LINKING FORAGE QUALITY WITH ECONOMIC VALUE

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ABSTRACT

Forage quality is often defined as the ability of a forage to support milk production when fed to cows, but that definition is very difficult to quantify. Relative forage quality (RFQ) was developed to quantify forage quality and should allow the price of forage to better reflect the milk production potential of a forage. The price of alfalfa hay is correlated with RFQ and depending on local markets a 10 unit increase in RFQ may increase the value (price) of alfalfa hay by $12 to $16/ton. The RFQ equation includes concentration of NDF (negative relationship) and in vitro NDF digestibility (IVNDFD) (positive relationship) and is essentially a proxy for energy intake. Energy intake is usually what limits milk production, but other nutrients are needed to produce milk and they also have economic value. Rather than using an index, a better approach would be to use actual nutrients. The nutrients that have the greatest value in forages are energy (expressed as NEL) metabolizable protein (MP) and NDF. Feed labs routinely measure NDF and generate estimated NEL concentrations in samples and MP can be estimated from measured crude protein (CP) concentrations. Methods are available to estimate the economic value of nutrients ($/Mcal of NEL; $/lbs. of forage NDF; and $/lbs. of MP). To arrive at a baseline value for hay, you need to calculate the amount of NEL, MP and NDF in 1 ton of hay, multiple each by its economic value and then sum. RFQ (or RFV) gives CP no value; it is not in the equations. The concentration of CP is moderately correlated with RFQ ($r^2 = 0.35$), but an alfalfa sample with an RFQ of 200 could range in CP from about 18% up to 27%. In addition to supplying nutrients, forage also affects feed intake. A lab measure that has a strong positive relationship to intake and milk production is IVNDFD. On average a 1 unit increase in IVNDFD increases intake and milk by 0.26 and 0.47 lbs./day, respectively. The baseline value calculated above needs to be adjusted based on the difference in IVNDFD between your sample and the average IVNDFD (this can be positive or negative). The adjustment depends on the price of milk and the cost of feed. For example, if feed dry matter is $12/cwt and milk is $24/cwt a 1 unit increase in IVNDFD above average is worth about $7.4/ton of alfalfa hay dry matter which would be added to the value based on nutrients. The calculations are more complicated than simply using RFQ but the calculations straightforward and more accurately values alfalfa which should benefit both the seller and buyer.

Key words: protein, energy, fiber, price, alfalfa

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INTRODUCTION

Although alfalfa is an excellent feed for dairy cows, diets do not have to include it. Therefore, the inclusion rate for alfalfa in diets depends on its perceived value relative to other feedstuffs and the nutrient needs of the cow. What is needed is a method to estimate the value of alfalfa and other forages and feedstuffs to determine which ingredients should be included in diets. The value of a feed should be related to its nutrient concentrations and its effect on yields of milk components (milk fat and protein). Over the last several years, researchers at Ohio State have attempted to integrate readily obtainable data into a system that can estimate the value of different forages, including alfalfa. This should aid both the seller and buyer of forages.

IMPORTANT NUTRIENTS

Alfalfa is routinely sampled and analyzed for nutrient composition. Labs can analyze feed samples for a wide array of nutrients and feed characteristics which all have use in some applications. However, to estimate the economic value of a feed we only need estimates of its concentrations of energy, protein, and fiber and energy, and in vitro fiber digestibility.

Energy. Cows require energy to live and produce milk. Net energy-lactation (NEL) is the most common expression of feed energy used by most dairy ration software programs. Labs cannot measure NEL but standardized equations based on measured components are available to estimate NEL. If comparing different forages, the same NEL equation must be used for all samples.

Protein. Labs measure crude protein (CP) but that assay is not the best measure of protein to compare across feed stuffs. For example, 1 lbs. of CP from a typical forage will support less milk protein synthesis than 1 lbs. of CP from soybean meal. Metabolizable protein (MP) is a more accurate estimate of the protein value of a feed. MP is based on ruminal degradability of the CP and the digestibility of the undegraded protein. Based on expected protein degradability and digestibility, factors have been developed to convert CP into MP (Table 1). For haycrop forages (hays and silages), a conversion factor of 0.56 should be used.

Fiber. Neutral detergent fiber (NDF) is the best current method to estimate fiber in feeds and is routinely measured by labs. Some of the NDF can be digested and provide NEL but the main economic value of NDF comes from its effects on rumen and cow health. NDF contained in larger particles stimulate chewing and rumination which are essential to maintain good rumen health. Various methods have been proposed to estimate effective NDF but for many situations simply separating NDF provided by forage from that provided by other feeds is adequate. Forage NDF (fNDF) is assumed to promote chewing and represents 'effective NDF'. All the NDF in alfalfa is fNDF and adds to its economic value.

In vitro NDF digestibility. In vitro digestibility of NDF (IVNDFD) is not a nutrient but it is needed to accurately estimate NEL and to estimate the milk production potential of forages.

Diets containing forages with high IVNDFD can be consumed in greater amounts which results in greater milk production. Most labs can measure IVNDFD at either 30 or 48 hours of incubation. Either incubation time will work but when comparing different feeds, the same incubation time must be used for all samples.

Table 1: Example of calculating metabolizable protein for common forages and soybean meal[1].

		% of CP			
Ingredient	CP, %DM	RDP	dRUP	MP[2], %DM	MP/CP
Alfalfa hay, immature	23	79	13.5	12.7	0.55
Alfalfa hay, mature	18	73	17.8	10.2	0.56
Alfalfa silage	22	79	14.6	12.4	0.56
Corn silage,	8.8	67	24.7	5.3	0.60
Grass hay, mature	13	58	25.2	7.3	0.56
Soybean meal, 89% DM	53	67	30.0	34.7	0.65

[1] Composition data from NASEM (2021)

[2] Metabolizable protein = CP $\times$ (RDP $\times$ 0.53 + dRUP) $\div$ 100, %DM

THE ECONOMIC VALUE OF NUTRIENTS

Knowing the nutrient composition of a feed is not adequate to assign it an economic value, you must know what each nutrient is worth. To estimate the value of 1 Mcal of NEL you could take the price of corn per pound and divide it by its NEL concentration, but this ignores the value of the other nutrients in corn and it assumes the price of all NEL is equal to that of corn. The price of a pound of MP or a pound of fNDF could be calculated the same way but that has the same problems. A procedure (SESAME) developed at Ohio State several years ago uses the price of many feeds (usually about 30) including forages, grains, protein meals, and byproducts and their composition to estimate the average price of NEL, MP, and fNDF. To obtain the most accurate estimates of economic value, current local prices should be used. Prices can change substantially over time and location. Nutrient prices generated for the Midwest (bimonthly) can be found in the Buckeye Dairy Newsletter (dairy.osu.edu/newsletter/buckeye-dairy-news) and other places (e.g., *Progressive Dairyman* publishes nutrient prices for different regions every other month). For this article, I used West Region prices published in the September 12, 2022 edition of *Progressive Dairyman* and the Midwest 5 year average prices from September 2022, Buckeye Dairy News (Table 2). Those two sources calculate the value of effective NDF but as explained above, I am assuming fNDF equals effective NDF.

Table 2. Dollar value of nutrients calculated using SESAME for Western and Midwestern US. Data are from Progressive Dairyman (Sept 12, 2022) and Buckeye Dairy News (Sept, 2022).

Nutrient	West region	Midwest price	5 Yr Midwest Average
NEL, $/Mcal	0.132	0.115	0.08

MP, $/lb.	0.519	0.538	0.41
fNDF, $/lb	0.312	0.125	0.09

VALUE OF NUTRIENTS FOR A FEED

After obtaining nutrient data from the lab and dollar value from published sources, calculate the amount of each nutrient in a ton of the feed, multiply by dollar value of each nutrient and sum to obtain total value of the feed. For example, a truckload of alfalfa hay has the following assayed nutrient composition and amounts per ton were calculated based on those data (Table 3).

Table 3. Nutrient composition and amounts per ton for an example alfalfa hay.

	Concentration	Amount per ton of as-fed hay
Dry matter	88.0%	1760 lbs.
CP	23.0% of DM	405 lbs.
MP	12.9% of DM	227 lbs.
NEL	0.69 Mcal/lb of DM	1214 Mcal
fNDF	39% of DM	686 lbs.
IVNDFD	55% of NDF	NA

The values of those nutrients and for the feed are then calculated (Table 4) using the data in Table 2 and 3.

Table 4. Value based on West and Midwest US markets (fall, 2022) for an example alfalfa hay.

	Amount per ton	Value (West)		Value (Midwest)	
		$/unit	$/ton	$/unit	$/ton
MP	227 lbs.	0.519	117.8	0.538	122.1
NEL	1214 Mcal	0.132	160.2	0.115	139.6
fNDF	686 lbs.	0.312	214.0	0.125	85.8
Total	**2000 lbs.**		**492**		**347**

This method works very well when comparing the value of different concentrates; for example, distillers grains versus soyhulls. Those feed, if fed in reasonable diets do not affect feed intake. Forages, however, can have a substantial effect on intake resulting in a substantial effect on milk production.

ADJUSTING FOR "FORAGE QUALITY"

Currently, the single best assay to evaluate intake potential of a forage is IVNDFD. Based on several studies, a 1 unit increase in IVNDFD (expressed as % of NDF) within a forage family (e.g. legumes or grasses) increases intake by 0.26 lbs/day and milk yield by 0.47 lbs/day (Oba and Allen, 2005). Those values are appropriate for a change in IVNDFD, not an absolute value.

For example, if cows were changed from a diet with a forage that had an IVNDFD of 50% to one with an IVNDFD of 55%, we would expect milk to increase by 2.4 lbs./day (5 x 0.47). We would expect the same increase when IVNDFD increased from 35 to 40%. Because we can only evaluate change in IVNDFD, we need to compare the forage of interest to a standard (Table 5). We chose to set the standard equal to mean values for alfalfa, grass, and corn silage from NASEM (2021).

Table 5. Average (NASEM, 2022) NDF and IVNDFD concentrations for common forages.

Forage	Mean NDF, % of DM	IVNDFD, 48 hour
Alfalfa	43	49
Corn silage	41	52
Cool season grasses	62	64

To calculate the quality adjustment, the difference between IVNDFD of the forage of interest and standard values are calculated (use the same incubation time period for both the sample and standard): IVNDFD(sample) – IVNDFD(standard). That value can be positive or negative. It is then multiplied by 0.47 to estimate the change in milk yield when the forage is fed. Change in milk yield then must be converted to a dollar value, which is a function of milk price and feed price. Dry matter intake is expected to increase 0.55 lbs. for every 1 lb. increase in milk yield (conversely if milk yield drops by 1 lb. we expect dry matter intake to decrease 0.55 lbs.). The value of the change in dry matter intake depends on the price of the diet. Lastly, to put these numbers on a per ton of forage dry matter basis, we need to assume a certain intake of forage dry matter. We chose 22 lbs. (55 lbs. of dry matter intake that was 40% of the forage of interest).

Example calculation of quality adjustment.

The forage of interest is alfalfa hay that had a 48 hour IVNDFD of 55%.

1. Difference in IVNDFD from standard: 55 – 49 = 6 units
2. Expected increase in milk yield: 6 x 0.47 = 2.8 lbs./day (assumed milk price $0.20/lb.)
3. Expected increase in DM intake: 6 x 0.26 = 1.6 lbs. (assumed feed price $0.10/lb. DM)
4. Expected gain in income over feed cost: (2.8 x 0.20) – (1.6 x 0.10) = $0.40
5. Converting to 1 lb. of forage DM: 0.19/22 = $0.018/lbs. = $32/ton of DM or about $27/ton of hay (85% DM).

That value is added (or subtracted) from the nutrient value calculated as described above. In the example above the alfalfa in Midwest had a nutrient value $347/ton (85% DM) and a quality adjustment of $27/ton; therefore, the total value of the example alfalfa is $374/ton. Table 6 has quality adjustments for various feed and milk prices. A user would use feed and milk price most applicable, find the quality adjustment and add (or subtract) it from the nutrient value.

The values calculated using this method is the maximum a dairy farmer should pay because basically it represents break-even cost for the forage (in other words, the dairy producer is getting what he paid for but the forage is not a bargain or overpriced)

Table 6. Quality adjustment ($/ton of forage DM) per 1 percentage unit change in IVNDFD from the standard. For example, if the forage had 3 percentage units lower IVNDFD than the standard and milk price was $22/cwt and diet cost $0.10/lbs. of DM, the quality adjustment would be -3 x 7.0 = $-21/ton.

	Milk Price, $/cwt					
Diet price, $/lbs. of DM	**16**	**18**	**20**	**22**	**24**	**26**
0.06	5.4	6.3	7.1	8.0	8.6	9.7
0.08	5.0	5.8	6.7	7.5	8.4	9.2
0.10	4.5	5.3	6.2	7.0	7.9	8.8
0.12	4.0	4.9	5.7	6.6	7.4	8.3

Limitations to the method

1. We assume the effect of a change in IVNDFD is the same regardless of forage inclusion rate, which is most likely not true. At low inclusion rates we are probably overestimating the value of quality and at high rates we are likely underestimating the value. We chose an inclusion rate of 40%
2. We assumed the same effect of a change in IVNDFD for all forages. This may or may not be true. The majority of the data in the paper by Oba and Allen (2005) is from corn silage-based diets; however several studies also included alfalfa. Grass was poorly represented in the data set.
3. The same effect of a change in IVNDFD is assumed for all milk yields. High producing cows probably are more sensitive to a change in IVNDFD than lower producing cows.

CONCLUSIONS

Comparing the value of different forages should be based on more than RFQ or RFV. Both those indices ignore the value of protein and only gives negative value to NDF even though forage NDF is a requirement nutrient for dairy cows. The method outlined above gives values to all major nutrients provided by forages and includes a separate adjustment for the effect forage quality has on intake. The calculations can easily be inserted into a spreadsheet and the method does not require analyses that are not typically conducted for forages.

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