Economics Of Forage Quality

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The three forages most commonly fed to dairy cattle in the western United States are alfalfa hay, corn silage, and winter cereal silages. Therefore, this discussion will concentrate on those forages. Each has unique characteristics that affect its nutritional and economic value in dairy rations, so they will be discussed separately

Alfalfa

Dairy producers and alfalfa hay growers are well aware of the tremendous difference in feeding value between alfalfa harvested at an immature stage compared with a more mature stage (e.g., bud-stage compared with mid- or full-bloom alfalfa). An alfalfa quality testing program has been in place in California for over 30 years based on research at UC Davis in the 1950's (Meyer and Jones, 1962) that showed greater digestibility, faster weight gains and higher milk production from cattle fed alfalfa harvested at an immature stage. Subsequently, similar forage testing programs were developed in many other states. Maturity of alfalfa is closely related to its fiber content; as stage of maturity increases, so does its fiber content, and digestibility of the plant decreases. Laboratories use tabular values to predict Total Digestible Nutrients (TDN) and Net Energy for Lactation (NEL) values for an alfalfa sample based on its fiber content. These values in turn are used for determining relative economic values of different lots of alfalfa hay, and for formulation of diets for animals consuming the alfalfa.

High-quality alfalfa must be nutritious and palatable and must be preserved in a manner that will retain these characteristics. Digestibility alone cannot characterize alfalfa quality. To be of greatest value, alfalfa must also be consumed at the highest level possible. High-quality alfalfa is consumed in greater quantities than low-quality alfalfa, thus magnifying its nutritional and economic benefits.

Visual factors such as stage of maturity, leafiness, foreign material, condition and odor, and green color, have been used to estimate alfalfa digestibility and palatability. A review of these factors and descriptions of chemical tests to estimate alfalfa quality based on its fiber content are contained in a University of California Cooperative Extension publication: "Testing Alfalfa for its Feeding Value" (Bath and Marble, 1989). The publication also contains tables that can be used to estimate relative economic values of alfalfa at various fiber and moisture contents. However, relative economic values in the bulletin are based on digestibility as estimated from fiber content and do not take palatability and consumption into consideration.

A computer program for formulation and analysis of dairy cattle rations called PCDAIRY (Bath and Strasser, 1990) can be used to determine the relative economic values of various lots of alfalfa based on their palatability and consumption, as well as nutritional values. The program requires a formulated ration to fulfill all nutritional requirements (National Research Council, 1989) within feed dry matter intake limits based on cow size and level of milk production. Therefore, the relative economic values determined with PCDAIRY are more accurate than those based only on digestibility.

To illustrate the use of the computer program, a comparison was made of three lots of alfalfa hay with varying fiber contents. Hay lots were characterized by their acid detergent fiber (ADF) contents, but modified crude fiber (MCF) could be used as well. The three lots contained 28%, 32%, and 37% ADF, respectively, which correspond to total digestible nutrient (TDN) levels of 55%, 52%, and 49% TDN at 90% dry matter. For comparison purposes, the lot with 32% ADF was specified to be worth $120 per ton on the open market, and all three lots contained 90% dry matter. Other feedstuffs available for the rations and their prices were:

Feedstuff	**$ per ton**	**Feedstuff**	**$ per ton**
Almond Hulls	80	Whole Cottonseed	180
Barley Grain	160	Dicalcium Phosphate	500
Beet Pulp	150	Limestone	100
Corn Grain	160	Molasses	90
Cottonseed Meal	200	Rice Bran	140
Wheat Millrun	150		

Rations were formulated for four levels of milk yields with each of the three hay lots. A summary of milk yields, feed costs, and income over feed costs (IOFC) with the standard hay (32% ADF and $120/ton) is shown in Table 1. Daily feed costs increased from $2.88 per cow for 46 lb of milk to $4.60 per cow for 104 lb of milk. However, daily IOFC increased even faster from $3.10 per cow for 46 lb of milk to $8.88 per cow for 104 lb of milk, illustrating the increased profitability of high-producing cows.

Table 1: Milk yields, feed costs, and income over feed costs of cows fed alfalfa hay with 32% ADF.

	Milk Production Group			
	Low	Medium	High	Super
Milk (lb/day)	46	66	86	104
Alfalfa hay ($/ton)	$120	$120	$120	$120
Feed costs ($/day	$2.88	$3.50	$4.16	$4.60
IOFC ($/day)*	$3.10	$5.08	$7.02	$8.88

*IOFC = Income over feed costs.

In a second set of computer formulations, the price of alfalfa hay with 28% ADF was allowed to vary so that IOFC would be the same as it was for the previous rations using alfalfa hay with 32% ADF at $120 per ton. Results are shown in Table 2. The relative value of alfalfa with 28% ADF varied from $127 per ton for the low-yielding cows to $139 per ton for the high-producers, or an increased value of $7 to $19 per ton.

Table 2: Milk yields, relative economic values of alfalfa hay, feed costs, and income over feed costs of cows fed alfalfa hay with 28% ADF.

Milk Production Group				
	Low	Medium	High	Super
Milk (lb/day)	46	66	86	106
Alfalfa ($/ton)	$127	$127	$131	$139
Feed costs ($/day)	$2.88	$3.50	$4.16	$4.90
IOFC ($/day)*	$3.10	$5.08	$7.0	$8.88

*IOFC = Income over feed costs.

In a third set of computer formulations, the price of alfalfa hay with 37% ADF was allowed to vary so that IOFC would be the same as it was for the standard hay (32% ADF and $120 per ton). The results are shown in Table 3. The relative value of alfalfa with 37% ADF was $111 per ton for the low-yielding cows, but declined to a negative value for the high-producers. In fact, the computer could not formulate a balanced ration for cows producing more than 89 lb of milk using the alfalfa with 37% ADF, even if large amounts of grain concentrates were fed. This illustrates the well-known fact that high-producing cows must be fed high-quality forages as well as liberal amounts of grain concentrates in order to maintain high milk yields.

Table 3: Milk yields, relative economic values of alfalfa hay, feed costs, and income over feed costs of cows fed alfalfa hay with 37% ADF.

Milk Production Group	Low	Medium	High	Super
Milk (lb/day)	46	66	81	89
Alfalfa ($/ton)	$111	$108	$81	-0-
Feed costs ($/day)	$2.88	$3.50	$3.47	$2.93
IOFC ($/day)*	$3.10	$5.08	$7.02	$8.61

*IOFC = Income over feed costs.

The relative values of the three hay lots at the four levels of milk production are summarized in Table 4. Assuming a price of $120 per ton for the alfalfa with 32% ADF (52% TDN @ 90% DM), the alfalfa with 28% ADF (55% TDN @ 90% DM) is worth from $7 to $19 more per ton depending on the level of milk production of the cows consuming it. Conversely, the alfalfa with 37% ADF (49% TDN @ 90% DM), is worth from $9 to $140 per ton less depending on the milk yields of the cows consuming it. The difference in relative values between the 28% ADF and 37% ADF hay lots is from $16 to $159 per ton depending on milk yields of cows being fed the alfalfa.

Table 4: Relative economic values ($/ton) of alfalfa hay lots varying from 28% to 37% ADF (55% to 49% TDN at 90% DM).

Milk Production Group		Low	Medium	High	Super
28% ADF (55% TDN)	127	127	131	139	
32% ADF (52% TDN)	120	120	120	120	
37% ADF (49% TDN)	111	108	81	-20	
Difference (28% ADF vs. 37% ADF)		$16	$19	$50	$159

Using Table 6, Relative Alfalfa Hay Values at Various ADF Percentages, in the bulletin "Testing Alfalfa for Its Feeding Value" (Bath and Marble, 1989), the difference in relative economic value between alfalfa hays with 28% and 37% ADF is calculated as $15 per ton based only on digestibility. This is very close to the $16 difference determined by PCDAIRY for low-yielding cows, but grossly underestimates the difference in relative values for high-yielding cows.

Managers of large dairy herds can use programs such as PCDAIRY to determine relative dollar values of various lots of alfalfa hay offered for sale. When the price spread between low- and high-fiber alfalfa is large, it may be cost-effective to purchase and feed the lower-priced, high-fiber hay to low-producing cows, dry cows, and growing heifers. However, it appears that there would have to be a tremendous price spread for it ever to be cost-effective to feed high-fiber alfalfa as the main forage source to high-producing cows within a herd.

Corn Silage

The nutritional value of corn silage is less affected by stage of maturity than alfalfa. As the corn plant matures, digestibility of the stalk decreases due to increased lignification, but this is offset by the concurrent development of the grain kernels which are highly digestible. Fiber content of the corn plant varies little between the milk stage and dent stage of kernel development. Thus, fiber content of corn silage is not a good predictor of its maturity.

Forage dry matter yield per acre and palatability of the silage are the most important economic factors for corn silage. Maximum dry matter yield occurs at physiological maturity of the corn plant when all kernels are fully dented. However, digestibility and palatability of the total plant decreases after this point, so a good compromise is to harvest corn for silage when the milk line is 2/3 of the way down the kernel. The corn plant contains about 65% moisture at this stage, which is ideal for fermentation of the forage in horizontal silos. Harvesting at a less mature stage is undesirable because forage dry matter yield per acre is reduced, the grain portion of the silage is reduced, and additional expenses are incurred to haul water contained in the forage. If the forage contains more than 72% moisture, seepage from bunker and stack silos is likely, resulting in further economic losses from nutrients lost in the runoff.

Harvesting corn after physiological maturity also results in economic losses. Yields are decreased due to excessive field losses from stalk breakage, leaf loss, and dropped ears. Further losses occur in horizontal silos due to difficulty in packing forage that is too dry (less than 62% moisture), resulting in losses from heating and oxidation of the silage.

Maximum economic benefits are obtained from feeding corn silage that is harvested when the milk line is 2/3 of the way down the kernel, the silo is filled rapidly, the forage is well-packed, and air and rain water are excluded from the silage mass. In the case of horizontal silos, the silage should be covered with plastic held down by automobile tires, or by other materials that will prevent air and water from contacting the silage. If the silage mass in horizontal silos is not covered and packed well, as much as 50% of the total silage may be lost from heating, oxidation, and run-off due to exposure to the elements.

Winter Cereals

Digestibility and feeding value of cereal forages are greatest at an immature stage (boot-stage), but as is the case with corn silage, the fiber content of cereals is not a good predictor of maturity. As the fiber content of the stem increases with maturity and becomes less digestible, the cereal grain kernels are developing at the same time. The grain, being very low in fiber, dilutes the increasing fiber content of the stem, resulting in very little change in total plant fiber content as the cereal plant matures. In fact, there is a slight decrease in fiber content as a cereal, such as oats, goes from the flower stage to the dough stage of kernel development (DePeters et al., 1989), resulting in a curvilinear relationship between fiber and maturity as the cereal plant goes from the early vegetative stage to full maturity. Therefore, the laboratory test for fiber used to estimate maturity and feeding value of alfalfa is inappropriate for cereal forages. Unfortunately, at the present time there is no laboratory test that can accurately estimate the feeding value of cereal forages.

Although there is no reliable laboratory test to predict the feeding value of cereal forages, feeding trials have demonstrated the superiority of oats harvested at the boot-stage compared with more mature stages. Data from research with oat forage conducted at U.C. Davis in the 1950's (Meyer et al., 1957) are shown in Table 5.

Table 5: Yield, composition and nutritional value of oat forage harvested at various stages of maturity.

	59% Jointing		16% Flag Leaf	21% Boot	1% Flower	18% Flower	44% Milk	42% Dough
DM (lb/Ac) 1800		4300	5400	5800	8000	9400	9200	
Lignin (%) 3.8		4.3	4.9	5.8	6.4	9.0	8.4	
Crude fiber (%)	16		19	21	24	27	29	27
Crude protein (%)	24		19	18	16	14	12	2
T.D.N. (%) 68		65	65	64	60	50	53	

Harvesting at the boot-stage results in less forage tonnage per acre (Table 5), but the available forage is more nutritious to the animal consuming it. How much is that higher nutritive value worth? The same procedure, as previously described in the alfalfa section of this paper, was used to answer that question.

A comparison was made of two oat silages, one harvested at the boot stage and the other at the soft dough stage. Nutrient values for the two silage samples were taken from the bulletin, "Nutrient Requirements of Dairy Cattle" (National Research Council, 1989). For comparison purposes, the soft dough stage silage was specified to be worth $25 per ton at 30% dry matter. Alfalfa hay at $100 per ton was restricted to seven pounds per cow daily to ensure that oat silage would comprise most of the forage in the ration. Milk price was specified to be $12 per hundredweight, and other feedstuffs available for the rations and their prices were the same as those used in the alfalfa example previously discussed.

Rations were formulated for four milk yields with each of the oat silages. A summary of milk yields, feed costs, and income over feed costs (IOFC) using the dough stage silage is shown in Table 6. Daily feed costs increased from $2.40 per cow for 45 lb of milk to $4.00 per cow for 94 lb of milk, which was the highest milk yield possible with this quality of silage as the major forage source. Daily IOFC increased even faster from $3.00 per cow for 45 lb of milk to $7.29 per cow for 94 lb of milk, illustrating the increased profitability of high-producing cows.

Table 6: Milk yields, feed costs, and income over feed costs of cows fed a ration based on oat silage harvest ed at soft dough stage.

		Milk Production Group			
		Low	Medium	High	Super
Milk (lb/day)		45	65	83	94
Oat silage ($/ton)		25	25	25	25
Feed costs ($/day)	2	.40	3.13	3.67	4.00
IOFC* ($/day)		3.00	4.67	6.29	7.29

*IOFC = Income over feed costs.

In a second set of computer formulations, the price of boot stage oat silage at 30% dry matter was allowed to vary so that IOFC would be the same as it was for the previous rations using dough stage silage at $25 per ton. All other feed prices remained the same as the previous example. The results are shown in Table 7. The relative value of boot stage oat silage varied from $39.92 per ton for the low-yielding cows to $78.26 per ton for the high producers. Also, it should be noted in Table 7 that a ration could be formulated for a cow producing 105 lb of milk daily with boot stage oat silage compared with a maximum of only 94 lb daily with dough stage silage. Higher maximum milk yield is possible because a cow can eat more total feed when her ration is based on the higher protein, more digestible, and more palatable boot stage silage. As was the case in the alfalfa example, this again illustrates the well-known fact that high-producing cows must be fed high-quality forages as well as liberal amounts of grain concentrates in order to maintain high milk yields.

Table 7: Milk yields, relative economic values of oat silage, feed costs, and income over feed costs of cows fed a ration based on oat silage harvested at the boot stage.

	Milk Production Group			
	Low	Medium	High	Super
Milk (lb/day)	46	65	85	105
Oat silage ($/ton)	39.92	42.37	45.19	78.26
Feed costs ($/day)	2.52	3.13	3.91	5.31
I OFC* ($/day)	3.00	4.67	6.29	7.29

*IOFC = Income over feed costs.

The relative values of the two silages at the four levels of milk production are summarized in Table 8. Assuming a price of $25 per ton for dough stage oat silage, boot stage silage is worth from $14.92 to $53.26 more per ton depending on the level of milk production of the cows consuming it. Therefore, under the conditions used in this example, relative value of boot vs. dough stage oat silage varies from 160 to 313%.

Table 8: Relative economic values ($/ton @ 30% dry matter) of oat silage harvested at the boot and soft dough stages of maturity.

	Milk Production Group			
	Low	Medium	High	Super
Oat silage, boot stage ($/ton)	39.92	42.37	45.19	78.26
Oat silage, dough stage ($/ton)	25.00	25.00	25.00	25.00
Difference ($/ton)	14.92	17.37	20.19	53.26
Rel. value, boot vs. dough (%)	160	169	181	313

There is no question that boot stage silage is more nutritious than dough stage silage. However, there are several other factors that should be considered, such as:

1). Harvesting at the boot stage results in less forage dry matter per acre than at the dough stage. However, if the land is being double-cropped with corn for silage, increased corn silage yields due to an earlier planting date for the corn may more than make up for reduced cereal silage yields.

2). Cereals harvested at the boot stage should be field-wilted to about 30% dry matter before ensiling. Direct-chopping should be avoided because boot stage forage is too high in moisture for good fermentation. Field-wilting adds another step to the harvest process, but the lower moisture content of the wilted forage results in less hauling costs from the field to the silo.

3). Cereals harvested at the boot stage require less water in areas where spring irrigations are necessary because fewer irrigations are needed. That fact may become even more important in areas where irrigation water is limited and demand for water for non-agricultural purposes continues to increase, as is the case in many western states.

In summary, the answer is a definite "yes" to the original question: "Does stage of maturity at harvest affect the feeding value of cereal silages?" How much the improved nutritional value is worth depends on the level of milk production of the cows consuming the silage. With the inputs used in this example, boot stage oat silage was worth from 160% to 313% of dough stage silage. If the silage is being fed to low-producing cows, dry cows, or growing heifers, the increased nutritional value of boot stage may be more than negated by decreased forage yields per acre. However, if the silage is used as a major part of the ration for high-yielding cows, the economics definitely favor cereal silage harvested at the boot stage.

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