PRACTICAL APPLICATION OF NEW FORAGE QUALITY TESTS

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INTRODUCTION

Routine evaluation of forage quality by the grower, crop consultant, feeder, or nutritionist has generally been related to the fiber content of the forage measured in a commercial forage testing laboratory and the energy content of the forage predicted from its fiber content. Indexes of forage quality, relative feed value (**RFV**; Rohweder et al., 1978) and milk per ton of forage dry matter (Undersander et al.; 1993), were based on energy content of the forage predicted from acid detergent fiber (**ADF**) content and dry matter (**DM**) intake potential of the forage predicted from neutral detergent fiber (**NDF**) content. The RFV index has evolved to the point where it is commonly available on commercial forage test reports, used routinely in evaluations and comparisons of hay-crop forage quality, and used in the marketing of hays. Data from Wisconsin quality-tested hay auctions show that hay buyers pay $0.90 per point of RFV above the RFV of a base quality alfalfa (Undersander, 2002). The milk per ton index has evolved to the point where it is commonly used in agronomic performance trials, because an estimate of forage DM yield often obtained in these types of trials multiplied times the estimate of milk produced per ton of forage DM provides an estimate of the milk produced per acre which combines yield and quality into a single term. This index, milk per ton or per acre, has become the focal point of corn silage commercial hybrid performance trials (Lauer et al., 2001; Lauer et al., 1997) and the corn silage hybrid-breeding program (Coors et al., 2001) at the University of Wisconsin - Madison.

Recently, the University of Wisconsin Marshfield Soil and Forage Analysis Laboratory began performing wet chemistry *in vitro* NDF digestibility (**NDFD**; % of NDF) measurements. Cumberland Valley Analytical Services (Maugansville, MD) and Dairy One (Ithaca, NY) also perform a wet chemistry *in vitro* NDFD analysis. Near infrared (**NIR**) calibrations for determining NDFD on hay-crop forage and corn silage samples are available at the UW Marshfield Soil and Forage Analysis Laboratory and some commercial forage testing laboratories. A summative energy equation (Weiss, 1996) has been used at some commercial forage testing laboratories to calculate the energy content of forages for several years; equation components include crude protein (**CP**), fat, non-fiber carbohydrate (**NFC**) and NDF, and the corresponding digestibility coefficients for these nutrients. Use of the summative energy approach is becoming more common with its inclusion in NRC, 2001.

We (Shaver et al., 2002) revised the summative equation of Weiss (1996) as follows:

- the CP and fat components were not altered,
- the NDF digestibility coefficient calculated using a lignin and NDF based equation was replaced by a direct laboratory measure of NDFD,
- the NFC component with constant digestibility was left unchanged for alfalfa and grasses, and
- the NFC component for corn silage was replaced with starch and non-starch NFC components with the starch digestibility coefficient varied in relationship to whole-plant DM content and kernel processing (Schwab and Shaver, 2001).

The revised summative energy equation has been made available to commercial forage testing laboratories and some have programmed it into their reporting system. Forage energy values generated from the revised summative energy equation (1x-maintenance TDN and 3x-maintenace NE_L) can be used in ration formulation packages that allow feedstuff energy values to be inputted, which does not include the NRC-2001 model or packages that incorporate its energy system completely. With the NRC-2001 model, NDF digestibility (% of NDF) can be inputted directly in the feed composition screen; this will influence the calculated energy value of the ration. However, the NRC-2001 model does not recognize the influence of NDFD on DM intake that was reported by Oba and Allen (1999).

The milk per ton index of Undersander et al. (1993) has been modified (Schwab and Shaver, 2001), and an easy to use Excel 5.0 spreadsheet called Milk2000 has been developed (http://www.uwex.edu/ces/forage/pubs/milk2000.xls). MILK2000 uses forage energy content estimated from the revised summative equation (Shaver et al., 2002) and forage DM intake calculated from NDF (Mertens, 1987) and *in vitro* NDFD (Oba and Allen, 1999) to predict milk production per ton of forage DM. In MILK2000, the intake of energy from forage for a 1350 lb. milking cow consuming a 30% NDF diet is calculated and the cow's maintenance energy requirement (proportioned according to the percentage of forage in the diet) is then subtracted from energy intake to provide an estimate of the energy available from forage for conversion to milk (NRC, 1989). Use of NDFD in the calculation of a revised RFV has been proposed (Shaver et al., 2002).

Fermentation analyses have long been used in university and industry research trials to assess silage quality. These analyses are now available for evaluating silage quality on farms through some commercial forage testing laboratories (Cumberland Valley Analytical Services, Maugansville, MD; Dairy One, Ithaca, NY; Dairyland Laboratories, Arcadia, WI; Rock River Laboratories, Watertown, WI).

USE OF MILK2000 SPREADSHEET (http://www.uwex.edu/ces/forage/pubs/milk2000.xls)

Milk per ton and milk per acre calculations provide relative rankings of forage samples, but should not be considered as predictive of actual milk responses in specific situations for the following reasons:

- equations and calculations are simplified to reduce inputs for ease of use,
- farm to farm differences exist, and

- genetic, dietary, and environmental differences affecting feed utilization are not considered.

Do not use different values for yield or quality measurements that are not statistically different. Animal response calculations are more sensitive than our measurement techniques of yield and quality. The spreadsheet will show a milk/ton difference when yield and quality may not be statistically different.

Standard inputs that are needed for MILK2000 include DM percentage and yield, CP percentage, 48-hour *in vitro* NDFD (*not* dry matter digestibility), NDF percentage, and starch percentage (corn silage only). Ash and ether extract should be entered if available, but book values can be entered instead (for normal corn silage, 4.3% for ash and 3.2% ether extract and for alfalfa/grasses, 10.0% ash and 2.7% ether extract, are recommended). Non-fiber carbohydrate and non-starch NFC are calculated values within the spreadsheet.

The MILK2000 alfalfa/grass worksheet contains NRC (2001) RFV100 and high quality alfalfa in rows 12 and 13 as a quality reference. You can begin entering your samples in row 14: sample identification in column A, quality data in columns B through G, and DM yield in column H. Calculated results are found in columns I through T. Depending on your spreadsheet settings, it may be necessary to push F9 after entering data for calculation of results

The MILK2000 corn silage worksheet contains NRC (2001) "normal" corn silage in row 12 as a quality reference. An example sample entry is included in row 13. You can begin entering your samples in row 14: sample identification in column A, processing in column B, quality data in columns C through J, and DM yield in column K. Calculated results are found in columns P through AC. Depending on your spreadsheet settings, it may be necessary to push F9 after entering data for calculation of results.

APPLICATION OF MILK2000

Corn Silage

Harvest timing

The optimum whole-plant corn silage DM content is about 35% with lower milk yield found for corn silage harvested too wet and especially too dry (Bal et al., 1997). The economic impact of harvesting corn silage at DM contents ranging from 25% to 45% was calculated using MILK2000 to determine milk per ton and assuming a $12.00/cwt.milk price; the loss in gross milk revenue incurred by harvesting corn silage too dry was $15,000 to $20,000 annually per 100 cows.

Kernel processing

The results of corn silage kernel processing trials have been mixed; Bal et al. (2000b) reported a 3.3 lb/cow/day increase in 4% fat-corrected milk yield and a 4.2 percentage unit increase in total-tract starch digestion due to processing, while Dhiman et al. (2000) found no advantage to processing on milk yield or starch digestibility by dairy cows in two of three studies. The economic impact of corn silage kernel processing was calculated using MILK2000 to determine milk per ton and assuming a $12.00/cwt.milk price; the gain in gross milk revenue related to kernel processing was about $6,000 annually per 100 cows. This calculation was done on 40% DM corn silage, and the estimated response to processing would be less on 30% DM corn silage and greater on 45% DM corn silage. Potential benefits of processing beyond starch digestibility related to chopping at a longer length of cut with less sorting of cobs in the feed bunk were not considered in this calculation. To be considered excellent for degree of processing there should be more than 95% kernel breakage and no cobs should be greater than a 1/8th concentric ring.

Height of cutting

Increasing corn silage height of cutting by 14 inches reduced whole-plant NDF and ADF contents by 7%- and 4%-units, respectively (Satter et al., 2000). High cutting would also be expected to increase NDFD, because the more highly lignified portion of the stalk would be left in the field. Satter et al. (2000) projected the DM per acre yield loss associated with high cutting at 5% to 8%. The economic impact of high cutting was calculated using MILK2000 to determine milk per ton and assuming a $12.00/cwt.milk price; the gain in gross milk revenue related to high cutting equates to about $8,000 or $3,000 annually per 100 cows for milk $/ton DM or milk $/acre, respectively. Height of cutting offers some flexibility for manipulating the quality of corn silage. In some situations, potential benefits of high cutting for reducing nitrates, mycotoxins, and(or) soil erosion may have merit. High cutting increases whole-plant DM content (Satter et al., 2000), which may be a plus for custom operators hoping to get started early in the harvest season on immature corn silage.

Hybrids

The estimated economic impact of various corn silage hybrids is presented in Table 1. Only bm_3 and nutri-dense hybrids show a significant positive deviation from the mean of all hybrids tested for milk per ton of corn silage DM. Milk per acre for the nutri-dense hybrids was similar to the average for all hybrids tested. Although milk per ton was highest for bm_3 of the hybrid categories compared, milk per acre for bm_3 was lowest of the hybrid categories compared and was $347 per acre lower than the average of all hybrids tested. Dairy producers buying corn silage from a grower and dairy producers growing their own corn silage may have a widely different view of bm_3 hybrids. There were no advantages to leafy hybrids. This observation agrees with the results of feeding trials with leafy hybrids (Bal et al., 2000a; Kuehn et al., 1999), but not Clark et al. (2002). High-oil and waxy hybrids were worse than the average of all hybrids tested for milk per ton and per acre (high-oil) and milk per acre (waxy).

Hay and Hay-crop Silage

Milk production decline with diminishing alfalfa quality (increasing ADF and NDF contents) is well established (Nelson and Satter, 1990). The MILK2000 spreadsheet was used to assess the impact of alfalfa quality on estimated milk per ton of DM and per acre. For the first scenario, alfalfa NDF content was varied from 40% to 50% while holding NDFD constant at 50% of NDF. The milk per ton and milk per acre results and gross milk returns are presented in Table 2.

The estimated milk per ton benefit for alfalfa with a relative feed value (**RFV**) of 175 (40% NDF) over alfalfa with an RFV of 125 (50% NDF) equates to about $10,000 annually per 100 cows. Because of reduced yield for the immature alfalfa, the estimated milk per acre benefit for

175-RFV alfalfa over 125-RFV alfalfa equates to about $3,000 annually per 100 cows. Data from Wisconsin quality-tested hay auctions show that dairy producers pay $0.90 per point of RFV above the RFV of a base quality alfalfa (Undersander, 2002). So, 175-RFV alfalfa would sell for $45 more than 125-RFV alfalfa. Based on the estimated milk per ton, the 175-RFV alfalfa was worth $49 more per ton than 125-RFV alfalfa. Because of the premium price paid for high-quality alfalfa, it needs to be targeted to high producing cows with the potential for a production response from the high quality. Average-quality alfalfa can be targeted to low-producing cows and replacement heifers.

Table 1. Impact of various corn silage hybrids on estimated milk per ton and per acre[1,2].

Hybrid	Milk lb/ton DM	Milk $/ton DM[3]	Milk lb/acre	Milk $/acre[3]
***bm*₃ (n=12)**	3410	409	21500	2581
Bt (n=130)	3140	377	25000	3000
High Oil (n=12)	3040	365	22500	2701
Nutri-Dense (n=10)	3240	389	24300	2917
Leafy (n=70)	3110	374	24600	2952
Waxy (n=56)	3090	371	22600	2712
All Hybrids (n=2407)	3110	374	24400	2928

[1]From MILK2000 (Schwab and Shaver, 2001; Schwab et al., 2001).
[2]Source: J.G. Lauer, UW-Madison Agronomy, 1995-2000 UW Silage Trials.
[3]Calculated using a $12.00/cwt. milk price.

Table 2. Impact of alfalfa quality on estimated milk per ton and per acre[1].

Alfalfa (%CP, %NDF, RFV)	Milk lb/ton DM	Milk $/ton DM[2]	Milk lb/acre	Milk $/acre[2]
(22, 40, 175)	2755	330	12398	1488
(19, 45, 150)	2549	306	12106	1453
(16, 50, 125)	2342	281	11710	1406

[1]Calculated using Milk2000 (http://www.uwex.edu/ces/forage/pubs/milk2000.xls).
[2]Calculated using a $12.00/cwt. milk price.

For the second scenario, alfalfa NDF content was set at either 40% or 50% while NDFD was varied from 40% to 60% of NDF within each concentration of NDF. The milk per ton results and gross milk returns are presented in Table 3. As NDFD decreased from 60% to 40% of NDF, milk per ton and $ per ton declined 671 lb and $80, respectively. This decline was greater than that observed with increasing NDF content from 40% to 50%, where milk per ton and $ per ton declined 413 lb and $50, respectively. Hay or hay-crop silage with low NDF content (40%) and low NDF digestibility (40%) shows lower predicted milk (lb or $) per ton than high NDF (50%), high NDFD (60% of NDF). The digestibility of NDF is a significant quality parameter that has been ignored in past forage evaluation schemes.

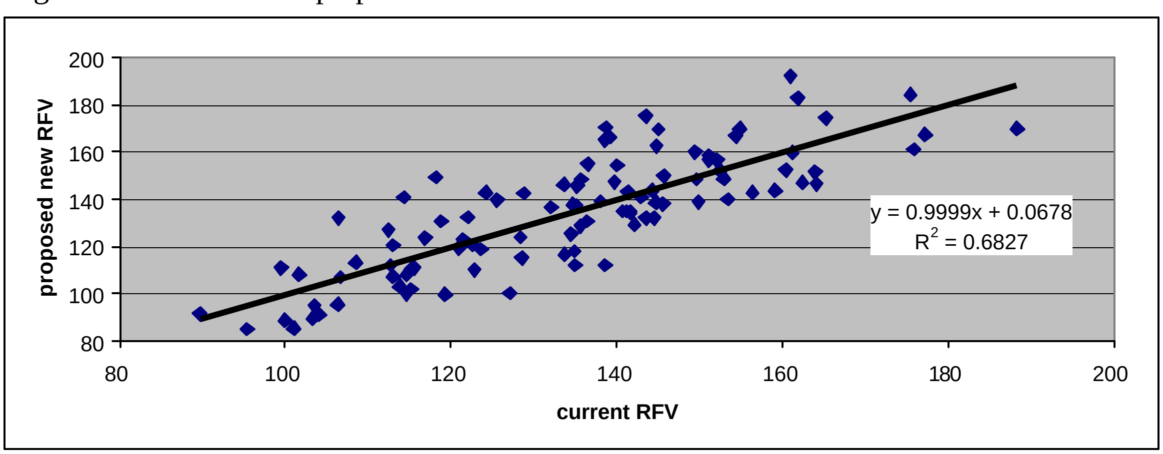
Table 3. Impact of alfalfa quality on estimated milk per ton and per acre[1].

CP%, NDF%	NDFD % of NDF	Milk lb/ton DM[2]	Milk $/ton DM
(22, 40)	60	3057	367
(22, 40)	50	2755	330
(22, 40)	40	2440	293
(16, 50)	60	2697	323
(16, 50)	50	2342	281
(16, 50)	40	1973	237

[1]Calculated using Milk2000 (http://www.uwex.edu/ces/forage/pubs/milk2000.xls).
[2]Calculated using a $12.00/cwt. milk price.

The RFV estimates used for forage evaluation and hay marketing are based on NDF and ADF concentrations, and have not considered differences in NDF digestibility. We (Shaver et al., 2002) proposed incorporating NDF digestibility measurements into the RFV calculations, where forage NE_L and DM intake would be estimated in a manner similar to that described for estimating milk per ton. The regression of current versus proposed RFV estimates is presented in Figure 1. The graph and its low R-square value (0.68) show that the proposed RFV varies above and below its line of equality with the current RFV. For example, samples with a current RFV of 140 have proposed RFV ranging from 110 to 170. The use of NDF digestibility measurements in forage evaluation schemes may detect variation in forage quality not previously detected in schemes based solely on fiber concentrations. The foregoing discussion may partially explain why dairy producers often report widely different animal performance from lots of hay with the same RFV under the current system. Factors that cause NDFD to vary include plant species, varieties within a species, stage of maturity at harvest, climatic condition that the crop was grown under, and interactions between these factors. We are hopeful that the proposed system, which incorporates dNDF into the calculation of RFV, will yield a better relationship with animal performance, but this has yet to be confirmed in feeding experiments.

Figure 1. Current versus proposed relative feed value calculations.



SILAGE QUALITY

Analyses commonly included in silage fermentation reports are pH, lactic, acetic, propionic and butyric acids, ammonia, and ethanol (Kung and Shaver, 2001). The pH of an ensiled sample is a measure of its acidity, but is also affected by the buffering capacity of the crop. In general, legume silages have a higher pH than corn or other grass silages and take longer to ensile because of their higher buffering capacity. Seldom do corn silages have a pH higher than 4.2. Such cases may be associated with extremely dry (>42% dry matter) silages that are overly mature or drought stricken. Because of its normally low pH (3.8), corn silage intake usually benefits from the addition of sodium bicarbonate prior to feeding to neutralize its acidity. Common reasons for legume silages having a pH higher than 4.6 to 4.8 include: ensiling at <30% dry matter (DM) which causes a clostridial fermentation, and ensiling at > 45-50% DM, which restricts fermentation. In the first example, a high pH due to clostridia is a definite indicator of an undesirable fermentation that has led to poor quality silage. However, in the second example, a high pH due to restricted fermentation is not always indicative of a poor fermentation or poor silage. But, silage from a restricted fermentation usually is unstable when exposed to air because insufficient amounts of acid were produced to inhibit secondary microbial growth.

Lactic acid should be the primary acid in good silage. This acid is stronger than the other acids in silage (acetic, propionic, and butyric), and therefore is usually responsible for most of the drop in silage pH. Further, fermentations that produce lactic acid result in the lowest losses of DM and energy from the crop during storage. Lactic acid should be at least 65 to 70% of the total silage acids in good silage. Extremely wet silages (< 25% DM), prolonged fermentations (due to high buffering capacity), loose packing, or slow silo filling can result in silages with high concentrations of acetic acid (>3 to 4% of DM). In such silages, energy and DM recovery are probably less than ideal. Silages treated with ammonia also tend to have higher concentrations of acetic acid than untreated silage, because the fermentation is prolonged by the addition of the ammonia that raises pH. A new microbial inoculant (Lactobacillus buchneri) designed for improving the aerobic stability of silages causes higher than normal concentrations of acetic acid in silages. However, production of acetic acid from this organism should not be mistaken for a poor fermentation and feeding treated silages with a high concentration of acetic acid does not appear to cause negative effects on animal intake.

The effect of high concentrations of acetic acid (> 4-6% of DM) in silages fed to animals is unclear at this time. In the past, some studies can be found where DM intake was depressed when silage high in acetic acid concentration was fed to ruminants. However, the depression in intake to high acetic acid in the diet has not been consistent. There has been speculation that decreased intake may be actually due to unidentified negative factors associated with a poor fermentation and not to acetic acid itself. For example, in recent studies, animals showed no indication of reduced intake when fed silages high in acetic acid due to inoculation with the bacteria Lactobacillus buchneri for improved aerobic stability. If a producer has intake problems due to silages with excessively high acetic acid (> 5-6% of DM), the amount of that silage should be reduced in the TMR.

A high concentration of butyric acid (>0.5% of DM) indicates that the silage has undergone clostridial fermentation, which is one of the poorest fermentations. Silages high in butyric acid are usually low in nutritive value and have higher ADF and NDF levels because many of the soluble nutrients have been degraded. Such silages may also be high in concentrations of soluble proteins and may contain small protein compounds called amines that have sometimes shown to adversely affect animal performance. High butyric acid has sometimes induced ketosis in lactating cows and because the energy value of silage is low, intake and production can suffer. As with other poor quality silages, total removal or dilution of the poor silage is advised.

High concentrations of ammonia (>12 to 15% of CP) are a result of excessive protein breakdown in the silo caused by a slow drop in pH or clostridial action. In general, wetter silages have higher concentrations of ammonia. Extremely wet silages (< 30% DM) have even higher ammonia concentrations because of the potential for clostridial fermentation. Silages packed too loosely and filled too slowly also tend to have high ammonia concentrations. Theoretically, high amounts of ammonia (by itself) in silage should not have negative effects on animal performance if the total dietary nitrogen fractions are in balance. However, if the high ammonia contributes to an excess of ruminally-degraded protein (RDP), this could have negative consequences on milk and reproductive performances. Blood or milk urea nitrogen can be used as an indicator of excess RDP. Often times, silage with high concentrations of ammonia coupled with butyric acid may also have significant concentrations of other undesirable end products, such as amines, that may reduce animal performance.

High concentrations of ethanol are usually an indicator of excessive metabolism by yeasts. Dry matter recovery is usually worse in silages with large numbers of yeasts. These silages are also usually very prone to spoilage when the silage is exposed to air. Usual amounts of ethanol in silages are low (< 1 to 2% of DM). Extremely high amounts of ethanol (> 3 to 4% of DM) in silages may cause off flavors in milk. We do not know the level at which ethanol becomes a problem in dairy cattle diets. Most ethanol that is consumed is probably converted to acetic acid in the rumen.

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