Ahead of the curve

Keys to next level forage management
Dairy farm nutrient mass balances (NMBs) are gaining traction in some parts of the U.S. and the European Union is considering widespread use on farms. This three-part series offers an in depth overview, including on-farm experience. Table Rock Farm, in western New York, has calculated their NMB every year since 2006. Meghan Hauser, one of the farm owners and general manager, offers suggestions based on her experience.

**HAS NMB HELPED KEEP CROP EXPENSES IN LINE?**

We don’t use NMB to measure expenses or to keep them in line, but it is a way for us to see if we are being effective with our nutrients, our farming practices and our management decisions.

For example, when we went to wide-swath hay harvest and more digestible corn, we made small changes to how forages were fed and saw a significant change in our nutrient balance.

Likewise, when we were required to stop using rBST, we could see that our nutrient balance was negatively affected.

As for fertilizer rate changes, we base these decisions more on farm trials performed by the Cornell University Nutrient Management Spear Program.

**HOW HAVE YOU USED THE NMB INFORMATION?**

There are many aspects of this tool that we find valuable. We like that the study tracks our progress over time. With a simple review we can clearly see if we are becoming better at nutrient balancing or not. We can also compare ourselves to our farming peers.

Trends can only be seen if you complete the study each year, so it’s important to share data each year. Multiple study years also allow you to see the effect a change in farming practices, the inclusion of a new nutrient or a change in bedding practices can have.

It is a tool we use to challenge ourselves to improve as farmers. It should be a goal for all of us to handle nutrients wisely, and the NMB is our annual report card in this area.

**ANY TRICKS TO MAKE ENTRIES EASIER?**

My tricks are not very tricky:

1. Keep good records during the year, including any details needed to complete the study (tons or yards of material used, manure exports, etc). A bookkeeping program that allows for notes or inclusion of weights/loads, etc is helpful.

2. Establish a spreadsheet that will give
you the study answers you need once you input that data.

3 For areas that require a formula or that follow a guideline (converting yards to tons for example), establish that information with an expert and record it in your spreadsheet for future use.

4 Keep data from previous years handy so you can refer to it and check that this year’s answers are reasonable.

5 Involve your nutritionist or other ag professional. I input tons of feed purchased, then share this with our nutritionist to make sure feed ingredient nutrient information is accurate.

6 Understand that after you get through the process once, making sure to adjust how you keep records will streamline the process for next year. For example, tracking tons of soymeal or canola meal purchased makes the total nutrient calculation much easier than if the accounting system only tracks total amount paid for a commodity. ■

Meghan Hauser and her father Willard DeGolyer, Table Rock Farm, New York.

Want to be better than average? Use dairy farm nutrient mass balances to improve performance

By Mart Ros, Karl Czymmek and Quirine Ketterings

With so many challenges in the dairy industry today, farm managers realize they need to be “better than average” to be in business for the long-term. Running a whole-farm nutrient mass balance (NMB) can help achieve this. The NMB assessment software and interpretation of results developed by the Cornell University Nutrient Management Spear Program can quickly evaluate a farm NMB. Tracking trends in NMBs for farms over the past 10 years in New York shows that farmers who calculate their whole-farm NMB each year tend to improve their balances over time. More farms meet the feasibility benchmarks now than in early years, illustrating that improvements can and are being made. Given the harsh reality in recent years with low milk and commodity prices, improving NMBs can provide profitable opportunities to improve operational efficiency.

By calculating their NMB using the Cornell University software (available at nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/MassBalances.html), farm managers are able to assess nitrogen (N), phosphorus (P), and potassium (K) use in a way that measures farm production performance and also serves as a key whole-farm sustainability indicator. A farm's year-on-year performance can be assessed to track progress and compare nutrient use efficiency to other farms. It is especially instructive when comparing with direct peers, such as farms with similar milk production levels or animal densities.

The NMB assessment tracks nutrient purchases through feed, fertilizer and other sources, as well as nutrient exports such as milk, feed and manure, and reports N, P, and K balances per acre and per hundredweight of milk produced. The software then calculates

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the whole-farm NMBs by subtracting the annual sum of nutrients exported from a farm from the nutrients imported onto the farm (Figure 1). The difference between these imports and exports is called the balance, and this is a measure of how many nutrients (in lbs) remain on the farm or are vulnerable to loss. The balance per tillable acre is a measure of the environmental impact of a farm (nutrient loss or accumulation per acre of cropland). The nutrient balance per cwt of milk sold is a measure for the amount of nutrients “used” to produce a unit of milk. This tells us something about the production efficiency at which the farm operates (in many cases equated to money left on the table).

The whole-farm NMB estimates a solid key performance indicator from a relatively small amount of data. To conduct a NMB assessment, participants fill out four sheets of paper with information on the size of the farm (number of acres and number of cows) and quantities of nutrient-containing imports and exports that entered or left the farm during a calendar year. These numbers are entered in the Cornell Nutrient Mass Balance software, which calculates the N, P, and K balances for the farm.

For imports, the NMB distinguishes between feed imports, fertilizer imports, purchased animals and bedding/manure. For exports, nutrients sold in milk, animals, crops and manure or other products are considered. Information on the quantity and the nutrient content of these items is needed to calculate the total amount of N, P, and K that enters and exits the farm. Using farm-specific nutrient analyses is preferred, but for several crops or products, book values are included in the software, and can be used as a substitute.

In addition to the imports and exports listed above, information is gathered on the forage and grain crops grown for feed on the farm itself. Although homegrown feed is not an import or an export, and therefore does not contribute directly to the balance, it allows calculation of other crop and ration performance indicators that can tell us more about the efficiency of the farm and opportunities to improve over time.

There are three general types of nutrient balance: negative balances, slightly positive balances and largely positive balances. It is important to understand that in terms of balances, “positive” and “negative” have unexpected meanings. Negative balances have higher exports than imports, which means that there is a net outflow of nutrients from the farm. In the short-term this may be desirable, for example when P levels in the soil are really high. However, if negative balances are sustained over a long time, soil mining of nutrients (such as P and K) will occur and when soil fertility levels drop below optimal, crop yields will be impacted. Slightly positive balances are desirable, as biological processes always need inputs that are a little larger than the outputs. It is therefore expected that nutrient imports will be larger than the exports, and as long as the difference remains small enough, this is a sustainable practice. However, when the nutrient imports are a lot larger than the exports, risk of environmental losses is increased. Although the difference can be temporarily stored in feedstocks on the farm, some portion of the remainder is often lost (this is mainly the case for N) or stored in the soil and slowly lost over time (for P and to a lesser extent for K). The ideal level of a NMB is thus larger than zero, but not so large that the nutrients are used inefficiently, as this costs money and is potentially harmful to the environment.

Feasible (target) balances were established for N, P, and K in collaboration with farmers and farm advisors in New York and are shared in the companion article “Better than average: Feasible balances for dairy farms that produce most forage needs.”

Mart Ros (m2249@cornell.edu) is with the Cornell Nutrient Management Spear Program. Karl Czymmek (kjc12@cornell.edu) is with the Cornell Nutrient Management Spear Program and Cornell CALS PRO-DAIRY. Quirine Ketterings (qmk2@cornell.edu) is with the Cornell Nutrient Management Program Spear Program. More information is available about the program and the NMB software at nmsp.cals.cornell.edu.

**FIGURE 1**
Overview of farm imports and exports included in a nutrient mass balance (NMB). Only easily measurable components are considered. The nutrients in the resulting balance either remain on the farm system or are lost to the environment.
Key performance indicators, such as milk urea nitrogen, ration nitrogen (N) and phosphorus (P) levels, corn stalk nitrate testing, and soil fertility assessments are only useful if we know what to strive for. Similarly, feasibility ranges are needed for whole farm nutrient mass balances (NMBs) as a key performance indicator of nutrient use efficiency at the whole-farm level. In New York, such targets, or feasible balances, were determined for the NMB per acre cropland and the NMB per hundredweight (cwt) of milk produced, based on NMB data from 102 New York dairies. Feasible balances per acre were set at the third quartile of the farm distribution. In other words: if three out of four New York dairy farms operate at or below this NMB, it should be feasible for the fourth farm to also do so. For the balance per cwt farms were divided in two groups, those below and those above, the average balance per cwt for all farms. The actual feasible balances that resulted from this are in Table 1.

Farms that operate in the feasible ranges for both balances (per acre and per cwt) are said to be in the optimum operational zone or “green box”. This is shown in Figure 1 for all three nutrients. The Green Box figures allow for a quick indication of a farm’s sustainability. Long-term records from a number of farms indicate that balances can be maintained in the Green Box for many years in a row.

Because there is information on the crops and nutrient amounts grown on-farm as well, the NMB assessment can provide efficiency indicators beyond the actual whole-farm balances and Green Box concept. The additional key performance indicators can give insight why a farm operates within or outside the green box. For most of these indicators, a threshold value is derived. Should a farm cross this value, it is likely that it will operate beyond the feasible balances. This way we can indicate where the farm is likely to have the largest opportunities to improve the balances. In the example below (Table 2) the “Example Farm” has high N fertilizer imports (64 lbs/acre) which may have contributed to a N balance that slightly exceeds the feasible range. The N imported through purchased feed (107 lbs/acre), however, is not crossing the indicator. This suggests that this particular farm may have more opportunities to reduce the N balances by re-examining fertilizer use, than by

### TABLE 1
Feasible balances for dairy farms in New York

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Lbs per acre</th>
<th>Lbs per cwt milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>0 ≤ 105</td>
<td>0 ≤ 0.88</td>
</tr>
<tr>
<td>P</td>
<td>0 ≤ 12</td>
<td>0 ≤ 0.11</td>
</tr>
<tr>
<td>K</td>
<td>0 ≤ 37</td>
<td>0 ≤ 0.30</td>
</tr>
</tbody>
</table>

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Better than average: Feasible balances for dairy farms that produce most forage needs cont’d from page 5

evaluating dairy rations and decreasing feed imports.

Although this table of indicators gives a general indication of where improvements in nutrient management can be made, it does not provide a detailed and guaranteed protocol to increase production with fewer nutrients. To make improvements in farm management, the NMB results need to be discussed with the farm’s nutritionist, crop specialist and planner. Collaboration among these experts can provide a level of detail that is lacking in the NMB assessment itself. For example, this farm may have higher N purchases because they have poorly drained soils, leading them to grow more grass hay, which responds to available N from fertilizer. Or perhaps they are supplementing corn with sidedress N because of less efficient manure use.

The Green Box figures, the Opportunity Table, and the trend figures for farms with multiple years of data make NMB information easy to interpret. In addition, the information needed is relatively quickly obtained if records are kept throughout the year. A companion article shows how some producers have adjusted recordkeeping to streamline the process. Multiple years of NMB assessments help evaluate the impact of management changes on balances, while also helping filter out effects of dry or extremely wet years with below-average yields, which may necessitate larger feed imports, and would thus result in higher balances.

In New York, a field-specific adaptive management approach to N management for corn was put in place by the partnership of the New York State Department of Agriculture and Markets (NYS DAM), the New York State Department of Environmental Conservation (NYDEC), the New York State Natural Resources Conservation Service (NY-NRCS), and Cornell University in 2013. The approach allowed farmers to increase N applications for corn beyond the foundational guidelines of the land grant university, as long as actual yields are recorded and the corn stalk nitrate test (CSNT) results of the fields that received the elevated N rates is managed below 3,000 ppm over time. The adaptive management process was revised in 2018 and now includes the statement: “Dairy farms that have whole farm nutrient mass balances (NMBs) with N balances of 105 lbs/acre or less, and that maintain a three-year running average N balance at or below 105 lbs/acre, meet the adaptive management guidelines and do not require additional field-specific evaluations beyond recording yield.” This addition to the adaptive

### TABLE 2
Opportunity table: efficiency indicators and the threshold values beyond which farms risk exceeding feasible balances. Red cells are indicators that exceed the threshold values.

<table>
<thead>
<tr>
<th>Indicator to predict likelihood of exceeding feasible balances</th>
<th>Example Farm 2016</th>
<th>High risk of exceeding the feasible balances if</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance per acre (lbs/acre)</td>
<td>106 N 13 P 29 K</td>
<td>&gt; 105 N &gt; 12 P &gt; 37 K</td>
</tr>
<tr>
<td>Balance per cwt milk (lbs/hundredweight milk)</td>
<td>109 N 0.14 P 0.30 K</td>
<td>&gt; 0.88 N &gt; 0.11 P &gt; 0.30 K</td>
</tr>
<tr>
<td>Milk per cow (lbs/cow/year)</td>
<td>25575 N - P - K</td>
<td>&lt; 20000 N - P - K</td>
</tr>
<tr>
<td>Animal density (animal units/acre)</td>
<td>0.8 N - P - K</td>
<td>&gt; 1.0 N - P - K</td>
</tr>
<tr>
<td>Whole-farm nutrient use efficiency (%)</td>
<td>38 N 45 P 45 K</td>
<td>&lt; 44 N &lt; 51 P &lt; 39 K</td>
</tr>
<tr>
<td>Purchased feed (lbs/acre)</td>
<td>107 N 19 P 35 K</td>
<td>&gt; 121 N &gt; 20 P &gt; 38 K</td>
</tr>
<tr>
<td>Feed (tons dry matter/animal unit)</td>
<td>3.7 N - P - K</td>
<td>3.5 to 7.5 N - P - K</td>
</tr>
<tr>
<td>Feed use efficiency (milk, %)</td>
<td>28 N 31 P 19 K</td>
<td>&lt; 20 N &lt; 25 P &lt; 11 K</td>
</tr>
<tr>
<td>Homegrown feed (% dry matter)</td>
<td>58 N - P - K</td>
<td>&lt; 62-65 N - P - K</td>
</tr>
<tr>
<td>Homegrown forage (%)</td>
<td>40 N - P - K</td>
<td>- N - P - K</td>
</tr>
<tr>
<td>Homegrown grain (%)</td>
<td>23 N - P - K</td>
<td>- N - P - K</td>
</tr>
<tr>
<td>Homegrown nutrients (% dry matter)</td>
<td>41 N 34 P 59 K</td>
<td>&lt; 50 N &lt; 50 P &lt; 50 K</td>
</tr>
<tr>
<td>Crude protein (CP) and P in all feed (%)</td>
<td>20 N 0.50 P 1.51 K</td>
<td>&gt; 17 N &gt; 0.40 P &gt; 0.60 K</td>
</tr>
<tr>
<td>CP and P in purchased feed (%)</td>
<td>28 N 0.79 P 1.47 K</td>
<td>&gt; 30 N &gt; 0.60 P &gt; 0.60 K</td>
</tr>
<tr>
<td>CP in homegrown feed (%)</td>
<td>14.5 N - P - K</td>
<td>&lt; 11.8 N - P - K</td>
</tr>
<tr>
<td>Fertilizer (lbs/acre)</td>
<td>64 N 6 P 18 K</td>
<td>&gt; 39 N &gt; 6 P &gt; 38 K</td>
</tr>
<tr>
<td>Crop exports (lbs/acre)</td>
<td>11 N 1 P 8 K</td>
<td>&lt; 1 N &lt; 1 P &lt; 1 K</td>
</tr>
<tr>
<td>Manure exports (lbs/acre)</td>
<td>18 N - P - K</td>
<td>&lt; 1 N &lt; 1 P &lt; 1 K</td>
</tr>
<tr>
<td>Overall crop yield (tons dry matter/acre)</td>
<td>33 N - P - K</td>
<td>- N - P - K</td>
</tr>
<tr>
<td>Acres receiving manure (%)</td>
<td>78 N - P - K</td>
<td>- N - P - K</td>
</tr>
<tr>
<td>Land in legumes with manure (%)</td>
<td>21 N - P - K</td>
<td>- N - P - K</td>
</tr>
</tbody>
</table>
management approach recognizes the value of on-farm evaluation of practices to find better management approaches and the need for flexibility in field management as every farm is unique, as long as key whole-farm performance targets are met.  

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**Cornell sorghum variety and establishment**

*By Tom Kilcer*

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Sorghum, mainly a crop of the deep south, is being planted on more acres across the northeast. Originally relegated as an emergency summer feed when earlier crops had failed, or for part-time livestock farms, the crop is going mainstream because of the number of economic and practical advantages it offers. The sorghum species is supported by major breeding programs and has a huge, diverse genetic base. This allows tailoring to a wide range of needs and conditions. With New York Farm Viability Institute support we researched best management practices and varieties for north of the Mason-Dixon line.

Genetic choice matters. Nearly all the energy from highly digestible fiber, sugar and starch is stored in plant cells. BMR agronomic types with the BMR gene have significantly less lignin in the plant, which makes the fiber portion more digestible, with more utilzable feed for your effort.

Sorghum is grown as a one-cut, full-season crop. It has been crossed with Sudan grass to make sorghum-Sudan, which is normally a multi-cut crop. Sorghums, and to some degree sorghum-Sudan, have had a problem with severe lodging. Having two lbs of grain, 12 feet in the air, on the top of a stalk as thin as a fishing pole, is a prescription for disaster. Recently, brachytic dwarf varieties have become available. This gene shortens the stalk between the nodes but leaves the full number of nodes for high forage yield and gives good standability. The shortened nodes of the brachytic make a fatter stalk that maintains yield. Grain sorghum is non-BMR and a true dwarf with less nodes and low forage yield. The short season (85 – 90 day) BMR brachytic dwarf sorghum we tested has averaged, in multiple nitrogen trials, yields of 25 or more tons of 35 percent dry matter (DM) silage at optimum nitrogen, on ground that normally yields 18 to 20 tons of corn silage. Unfortunately, that short season variety is no longer sold, although longer season varieties are still available.

Recently in a NYFVI variety trial we tested another genetic line that has a male sterile gene. It does not produce pollen and so no seed is set (unless there is another pollinating variety nearby). Thus, there is no seed head to pull the crop down, yet the variety still has very high energy stored in the plant cells. In our 2017 replicated variety trial, a male sterile from Richardson seed, 400/36, yielded a mean of 31.59 tons of 35 percent dry matter silage/acre, in a trial where the overall mean was 21 tons silage/acre. (Caution, not all are equal, a different company’s male sterile only yielded 16.18 tons of silage.)

We tested sorghums within 20 miles of the Canadian border where in 2017 the yields were from 12 to 20.8 tons of silage/acre with a mean of 17. In 2018, a warmer summer, varieties ranged from 20.6 to 26.8 tons of 35 percent DM silage/acre at the same site. Our overall experience is that BMR sorghum frequently equals or exceeds corn silage in yield. Sorghum really shines when it turns hot, dry, or both. It will produce twice as much dry matter on an inch of water than does corn silage. It cannot get by on no water, but does give you more on limited water. Corn silage shuts down at temperatures over 85°F. Sorghum continues to grow up to 105°F. This is critical in southern areas with their hotter summers. Conversely, in cool or cold summers, all sorghums stand still. Corn will clearly out-yield the heat-requiring sorghum species.

A critical factor with sorghum is that it needs to be planted in warm soils. Temperature must be over 60°F with an increased forecast. I had a complete wipe-out of a research trial where we planted when the soil was 62°F. Three days later an unexpected cold rain dropped soil temperatures to 40°F, killing the seeds with imbibing chilling injury. I have also seen this happen with corn.

As sorghum is planted after haylage is finished, this fits very well in a double crop with winter forage. The winter forage adds eight to 10 tons of very highly digestible, high protein forage. From that same acre of land, sorghum can produce yields equal or exceeding corn silage. Because of allelopathic compounds from the winter forage, it is not suggested to no till sorghum into the winter grain stubble. The soil needs to be worked shallow, vertical tilled, or zone tilled (incorporating manure) or have several inches of rain to move the...
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Allelopathic compounds out of the seed zone.

Planting depth is best at ¾ to one inch deep. Cultipacker seeders plant it too shallow, so it is susceptible to drying, which can kill the emerging seedling. Narrow drilled rows and 15-inch row widths work best with sorghums, but planting in 30-inch rows to match your chopper is possible (do not use 30-inch rows for organic systems). Drilled BMR sorghum is suggested at 10 lbs of seed/acre. For 15-inch rows, eight lbs of seed is enough. For 30-inch rows five lbs of seed/acre is the suggested maximum. Higher seeding rates significantly increases the lodging. An attractive part of sorghum is that seed cost is about $120 less/acre than many of the corn varieties. Another benefit of sorghum is that it will tiller profusely and fill in thin areas until all sunlight is captured. A major problem with using even modern double disk drills is that the seed drop tubes are corrugated flexible rubber. As they flex on a pass over the field, the corrugations hold the seed, and then as it straightens, the seed is dumped in a pile, instead of being spread uniformly. We highly recommend that these be switched for sleeved tubes that deliver more uniform seed placement. This is critical for winter forage planting also.

Fertilizer is similar to corn silage. Slightly higher nitrogen (sulfur is critical if no manure has been applied) will give higher crude protein and thus increase the feed value of the forage produced. Caution: too much nitrogen even from manure, and especially when there is a shortage of sulfur, plus dry conditions followed by rain, can cause nitrate issues. We have grown sorghum very successfully on clay but it does not tolerate wet feet in a soggy summer. Topdressing nitrogen will help to pull the crop through, but it will not fix anaerobic conditions.

For the sorghums that emerge slower, especially the brachytic dwarfs, herbicide is critical. With a safener applied to the seed, atrazine plus metolachlor can be used. It is critical that the herbicide be applied immediately after you finish planting, not a week later. If annual grass gets started there are no post emergent herbicides available to control the weeds and you can lose the crop.

Sorghum-Sudan normally emerges much faster than most sorghums, especially the slower brachytic sorghum type. By utilizing a stale seed bed (prepare the field, wait a week for weeds to emerge, then harrow to kill them and immediately plant) and a higher seeding rate (60 to 75 lbs seed/acre instead of 40), we have completely controlled weeds with no herbicide. This has been a boon to organic farms (sorghum-Sudan is not GMO, but is traditional breeding) that spend considerable time cultivating corn during the critical period when they should be harvesting haylage. Rapidly emerging sorghum-Sudan in narrow rows controls weeds by shading, eliminating the cultivating and the soil erosion from corn, while providing high-energy forage.

Pests are few. Pea aphids feed on the plant but do no damage; the sorghum aphid is confined to the south. A very intense outbreak of armyworm will need to be controlled. On the plus side, sorghum species’ natural compounds kill corn rootworm larvae. The rootworm adults also do not lay eggs in the crop. Thus, for a year or unusually two after sorghum, you will not need to plant the more expensive rootworm resistant corn. Another benefit we found was that deer hide in the sorghum and come out to eat the neighbor’s corn. They leave the sorghum alone.

Sorghum is not a magic crop. You need to soil test before planting, use a recommended fertilizer program, control weeds, and harvest properly. With this basic management, sorghum is a crop for northeast farmers to consider. It is one more way to reduce risk in your forage production and to perhaps lower your digestible forage costs.

Tom Kilcer (tfk1@cornell.edu) is a former Cornell Cooperative Extension program leader and is a private consultant with Advanced Ag Systems. Look for his harvest and feeding strategies article in the upcoming July The Manager issue.

On-farm instant quality analysis

By Jerry Cherney and Debbie Cherney

Near infrared reflectance (NIR) spectroscopy has been used to evaluate forage quality since the early 1980s. Until recently, these were relatively sensitive, large laboratory instruments that required finely-ground, dry forage samples for analysis. New technology has allowed the development of small, hand-held instruments that required finely-ground, dry forage samples for analysis. New technology has allowed the development of small, hand-held
NIR units that can work with wet, chopped forage or silage.

**WHAT IS NIR SPECTROSCOPY?**

Light from a spectrometer is either absorbed or reflected off a sample. By evaluating the spectra (wavelengths of light reflected), the instrument can relate the spectra to the known laboratory quality values for a particular sample. A representative group of samples with known quality values is scanned and used to calibrate the instrument for a particular type of sample (e.g., corn silage). When a sample with unknown quality values is scanned, the calibration equation predicts the quality of the sample. All NIR results are predictions based on calibration equations or algorithms. As long as the calibration sample set is representative and robust, the predicted values are likely to be accurate.

**PORTABLE NIR UNITS**

Research studies have documented that forage or silage significantly changes in composition from day-to-day, particularly the dry matter (DM) composition. Daily adjustments to reduce variability between formulated and delivered rations has the potential to either increase dry matter intake and increase milk production or to significantly reduce feed costs. Multiple scans with a handheld NIR will provide a more representative sample for analysis and will also assess variability in a forage lot.

Handheld, on-farm instruments and laboratory NIR instruments have three major differences.

1. The technology must be redesigned in a much smaller package for handhelds.

2. The software must deal with the relatively high moisture content of samples (vs. dry samples).

3. The scanning procedure must be modified to account for relatively large particle size (chopped or whole hay vs. finely ground samples).

At least five companies produce handheld NIR units that potentially can be used with forage/silage crops (Table 1). All were developed outside of the U.S. All are sold in the U.S., with the exception of the poliSPEC, which can be purchased in Canada. All were developed primarily to focus on forage crops, with the exception of the SCiO, which was developed for much broader use. Stratio (a U.S. company) will release a small unit somewhat larger than SCiO (LinkSquare-SWNIR, 800 to 1600 nm) in early 2020.

All units are basically a miniaturized version of a laboratory NIR instrument, with the exception of the SCiO, which has a solid-state spectrometer on a chip. All units have an occasional or more often regular requirement to be standardized with a reference or check scan. All hand-held units have an onboard computer to process spectra and generate results, with the exception of the SCiO, which transmits spectral data to a cell phone, with data analysis on the web. The Aurora and SCiO are all being evaluated for plant breeding selection purposes because they allow user calibration.

**FREQUENTLY ASKED QUESTIONS**

Are these portable units robust enough for on-farm deployment?

Small NIR units have been shown to be robust enough to be mounted on field harvesting equipment, so it is likely that hand-held units can be developed that are sturdy enough for on-farm use.

Are these NIR units capable of sufficient accuracy with wet, chopped samples?

Accuracy of lab NIR units has historically been based on having a dry, finely-ground forage sample, which maximizes the uniformity of the sample exposed to the NIR light source. Wet, chopped forages are much more difficult to analyze accurately. The sample area actually analyzed by a handheld NIR is less than 0.5 inches in diameter. Chopped forage has individual pieces much larger than 0.5 inches.

Particle size is addressed by either increasing the number of scans per sample and/or exposing the NIR to a larger area per scan or by moving it over the sample during the scan (Table 2). While moving the NIR light source over the sample during scanning increases the area analyzed, it also increases the possibility of external light interfering with the spectral data collected.

Are calibrations either specific to your region, or sufficiently global, to provide reasonable results?

To-date, most calibrations for handheld NIRs have been developed outside of North America. Companies
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are in the process of developing forage quality calibrations that are more specific to North America. Samples analyzed by any NIR need to come from the general population of samples that was used to calibrate the instrument. If a farmer’s sample is outside the range of the calibration sample set, values generated by the instrument may be unreliable.

Which forage constituents can be analyzed accurately?

The relative accuracy of NIR for evaluating forage constituents is generally:
- DM (or moisture) > CP > NDF > ADF > ADL > IVTD > NDFD
- Which forage constituents can be analyzed accurately?

The range in accuracy among constituents is mostly due to the degree of variability in laboratory determinations. Lab digestibility measurements will always be less precise than chemical analyses. It is unclear at this time whether handheld NIRs will be sufficiently accurate enough to evaluate digestibility or fiber digestibility.

Testing in NY

We obtained the Aurora, the NIR4, the SCiO, and the X-NIR for testing in New York and hope to clarify the potential of instant, real-time nutrient analysis of forage to be rapidly incorporated into farm management decisions. Range in cost is from less than $1,000 to over $20,000 for the instruments, typically with annual contracts for maintenance and calibration updates of several thousand dollars. If these units can significantly reduce day-to-day variation in ration composition even the most expensive units have the potential to pay for themselves in a year or two, depending on herd size. As this is not an example of “size-neutral” technology, the number of cows in your operation will factor into the economic feasibility of on-farm, handheld NIR.

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Exploring the relationship between physically effective and undigested fiber

By Rick Grant and Wyatt Smith

Recent research at Miner Institute has focused on the relationship between undigested and physically effective NDF (abbreviated as uNDF and peNDF). Physically effective NDF is commonly measured using the 4-mm screen in the Penn State Particle Separator and uNDF is measured as the undigested NDF following 240 hours of in vitro fermentation. Both of these measures are highly useful in the field because they allow us to do a much better job of predicting the cow’s response to NDF. How dietary fiber particle size and digestibility interact to affect the chewing, intake, and productive responses of the cow is a hot topic among nutritionists. We aimed to answer these questions with our research:

1. Are there optimal peNDF concentrations as uNDF240 varies in the diet?
2. Can we adjust for a lack of peNDF by adding more uNDF240 in the diet?
If forage uNDF240 is high, can we compensate by chopping the forage finer?

Some nutritionists have questioned whether particle size is actually that important if we truly understand fiber digestibility (i.e., uNDF240, fast- and slow-fermenting NDF). Our work indicates that particle size, measured as peNDF, is important – just maybe not for the reasons we have always assumed, such as rumination. In fact, forage particle size seems to influence eating time more than ruminating time, which has important consequences for the cow’s time budget and feedbunk management.

THE MINER PENDF AND UNDF240 STUDY

We evaluated the effect of feeding lower (8.9 percent of ration dry matter) and higher (11.5 percent of ration dry matter) dietary uNDF240 with either low or high peNDF. The diets contained approximately 35 percent corn silage, 1.6 percent chopped wheat straw, and chopped timothy hay with either a lower or higher physical effectiveness factor (pef). A Haybuster with its hammer mill chopping action created the two particle sizes of dry hay. The lower uNDF240 diets contained about 47 percent forage and the higher uNDF240 diets contained about 60 percent forage on a dry basis. The main dietary ingredients are shown in Table 1.

Table 2 summarizes the main fiber fractions in these four diets. In addition to the uNDF240 and peNDF, we have reported a new measure – peuNDF240 – which was calculated as pef x uNDF240. Note that the low uNDF240, high peNDF diet and the high uNDF240, low peNDF diets, although differing in uNDF240 and peNDF, contain the same peuNDF240 value. Considering the effects of particle size and uNDF240 together (as with peuNDF240) helps to explain cow productive responses as shown in Table 3.

The “bookend” diets that contained the extremes in either uNDF240 or peNDF (i.e., low uNDF240 and peNDF versus high uNDF240 and peNDF) consistently and predictably differed in DMI, milk yield and composition, and chewing behavior. The two intermediate diets that contained either low uNDF240 and high peNDF or high uNDF240 and low peNDF resulted in similar DMI and energy-corrected milk. It is interesting and important to note that that cows had similar energy-corrected milk production regardless of whether the diet was higher in uNDF240 but chopped more finely, or lower in uNDF, but with a coarser particle size.

Cows on the low uNDF240, low peNDF treatment spent roughly 45 minutes less each day at the bunk eating – while eating over five lb/day more of total mixed ration. The difference in eating time was driven by the time it takes the cow to reduce the TMR

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Exploring the relationship between physically effective and undigested fiber cont'd from page 11

Cows fed these types of silage-based diets tend to chew TMR to a common particle size before swallowing, therefore rumination time will be largely unaffected. Excessive time spent at the bunk chewing feed in order to swallow it needs to be avoided since cows should only spend about three to five hours per day eating to have natural feeding behavior.

THE BOTTOM LINE

Physically effective uNDF240 (pef x uNDF240) appears to be a useful concept when formulating diets. We were able to elicit the same response by the cow whether we had lower uNDF240 in the diet chopped more coarsely, or whether we had higher uNDF240, but chopped more finely. If future research confirms this response across a wider range of diets, then when forage fiber digestibility is lower than desired, a finer forage chop length should enhance feed intake and energy-corrected production.

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Controlling compaction: Do’s and don’ts

By Peter Wright and Joe Lawrence

Farming is ever-changing and improvements to perform timely field operations can impact soil health. Larger, road-ready trucks and equipment with higher tire pressures and larger axle loads made to spread manure, plant, spray and harvest quicker can cause severe soil compaction. Predicted wetter seasons and the need to maximize crop yields and forage quality increases the time pressure for field operations.

Compaction by field operations during wet conditions (if you can form a ball of soil in your hand it is prone to excessive compaction) reduces the soil pore sizes and interconnectivity of the soil pores. This will:

- Reduce crop yield potential by impeding root growth and limiting the volume of soil explored by roots, thus decreasing the ability of crops to take up nutrients and water efficiently from soil.
- Increase the potential for water runoff and soil erosion.

During wet seasons, this will:

- Reduce crop yield potential by water logging the soil, limiting aeration and slowing soil warming.
- Increase the potential for water ponding on the surface.

Preventing soil compaction needs to be considered when devising your agronomic system. Plan cropping systems, including crop rotations, tillage methods and equipment, used to minimize compaction.

DO:

- Investigate your soils to determine the extent of compaction damage:
  - Look for damage from areas with high traffic, ponding, low yields or erosion.
  - Dig holes to look for limited or horizontal root development.
  - Understand the differences between surface and subsurface compaction layers.
- Use a soil health indicator to continually monitor physical and biological characteristics.
- Plan rotations to include a variety of fibrous and tap rooted crops.
- Utilize cover crops that provide rooting systems that will mature.
- Minimize tillage operations.
- Limit field work during wet conditions where possible until soil (even subsoil) is friable.
- Limit axle weight to less than 10 tons and tire pressures to less than 35 psi for field equipment.
- Long-term items to consider:
  - Investigate practices that allow your farm to move to more reduced and no-till practices.
  - Use precision agriculture to define traffic lanes.
  - Install drainage systems.
  - Develop the capacity (with your equipment and/or custom operations) to perform field operations quickly enough after waiting for friable soil conditions.

DON’T:

- Ignore the impacts of compaction when operating on wet fields.
- Spread traffic out: 90 percent of
compaction damage can occur on the first pass.

- Use road trucks in fields (or limit them to headlands or defined paths).

- Arbitrarily deep till without determining the depth needed (at least an inch below the compacted layer) and without waiting for dry conditions.

- Count on frost to repair compaction damage.

Soil health is vital to obtain consistent high yields. A number of commercial soil tests are available to help assess soil health. These can be valuable tools to develop a strategy to control compaction; however, when choosing a soil health assessment tool, be sure to review the results the test will provide and ask if the results will help point to actionable remediation/improvement strategies. The physical and biological properties relating to compaction include: soil texture, bulk density, available water capacity (relates to soil pore size), aggregate stability, surface and subsurface hardness (use a penetrometer if available) and organic matter content.

Minimizing tillage to increase soil cover and reduce field operations can have significant benefits to control compaction. Limiting the number of times that fields are trafficked by reducing tillage can significantly reduce compaction. Continued deep tillage can create a plow pan just below the tillage implement that resists root penetration. Residue on the surface may help support wheel loads.

Crop rotations that include alfalfa, sorghum and cereal cover crops encourage root development to both break up the soil but also to increase organic matter and improve aggregate stability. These are an important part of an agronomic strategy to limit compaction impacts.

To provide the forage needs of your dairy animals, dependable high yields of quality forages are vital. Don’t let compaction limit the productivity of your crop fields.

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Bunker silo and silage pile safety

By Julie Berry

People are the greatest resource on a farm. Accidents are never planned, but those few minutes can have long-lasting and traumatic impact. Proactive steps can help reduce risk during corn silage harvest and feed-out.

“The word ‘safety’ needs to be used as a verb rather than a noun on today’s dairies,” said Doug DeGroff, Diversified Dairy Solutions, who was seriously injured in a farm accident 10 years ago.

Horizontal silo forage storage systems are widely used because they are economical and maintain high-quality forage at low cost, with acceptable shrink. Known hazards associated with fatalities and serious injuries in bunker silos and drive-over silage piles are tractor or truck rollover, run-over by or entanglement in machinery, fall from height, crush/engulfment by collapsing silage and complacency or fatigue.

All farms should develop and follow written silage safety guidelines, conduct mandatory safety training and have regular safety meetings, said Curt Gooch, Cornell CALS PRO-DAIRY, to cooperative extension educators at a regional training session.

“Send everyone home safe,” is the mantra of the Keith Bolsen Silage Safety Foundation, a 501(c)(3) non-profit organization dedicated to promoting safe bunker silo and silage pile management, and providing safety educational resources and materials for the global silage industry. The nonprofit was launched at World Dairy Expo 2017 by Dr. Keith Bolsen, Kansas State University Professor Emeritus, and his wife, Ruthie. In 2018, Dr. Bolsen published a review of safety considerations in the Journal of Dairy Science.

ROLLOVER RISK REDUCTION

Rollovers account for half of the 250 annual tractor-related fatalities reported to the United States Institute for Occupational Safety and Health, according to Dr. Bolsen’s 2018 article “Silage review: Safety considerations during silage making and feeding,” which includes profiles of several accidents.

A 62-year old Pennsylvania man was...
killed when a tractor he was operating rolled over on top of him. The accident happened when the man was driving the tractor on an incline while packing silage in a bunker silo.

A 21-year old Texas man was killed when the dump-bed truck he was driving tipped over on a bunker silo at a cattle feedyard. According to the county sheriff, the circumstances of the accident are not uncommon and “those trucks have been known to do that if not operated correctly.”

• Use low-clearance, wide front-end tractors equipped with well-lugged loaded tires with added front and back weights.

• Fill in a modified-wedge pattern. Form a progressive wedge of forage when filling bunkers or piles and maintain a packing ramp with a 1-to-3 slope, or shallower.

• Keep transverse (lateral) slopes to 6-to-1 or less.

• Use sight rails (with lights if packing at night).

• Pack each forage layer tightly.

• Don’t use hay bales for bunker walls.

• Never fill a bunker silo higher than the top of the wall.

• Use cab tractors or tractors with roll-over protection structures (ROPS) and wear seatbelts.

• Unload trucks on a flat, firm surface.

**RUNOVER RISK REDUCTION**

The 29-year-old son of a Nebraska silage contractor was talking with an employee who was in the cab of a large forage harvester near the edge of a field. The employee, who thought the contractor’s son had left the area, drove the machine out of the field. A few minutes later, another employee found the contractor’s son lying unconscious in the field and he died two hours later in the hospital. Although the details surrounding the fatal accident are unclear, the son appeared to have been run over by the rear tire of the forage harvester.

• Stay in the tractor/truck while in or near a bunker or pile.

• Use radios to communicate.

• Develop a traffic plan and implement it.

• Use reverse alarm devices, including lights or beepers.

• All employees should wear high-visibility safety vests at all times.

• Never allow bystanders and people on foot (especially children) near moving harvest and transport equipment in the field or near packing and feeding equipment in a bunker silo or drive-over pile.

**FALL FROM HEIGHT**

In an email to a friend, Dwight Roseler, a dairy nutritionist in Ohio and Cornell University Ph.D. graduate, told about a local dairy farm that had a tragic bunker silo fatality. A 62-year-old employee fell 10 feet from the top of a bunker silo and was killed. The man was a loyal worker and dairy industry advocate with many years of experience working on farms and prior to that as a dedicated dairyman. He was a community and church supporter.

• Install guardrails on all above-ground-level walls.

• Use caution when removing silage coverings and tether to a stationary object when on piled silage above six feet high.

• Never stand closer to the edge of the feed-out face than the face height of the pile.

• Use equipment operated from the ground to remove surface spoilage.

• Don’t ride in a front-end loader bucket.

**CRUSH/ENGULFMENT BY COLLAPSING SILAGE**

Six tons of alfalfa haylage in a bunker silo collapsed on a Wisconsin dairy farmer. He was standing about seven feet from the feed-out face that was about 11 feet tall. The dairyman was rescued in a matter of minutes. However, he suffered a C6 spinal cord injury, which classified him as a quadriplegic.

NY native and California nutritionist Doug DeGroff’s testimonial is featured on the Silage Safety Foundation website. In August 2009 DeGroff was pulling a routine silage sample from a feed-out face that was nearly perfect and looked completely safe. The height of the face was only 11 or 12 feet. As he walked away from the pile, 20 tons of silage fell on him.

“...It registered in my brain that the feed is coming down. Immediately it hit me, and I went to the ground,” DeGroff said. “I remember thinking I don’t want to die here today! While I was able to push silage away from my face with one hand, my other arm was trapped below me. Thankfully, I was able to brush the feed away from my head.” Months after the accident, DeGroff said that he learned the hard way that there is no such thing as a safe bunker silo or silage pile.

• Maintain a vertical feed-out face.

• Don’t undermine the feed-out face.

• Don’t fill a bunker or build a pile higher than the unloading equipment can safely reach.

**Bunker silo and silage pile safety cont’d from page 13**
• Don’t put plastic covering down between silage crops or cuttings and leave it there.

• Don’t stand closer to the feed-out face than three times its height.

• Never work alone in a bunker or pile.

• Take forage samples from a loaded bucket after it has been moved to a safe distance from the feed-out face.

• Post signs at access points of a bunker or pile to warn of danger.

COMPLACENCY/FATIGUE

A nutritionist almost lost his life taking samples from a bunker silo with a 21-foot-high feed-out face on a dairy farm in Texas. Even though he was standing 20 feet from the face, 12 tons of silage collapsed on him. He did not see or hear anything. He had been in silage pits hundreds of times and had become complacent because nothing ever happened. It just took one time.

Keith Bolsen himself had an accident. “It happened on Saturday afternoon June 16, 1974, while making dough-stage wheat silage at Kansas State University’s Beef Cattle Research Unit in Manhattan. The blower plugged for about the eighth time that afternoon, and I started to dig the forage out from the throat of the blower. The PTO shaft was making one more very slow revolution. Zap! The blower blade cut the ends off of three fingers on my right hand. Why did the accident happen? I was physically worn out, mentally exhausted, and in a hurry. When I pulled my hand from the throat of the blower, I knew immediately that I had made a terrible mistake and done something pretty stupid.”

• Ensure the silage team is of sufficient size to perform all tasks safely.

• Get a good night’s sleep. A tired employee is more likely to make mistakes.

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