

AGRONOMIC PRACTICES AND FORAGE QUALITY

By Dan Putnam, Steve Orloff, and Tracy Ackerly¹

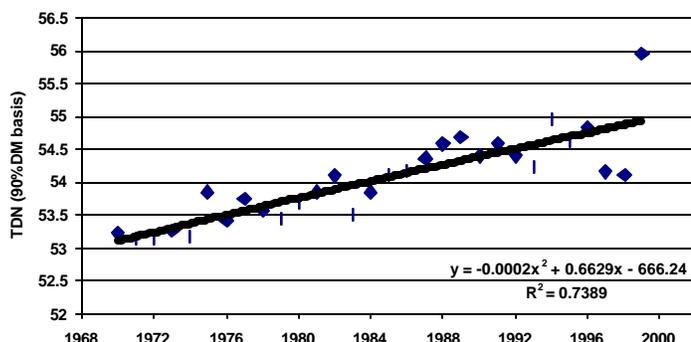
ABSTRACT

Agronomic practices have a large effect on the quality of the harvested alfalfa crop. The primary mechanisms that affect forage quality are changes in plant maturity, leaf stem ratio, changes in chemical constituents due to environment, weeds, and curing effects. There are a host of environmental and agronomic practices that can change these factors, some of which are under the control of the grower. This article reviews definitions of forage quality, the mechanisms that influence forage quality, and discusses agronomic techniques for achieving high quality hay.

INTRODUCTION

One of the largest challenges faced by alfalfa growers during the past 30 years has been the increased emphasis on forage quality. Forage quality requirements affect both marketing and crop management, and the demands for high quality by the marketplace have been relentless. Although crop yield is still the primary economic factor determining crop value per unit land area, forage quality has rapidly become a close second. Production per cow has increased about 60% since the 1970s, greatly increasing the need for highly digestible, high-intake forage. This requirement for high quality forage is reflected in the marketplace. It is estimated that at least 20% (\$200 million) of the value of California's alfalfa crop is currently determined by quality factors. The average quality of hay tested by labs from the 1970s has increased (Figure 1). Producing high quality alfalfa is often the key factor determining profitability. Unfortunately for growers, the pressure to produce high quality forage is likely to increase in the future.

Figure 1. Change in Total Digestible Nutrients (TDN) over time-
Petaluma Hay Testing Lab, Petaluma, CA



WHAT IS FORAGE QUALITY?

Forage quality is a complex trait in plants, and is influenced by a range of factors including genetic, environmental, and agronomic. 'Forage quality' from an animal perspective is also complex, since 'quality' depends upon class, species, feed formulation, and level of animal production. A full discussion of forage quality is beyond

¹ D. Putnam, UC Cooperative Extension Specialist, Alfalfa & Forage Crops, Department of Agronomy and Range Science, University of California, Davis, CA 95616. T. Ackerly, same address. S. Orloff, UCCE Siskiyou Co., Yreka, CA. Email of senior author: dhputnam@ucdavis.edu. Published in: Proceedings National Alfalfa Symposium, 10-12 December, 2000, Las Vegas, NV. Abbreviations: ADF = Acid Detergent Fiber, NDF = Neutral Detergent Fiber, CP = Crude Protein, NCS = Non-Structural Carbohydrates, TDN = Total Digestible Nutrients, RFV = Relative Feed Value.

the scope of this presentation. Forage quality is most often defined in terms of dairy production, since most of the alfalfa crop is used by this industry. The key elements are:

Energy calculated from fiber. The primary consideration for most dairy producers is high total yield of digestible energy per ton of hay or forage. Unfortunately, this cannot be measured directly but is instead estimated or predicted. Most energy estimates (TDN or NEL) are calculated from a fiber measurement (ADF or NDF). Thus, from a practical viewpoint, TDN or NEL estimates are equivalent to the ADF or NDF measurement.

Intake Potential. Since forage intake (lbs/animal/day) is such an important aspect of dairy nutrition, there is a need to detect potential differences between forages in the speed of digestibility of the fiber fraction for high producing dairy cows. There are several approaches to digestibility estimates, including IVDDM, gas-estimates, and NDF digestibility. NDF itself, and NDF digestibility estimates are likely to be used more frequently in the future (Robinson, 1999, Undersander et al., 1993).

Protein. High protein levels are favored in the marketplace compared with low protein hays, but CP levels do not determine overall feeding value to the same degree as

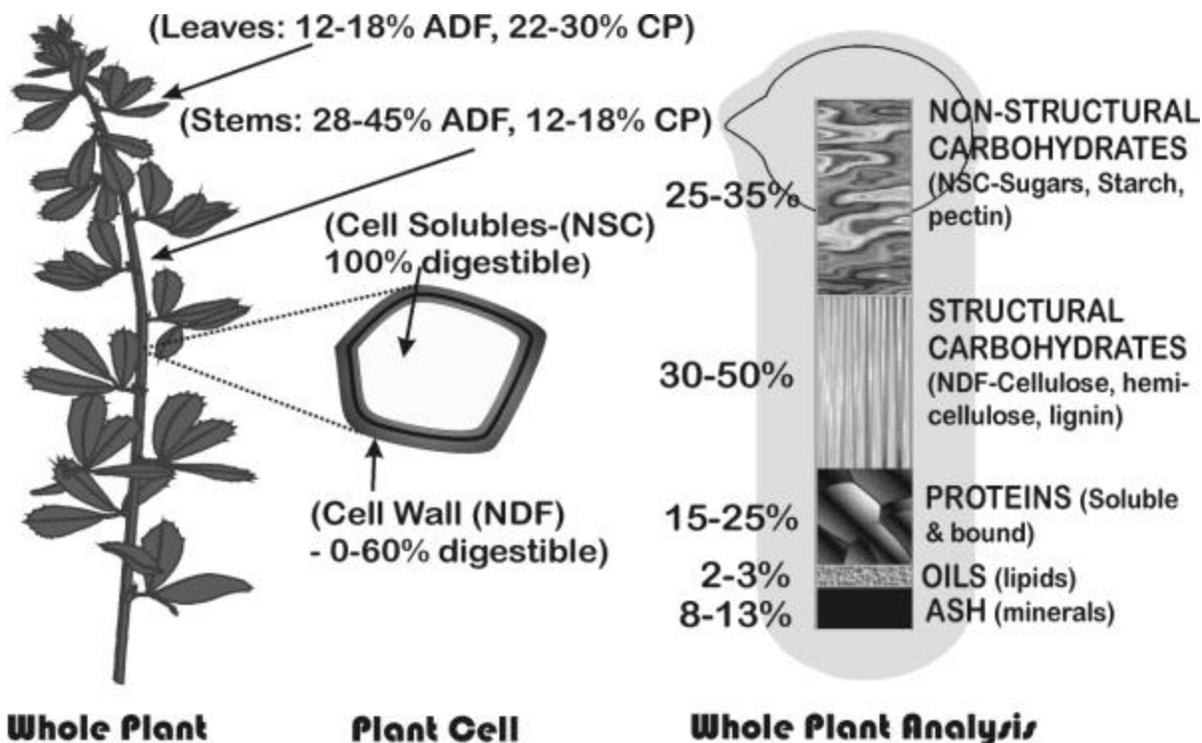


Figure 2. Alfalfa forage consists of structural components that differ dramatically in forage quality. Leaves are much more digestible and lower in fiber than stems, and can have 2-3 times the protein. Within the cell, soluble components are 100% digestible whereas the cell wall is only partially digestible. Since the cell wall is the plant part most difficult to digest, it is the focus of chemical analysis. NDF approximates total cell wall and ADF approximates the most difficulty-digested portions of the cell: cellulose and lignin. Total plant quality is determined to a large extent by leaf-stem components, and development of the cell wall; both are affected by plant maturity.

energy (fiber or TDN) or intake. Many nutritionists may be more interested in the quantity of the protein fraction that is degraded in the rumen not just total CP levels. Estimates such as UIP (Undegraded Intake Protein) or RUP (Rumen Undegradable Protein) are likely to be of greater importance in the future. Excessive CP levels may constitute a negative factor, representing an energy cost to the animal for excretion and an environmental hazard in wastes.

Other Quality Factors. Forage quality is a multi-faceted characteristic. Mold, dust, texture, odor or other conditions are factors affecting palatability, animal acceptance as well as nutritional value. Presence of toxic weeds or toxic minerals (e.g. very high selenium levels) may affect quality. Thus, forage quality is only partially measurable using lab tests—subjective evaluation and feeding small amounts to evaluate hay remain important considerations when evaluating quality.

HOW DO QUALITY FACTORS TRANSLATE TO THE MARKETPLACE?

Forage quality has a direct effect on value per unit (\$/ton). Both the 'cutoff level' for dairy quality and the price premium for quality are functions of the supply and demand situation in a given year. Differences between quality categories of Premium and Fair (defined by ADF, see Table 1), averaged about \$32 to and \$39/ton (in Northern California and Fresno, California respectively, during the 1990s (USDA Marketing Service, 1999—see article by Orloff et al., this symposium). Additional considerations in the marketplace are the CP content, as well as cutting and location of where the hay is grown, condition of the hay, and subjective quality factors.

Table 1. USDA Guidelines for reporting economic data (2000 USDA Livestock, Hay & Grain Market News, Moses Lake, WA). **IMPORTANT:** Classification of hay using the ADF method is significantly different than classification of hay using RFV method (for example, a premium hay determined by ADF may be different than premium hay using the RFV method) The best way to compare between regions is to use actual ADF or NDF values, not categories.

Hay Quality Category	ADF (100% DM)	TDN (90% basis)	RFV
Supreme	<27	>55.9	>180
Premium	27-29	54.5-55.9	150-180
Good	29-32	52.5-54.5	125-150
Fair	32-35	50.5-52.5	100-125
Low	>35	<50.5	< 100

TDN based upon calculation from ADF: $TDN (90\%) = \{82.38 - (0.7515 \times ADF)\} \times 0.9$ according to Bath & Marble, 1989. RFV is calculated from ADF and NDF

Marketing Standards.

There have been numerous attempts to standardize methods for trading hay nationally, but methods remain diverse throughout the US. This is due to both genuine differences in quality between regions, market considerations, and differing histories of hay testing and analysis in different regions. In many Midwest states, the Relative Feed Value index is calculated from both ADF and NDF lab values and used for marketing hay. High quality forage in the California marketplace is defined primarily as having a low fiber a correspondingly high TDN value. A universal national hay test currently consists of ADF, NDF, CP and DM, which can be used to compare hay across regions. The USDA has defined quality guidelines for alfalfa in the National Hay, Feed & Seed Summary Report as in Table 1. It should be noted that these two methods (ADF and RFV) do not match. This author examined lab results from thousands of alfalfa hay samples from Kansas and California, and found that a very large percentage (>50%) of these samples would be classified differently using the ADF compared with the RFV method for categorization

as premium, supreme, good, etc. The best method to compare hay across regions is to look at the original ADF, NDF, and CP values (at 100% DM).

MECHANISMS WHICH INFLUENCE FORAGE QUALITY

There are several primary mechanisms by which alfalfa hay quality is impacted. These are 1) plant maturity at harvest, 2) leaf percentage 3) changes in chemical constituents due to environment, 3) mixture with other species (weeds), and 4) conditions during harvest. There are many additional agronomic factors that affect alfalfa quality, but these are the primary mechanisms by which quality is changed. All of these interact, sometimes in complex ways.

Plant Maturity

It is a universal axiom of alfalfa forage production that as a plant grows and develops, forage quality declines. This is due to two major mechanisms.

First, after a period of initial growth (often about 2-3 weeks) during early bud development, leaves do not significantly increase in yield, but stems continue to increase in length and weight. Therefore, **the leaf percentage of alfalfa declines** as the plant grows (Figure 3).

Second, although the leaves do not change much in quality, **the quality of the stem fraction declines** precipitously as the plant continues to grow. Not only are stems a greater and greater portion of the forage, but they decline in quality each day. In data collected at Davis, CA, stems changed from 54 %TDN (90%dm basis) to 44 %TDN during a growth period, lowering the whole plant TDN from about 57 %TDN to 51 %TDN, though leaves remained unchanged (Figure 4). This is due to what is happening on the cellular level; the young tender primary cell wall is strengthened by highly lignified secondary cell wall.

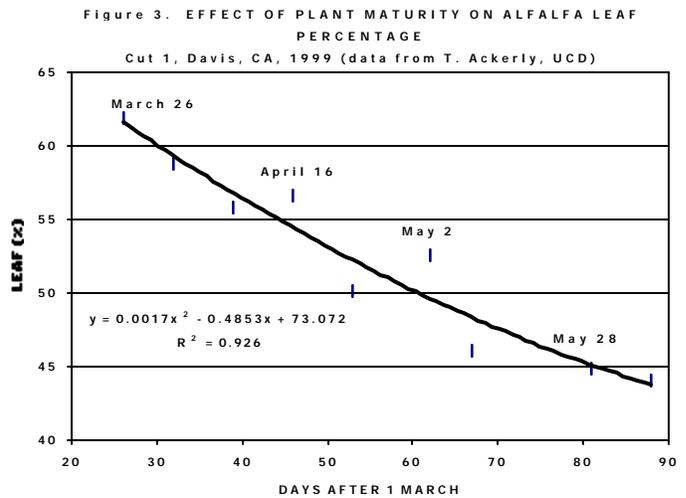
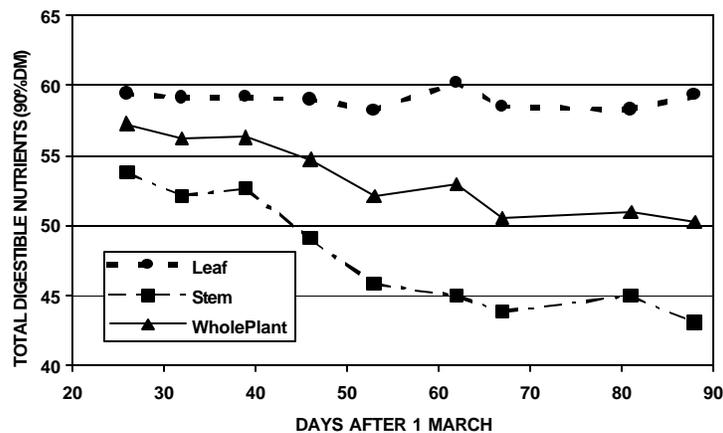


Figure 4. PLANT MATURITY EFFECTS ON TDN
Cut 1, Davis, CA, 1999



Staging the growth of the plant according to vegetative and reproductive development is an important predictor of potential feeding value. Stages include vegetative, early bud, late bud, early flower, late flower, and seed production. Most growers in recent years have found it necessary to harvest alfalfa in early to late bud to meet the demands for low fiber, high TDN hay by dairies. There are several methods, including the UC Intermountain Alfalfa Quality Stick, available to help predict the forage quality of standing alfalfa crops for harvest decisions.

Leaf Percentage

The leaf percentage as a determinant of forage quality cannot be overemphasized. Leaves may have two to three times the protein content of stems (Marten et al., 1988), and in some forages consist of 2/3 of the feeding value, though may consist of 50% of the DM or less. Stems decline in digestibility about 1/percentage point per day (Marten et al., 1988), whereas leaves decline only very slightly (see also Figure 4). Although plant maturity has a dramatic effect on leaf percentage, there are many other factors that influence leaf percentage. These include insect damage, variety, irrigation, harvest and curing effects, and environment. Thus, any agronomic practice that impacts leaf-stem ratio or plant maturity at harvest will affect forage quality. Leaf component is a major mechanism for manipulation of forage quality.

FACTORS AND PRINCIPLES THAT INFLUENCE ALFALFA QUALITY:

PRIMARY MECHANISMS:

- Plant Maturity at Harvest
- Leaf Percentage
- Mixture with Weeds
- Environmental Effects
- Curing of Hay/Silage

AGRONOMIC FACTORS:

- Rain Damage
- Time of Day for Harvest
- Harvesting Effects
- Variety
- Stand Density
- Soil Type and Fertility
- Irrigation
- Pest Interactions

Weeds & Species mixtures

Most weeds, especially grassy weeds, have a negative effect on alfalfa forage quality, and in practice, weeds are one of the major factors that reduce alfalfa forage quality. Although weeds can have neutral, positive, or negative effects on alfalfa forage quality, the overwhelming effect is typically negative. Ironically, many weeds can increase yields of sparse alfalfa stands, since they 'fill in' the bare areas, but this yield increase rarely compensates for the lower quality of the hay. The primary considerations are the species of weed and time of harvest. Some weeds, such as pigweed, lambsquarters, volunteer sorghum or sudangrass may provide good feeding value if harvested early, but can also contain high nitrate levels, contributing a significant risk to animal health. Some weeds like common groundsel and fiddleneck are toxic to animals and thus significantly lower the feeding value, even if TDN or CP are not affected. Green & yellow foxtail, foxtail barley, yellow starthistle, Russian thistle can all contribute to low palatability and animal acceptance, due to physical attributes. Even in cases where weeds do not reduce the analytical feeding value, they may reduce the marketability of the hay due to perception of the buyer. In practice, inability to control weeds is one of the most common causes of low forage quality of alfalfa.

Sometimes, when alfalfa stands become thin, growers intentionally overseed other species to ‘thicken’ old alfalfa stands. This may be done with oats, perennial grasses, or other legumes such as berseem clover or red clover. Overseeding usually increases yield, but may lower the alfalfa forage quality if a significant grass percentage is achieved. Conversely, overseeding may improve the quality compared with weedy alfalfa fields, especially if legumes are used (see Canevari et al., 2000).

The effect of harvest schedule, plant maturity at harvest on yield, quality, weeds and stand life is illustrated in Table 2. This classic dataset shows the dramatic and powerful effect of cutting schedules on forage quality. It should be pointed out that yield is also dramatically affected by harvest interval, as is weed infestation and stand (the forage quality data in this table does not reflect the weed component of the sward). The tradeoff between yield, quality, and stand life is a major issue for forage producers, and is of tremendous economic importance. The optimum profitability point as determined by cutting schedule is rarely the point where maximum quality is obtained, nor at the point where maximum yield is obtained. This is a complex relationship, and one that has challenged forage producers for decades. This is the subject of companion articles at this symposium (Orloff et al., and Ackerly, et al., 2000).

Table 2. Effect of Maturity at harvest and harvest interval on alfalfa yield, quality, and leaf percentage weeds and stands life.

Maturity at Harvest	Harvest Interval (days)	Yield T/acre	TDN	ADF	CP	Leaf	Weeds	Stand
			-----%-----					
Pre-Bud	21	7.5	56.3	26.3	29.1	58	48	29
Mid-Bud	25	8.8	54.2	29.5	25.2	56	54	38
10% Bloom	29	9.9	52.4	32.2	21.3	53	8	45
50% Bloom	33	11.4	52.0	32.7	18.0	50	0	56
100% Bloom	37	11.6	50.1	35.5	16.9	47	0	50

Source: V.L. Marble, 1974. Proceedings, 4th CA Alfalfa Symposium, Dec. 4-5, 1974. UC Cooperative Extension.

Environment/Temperature

Most alfalfa growers and dairy producers understand the variations in forage quality that occur over the season. Alfalfa forage quality is generally highest in the spring (first and second cuttings) and late fall, and lowest in the summer, but forage quality will also change depending upon temporary weather patterns. One hay grower jokingly remarked that the easiest way to get high quality hay was to harvest it all in the late fall and early spring! Data collected over 3-years using 8-10 mostly non-dormant varieties at Kearney Agriculture Center in Fresno County, CA show large differences over the season and between years (Figure 5). Seasonal and environmental differences were far greater than the differences between varieties in this trial; these results concur with similar trials from other regions.

Seasonal and yearly variations have their effect primarily through temperature, but daylength and light intensity are also important. The high temperatures of summer increase growth rate (primarily stem growth), hasten plant maturity, and increase lignification of the cell wall. Thus, the primary effect of season and temperature is on the

leaf-stem ratio and plant maturity. High temperatures hasten biological processes that decrease forage quality.

High temperatures also hasten respiration rates, which in turn reduce the quantity of soluble carbohydrates in the stem and leaves.

Respiration turns sugars and starches into CO₂ and produces energy to produce other compounds in the plant, such as cell wall material or protein. Thus, high rates of respiration

have the dual effect of lowering the 'sugar pools' in the plant (which are highly digestible) and hasten growth and maturity.

These changes in non-structural carbohydrates may be implicated in the observed differences between 'mountain hay' grown under cool sunny conditions and 'valley hay' grown under hot conditions during the summer. The latter has a reputation for high fiber (ADF) and corresponding low TDN, but also high protein, whereas the 'mountain hay' from Nevada or Intermountain California or Oregon has a reputation for low fiber but also low protein.

AGRONOMIC PRACTICES INFLUENCING FORAGE QUALITY

Obviously, some of the mechanisms listed in the above section are under the control of the grower and others are not. Additionally, some agronomic factors are undoubtedly much more important than others in affecting forage quality. For example, cutting schedule generally has a more powerful effect upon quality in practice than does variety choice. Several of the above 'mechanisms' can be manipulated in a number of ways. Some of these agronomic methods may have minor effects, or no effect, but since growers are interested in 'any trick in the book' to improve crop value, all are discussed below in relationship to their likelihood of contributing to improved forage quality.

Cutting Schedule. Cutting schedule is, overwhelmingly, the most powerful method under a grower's control to manipulate forage quality, since both maturity and leaf percentage is impacted. Changes in quality due to cutting schedule are illustrated in

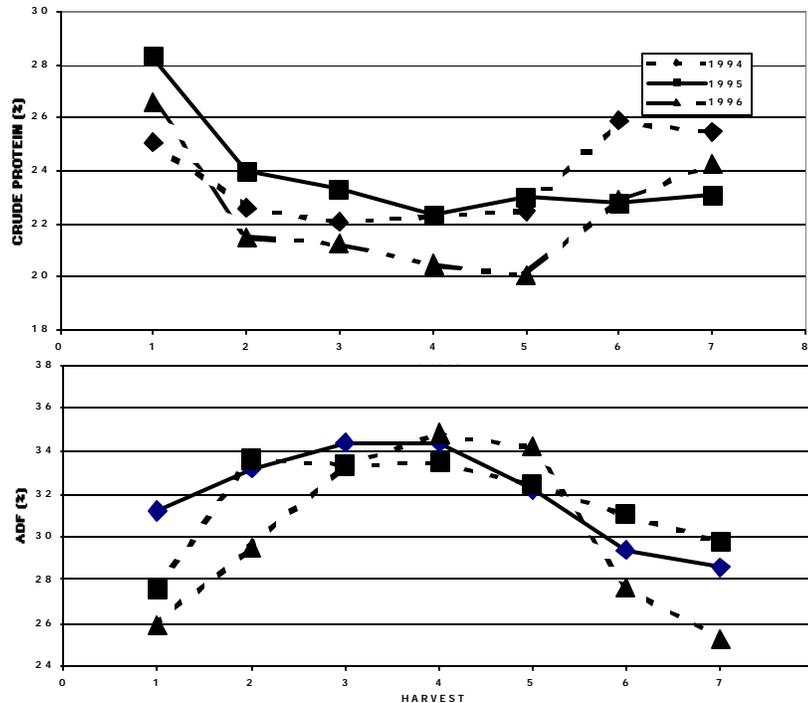


Figure 5. Seasonal influences on Crude Protein (top) and ADF (bottom) values, Fresno, CA. Data average of 10 non-dormant varieties, 1994-1996.

Table 2. Since harvest scheduling and changes in yield and quality due to timing of harvest are extensively reviewed in companion articles (Orloff et al., Ackerly et al., 2000) at this symposium, this issue will not be discussed in detail. If yield, stand persistence and weeds were not important, the earliest cutting dates would typically provide the highest quality forage (Table 2), but these dates would rarely provide the highest optimum economic returns. The vigorous cutting schedules commonly practiced to attain high quality may ultimately work against high quality production, since stands may thin and weeds may invade (see Table 2). Clearly, a more integrated approach balancing yield, quality, persistence and economics is required.

Harvest Effects. The process of drying, handling, and baling hay has long been known to affect forage quality. Since leaves dry faster than stems, growers need to wait past the point where leaves can be harvested to completely dry the stems. Therefore, hay is often harvested at a point where leaf shatter is a hazard, at least in Western States. Leaf shatter can greatly affect forage quality by reducing leaf-stem ratio. Any method (mechanical or chemical conditioning, swath width or skillful raking) that speeds the drying process of stems may improve forage quality (Orloff, 1992).

The greatest risk for leaf shatter is probably during the raking process, not during baling, though any field operation may increase leaf shatter depending upon conditions. Any field operation (intensive conditioning, wide windrows) that hastens drying of stems to more closely match the drying rate of leaves may help preserve forage quality. Baling at the proper moisture content will help preserve the leaf component of the forage. Some hay preservatives may enable growers to bale under more moist conditions, thereby conserving leaf material. However, they are generally not believed to be cost-effective under most CA conditions. Where extremely dry baling conditions prevail, some growers have found ways of allowing the stems to dry, and then re-wetting windrows to soften leaves just before baling. However, skill in the harvest procedure remains a major challenge to growers in order to maintain forage quality.

Switching to haylage can improve leaf retention, approaching 100%, since the forage is wilted, not dried, before handling. A major advantage of haylage is the ability to get the crop off the field rapidly in the spring when rains threaten, and in some cases, an additional harvest is possible. However, production of haylage may entail DM losses during the ensiling process that may be equal to or greater than those losses in the baling process.

Conditioning or Maceration Effects. Maceration, or intensive conditioning, may have dramatic effects on forage quality (Orloff et al. 1997). Maceration is the 'pre-chewing' or cell rupture of forage, not just crushing or conditioning. Since commercial-scale macerators are not currently available, this discussion will be short, but this aspect deserves mentioning. Drying rates are reduced to as little as a day, and a 'mat' is produced which can then be picked up and baled or cubed. Maceration changes micro-particle size, making the cells more available for rumen fermentation. The immediate availability of the soluble fraction of forage, as well as the rate of fermentation of the NDF fraction have been shown to be dramatically affected by maceration in studies at USDA Dairy Forage Research Center (Madison, WI) and at UC Davis. If commercialized, this technology may have a major effect on forage production and quality (Orloff et al., 1998).

Ordinary conditioning, or severe crushing of the stems may affect forage quality, but not to the same degree as maceration. If the conditioning process allows rapid drydown of the hay and leaf retention compared with little or no conditioning, then leaf percentage and forage quality will be improved.

Time of Day. Observations from the 1940s have shown changes in soluble carbohydrate levels in alfalfa due to time of day. More recent data from Idaho (Mayland, 1998, Shewmaker, 1999) and California (Putnam et al, 1998) have pointed to an advantage to harvesting alfalfa in the late afternoon, to take advantage of temporary accumulation of soluble carbohydrates associated with photosynthesis. Accumulation of sugars (and other soluble components) in the cells may lower the fiber and the crude protein concentration due to dilution with cell solubles. As the alfalfa plant rapidly photosynthesizes in the late morning, sugars and starches may accumulate in plant tissue. At night, these compounds are respired and utilized by the plant, slightly increasing the fiber level (by difference). If hay is cut in the afternoon, and respiration in windrows is minimal, then the higher concentration of soluble carbohydrates may contribute up to 1-1.5% to the TDN of the forage (Putnam et al., 1998). There is evidence that animals prefer afternoon-harvested hay (Mayland et al., 1998). These effects will not always occur, however. It is likely that the advantage of afternoon harvest would be greatest under cool, bright sunshine conditions, and under conditions where the forage is highly conditioned to increase drying rates and minimize respiration in the windrow after harvest. Afternoon harvests are not necessarily appropriate in humid environments where rain damage is the more important worry—every hour of drying time is important.

Rain Damage during harvest. Rain reduces the level of available carbohydrates or available energy by leaching soluble components from the plant material. It also decreases forage quality by increasing leaf shatter. Since soluble components are 100% digestible, leaching decreases TDN value significantly, as well as protein content and dry matter. Table 2 indicates the effect of simulated rain on total dry matter losses due to leaching. The extent of leaching is influenced by stage of maturity, forage moisture at the time of the rain, amount and intensity of rain, and condition of the hay during the rain event. Rain can increase dry matter losses due to leaching and leaf shatter from about 10% up to over 50%, depending upon the amount of rainfall (Table 2).

Table 2. Effect of rain on dry matter losses in bud stage alfalfa and red clover as a percent of initial dry matter (% loss)

Loss	No Rain	1 inch	2.5 inches
	-----% loss in Dry matter-----		
Leaf Shatter	7.6	13.6	17.5
Leaching & respiration	2	6.6	36.9
Total Loss (%)	9.6	20.2	54.4

* Source: Rohweder, 1983

Variety. Research from a number of locations has shown differences between some varieties when placed under the same cutting schedule. Varieties differ primarily due to changes in leaf percentage, or due to slower growth rates (often a function of fall dormancy), or due to more subtle changes in cell wall structure. Multifoliolate varieties

(varieties which produce more than three leaflets per leaf) can in some cases result in higher quality, but this is not always so. The key issue is leaf percentage, as illustrated by Table 3. Some varieties may be called 'multi-leaf' or 'multifoliolate', but have no greater percentage of leaves on a weight basis than traditional trifoliolate varieties. Some trifoliolate varieties have also been developed to have a superior quality (Table 3).

It is important to judge the quality of a variety in relationship to the yield of that variety. In Table 3, the yield of the varieties in that trial did not differ. However, it can be shown that some varieties with supposedly higher quality are also lower in yield. Their growth rates may be significantly below that of other adapted varieties in a region. Although there may be some economic conditions where growers must sacrifice some yield for forage quality, yield is still the predominant economic factor for alfalfa growers, and forage quality secondary. When considering forage quality of varieties, it is important to ask for data that proves the point, and to evaluate the quality claims in relationship to the yield potential of that cultivar using replicated independent field trials.

Table 3. Effect of multifoliolate (MF) and trifoliolate (TF) varieties on yield, CP, and ADF, average of 2 years (MN Study, Juan et al., 1993).

Entry	Multileaf	Leaf	Yield	Protein	ADF
	Expression	Percentage		-----%	-----%
			t/acre		
Multi-7 (MF)	58	59	4.7	19.7	30.5
MultitKing (MF)	16	57	4.6	19.3	29.5
EXP (MF)	9	55	4.8	19.3	33.6
Legend (MF)	3	52	4.6	19.0	32.5
WL322 (TF)	0	56	4.5	20.6	30.0
SaranacAR (TF)	0	53	4.5	19.5	32.6
LSD (P<0.05)	3	2	n.s.	0.4	0.8

Stand Density. Leaf percentage, percent CP, ADF, and lignin are not largely affected by stand density per-se (Marble, 1990). Evidence from a WI study showed that leaf percentage, CP, ADF, and lignin were not affected by initial seeding rates (Sund and Barrington, 1976). This is due to the fact that at higher plant densities, the numbers of stems per crown is greatly reduced, so that the numbers of stems per unit area actually does not differ very much between very high and moderately low densities. However, stem thickness may be slightly greater under low densities. Counteracting this effect, the light penetration into the lower sections of the alfalfa canopy may improve leaf retention compared with thick stands. A critical issue is that when stand densities fall below a certain number (between 4 and 10 plants/square foot, depending upon the age of the stand), open spaces are made available for the growth of weeds. The weeds, in turn, can have a significant impact upon forage quality. This is likely the most important consideration of alfalfa stand density in relationship to forage quality.

Soil Type. It has long been known that alfalfa produced on certain soils, primarily heavy clay or salty soils, produces higher quality alfalfa than that produced on sandy or loamy soils (Marble, 1990). This has been attributed to greater plant stress on those soil types, and slower growth rates, perhaps due to lack of oxygen in the root zone or salt effects. The stress seems to produce a shorter, finer stemmed, leafier alfalfa than alfalfa

harvested at the same harvest interval on sandy or loamy soil (Marble, 1990). It should be noted, though, that climatic influence might be a factor in some of those areas, as well as the soil type.

Fertilizers. As a rule, fertilizers are likely to have either no effect, or decrease the quality of alfalfa. There have been a number of claims of fertilizers improving alfalfa forage quality. However, unless these can be clearly demonstrated through well replicated, carefully done field trials, they should be looked on with some suspicion. Most fertilizers improve yields of alfalfa when the elements contained in the fertilizer are in short supply in the soil. Thus, if phosphorus, potassium, sulfur, or micronutrients are low in soil or tissue tests, yields of alfalfa will improve with application of those fertilizers. In most cases, however, the improvement in yield that results from application of fertilizers will result in more rapid growth rates, which will likely decrease, not increase forage quality. There may be exceptions to this, but those exceptions must be clearly demonstrated in field trials, replicated over time and space, before they are accepted.

Several years ago, there were claims of improved quality with applications of potassium sulfate, even if potassium (K) was present at high levels in the soil. Subsequent trials conducted by UC clearly showed no forage quality advantage with potassium sulfate or chloride fertilizers in California, though yields were improved where K was deficient in the soil (Meyer and Mathews, 1995). A similar study at the University of Wisconsin showed a decrease in forage quality due to K fertilization on K-deficient sites. These results are not surprising considering the importance of K in improving alfalfa growth and yield.

Additionally, nutritionists have lately emphasized the importance of minimizing the amount of K in hay fed to close-up cows (pregnant cows nearing birth), to prevent problems with calcium nutrition and milk fever. When K is added to the soil when already in ample supply, 'luxury consumption' occurs, and the K concentration of the forage increases without an increase in yield. This is clearly not desirable either from the grower's point of view (an expense is incurred without an increase in yield or value), or from the nutritionists' point of view (danger of excess K in the forage). This problem has been increasingly recognized, and a niche market for low-K hay has emerged.

Some growers feel that nitrogen (N) fertilizers improve the quality of alfalfa. Routine applications of N fertilizers to alfalfa are common in some areas of the West. However, there is little evidence to support this practice for either yield or quality. N fertilizers are unlikely to improve TDN or reduce fiber. There are some instances of N fertilizers causing slight improvements in CP concentration, but an equal or greater number of field trials show no effect of N fertilizers on CP. N fertilizers applied to alfalfa are likely to contribute to non-protein N fraction in the plant, it is questionable as to whether this contributes much to the genuine nutritional value of alfalfa to the cow, even if CP is improved slightly. Non-protein N in the plant is mostly metabolized and excreted by the animal, which costs energy, and may contribute to environmental problems with greater N in the waste material. N fertilizers encourage grassy weeds more than alfalfa, which may lower quality. Although applications of N fertilizers may make the plants look a little greener, it is not recommended to apply N fertilizers to alfalfa in attempts to improve forage quality or yield.

Irrigation Management. Irrigation management is probably the most important yield-limiting factor in western states. Over-applications of water, water stress, and lack of

drainage are major problems with alfalfa production. Water stress often improves forage quality, since the leaf-stem ratio is improved due to lack of growth of the stem component (Marble, 1990). However, yields are linearly related to water availability, and are dramatically reduced by water stress. The loss in yield associated with water stress is too great to justify stressing the alfalfa for water as a means of improving quality.

Insects and Diseases. Insect and disease pests can have a positive or a negative effect on forage quality. Most insects have a negative effect since their feeding habits include chewing of leaves and decreasing leaf:stem ratio. Sucking insects, such as aphids, may reduce soluble carbohydrates, therefore reducing forage quality. However, some insects and diseases may actually improve quality, since they create plant stress, which tends to increase leaf:stem ratio and shorten internodes. Insects that intensively suck plant sap (such as the Sweet Potato Whitefly in the Imperial Valley) cause widespread stickiness on the plant surface, which in turn causes a fungus to develop (sooty mold), which lowers palatability and consumer acceptance. Generally, insects must be controlled to maintain high quality alfalfa.

CONCLUSIONS

The primary mechanisms that determine alfalfa forage quality are plant maturity at harvest, leaf-stem ratio, environment, and weed composition. It is difficult for growers to change the crop environment (particularly temperature), but a number of agronomic practices may have impacts on maturity, leaf-stem ratio, and weeds. The most powerful mechanism for growers to influence forage quality is to change the cutting schedule or maturity of the plant at harvest. Skill in harvesting to retain quality without leaf loss or rain damage also has a major impact, as does good weed control practices. Efficient conditioning, rapid drying methods, baling at the right moisture, harvesting during the afternoon, choice of variety, and prevention of insect pest damage may also impact quality. Use of fertilizers, manipulation of irrigation, or change in stand density are not likely useful methods to improve forage quality. Generally, any agronomic practice that improves leaf percentage in the bale, allows harvest of immature plant material, prevents rain damage, and reduces the weed component will improve the quality of the forage. However, since forage quality is attained often at the expense of yield, agronomic practices to increase quality must be carefully balanced with the need to maintain yields, stand persistence and economic returns.

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