times \left(\begin{array}{c}\text{normality of}\\ \text{standard acid}\\ \text{0.1 moles/L}\end{array}\right) \times \left(\begin{array}{c}\text{sample ml of}\\ \text{standard acid}\end{array} - \begin{array}{c}\text{blank ml of}\\ \text{standard acid}\end{array}\right)}{\text{Sample weight x dry matter fraction x 1,000}} \times 100$$

This can be reduced to the following formula.

$$N\% = \frac{0.07005\ (\text{ml standard acid for sample} - \text{ml standard acid for blank})}{\text{dry matter}}$$

The amount of crude protein contained in the sample is then calculated on a 100 percent dry basis (crude protein percentage = N % x 6.25).

Reagents.

- Sulfuric acid, concentrated 93 to 98 percent, specific gravity equal to 1.84

- Mercuric oxide or metallic mercury, HgO or Hg, reagent grade and nitrogen free

- Copper sulfate, reagent grade, anhydrous

- Potassium or anhydrous sodium sulfate, reagent grade, nitrogen free

- Sodium hydroxide (50% solution)
  Dissolve 500 g of solid sodium hydroxide in distilled water, cool, and dilute to 1.01, (specific gravity of solution should be ≥ 1.36)

- Zinc dust, impalpable powder

- Indicator solution
  Dissolve 1.25 g of methyl red and 0.825 g of methyIene blue in 1.0 L of 95 percent ethanol

- Boric acid (3% solution)
  Dissolve 30 g of U.S.P. grade boric acid in 1.0 L of distilled water

- *N* standard solution of sulfuric or hydrochloric acid
  Standardize according to Association of Official Analytical Chemists method 50.015 using indicator solution as prepared above

To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products that are not mentioned

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CONTRIBUTIONS OF ALFALFA TO WILDLIFE AND THE ENVIRONMENT

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ABSTRACT
Alfalfa growers throughout the world appreciate the high-yielding, high quality characteristics of their crop, and its value to the farm enterprise. However, this appreciation typically ends at the farm gate. There are few individuals in the general public who are aware of the economic importance of alfalfa (the third largest US crop, worth 7 billion) much less the other benefits that alfalfa provides to the landscape. The unique characteristics of alfalfa contribute significantly to broader societal goals, such as preservation of wildlife habitat and protection from erosion. Alfalfa has a significant role as a nitrogen fixer, for improvement of soil tilth and soil organic matter, for reducing fuel requirements of agriculture, as an insectary for beneficial insects, and as a habitat for many species of wildlife. These important contributions are in addition to its significant economic value in its own right, and the critical role alfalfa plays in dairy and other livestock industries. Although steps can be taken by growers to improve interactions between forage production and wildlife (such as protection of nesting waterfowl), alfalfa should be more broadly recognized by the general public for its diverse benefits, and for its fundamental contribution to the long-term sustainability of agricultural systems and to improved wildlife habitat.

INTRODUCTION
The economic importance of alfalfa to farms and ranches throughout the US is well known in the agricultural sector. The direct economic value of alfalfa, the nations 3rd largest crop, is about 7.1 billion dollars each year. In addition to this, alfalfa plays a vital role in the dairy and livestock industries. Many nutritionists value the highly-digestible fiber and high protein of alfalfa in dairy, sheep, horse and other livestock rations. Because it is the beginning of a food chain involving many steps, the economic value of alfalfa is complex and much larger than this $7.1 billion. Alfalfa is intertwined with many different enterprises which are partially or wholly dependent upon the crop as a critical feed component. In particular, dairy farming is the most important enterprise in many states, and largely dependent upon alfalfa.

However, alfalfa does not easily translate into something of widely-recognized value to the consumer. There are few ice cream lovers who would make the connection between a lush green alfalfa field and the ice cream cone they are enjoying. How many buyers of wool sweaters know the important role that alfalfa may have played in the "growing" of their purchase? It's hard to make the connection for most people. Partly as a result of this disconnection, forages in general, and alfalfa in particular, are not widely appreciated or understood by society as a whole.

I am reminded of a story which illustrates this point. A colleague at the University of California was discussing the issue of water-use and alfalfa with an individual from Los Angeles representing urban water-users. Their discussion lasted over two hours as they discussed the intricacies of water-use-efficiency, comparisons between crops, etc. At the end of the conversation, the lawyer casually asked: "let's see, alfalfa.... hmmm. Does that have anything to do with hay?"

In situations such as these, the gulf of understanding about agriculture and forages in particular becomes clear. Is it any wonder, then, that the many benefits of alfalfa are rarely understood by the general public, and the crop is even targeted in some quarters for its use of pesticides, excessive water use, and other crimes? Even among growers, forages are often considered the "Rodney Dangerfield" of crops, getting less respect than row crops.

American Bald Eagles grace sprinklers waiting to irrigate an alfalfa field.

AGRICULTURE vs. THE ENVIRONMENT: A FALSE DICHOTOMY

Most frequently in news accounts, one finds 'environmental interests' pitted against 'agricultural interests' in public discussions about pesticides, water quality, endangered species and wildlife. There is a widespread assumption among those who are most vocal about environmental issues that if land is allocated for agriculture, it is lost for wildlife habitat or environmental preservation. To them, it appears that agriculture is always a 'negative' environmentally. Such dichotomies of thinking are sometimes useful for political causes, for selling books, or for raising money, but they rarely represent the true picture.

While it may be true that agriculture puts its share of pressure on the environment, there are many aspects of farming which should clearly be placed on the positive side of an environmental balance sheet. Alfalfa in particular provides a number of important contributions which should be considered of value to the goals of cleaner air and water, better habitat for wildlife, and more judicious use of resources. As the United States (and the world) face ever rising urban populations, the value of agriculture, and alfalfa in particular, in maintaining open spaces for wildlife and other important functions should be increasingly recognized.

It is incumbent upon the practitioners of agriculture to communicate this broader value to the general public. In the late 20th century, it is no longer sufficient to produce excellent quality food products, but to communicate to a sceptical public that farmers are good stewards of the land and will take steps to further protect the land, water, and wildlife. Several of these important functions pertaining to alfalfa's contributions to environmental health and wildlife habitat are discussed below.

ALFALFA-THE BEGINNING OF AN IMPORTANT FOOD CHAIN

Alfalfa forms the basis for a complex food and utilization chain which touches many forms of life. It is of course economically important to many human enterprises, primarily dairy farming, and supports many other industries from cheese making to horse racing. However, the inclusion of alfalfa in the landscape makes many contributions far beyond its narrow economic value, or its value to the livestock industries. It is the beginning of a food chain for a host of other wild species which live nearby, within, underneath, feed upon, and temporarily nest in alfalfa fields. Clearly, the trade-off between alfalfa production and environmental goals is not a "zero sum game" with the environment being the automatic looser when land is allocated to alfalfa.

ALFALFA - AN "INCREDIBLE" INSECTARY

A fieldside view of an alfalfa field may show little apparent activity - simply a mass of green. However, each successive regrowth of alfalfa creates an environment which teems with insect life. The numbers and kind of insects that inhabit alfalfa have been described as "incredible" (Manglitz and Ratcliffe, 1988). A count of 591 species was recorded in a field near Ithaca, NY (Pimental and Wheeler, 1973). Insects are so abundant in alfalfa fields that university entomology classes can often be found sweeping in alfalfa fields to study the diversity of insects to be found there.

Important host for beneficial insects: Some of these insects, of course feed on alfalfa as a primary source of food, but there are many beneficial insects as well. These 'beneficials' prey on herbivorous or sucking insect pests of alfalfa. Dozens of predacious and parasitic insects occur in alfalfa, and several "work horses" of biological control are especially abundant (Leigh, 1991). Bigeyed bugs (Geocoris pallens and G. puncitipes), damsel bugs (Nabis americoferus), and minute pirate bugs (Orius tristicolor), are some of the major predators. Lady beetles (Hippodamia spp.) have long been recognized to control many types of aphids, and are often abundant in alfalfa fields. A parasitic wasp (Lysiphlebus testaceipes) is of importance in aphid control in alfalfa, and several other wasps help control beet armyworms, and other lepidopterous pests of alfalfa and other field crops.

The role of beneficial insect pests in helping to reduce crop damage in an alfalfa integrated pest management (IPM) program has been understood for some time. However, several of the species present in alfalfa also affect a number of other neighboring crops where they may greatly reduce the threat of pest damage. Due to its reservoir of insects, planting alfalfa in strips with other crops has been proposed to help distribute and nurture beneficial insects (Leigh, 1991).

Alfalfa is also the primary honey crop in the US. It accounts for about one-third of the annual honey production in the US (Barnes and Sheaffer, 1988), which is produced during alfalfa seed production. This is a "spin-off" industry of seed production in some areas, particularly in Western States, which benefits both alfalfa and the consumer.

The contribution of alfalfa to biological diversity and for the nurturing of beneficial insects for other species often goes unrecognized. This should be considered an important environmental benefit of incorporating alfalfa into a cropping system.

ALFALFA ATTRACTS WILDLIFE

While it is true that alfalfa production fields often represent a significant change from the naturally occurring flora and fauna of a region, it is not true that wildlife are automatically losers in this trade-off. Agricultural activities interact significantly with wildlife on several different levels, and many forms of wildlife adapt, adjust, or even thrive within and alongside agriculture.

Since alfalfa is a productive and palatable plant and a productive insectary, it provides an important food source for many types of creatures which inhabit nearby areas. Songbirds in particular are attracted to the insect population. There is also considerable below-ground biological activity in alfalfa fields. Since it is a perennial, gophers, ground squirrels, mice, voles and other rodents often abound in alfalfa, and in some areas are important pests, along with rabbits and other herbivores. This biological activity, sometimes the bane of growers, has its positive side - providing an important habitat for wildlife. Hawks, raptors, foxes, and other hunters frequent alfalfa fields looking for prey.

Wildlife aggregates in alfalfa: In extensive surveys conducted in the Sacramento Valley, California and in subsequent analysis by wildlife biologists, many species of wildlife were found to be present in alfalfa fields. Of the 643 regularly-occurring resident and migratory terrestrial wildlife (amphibians birds, mammals, and reptiles), 162 species or 25% were considered regular users of alfalfa fields to varying degrees (Kuhn et al.). Ten percent use alfalfa extensively for breeding and reproduction. A partial listing is provided in Table 1. Furthermore, many of these wildlife species show a strong preference for alfalfa, including several endangered or threatened species. Alfalfa has been found to be visited by 18 times the number of species than would be expected by chance (Smallwood and Geng, 1993). Predators of small mammals and ground-dwelling invertebrates were most selective for alfalfa. Several migratory Hawks, Falcons, the Great Blue Heron, White-faced Ibis, Killdeer, Northern Harrier, Brewer's Blackbirds, American Crows, Yellow-billed Magpies, and European Starlings. In the western US, the fact that all the western states, from California through Washington have large acreage of irrigated alfalfa is significant for the Pacific flyway for both waterfowl and raptors. The same is likely true throughout Midwestern states.

Alfalfa - Important for threatened species: Several species which have been classified as "threatened" or "special concern" show strong preference for alfalfa habitats. Of all the species that use alfalfa, six are on the federal endangered or threatened species lists. Two of these, the peregrine falcon and San Joaquin kit fox, use alfalfa peripherally or for finding prey. Three of these, the giant garter snake, loggerhead shrike, and Aleutian Canada goose, use alfalfa and association ditches to a greater extent. The Swainson's Hawk is a CA-listed threatened species and a candidate for federal threatened species list. It travels 11,000-17,000 miles yearly from S. America (Kemper, 1995), and visits alfalfa fields 10 times the number of times expected by chance (Smallwood, 1993). Alfalfa is also strongly selected by the Norther Harrier and White-faced Ibis, which are state-listed species of special concern.

Food for large vertebrates: The characteristics which make alfalfa the premier dairy forage also are quite attractive to wild species. In many parts of the US, deer, elk, and antelope are a significant factor in alfalfa production. It is difficult to maintain fences around alfalfa fields, and deer are a major "pest" in many eastern states. In certain areas of the north-western US, elk are the primary yield-reducing "pests", and large herds are often supported by remote alfalfa fields when naturally-occurring vegetation is limiting and herd numbers are high. This should in many respects be viewed as a positive contribution of alfalfa to wildlife habitat.

Table 1. Partial listing of types of wildlife observed in alfalfa fields. Of 643 forms of wildlife, 25% are found in alfalfa fields. Asterisks indicate species which have a preference (*) or a strong preference (**) for alfalfa based upon transect studies, Kuhn et al., and personal observations. Lack of asterisks indicates no preference or unknown.

Species	Food	Species	Food	Species	Food
Killdeer**	I	Ring-necked Pheasant*	G	Ash Throated Flycatcher*	I
Dunlin**	I	Great Blue Heron*	V	Scrub Jay	I,P
Red-Tailed Hawk*	V	Great Egret*	V,I	Common Raven*	G
Swainson's Hawk**	V,I	Snowy Egret*	I,V	American Robin	I
Ferruginous Hawk**	V	Black-Crowned Heron*	I,V	Cliff Swallow	I
Rough-legged Hawk*	V	White-faced Ibis**	I,V	Valley Quail	I,P
Northern Harrier**	V,I	Cattle Egret*	I,V	Coyote	V
White-tailed Kite**	V,I	American Avocet	I	Desert Cottontail**	P,D
Prairie Falcon*	I,V	Brewer's Blackbird**	I	Blacktailed Jackrabbit*	P,D
American Kestral*	I,V	Redwinged Blackbird	G	Grey Fox*	V,I
Turkey Vulture	S	Rock Dove	P	Striped Skunk	I,V
Yellow-billed Magpie*	G	Mourning Dove	P	Raccoon	I,V
American Crow*	G	Golden Eagle*	V	CA Ground Squirrel*	P,D
Loggerhead Shrike*	I	Western Meadowlark	I	Pocket Gopher**	P,D
Western Kingbird*	I	Merlin*	I,V	CA Vole**	P,D
European Starling*	I	Long-billed Curlew**	I	W. Fence Lizard	I
California Gull*	G	Mallard Duck*	G	Gopher and Racer Snakes*	V,I

* Indicates species has preference for alfalfa (population is 1.3 to 3 x the population to be expected by chance), ** indicates species has strong preference for alfalfa (greater than 3 x the population expected by chance). Designations are a mixture of transect study designations in the Sacramento Valley, CA, and subjective evaluation (Smallwood, 1997, pers. comm.). Data collected and reported by Smallwood and Geng, 1993, Erichsen et al., 1996).

Food Source: V = vertebrate animals, I = invertebrate animals and insects, S = scavengers of dead animals, P = plant matter, G = general, D = causes some damage to alfalfa.

ENHANCING WILDLIFE IN ALFALFA FIELDS

Although this summary shows that alfalfa is a significant habitat for many species of wildlife, there is more that growers can do to produce alfalfa in a way that is beneficial to both wildlife and the environment. Pest management can be practiced in a fashion that protects and utilizes the beneficial insects in alfalfa, which benefit other crops as well as wildlife (Integrated Pest Management). Several growers have taken steps to provide nesting sites for owls and bats to encourage their rodent and insect-eating habits. Other growers have installed perch poles in an otherwise horizontal landscape to encourage raptor activity. A grower in the Sacramento Valley each year retrieves waterfowl eggs from fields prior to first cutting, and incubates them and releases a significant quantity of ducks each year. This is done in several CA counties, in cooperation with many volunteer groups, and they release thousands of waterfowl per year.

Other growers have tried to develop devices to be mounted on swathers (flushing bars) to help protect nesting birds in alfalfa fields. Unfortunately, few major equipment manufacturers have taken an interest in these devices. Sound-warning devices mounted on swathers may not be effective, since the birds and nesting fawns may become sensitized, but further research on these methods may be necessary. Leaving nesting areas near ponds for waterfowl is a good method of attracting nesting waterfowl away from the swathers in the spring.

Grazed alfalfa fields can provide important wildlife habitat. However, continuously grazed alfalfa likely does not provide sufficient cover or food for wildlife habitat. Adjustment of grazing practices to rotational grazing to allow better nesting habitat has been studied in the upper Midwest, and grazed pastures can be better managed to provide superior wildlife habitat, as well more efficient grazing results (Undersander & Westmoreland, 1997).

Raising community awareness is an important way to increase the public's knowledge of wildlife on you farm. Farm Bureau or other farm organizations can help with this. Many growers have been quite innovative in enhancing the wildlife on their farms, but need to be better at publicizing their efforts. Arranging field tours with local nature groups, waterfowl groups are important. Participation in county and state regulatory processes are also important. A group of farmers in Merced Co., CA became active with the EPA's efforts to protect the threatened Aleutian Canada goose. Their awareness and data collected about the importance of alfalfa as habitat for this goose resulted in much-reduced regulatory measures (Kuhn et al., 1996). This is an example of the ability of growers to become proactive on wildlife and regulatory issues.

These and many other steps would enable an enhancement of the benefits to wildlife of the alfalfa production system.

IMPORTANCE OF ALFALFA TO CROPPING SYSTEMS, SOIL CONSERVATION

One of the most important characteristics of alfalfa is its role in maintaining and improving soil health, preventing soil erosion, and boosting the yields of subsequent crops. These characteristics are considered common knowledge among growers and agricultural scientists, but not appreciated more widely. The historical use of alfalfa as a "soil amending" crop, is a complex effect of several important characteristics:

Dinitrogen fixation. One of the most important characteristics of alfalfa is its ability to "fix" atmospheric nitrogen so that it is available for plant growth. This is accomplished by symbiotic association with Rhizobium meliloti, N2-fixing bacteria which infect the roots. Biological fixation contributes an estimated 140 million metric tonnes of N annually to the earth, about 80% of which comes from symbiotic relationships such as alfalfa/R. meliloti (Vance et al., 1988). It is estimated that over 6 million metric tons of N is fixed each year by leguminous crops in the USA, approximately 1/3 of which comes from alfalfa (Phillips and DeJong, 1984).

This partnership completely negates the need for N fertilizers in alfalfa, and reduces the need for fertilizer N in rotated crops. Some growers of specialty crops would likely continue to grow short-rotation alfalfa with little direct economic return due to its ability to aid in the success of subsequent crops. Alfalfa consistently produces a higher nitrogen yield from N2 fixation and a higher percentage of N derived from fixation than other legumes on a seasonal basis (Vance et al., 1988). Estimates of N2 fixation in alfalfa vary from 114 to 536 lb of N per acre per year (Evans and Barber, 1977), and averages about 200 lbs/Nacre fixed per year in the US.

There are at least two environmental benefits of the N2-fixing ability of alfalfa in a cropping system:

1. The substitution of alfalfa for high N-demanding crop, and
2. The benefits of N2 fixation which accrue to the following crop in a rotation with alfalfa

Alfalfa replaces high N-requiring crops. If alfalfa were not grown as the primary forage in a region, what would the environmental costs be? The substitution of crops such as corn, sorghum, wheat, barley, cottonseed, or grass forages for alfalfa would require substantially higher use of N fertilizers and energy than currently used. An example from California illustrates this point. Approximately 7 million tons of alfalfa hay was produced in California in 1997. This resulted in a harvest of more than 224,000 tons of N (average of 20% Crude Protein in the Hay). If 60% is considered to come from N2 fixation (a conservative estimate), 134,000 tons of N was added to the cropping system from the atmosphere by the alfalfa crop that year.

At a minimum, this amount (134,000 tons) of N as fertilizer would have to be added back to the system as fertilizer to provide this amount of protein N from other crops. However, this is a minimum estimate. This amount does not allow for inefficiencies of fertilizer uptake, leaching, and differences in plant incorporation, which would further increase this amount. If the 1.4 million tons of protein produced in California that year were produce by corn silage (at 8.5% CP), an additional 650,000 acres of corn would be required, removing over 220,000 tons of N from the soil, a requirement which would primarily need to be met through N fertilizers. Since the Haber/Bosch process for N fertilizer manufacture is very energy intensive, substantial additional quantities of fossil fuel would be consumed each year to meet this need. Alfalfa has an important role in reducing the fossil fuel requirements of cropping systems, by saving the substantial N fertilizer inputs required for non-legumes.

Alfalfa provides N to a subsequent crop: Legumes such as alfalfa have long been know to improve the yields of subsequent crops (Pieters, A.J. 1927, Baldock et al., 1981). There is typically an N credit of 50-170 lb/acre N given to corn when grown after alfalfa or other legumes (Kurtz et al. 1984). Nitrogen fixation is a significant factor in this yield benefit, but other factors, such as improved soil tilth, are also important. Nitrogen stored in roots and above-ground plant matter can be made available to a subsequent crop through degradation after plowdown. Considerable N is removed at each cutting, but much of this is "renewable" through N fixation of subsequent regrowth. The amount of N provided to a crop following alfalfa is quite variable, and will depend upon a number of factors, primarily the stand, yield and stage of growth when the alfalfa is plowed down, and uptake of N by that crop. Nitrogen application to corn can be reduced by 100-150 lb/acre if it is preceded by alfalfa or red clover (Miller and Heichel, 1995). This, in addition to substitution of high N-requiring crops, substantially reduces the environmental pressure of cropping systems.

Alfalfa is Deep-Rooted and Improves Soil Tilth: The "rotation effect" is the benefit in growth and yield of a crop which is grown after alfalfa. This is not simply the result of the transfer of elemental N. This rotation effect is a result of complex causes of improved water-holding capacity, better soil tilth (improved structure), increased soil organic matter, and reduction of soil pathogens, and possibly other factors (such as shifts in micorrhizal populations) in addition to the N residues supplied (Barnes and Sheaffer, 1995). The "rotation effect" is especially apparent with alfalfa.

Alfalfa roots have been measured at a 39 meter depth and 5 meters depth is common (Sheaffer et al., 1988). Alfalfa roots penetrate much more deeply than most grass species or annual field crops. Therefore, alfalfa roots create many channels in the soil which (if undisturbed) are used by subsequent crops to more fully explore the soil. In addition, there is a tremendous amount of biological activity in the alfalfa rhizosphere, and a number of organic acids are secreted by alfalfa roots which contributes to soil "tilth" - the crumbly soil structure which is so beneficial for plant growth.

In a recent study at the UC Davis campus, we plowed up an experimental plot which contained strips of 4-year old alfalfa, and 4-year old fallow strips. The difference in the soil structure was dramatic and obvious: blocky, tight clods which were very difficult to cultivate were present in the fallow strips, and crumbly, loose, well aerated soil in those areas occupied by alfalfa. This "mellowing" of the soil following alfalfa is known to most growers, who have observed the differences in soil tilth and subsequent crop performance.

Erosion protection: Although much of current concern about the environmental effects of agriculture focuses on the possible contamination and harmful effects of pesticides, soil erosion has always been a significant environmental hazard of agriculture. The development of the Soil Conservation Service received its impetus from the dust bowl days of the 1930s; and the primary cause of wind and water erosion being excessive tillage with row crops. One of the major thrusts of these efforts was to encourage the incorporation of leguminous cover crops and perennial forage crops which are far superior at preventing erosion than highly cultivated field or horticultural crops. Most agronomists in the corn belt feel that incorporation of alfalfa into corn/soybean rotations would be desirable for protection from erosion.

Perennial legumes protect the soil in several ways: by reducing the amount of cultivation per year, by hold the soil in place through extensive rooting, and by providing a vigorous above-ground canopy which prevents rain droplets from loosening soil. These are very real and tangible effects, especially on highly erodible soils. Any cost-benefit analysis of alfalfa's role in the environment should incorporate these considerations.

Protection of groundwater, help with waste problems. The deep rooted characteristics of alfalfa have led soil scientists to look at alfalfa as an important crop in helping to "mop up" subsurface nitrate in the soil (Russelle, 1994). Nitrate contamination of groundwater (sometimes from N fertilizers) is a problem on some sensitive, sandy soil types. Alfalfa, due to its vigorous roots, is recognized as being important in mitigating groundwater pollution with nitrate. Additionally, scientists are looking at alfalfa to help with "bioremediation" of contaminated sites, and for helping in the disposal of municipal wastes, or for the disposal of dairy wastes. The robust biological characteristics of alfalfa have not escaped notice for these applications.

Alfalfa as a renewable fuel: As the world faces a highly urbanized future, with its associated environmental pressures, development of renewable sources of energy should be an important broader societal goal. A project in Minnesota, initiated by the Northern States Power Company, has analyzed the potential of using alfalfa as a renewable source of energy (Martin and DeLong, 1995). This concept, which would benefit the environment, the consumer, and the dairy industry, is to use the high-lignin alfalfa stem for energy, and use the leaves, which are higher in feed value, as a high quality dairy feed. The major reason that alfalfa was examined (rather than the more ubiquitous corn) was the lack of energy requirement for fertilizers in alfalfa, and alfalfa's many benefits to the sustainability of cropping systems in the corn belt, as described above. While it remains to be seen whether all aspects of this program will be feasible, other regions may find it important to examine this option as a method of producing renewable energy in the future, a strategy which may benefit both urban and agricultural interests.

ALFALFA-AN EFFICIENT USER OF WATER

Most of the alfalfa (>95%) grown in the western United States is irrigated. Many do not know that alfalfa was first successful in the West in the 1850s after the advent of large-scale irrigation. It was immediately well adapted to the Mediterranean climate of California after the Gold Rush, and the deserts of the Southwest, and the more temperate mountainous valleys of the Northwest and the high mountainous deserts of Nevada and Utah. From there it spread eastward to become successful throughout the Midwest and eastern states in later years, after cold-hardiness characteristics were incorporated into improved varieties.

Alfalfa is commonly criticized for its water-use in western states. This is somewhat ironic, since alfalfa and other perennial forages have been promoted in the Corn Belt and elsewhere by both agronomists and environmentalists as a way to lessen the environmental impact of agriculture. However, there is a critique of irrigated alfalfa production in the West which goes something like this: "Alfalfa uses a large amount of water per unit of dollar return. Therefore, water should be shifted from alfalfa and allocated to higher value crops, or allocated to environmental or urban uses which have broader societal value." Here are a few quotations:

"I've singled out the four largest water users in California for special condemnation. The No. 1 water user in this state is irrigated alfalfa, No. 2 is irrigated pasture, No. 3 is irrigated cotton, No. 4 is irrigated rice."

-Marc Reisner, (Author of Cadillac Desert, as quoted in Beard, 1994).

"The main objective of this scenario is to eliminate the estimated annual overdraft in the year 2020 by reducing alfalfa and irrigated pasture acreage"

- California Water 2020, Gleick et al., 1995.

This recommendation for solving the West's water problem by eliminating "low value" crops such as alfalfa is commonly heard. This usually means that the crop is of low value to the one making the recommendation, and that their priorities (presumably of higher "value") would receive preference. There is little doubt that there are crops which yield higher economic return per unit area than alfalfa (alfalfa shares this characteristic with other agronomic species: wheat, rice, sugarbeets, and corn). It is also true that a substantial amount of water is used to produce alfalfa. The consumptive water use of alfalfa varies considerably throughout the West, and likely ranges from about 30 inches to 80 inches/year, depending upon location.

However, alfalfa is quite efficient with its use of water. Water allocation to crops should be compared with the yield, growth characteristics, acreage, and food value obtained, not just total water used. Alfalfa is harvested throughout the year (in Imperial Valley, CA, they harvest 9-10 times, from February through December). Alfalfa is also grown on large acreage thereby increasing water-use compared with other crops of lower acreage. It is a very high-yielding crop, and the entire above-ground plant is harvested and used, unlike most field and horticultural crops. This season-long productivity means that yearly water-use is high, but also that the efficiency of conversion to useful plant material is very high. A comparison of the water-use efficiency (which factors the component of the crop harvested) of several species showed alfalfa to be the highest in water-use efficiency compared with several species, including corn for grain, sugarbeet, barley, and dry edible beans (Loomis and Wallinga, 1991).

CONCLUSIONS

Farmers generally have a deep and abiding appreciation for the wildlife on their farms. In fact, that is probably one of the primary incentives for many who pursue this profession: the love of the outdoors, and of nature. However, alfalfa growers need to be more articulate about the importance of their crop to wildlife. In the 1990s, agriculture must increasingly convince a sceptical public that it provides other benefits as well, by providing open spaces, and nurturing of many wildlife species which enhance the aesthetic value of the landscape.

Often, in arguments between "environmental interests" and "agricultural interests", the complexities of crop landscape ecological interactions are lost. A too narrow view of agricultural land-use, which only ascribes benefits to agriculture, confuses the public about the value of a productive agriculture to the overall societal well-being, including protection of the soil, biological diversity, and wildlife. Alfalfa makes many important contributions to broader societal goals relating to a sustainable agriculture and the environment. Removal or severe reduction in alfalfa acreage would not only have large economic consequences, but also reduce these benefits. While there is considerable room for further enhancement of the benefits of alfalfa to cropping systems and wildlife, it should be recognized that perennial legumes, particularly alfalfa, are vitally important to the future of our environment.

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