SHOULD FORAGES BE PRICED LIKE A SACK OF NUTRIENTS?

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ABSTRACT

The economic value of forage should reflect its nutrient composition relative to market conditions. The major nutrients provided by forage are energy (expressed as net energy, NEL), protein (expressed as metabolizable protein, MP) and fiber (expressed as neutral detergent fiber, NDF) which can be assayed or calculated by commercial feed labs. By using a statistical technique and the nutrient composition and prices of multiple feeds, including forages, we can determine the average economic value of those nutrients. With those two pieces of information, we can estimate the economic value of a feed based on the average cost of nutrients within a specific market and its nutrient composition. For example alfalfa hay may have 0.62 Mcal/lb of NEL, 13%MP and 40% NDF (100% DM basis) and in central Ohio in September, 2019 average NEL was worth $0.09/Mcal, MP was worth $0.30/lb and forage NDF was worth $0.12/lb. In this example 1 ton of this alfalfa (85% DM) has 1054 Mcal of NEL worth $95, 221 lbs of MP worth $66 and 680 lbs. of NDF worth $82 for a total value of $243/ton. However, pricing totally on nutrients ignores the effect forage can have on feed intake, which ultimately affects growth or milk production. Concentration of NDF and in vitro NDF digestibility, relative to some standard can be used to adjust the value of forages but the adjustment depends on the type of forage (e.g., grass, legume, corn silage), milk price and diet cost.

Pricing Nutrients

The inherent economic value of any feed is its ability to support productive functions when fed to livestock. However, because dairy cows are fed diets, not single ingredients, we cannot describe feeds in terms of production potential. For example, we cannot say that 10 lbs. of a specific alfalfa will support 15 lbs. of milk. However, we can say, with reasonable accuracy, that 10 lbs. of a specific diet will support 15 lbs. of milk. The amount of milk or body weight gain a diet will support is a function of the nutrients in the diet, and the amount of the diet an animal can eat. Therefore, rather than valuing a forage (or any feed) based on its ability to support growth or milk, we can value a feed based on its nutrient composition. Forages are routinely sampled and analyzed for chemical components and with that information we can calculate or estimate the concentration of major nutrients. The NEL concentration of forage is mostly a function of NDF content (higher = lower NEL), NDF digestibility (higher = higher NEL), and ash (higher = lower NEL). Labs have equations to estimate NEL and that value is provided on their reports.

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Metabolizable protein is a function of the type of crude protein and energy intake and can only be estimated accurately for a diet, not a feed. Therefore, it is not usually put on lab reports. However, it can be estimated for a feed by assuming average conversion of rumen degradable protein (RDP) into microbial protein and using feed specific digestibility coefficients for rumen undegradable protein (RUP) from the NRC (2001). In this example (Table 1), we assumed the forages are part of a well formulated diet sufficient in NEL and RDP and for typical dairy cows consuming 4% of their body weight as DM. The amount of CP as RDP and RUP are from NRC (2001). Similarly, for digestible RUP, feed specific digestion coefficients are used to convert RUP into the protein available to the cow (i.e., the MP). The digestibility of RUP and the amount of RDP typically decreases as forage quality decreases. If cows are fed exactly to their RDP requirement, the efficiency of converting RDP into MP is 0.55; however because RDP is usually fed in slight excess an efficiency of 0.53 is more realistic. The total MP of the feed is then the sum of digestible RUP and RDP x 0.53. To estimate MP for a specific forage, find the forage in Table 1 that is most similar to your forage and multiply the assayed CP value by the MP efficiency (MP/CP) shown in the table.

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

		% of CP			
Ingredient	CP, %DM	RDP[1]	dRUP[2]	MP[3], %DM	MP/CP
Good alfalfa hay, 85% DM	23.0	82.3	13.3	13.1	0.57
Alfalfa hay, 85% DM	18.0	75.9	15.7	10.1	0.56
Corn silage, 35% DM	8.8	64.7	24.7	5.3	0.59
Grass hay, 85% DM	13.3	69.5	19.8	7.5	0.57
Soybean meal, 89% DM	53.8	57.4	39.6	37.7	0.70

[1] Rumen degradable protein, % CP = 100 – RUP, %CP

[2] Digestible rumen undegradable protein, % CP = RUP, %CP × RUP digestion, %

[3] Metabolizable protein = CP × (RDP × 0.53 + dRUP) ÷ 100, %DM

Labs routinely measure and report NDF concentrations of feeds. Different expression of NDF are reported (e.g., ash-free NDF or NDF_{OM}), but for this discussion any measure of NDF is adequate. The NDF in forages provides some energy but it has unique economic value because it is needed to maintain rumen health. Fiber from other feeds provides energy but have little effect on rumen health so that fiber has less value than forage fiber.

Using computer software (e.g., SESAME) and nutrient composition and ingredient prices for several feeds (including forages) within a specific market, the average economic value of the major nutrients can be estimated. In this example, we used the average nutrient values in September, 2019 for central OH (Table 2; from Tebbe, Buckeye Dairy News, September 2019). These

Table 2. Prices of dairy nutrients for OH, September 2019

Nutrient,	Estimate
NE_L, $/Mcal	0.09 ± 0.017*
MP, $/lb	0.30 ± 0.053*
e-NDF, $/lb	0.12 ± 0.039*
ne-NDF, $/lb	-0.05 ± 0.033

* estimate is not equal to zero (*P* < 0.01)

values are specific to central OH and do not reflect the prices on a historical basis. Price estimates can also have a negative value meaning they are discounted. The discount is primarily because the two main drivers of ingredient markets (i.e., chickens and ethanol) do not want fiber. This is common for non-effective NDF; however, forage fiber is almost all effective NDF and should not be discounted. Monthly nutrient prices are also available in Progressive Dairy magazine for six different regions in the U.S (https://www.progressivedairy.com/).

With the nutrient composition of a forage and average nutrient prices, we can determine the economic value of a feed within a specific market. For example, alfalfa hay has 0.62 Mcal/lb of NEL, 13%MP and 40% NDF (100% DM basis) and in central Ohio in September, 2019 average NEL was worth $0.09/Mcal, MP was worth $0.30/lb and forage NDF was worth $0.12/lb. In this example 1 ton of alfalfa (85% DM) has 1054 Mcal of NEL worth $95, 221 lbs of MP worth $66 and 680 lbs of NDF worth $82 for a total value of $243/ton.

The total value calculated ($243/ton) would be the average estimate of this alfalfa; however, estimates have inherent variation and must be considered. The inherent variation accounts for variation in the nutrient composition and market prices for ingredients used to calculate the price estimates in Table 2. The variation in nutrient price estimates can be used to calculate our confidence in the estimate. For example, with 75% confidence, the true NE_L value of premium alfalfa hay is between $74 – 115/ton [i.e., $95/ton ± (0.017 × 1.15 × 1054 Mcal of NE_L)]. With 95% confidence, the range in true NE_L value for premium alfalfa hay is wider and between $60 – 130/ton [i.e., $95/ton ± (0.017 × 1.96 × 1054 Mcal of NE_L)]. The same calculation can be applied to the other nutrients. Calculating the 75% confidence intervals of the final estimate is much more complicated and beyond the scope of this talk. A good estimate for the calculating 75% interval for forages would be ± 12.5% of the mean or $215 – 275/ton for the premium alfalfa. The take away message is that the total value calculated should have a range.

This approach works quite well when comparing corn grain to barley grain or soybean meal to canola meal because differences in nutrient composition between those feeds account for most of the differences in milk yield or growth when those feeds are fed. Factors in forages other than basic nutrients can affect feed intake which can have profound effects on animal productivity. Adjusting prices for effects on intake is difficult because the effect a forage has on intake depends on the inclusion rate of the forage, the make-up of the entire diet, and the milk yield and physiological state of the cow.

Adjusting for forage quality

Forages are now commonly analyzed for in vitro NDF digestibility (IVNDFD) which is probably the best single assay to estimate effect of forage on intake and production. Cows consume higher amounts of feed when fed diets that contain forages with increasing IVNDFD. Labs use different incubation times but 30 and 48 hour are most common, and either incubation time point can be used to adjust nutrient prices. On average a 1% unit increase in IVNDFD (expressed as % of NDF) increases intake by 0.26 lbs. and increases 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 5 x 0.47 = 2.4 lbs./day. We would expect the same increase when IVNDFD increased from 35 to 40%. Because we can only evaluate change in IVNDFD, we have to compare the forage of interest to a standard (Table 3). We chose to set the standard equal to mean values for alfalfa, grass and corn silage (means obtained from DairyOne, Ithaca, NY; https://dairyone.com/services/forage-laboratory-services/feed-composition-library/).

Table 3. Average NDF and in vitro NDF digestion of common forages

		Mean IVNDFD, % of NDF	
Forage	Mean NDF, % of DM	30 hour	48 hour
Alfalfa	39	41	47
Corn silage	43	53	62
Cool season grasses	57	61	65

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 has to be converted to a dollar value, which is a function of milk price and feed price. Based on the data from Oba and Allen (2005), 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, an intake of forage dry matter must be assumed. 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 – 47 = 7 units
2. Expected increase in milk yield: 7 x 0.47 = 3.3 lbs/day (assumed milk price 0.19/lb.)
3. Expected increase in DM intake: 7 x 0.26 = 1.8 lbs (assumed feed price $0.08/lb DM)
4. Expected gain in income over feed cost: (3.3 x 0.19) – (1.8 x 0.08) = $0.49
5. Converting to 1 lb. of forage DM: 0.49/22 = $0.022/lbs = $44.5/ton of DM or about $38/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 had a nutrient value $243/ton (85% DM) and a quality adjustment of $38/ton; therefore the total value of the example alfalfa is $281/ton. Table 4 has quality adjustments for various feed and milk prices. A user would match feed and milk price most applicable, find the quality adjustment (in $/ton of DM) and add (or subtract) it from the nutrient value.

The values calculated using this method is the absolute 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 4. 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					
Feed 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. We assumed the same effect of a change in IVNDFD for all milk yields. Most likely high producing cows will be more sensitive to a change in IVNDFD than lower producing cows.

CONCLUSIONS

Forages are more than just a sack of nutrients, however the initial value of forage should be based on the nutrients the forage prices and the value of those nutrients. Pricing forage only on an energy, protein and fiber basis ignores the effect (positive or negative) forage quality has on milk yield and income over feed costs. The use of IVNDFD can help put a dollar value on forage quality. Although our method has limitations, on average it is an acceptable way to price forage.

REFERENCES

Oba, M. and M. Allen. 2005. In vitro digestibility of forages. Pages 81-91 in Proc. Tri-State Dairy Nutrition Conf., Ft. Wayne, IN.