Fine-Tuning the Ration Mixing and Feeding of High Producing Herds

James A. Barmore[1]
Technical Service Specialist
Monsanto Dairy Business

Introduction

Feed is the single largest operating expense on dairy farms and should be considered one of the most important variables behind successful production, animal health, and profitability of a dairy. Annual feed costs per milking cow can average $1000 to $1200 per year, or $100,000 to $120,000 for every 100 milking cows. Despite this fact, only a minority of dairy farms closely track feed quality variation, feed mixing, inventories, feed bunk delivery, shrink, and corresponding animal performance. The result is lost opportunity to improve cow performance and to better management expenses. Total mixed rations **(TMR)** have rapidly grown to be the preferred method of feeding for non-grazing herds. Although TMR caught on many years ago, the art and science of how to best manage specific mixers continues to evolve. The questions have largely moved beyond the advantages of a TMR and are now more focused on "How can my TMR mixing and feeding be improved?"

Feedbunk management is more than just feed delivery and removal of refusals. It also involves ingredient characteristics and feedstuff quality control, feed processing and mixing, and factors related to feed presentation. On many dairy farms, the manager or employees responsible for feeding don't fully appreciate the impact their role has on the overall profitability and success of the dairy farm. In reality, the feeding management practices from forage harvest and storage to feedbunk delivery provide a large window of opportunity for improvement in cow performance and expense management on most dairy farms. The feed manager is responsible for handling over 50% of the variable costs of the dairy farm, and often the equipment that is worth several thousands of dollars.

In this paper, I want to focus on some key areas I see on high performing dairy farms that allow them to better monitor and manage the variability and shrink that occurs with feeding TMR's, specifically looking at the large financial opportunities gained by establishing better process controls as part of their daily feeding and bunk management. Specifically, lets address 1) forage variation and feed-out management, 2) the actual TMR mixer and mixing, and 3) feed delivery and bunk management. Many of the management items discussed in this paper were described for nine Wisconsin dairy herds surveyed in January 2002 (Appendix I).

Feed will vary as it's pulled from storage for mixing and feeding, while human mixing errors will also occur. Both are sources of variation in the actual rations delivered and consumed by cows. In turn, ration variation places production, cow health and feed efficiency at risk. Cameron et al. (1998) implicated that feed bunk management is a risk factor for left-displaced abomasums **(LDA)** through the variations associated with day-to-day feeding and bunk management, and thus the actual nutrients

[1]Contact at: 7905 Black River Road, Verona, WI 53593, (608) 833-1552, FAX (608) 833-1035, Email: james.a.barmore@monsanto.com

consumed by the cows. An excellent discussion of how feeding and bunk management can impact cow health, and specifically LDA, was recently presented (Shaver, 2001b).

Fine-Tuning Goals

The overall purpose of this paper is to address these key goals of fine-tuning the ration mixing and feeding of high-producing herds:

1. Minimize the within batch and between batch variation in the DM, energy, and effective fiber for all ingredients, but in particular forages.

2. Minimize any effective fiber reduction during handling, mixing, or feeding, while assuring uniform mixing and a consistent ration in terms of physical attributes.

3. Provide a fresh, high-quality, non-sorted ration at all times. Cows should be able to get feed when they want, in unlimited quantities, without competition from other cows. Both feed and water must be available in a comfortable environment.

4. On-going monitoring, record systems, and training of key employees will allow proactive evaluation and review of the mixing and feeding, which in turn limits unexpected events and risk and allows better measurement of management changes.

Managing Risk

The success of any team or dairy farm depends on its ability to consistently execute the basic fundamentals, or as some say the "blocking & tackling". For the dairy farm, the financial fundamentals of success are maximizing revenues and controlling costs. Financially speaking, a large order of magnitude for a dairy is to have better management of feed inventories, feed mixing and delivery, feed shrink, and other expenses associated with feeding. One might consider this "blocking and tackling" of feeding. It's important to note that controlling costs within defined production parameters, while minimizing wide variations in expenses, does not necessarily equate to "cutting costs" (Fetrow, 2001).

Many dairy farms forego very significant profit opportunities in the false pursuit of cost-cutting and reducing inputs. By focusing largely on the costs of inputs, rather than the inputs' marginal impact on revenue (typically more milk or better herd health), many dairy farms place a ceiling on profits. Better management of the feeding program should not be simply positioned as a cost-cutting strategy versus opportunities associated with minimizing variation and improved feeding and nutrition largely created through better day-to-day consistency and quality of the feed consumed.

One of the first steps to maximizing revenue involves identifying and managing areas of risk and developing appropriate management plans to limit unexpected expenses, controlling the income stream, and reducing the exposure and impact of animal health or catastrophic events that may occur on a dairy. An example of this would be having a relatively simple yet very well implemented plan in place for the feed mixing, feed delivery, and bunk management.

Suffice it to say, things don't always turn out as planned. To some degree, every dairy farmer tries to minimize risks and variability as part of day-to-day management, but breakdowns are common and opportunities abound in the area of mixing, feeding, and bunk management. There are different types and levels of risks that occur on a dairy farm, which can be managed in three fundamental ways (Fetrow, 2001):

1. Reducing the chance of an undesirable event or outcome (e.g. mixing and delivery monitoring systems for early signs of breakdowns or losses),

2. Reducing the impact of an event if and when it does occur (e.g. having treatment protocols in place for health challenges caused by breakdowns), and

3. Transferring risk to others (e.g. contracting for a blend of proteins and minerals).

Reduce Variation, Improve Consistency

Variability, or *lack of consistency*, is a dimension of risk and involves feeding management on dairy farms (Fetrow, 2001). There inherently always will be some variation in outcomes on a dairy farm when we are dealing with biological units...or cows! Making milk is a manufacturing process. In any manufacturing process, there will be some degree of variability when inputs are put through a process. Cows fed the same ration will differ in their milk production; even the same cow varies in production from day to day. Variation makes operating a dairy farm more difficult and less profitable because the outcome of a process (e.g. mixing feed) is not precisely known.

The unpredictability of a process (caused by variation) makes planning of future outcomes more difficult. For example, not knowing the packing density and moisture of silage can make planning for future rations somewhat difficult. Another example would be not having any mixing or feed intake records, making the monitoring of the impact of nutrition on cow health and production very difficult. In both cases, variation or deviation from the target points or goals impacts the outcome. Without records, or a monitoring system, the variation cannot practically be measured or managed. In this case, the old adage "if you can't measure it, you can't manage it" is quite true. Figure 1 can be used to depict how distribution of variation might change and improve before and after a mixing and feeding monitoring process and system are implemented.

Lack of consistency in the day-to-day feeding and bunk management creates challenges associated with normal rumen function and animal health. The idealistic rumen environment to maximize production and feed efficiency would be "steady-state" conditions. Biologically and practically speaking, striving for steady-state rumen conditions aren't realistic, but the point to be made is reducing variation in the feeding can significantly improve cow performance by improving rumen function and digestion.

Variation makes it more difficult to monitor the effects of any management intervention or action (e.g. producer decides to feed sodium bicarbonate), since the actual effects of the action may be obscured by normal variation. To verify this point, consider how much the bulk milk tank will vary daily due to every day influences, such as weather. If the hypothetical dairy farm that added sodium bicarbonate has wide daily swings in milk production due to variable forage quality, inconsistent mixing practices, and variable forage moisture content, then it will be difficult or impossible to tell if adding the sodium bicarbonate to the ration actually improves production or health. The effect of sodium bicarbonate might be positive and cost-effective but hidden under the daily swings and accepted variation. Management in this case is significantly limited in being able to make accurate and solid business decisions due to the high level of variation (Fetrow, 2001).

The best-managed and typically most profitable dairy farms seek ways to reduce variation in daily processes. Dairy farms that can create consistency through protocols and routines will improve their ability to plan and improve management. While breakdowns will still occur, these dairy farms will be quicker to modify systems and make needed adjustments. In the long-term, dairy farms that are able to minimize variation and create better day-to-day consistency within the feeding program will likely be more successful. The answer to getting started with improving variation in the feeding, lies in better implementation of good plans with supporting monitoring systems. **Day-to-day consistency in the mixing and feeding is a key driver of profitability on well-run dairy farms!**

Mixing & Feeding Risk Exposure – Self-Assessment

A dairy farm that has a sound mixing and feeding management plan that minimizes variation, and thus limits risk exposure, should be able to answer these questions:

- What criteria and benchmarks are used to measure and determine if the feeding management is on track? Do the feed manager, owners, nutritionist, and veterinarian agree on what type of assessment criteria are collected and evaluated?
- How are cow head counts for pens or barns recorded and available to the feeder daily? How does the feeder determine the proper batch size based on cow numbers?
- At what maximum percentage of "struck full" capacity is the mixer still fully effective?
- What is the recommended mixer fill order sequencing of ingredients? Do the TMR manufacturer and the nutritionist agree on the sequencing order?
- What is the target level of daily TMR refusals, and how much does this vary from day-to-day? How much can the actual intake vary from projected, for a given number of cows, before a new ration should be balanced?
- How will TMR refusals be utilized or discarded? What is the maximum level of refusals that can be re-fed?
- Are refusals monitored for particle size relative to the fresh TMR by the feeder?
- When should haylage moisture be measured and why? What is the procedure for taking a haylage sample for moisture testing, and what is the agreed upon DM determination method that will provide consistent results?
- How reliable and consistent is the forage moisture determination method on the dairy farm?
- What is the recommended mixing time for the specific mixer on the dairy farm?
- Who's responsible for TMR mixer maintenance; what and when does this constitute?

Forage Variation and Feed-Out

One of the greatest areas of feed quality variation is with forages (Buckmaster and Muller, 1994). Variation in forage quality, moisture, and shrink occurs by two modes: 1) forage loss as it moves through different handling and storage processes, and 2) microbial deterioration and fermentation DM losses. The obscurity of microbial deterioration has led many to believe that they have relatively modest forage losses and quality issues. In fact, DM losses of 5 to 20% may be occurring before one actually sees visual evidence of molds on forage (Holmes and Muck, 2000). Actual forage losses and shrink are highly dependent on harvest and storage structures. Data adapted from Holmes and Muck (2000) indicate total forage DM losses can range from about 10 to 50%, including the losses associated with filling, seepage, fermentation gasses, surface spoilage, and feed-out losses.

There are several factors that impact the forage quality delivered to the bunk. Following accepted recommendations for harvest maturity, filling, packing, storing, and unloading minimizes quality losses and shrink. Feed managers must understand and manage the process of ensiling and fermentation in order to have high quality forages.

Have we as consulting nutritionists and veterinarians truly invested in training the proper people that have a key role in the feeding management? Bucholz (1999) pointed out the gaps in understanding recommendations between nutritionists and the feeders that were encountered in their extension feeder training programs. Something as key, and relatively straight forward, as moisture determination had several breakdowns due to lack of understanding and clarity on the behalf of many of the feeders.

Several common breakdowns related to forage quality variation that limits cow performance, include: 1) variable packing density of ensiled forages, 2) removal rate and uniformity of ensiled forages, 3) feeding of moldy or spoiled forages, and 4) lack of accurate moisture determination of the forages. In many respects, each of these are closely related.

Packing Density – Quality Forage

Achieving a high packing density of ensiled forage is an important goal for dairy farms. Density and DM content determines the porosity of the silage, which affects the rate at which air can penetrate the silage mass at the feed-out face. Often packing density of bunker silos and even bagged silage are not sufficient to prevent high DM losses or to ensure consistent high-quality silage. Moisture variation and low packing density within a forage storage unit creates challenges for the feeder from the moldy and spoiled feed that occurs, and difficulty in trying to determine at what moisture should the forages be balanced in the ration. While it's recommended that the minimum DM density for both haylage and corn silage be 14.0 lb/cu.ft. or greater (Bolsen, 2001a), there continues to be a huge range of silage densities seen in bunkers, piles, and bags. Holmes and Muck (1999) found that significant variation existed in the packing density of both haylage and corn silage when 168 bunker silos were surveyed in Wisconsin (Table 1). Subsequent research by Holmes and Muck, 2001 (personal communication) showed that significant variation in packing density can also occur in silo bags.

Packing bunker silage in layers no greater than 6 to 10 inches in depth is key to achieving recommended packing densities and good fermentation. Often the ability to deliver large quantities of forage to the bunker has outstripped the packing tractors' ability to adequately pack the silage. Calculating the recommended packing tractor weight relative to the mass of silage being delivered per hour is an important step that should be reviewed (Batchelder, 1998; Holmes and Muck, 1999). Adding additional packing tractor weight; or an additional packing tractor may be an option. Because it requires no additional capital, strongly consider reducing the packing layer thickness while continuing to use the existing packing tractor. Although often achievable, the challenge is to manage or moderate the delivery rate of freshly chopped silage to the silo so the packing layer thickness can be decreased. With the growing popularity of custom harvesting and more tonnage per hour of harvested material with bigger equipment, adding an additional packing tractor may be required.

Silage Feed-Out

Silo bags offer flexibility for segregating forages by type and quality so inventory can be better managed. Bunker silos need to be sized appropriately and kept narrow enough so adequate silage can be removed from the silage-face to ensure fresh forage and minimize heating. Corn silage should be fed at a rate to allow at least 12 inches or more of silage to be removed during warmer months, and 8 to 10 inches during cooler temperatures. Splitting bunker silos to reduce the width of the silage-face can be an effective way to achieve an adequate removal rate of the silage, while minimizing the amount of DM loss and shrink due to air exposure. Always avoid knocking down more silage than is needed for immediate mixing and feeding; this should also apply during cooler weather where secondary fermentation can still occur. Some dairy farms have gone to putting corn silage in bunker silos and hay silage into bags, with the idea that corn silage is an easier crop to handle in bunker storage. Silo bags must be packed with adequate tension on the bagger, kept on a solid surface (not dirt or mud), and located to minimize punctures to the plastic from animals, equipment, or kids. Carefully monitor and manage any moisture changes that can occur abruptly with bagged haylage due to field differences.

Silage De-facers

Silage "de-facers" are currently getting lots of attention, with several dairy farms purchasing one in the last 1 to 2 years. Different commercial de-facers are available as attachments to telehanders or skid-loaders. More expensive stand-alone units are also available which allow direct loading to the mixer after silage face removal. Essentially, de-facers are a mechanical means of loosening and removing silage from the bunker-face without disrupting the overall silage-face, otherwise caused by the lifting with a loader-bucket. It's the lifting of the silage mass with the loader that tends to expose more silage to oxygen and creates secondary silage fermentation, heating, shorten bunk-life, and spoiled feed. Feedback from dairuy farms utilizing de-facers has generally been very good, with the primary reason for satisfaction being the better consistency of silage being fed. Safety has also been mentioned as a benefit of the de-facer by allowing the bunker or silage pile to be higher while not risking the silage "cave-ins" that can occur when removing silage with a loader. Equipment cost and "wear and tear" on the de-facer and associated equipment must be considered, along with possibly additional time required to load forage.

Questions on whether the effective fiber and particle size of forage would be reduced from the grinding action of the de-facers were recently addressed in a controlled field study (Sutter and Shaver, 2001). In this study, three commercial de-facers (Valmetal, Bunker Claw, and Bunker Buster) were compared to bucket removal (positive control) and hand-removal (negative control), looking at any differences in particle size reduction due to the type of removal method. No reduction in effective fiber occurred with either hay silage or corn silage with any of the three different commercially available de-facers when compared to either hand-removal or unloader-bucket removal (Table 2).

Moldy Feed

Rations should be fresh, palatable, and contain only quality forages. Spoiled and/or moldy forage should be discarded. Unfortunately, discarding spoiled forages is not always a common practice. In a recent study at Kansas State University, growing steers were fed high silage rations, which contained 90% well-preserved corn silage or a blend of the well-preserved corn silage, and some spoiled corn silage (from the top of the unsealed bunker silo) (Whitlock, 1999). Steers receiving the ration with spoiled silage had significantly lower DM intake and lower organic matter, protein, and fiber digestibilities. Preventing the formation of moldy silage and having a well-communicated plan on how to handle and toss any moldy silage is key to achieving high performance. A common practice amongst the highest performing dairy farms is their commitment to avoid feeding moldy or spoiled forages or feeds, albeit this can require that feed be discarded and hauled. The prevailing attitude should be "lost feed is better than lost milk and/or cow health that is caused by moldy spoiled feeds".

Moisture Monitoring

Successful feeding management is highly dependent on delivering the proper amount of each ingredient, which in turn is highly dependent on accurate measurement of DM of the feed. Errors commonly occur in delivering an accurate ration that doesn't match well with the formulated ration because of the failure to either routinely or accurately measure the DM content of wet ingredients, and then adjust the rations accordingly to maintain the proper proportions of ingredients. This is especially true for the DM proportion of effective fiber and forage to concentrate levels.

There are a couple of primary reasons behind when delivered rations are not well balanced (although often well-formulated by the person doing the nutrition work) due to DM variation and inaccurate DM values on the feeds (typically forages). **Reason #1 – lack of a specific agreed upon plan for testing forages.** Rather than some type of random DM testing, or testing forages after a production drop or negative situation has occurred, a specific plan should be in place for testing forages based on type of forage, storage structure, weather, and/or the interval between testing. The mind-set needs to be that regular forage DM testing is an "investment" rather than a cost. Have a plan!

Reason #2 – lack of the right equipment and a procedure that's well understood to measure and determine DM in forages. Using either a microwave or Koster-tester with accurate scales (+/- 1 gram) has been shown to be an effective method of consistent and reliable on-farm DM determination. Although a specific method must be followed with care, either system is capable of generating reliable results. Neither the microwave nor Koster-tester are particularly difficult to operate nor are expensive. Breakdowns in the accuracy or reliability of the DM measurements on-farm typically come from corners being cut in the methodology (either rushing or over-drying and burning the sample) or poor scale accuracy. Variation in chop length of the silage (particularly corn silage) will affect accuracy. The finer the chop, the more accurate the DM measurement can be. It's in the best interest of every nutritionist to take time to have a written DM determination procedure that is well understood by the feeder and is posted at the farm in a convenient location for review. Take time to make sure the math in the calculations is understood .

On-Farm Versus Laboratory Moisture

There continues to be some frustration over the "residual moisture" that isn't accounted for with on-farm moisture testing. Often, a silage sample is tested carefully on the dairy farm, only to have the same silage DM come back from a commercial laboratory at 2 to 3% units lower (Peters, 2000). Approximately 2 to 3% residual moisture is typically measured in samples submitted to commercial laboratories over and above the moisture content measured on-farm using a microwave or Koster-tester. In other words, an identical sample of silage could have a DM content of 34% as measured on-farm, while the same sample tested in a commercial laboratory might indicate the silage contained 32% DM. Lab tested results will typically be higher moisture, or lower DM content, due to residual moisture. The residual moisture figure can range from 1 to 6%, depending on operator accuracy at the farm, and the type of silage sample being tested. Although both microwave and Koster-testers have similar accuracy when operated under sound methodology, the results with a microwave will tend to be more variable on-farm due to more frequent incomplete drying or burning.

Figure 2 shows the results of different methods widely accepted and used to measure DM content. The unpublished results (Barmore, 1997) were completed through a research project team, including the Dairy Science Department at the University of WI-Madison , School of Veterinary Medicine at the University of WI, Rock River Laboratory (Watertown, WI), and Vita Plus Corporation (Madison, WI). These results on both corn silage and haylage clearly showed that the widely accepted oven-methods of drying forages, namely forced-air and convection oven-drying, resulted in lower moisture and higher DM content than the procedure (Karl Fischer) utilized to measure total moisture, including what many consider the residual moisture. During the time of the research, the laboratory industry did not have a standardized procedure for testing moisture. Now as of January 1, 2002, the National Forage Testing Association has implemented a standardized moisture test, where all certified forage testing labs will use an oven-dry at 105° C for exactly 3 hours. Having all certified forage testing labs using a standardized moisture testing procedure should help bring some consistency and answers to the often asked question of why moisture testing results are quite variable.

So if residual moisture is real, does it really make sense to take the time to measure forage moisture on-farm? **Absolutely!** Even though a commercial laboratory DM content should be used to balance rations, regularly measuring forage moisture on-farm allows the DM content to be watched and monitored closely. On-farm moisture determination can be accurate and repeatable with excellent operator procedure; however, the results will be biased towards the moisture being lower than commercial laboratory values on moisture. Having current DM values on the forages at the dairy farm allows relatively simple ration adjustments in the forage levels to be made immediately, without having to wait for an entirely new ration to be rebalanced and implemented, often with a lag of several days. Of course, significant DM changes in the forages should signal that new rations be balanced to make sure other nutrients, such as fiber and protein, haven't changed. With regular DM monitoring on-farm, a relationship of the on-farm DM percentage and the corresponding lab DM content will develop quickly. Having on-farm DM content is invaluable during corn silage harvest when dry-down occurs rapidly, and the harvest window must be closely managed to prevent corn silage from getting too dry.

TMR Mixers

According to Kammel (1999), there are over 20 different mixer manufacturers in the industry, and in general, the different types of mixers seem to be doing an adequate job of mixing TMR. Types of mobile TMR mixers include auger (1,2,3, and 4 auger models), reel auger, and vertical screw mixers. Mixers vary considerably in their ability to handle and mix long hay, with vertical screw mixers having the greatest capacity for handling hay. Over only a few years, the market demand has produced mixers that can process and mix a high level of hay, to the other extreme of mixers that fail at uniformly mixing hay. The design change to allow processing and mixing of hay has created another potential problem with misuse of the mixers designed for hay (really a processor), causing particle size reduction when excessive mixing times occur. Kammel (1999) has a complete discussion of TMR mixer design, selection, and operating guidelines that should be reviewed.

Huffman (cited by Hutjens, 2001c) found five different TMR mixers (two auger mixers, two different reel mixers, and one vertical) to be similar in their mixing characteristics of a TMR that included 5.4% hay (of the DM). The particle size distribution and evaluation was done using the Penn State Separator box (Lammers et al., 1996). A key cited by the author was that the mixing sequence of ingredients was determined by factory representatives for their respective TMR mixer and that recommended mixing times might vary by type of mixer. Similar work comparing horizontal and vertical mixers found little difference in particle size distribution when mixing times were followed (Rippel et. al., 1998).

Proper blending and uniform mixing requires that there be no dead spots or non-mixed feed in the mixer. While most mixers are designed with this in mind, some do not have sufficient ingredient flow to adequately blend liquids or minerals that are rapidly added to the mixer. Some mixers do not have proper ingredient flow and movement when the batch size is too small for the mixer capacity potentially creating a real challenge with transition rations often mixed in smaller batch sizes. A TMR mixing accuracy check should be done with all rations but in particular smaller batch size mixes, such as transition cow TMR. As discussed by Buckmaster (1998), mixer capacity is key to designing and selecting a TMR mixer feeding system.

Mixing Hay

Dry baled hay is one of the biggest challenges to proper TMR mixing and feeding. Without grinding or processing the hay prior to mixing, it is almost impossible to use an auger or reel type mixer and consistently get a good TMR mix of hay where the hay won't be sorted by the cows. This becomes even a bigger challenge when feeding Midwest grown hay versus western or Canadian hay that tends to mix better with smaller stem size and typically being of higher quality. Although very palatable, high quality grass type hays usually cause problems for most mixers because it wraps around the augers and is difficult to incorporate into the mix.

The amount of hay that can be incorporated and properly fed is a function of the type of mixer (Salfer, 2001). Most auger type mixers on the market can handle a small amount of hay (less than 5 to 8% of DM). Larger amounts of hay can be incorporated in more aggressive auger type mixers and virtually all vertical mixers. Clearly, the vertical mixer design is the best overall at processing either long-stem hay or wrapped balage, and thus this has led to their growing popularity. It's key with any type of mixer, and particularly with vertical mixers or mixers with a "hay unit or saw tooth augers", that the mixing time, sequencing of ingredients, and evaluation of forage particle size in the fresh TMR and the feed refusals be followed and monitored continuously.

Mixer Capacity

Shaver (1998) listed six areas of mixing error that can occur, including: 1) batch size too small, 2) batch size greater than mixer capacity, 3) trying to mix too much hay, 4) improper sequencing of ingredients, 5) under-mixing or inadequate uniformity in the mix, and 6) over-mixing causing reduction of forage particle size. Most mixers are not very effective at uniformly mixing a ration when too full. Mixer manufacturers typically refer to the maximum fill capacity as a percentage of "struck full" or level-full capacity. Fill capacities given by manufacturers range from about 60 to 90% of struck full capacity in order to achieve optimum mixing efficiency.

To determine the optimal size of a TMR mixer, figure that a typical ration will range between 15 to 20 lb per cubic ft, with an average Midwest ration having a TMR density around

17 lb per cubic ft. Feed intake varies due to many factors, but a large breed lactating cow will typically consume between 5 and 7 cubic ft/day of TMR . As hay content increases, the cubic feet consumed daily also increases. In order to estimate an approximate TMR mixer size, take the maximum number of cows in a group, multiplied by 6 to 6.5 cubic ft per cow, and then divide by the number of feedings per day (Kammel, 1999). This figure in turn should be divided by the maximum fill capacity (60-90%) to determine the overall TMR mixer size.

Mixing Time

The goal and reason behind adhering to a constant mixing time is to obtain a uniform mix, while maintaining the desirable forage particle length…each and every day! Over-mixing is clearly a problem as far as reducing particle size of long forage (Rippel et al., 1998). Different mixer types and sizes carry different recommendations regarding mixing times and protocol. Typically, the manufacturer's recommended mixing times range from 3 to 6 minutes (Kammel, 1999). Over-mixing continues to be a problem, but maybe even more common, is the problem with inconsistent mixing times.

If insufficient mixing time occurs, the ration composition can be altered considerably. If the load is split between two groups, this can become a big issue. Even if the incompletely mixed ration is delivered to just one pen, consider the impact of the altered ration composition on individual cows. The question becomes…"Is the recommended mixing time while loading all ingredients or is it after all ingredients are added?" With rations heavily dependent on commodities, it is common for loading times to exceed 15 to 20 minutes. Should the mixer be running during the entire loading period? When determining the optimum mixing time, the goal is to consistently achieve a well-mixed uniform ration while maintaining the effective fiber and forage length. Depending on the mixer type, this often means that the grain, protein, and small particle feeds are loaded first, mixed, and then the long particle forage is added last, with a mixing time of 3 to 6 minutes followed after the forage is added. There are many situations where the recommended mixing times and sequencing of ingredients is not followed due to the load sheet format, the storage location of ingredients and forages, location of the feed bunks, use of bulk bins, etc…

Ingredient Sequencing

The physical properties of different ingredients can influence the mixing, particle size, density, adhesiveness, and dustiness of the TMR. Particle size, particle shape, and density are believed to have the greatest impact on ration mixing and uniformity. Particle retention on the top screen was manipulated as much as 30% by altering the inclusion of hay from the first to the third order in loading sequence (Rippel et al., 1998). The bulk density differences of grain compared to forage, and mineral being two to three times more dense than grain or protein, creates mixing challenges. Generally, the lighter and larger particles tend to move upward in the mixing process, while the smaller more dense particles gravitate downward in the mixer. Because of this, some recommend that the larger particle sized forages be added first, with grains, proteins, and minerals last. However, any reduction in forage particle size from this method of mixing would have to be questioned. The best compromise may be to utilize a "pre-blend" where the smaller and more dense ingredients (protein, grain, minerals, fats, additives, etc…) are pre-blended prior to adding to the mixer, and then added as "one ingredient" to the TMR mixer. This allows forages to be added towards the end of the mixing process, while ensuring a uniform mix on the other ingredients. Buckmaster (1998) discussed how mixing can be evaluated and modified on the dairy farm.

Utilize Pre-blends

Whether multiple ingredients are blended together on-farm or as a service provided by a feed company or local mill, the merits of pre-blending to minimize mixing errors and to reduce shrink should be strongly considered. Mixing ingredients together, such as proteins, minerals, vitamins, feed additives, and energy sources, in a large quantity as a pre-blend or "surge mix" improves the odds of a more consistent ration, while reducing shrink caused by mixing error.

Consider a situation where a ration calls for five different ingredients, other than forages, that are added to the mixer individually. If a feeder overfeeds (usually over-fed versus under-fed) each ingredient by an average of 20 lb per load (just an extra shake of the loader bucket), then by adding five ingredients separately, the feeder would be wasting 100 lb of feed per load. If six loads of TMR were being fed each day for all milking pens, then a total of 600 lb/day of extra feed would be mixed. With an assumed average value of $0.065 per pound for all five ingredients, this would amount to $1170 per month of "feed shrink".

Compare this to using a pre-blend of the five ingredients, where instead of adding five different ingredients to all six TMR loads, only the one pre-blend is mixed. With the same over-feeding rate of 20 lb for the pre-blend, multiplied by the six TMR loads daily, the amount of pre-blend over-fed per month would be 3,600 versus 18,000 lb for the five separate ingredients. Assuming a mixing or labor charge of about $15 per ton, the pre-blend average cost becomes $0.0725/lb or a total of $261 per month compared to the $1170 charge when the ingredients were fed separately. On an annual basis, this would amount to a feed cost savings of $10,908 using the pre-blend versus individual ingredients. Although, variation in mixing errors would be expected from dairy farm to dairy farm, experience has shown that mixing errors (over-fed) less than 20 lb per ingredient would be the exception rather than the rule. It's only natural that low inclusion rate ingredients are more susceptible to mixing errors, as are ingredients that tend to be sticky or are more difficult to handle.

Pre-blends also will minimize the amount of over-mixing and potential forage particle size reduction that could occur. Shaver (2001a) has discussed mixing errors and effective fiber evaluation.

Advantages of a Pre-blend:

- Reduces carrying cost of ingredient inventory,
- Improves ingredient quality control,
- Just-in-time inventory, potentially fresher feed available,
- Risk exposure reduced and shared with third party,
- Minimal cost differences for blending,
- Additional services possibly provided in conjunction with pre-blend, and
- Labor savings and more cost-effective deployment of on-farm labor.

Accuracy of Loading

Knowing the accuracy of how ingredients are loaded into a mixer is important to minimize mixing errors which will limit milk production and likely compromise cow health. From an expense management perspective, knowing the accuracy of loading and mixing is key. Some of the common tools used to determine the accuracy of loading and mixing are: 1) TMR nutrient analysis, 2) particle size evaluation, 3) marker or tracers blended and tracked, 4) hand-recorded feeding logs, and 5) use of software programs which interface with mixer scales.

A big potential advantage of implementing a monitoring program is the ability to better manage the consistency of the day-to-day rations being delivered to high producing and special needs cows. The key to improving mixing accuracy, feed inventory control, and reducing shrink and variation is setting up a well-understood and effective monitoring system for measuring feed disappearance charged against inventory. Many examples can be cited of a dairy farm that experienced a significant health challenge with fresh cows, or a dairy farm that lost a large amount of milk production and income over time because of errors that were being made in the mixing or feeding program, yet essentially no records were available to determine specific causes or to allow implementation of a better management plan.

There are several methods for monitoring and tracking the actual loading, mixing, and feeding process. No one system will fit all dairy farms, and no system is 100% accurate. Essentially, there are three ways to approach setting up a monitoring system, including: 1) using a simple "pencil & paper" system of recording, 2) using spreadsheets, or 3) using a computerized software program specifically developed for tracking and monitoring feeding and inventories. For any of the systems used, determining forage inventories can be one of the more difficult steps. Forage storage capacity charts can be used to fairly accurately determine how much forage is in inventory based on measured compaction density and the size of the bunker or bag. A detailed discussion of monitoring systems can be reviewed in the paper by Barmore (2001) or as presented by Bucholtz at this 2002 Tri-State Conference.

Feed Delivery & Bunk Management

Feed bunk management can be quite comprehensive, including all aspects of determining the batch size, frequency of feeding, timing of feeding, feed delivery to the bunk, feed push-ups, feed stability and bunk-life, actual intake and recordkeeping, feed sorting, feed refusal management, and the bunk environment, including stocking density and manger design. The goal is provide a fresh, high-quality, non-sorted ration at all times, where cows can get feed when they want in unlimited quantities, without competition from other cows with both feed and water available in a comfortable environment. Bunk management practices that cause cows to eat fewer and larger meals more quickly may be associated with an increased incidence of ruminal acidosis and laminitis (Shaver, 2001a). Ruminal pH declines following meals, with the rate of decline increasing as meal size increases and as dietary NDF concentration decreases (Allen, 1997). Several reasons that cause slug feeding, or larger meals, were cited by Shaver (2001a), including: 1) limited bunk space, 2) limited feed access time, 3) restricted feeding, 4) inconsistent feeding schedule, 5) infrequent TMR push-up, and 6) bunk competition.

Frequency of Feeding

Feeding the TMR once per day has been successful in research trials and on high-producing dairy farms. The advantage is the lower labor required for feeding and that the feed mixing is typically controlled by one person or a single labor shift. Providing abundant feed to the full length of the bunk, with extra TMR in the areas closest to the waterers, is required, along with frequent TMR push-up to make once per day feeding work well. The TMR push-up of at least four to six times daily is common, with constant availability of non-sorted fresh feed being the key rather than a specific number of push-ups. Minimizing sorting of the TMR is very important, with a goal of the top screen of the Penn State Shaker box not changing more than 5% units over the 24 hour feeding period (ie. fresh TMR on top screen = 8%, refusals at 23 hours on top screen <13%). If excessive sorting occurs, ration conditioners such as water, liquid molasses, and wet by-products can be effective in reducing the amount of sorting that occurs. Shaver (2001a) identified several practical management practices that can be implemented to minimize and address sorting issues. The frequency of mixing and feeding fresh TMR should be increased anytime the TMR is heating in the bunk due to warm conditions or unstable silages. Often herds that practice once per day feeding in the winter will shift to twice a day mixing and feeding in the spring as temperatures begin to rise. Those feeding at outside bunks may need to increase feeding frequency during periods of inclement weather.

Bunk Space & Access Time

The combination of limited bunk space (<16 to 18 inches per cow) space and limited feed access time (<18 to 20 hours per day) is worse than either alone. Overcrowding of a pen or pens with a feed alley less than 12.5 to 13 ft in width can also limit the access time to the bunk. Six-row barns with feed alleys less than 12.5 to 13 ft in width should not be overstocked beyond 100% since the square footage per cow is already reduced due to the barn design; overstocking can significantly compromise the bunk access time and potentially feed intake and efficiency. Currently, my recommendation for lactating cows is that bunk space always be greater than 16 to 18 inches per cow, with 2 ft per cow preferred. Special needs cows or transition cows should have a minimum of 2 ft per cow, with 3 ft per cow preferred. Michigan State data (Dado and Allen, 1994) would suggest that the meal behavior of first-lactation heifers is different from older cows, and work from Krohn and Krongaard (1979) indicated advantages to having first-lactation heifers eating separate from older cows. My field experience strongly supports these data, particularly where stocking density or crowding are an issue. First lactation heifers should be allowed to access a bunk separate from older cows if possible; this seems to promote better bunk access time for them.

Bunk-Life and Stability

Bunk stability refers to the freshness and stability of the TMR over time. Problems arise with warm or hot feed, moldy or musty smelling feed, and slimy or stinky feed particles (Hutjens, 2001b). In general, high producing cows will not eat as much DM with even moderate levels of heating of the ration occurring, with transition cows being even more selective. Feed digestibility can decline due to warm or heating rations, while the risk of mold spores growing and multiplying increases significantly. Adding mold inhibitors can slow ration deterioration caused by heating, often stretching the time necessary between feedings. Products containing a blend of organic acids often will provide better bunk-life and stability, but typically these products are more expensive than using only proprionic acid. Safety with any liquid mold inhibitor should always be a priority.

Timing of Feeding

Cows have major TMR meal patterns after milking (Menzi and Chase, 1994; Shaver, 1998), thus fresh TMR should be available to cows after they come back to the bunk from milking. This also serves the purpose of encouraging cows to remain standing to allow more compete teat-end closer before lying down. Pens with higher stocking density or limited bunk space will typically respond positively to having fresh feed available as the first cows return from milking. As these cows finish eating and begin to return to the freestalls, the last of the cows from that pen are returning from milking and are able to find open space at the bunk. During warmer weather, cows will shift a higher portion of their total feed intake to the late evening and early morning, thus fresh feed should always be provided in the evening.

Feed Refusals

Feeding for 4 to 5% refusals is a common recommendation. This is particularly important with pens where cow numbers fluctuate widely or frequently or for pens of early lactation cows where feed intake is ascending rapidly. Typically, refusals are pushed out and fed to steers, low group cows, dry cows, or replacement heifers. With stronger emphasis on biosecurity and Johnes disease, the recommendation is often made not to feed any refusals to replacement heifers or younger animals. Having steers available really doesn't provide a viable option for many dairy farms, thus leaving the question of how to best manage the refeeding and use of refusals to dry cows and/orgroups of low producing cows. Lets clarify an important point…there are good quality refusals and then there at times "garbage" refusals where the feed is hot, slimy, and stinky. Real simple…garbage refusals should be discarded and not fed to any animals. Refusals that still have good feed quality can be remixed and fed, preferably to the low group cows at a fixed rate and small percentage of the overall ration. Although feeding refusals to dry cows can work, the amount of refusals available often varies considerably along with having limited numbers of dry cows. This in turn results in dry cows getting too much good feed and becoming over-conditioned. This is a real watch-out with feeding refusals to dry cows.

Slick Bunk Management?

So what about the idea of feeding lactating cows to an empty bunk? Loerch (2001) suggested that the dairy industry should investigate the application of "slick bunk" management for lactating cows, based on the experiences of many in the beef feedlot industry. He suggests that having feed always available isn't bunk management but rather a "high labor, high cost, self-feeder". He brings forward several good points that the dairy industry should consider further. Several research studies with beef cattle have shown better feed efficiency, similar animal performance, less digestive disorders, and more consistent feed intakes when fed to a slick bunk (Pritchard, 1998).

In fact, a few dairy farms have successfully implemented a slick bunk management scheme and are quite satisfied with the cow performance and are very pleased with the reduced level of feed refusals. So for the dairy industry, a question may be "If slick bunk mangement is being considered, is it to reduce the level of feed refusals or to improve cow performance?". Because lactating cows eat much greater quantities of feed than beef cattle and because it is widely accepted that milk production is largely driven by feed intake, I feel quite comfortable saying that slick bunk management will not improve lactating cow performance over feeding for a 4 to 5% refusal level. Milton (1998) reported that feedlot cattle fed to a slick bunk had reduced frequency of meals (4.5 versus 8.2 meals per day) and had greater average meal size (7.7 versus 3.5 lb per meal) than cattle fed ad-libitum. As stated earlier, Allen (1997) has shown that increasing the meal size of lactating cows will cause a decline in ruminal pH. Milton (1998) also reported that deviations of 2 to 4 hours from a normal feeding schedule greatly increased the risk of acidosis in feedlot cattle.

From my perspective, a logical discussion around slick bunk management deals with the growing costs associated with the large quantities of feed refusals larger dairies are experiencing. With 1000 milking cows on a dairy farm, feeding TMR for a 5% feed refusal often amounts to over $50,000 worth of feed being at best devalued and at worst discarded over one year. If refusals could be managed closer to 2 to 3% across the milking herd, this would account for $25,000 to 30,000 in feed savings annually.

Realistically, I don't see most dairy farms capable of managing for a slick bunk given the large amount of variation that occurs in forage moisture, cow movement between pens, feeding times varied, limited controls, and monitoring of the feeding process. I do think an achievable goal for very well managed dairy farms is to reduce the level of feed refusals to 2 to 3% versus the more common 4 to 6% levels, allowing significant feed savings to occur without compromising cow performance. This requires excellent forage quality, mixing and feeding, and overall management. For even the well managed dairy farm, my quick answer to the feasibility of slick bunk management is "It's possible, but not very practical or realistic for the vast majority of dairy farms given the challenges with labor and day to day inconsistencies that typically occur". From a research perspective, the concept proposed by Loerch (2001) on slick bunk management for the dairy industry probably warrants more investigation.

Water Delivery

Although not technically part of the feeding, water delivery needs to be mentioned in this paper to help bring awareness to what I believe is a water delivery problem on many dairy farms. Historically, the most common problem seen on dairy farms with water was the filth and quality of the water due to dirty waterers and the difficulty to keep them clean. Although it is a constant challenge to keep fresh quality water available to cows, the issue of keeping waterers clean has improved considerably in the industry. A more common water delivery challenge seen in my on-farm work involves giving the cows adequate space around the waterers so more than 1 to 2 cows can drink at any given time. This was discussed in an article by Roenfeldt (2000), while an excellent paper on water delivery was done by McFarland (1998).

Monitoring and Tracking Success

Understanding and implementing a comprehensive monitoring program for the mixing, feeding, and bunk management needs to incorporate a number of observations and recordings, many of which have been mentioned in this paper. Further discussion on how to fully monitor the success of the feeding management is really outside the scope of this paper. Recent papers and articles by Barmore (2000),Batchelder (1998), Bethard and Stokes (1999), Dickrell (2001), Hall (2001), Hutjens (2001a), and Shaver (2001a) fully cover the topic and can be reviewed.

Implementation & Summary

Feed costs represent the single largest variable expense of producing milk. Many dairy farms have the ability to monitor and track inventories, mixing, and feeding but lack a well thought out system and plan. The economic incentives for creating such a plan are large. Often, when data are available, they are under-utilized. Collecting feed quality and variation information, feed disappearance, and feed inventory information allows one to more quickly uncover areas of needs to avoid issues that otherwise would arise with cow health, lost production, or higher than expected feed costs.

Experiences have shown that by establishing as part of a feeder's job description the expectations for monitoring feeding and mixing, and at the same time giving the feeder the monitoring tools, that significant reductions can be made in the variation that occurs from load-to-load or day-to-day. Reducing the variation in the rations delivered, while reducing feed shrink, are real opportunities available to the dairy producer for better managing a significant area of risk. Records and monitoring are always a key to improving and must be considered a key to building a better feeding management plan to address reducing risk exposure.

Begin by making a commitment to improving the mixing and feeding management and managing the feeding process on a daily basis; speak to this commitment with employees and other professionals supporting the dairy farm. Understand the areas which contribute to the greatest variation, while better understanding how to best manage specific types of mixers. Clearly communicate that feed inventory, feed removal from storage, mixing, and shrink along with bunk management are part of the feeder's responsibilities, including writing it into the job role and description. Provide on-going training for these same employees.

Develop an organized, yet simple, monitoring program that will be embraced by the feeder, nutritionist, veterinarian, ag lender or accountant, and management team alike. Recognize the significant costs associated with variation and feed shrink that occur in a feeding program, deploying the proper amount of resources in labor and capital to allow improvements to be made. Investment and changes in feeder training, proper feed handling equipment, mixers, storage facilities, and bins and computer feeding software often are solid investments with relatively quick returns. Set clear expectations with the entire dairy management team as to what the goals and commitments are for improving mixing, feeding variation, and feed shrink.

Now get busy, and celebrate the success and improvements along the way!

References

Allen, M.S. 1997. Relationship between fermentation acid production in the rumen and the requirement for physically effective fiber. J. Dairy Sci. 80:1447-1462.

Barmore, J.A. 2001. Monitoring and managing feeding, inventory, and shrink. Proceedings in Four-State Applied Nutrition and Management Conference. LaCrosse, WI. Pg. 75-86.

Barmore, J.A. 2000. Feeding and bunk management. In: Dairy On-line Connection **(DOC)**. Monsanto Dairy Business, St. Louis, MO.

Bethard, G. and S. Stokes, 1999. On-farm tools for monitoring, feeding, and production. Proceedings Western Dairy Management Conference. April 8-10. Las Vegas, NV. Pg. 114-123.

Batchelder, T.L. 1998. Successfully training and managing feed systems workers. Proceeding Dairy Feeding Systems, Management, Components, and Nutrients Conference. Camp Hill, PA. NRAES-116. Pg. 131-148.

Bolsen, K.K. 2001a. The silage triangle and important practices often overlooked. Proceedings Profit Symposium, Professional Dairy Producers of Wisconsin, Appleton, WI. Dec. 11-12, 2001.

Bolsen, K.K., 2001b. Feedbunk Management: Evaluation Techniques. Proceedings from Profit Symposium, Professional Dairy Producers of Wisconsin, Appleton, WI.

Bucholtz, H., 1999. Communicating with the person mixing the feed. Tri-State Dairy Nutrition Conference. Fort Wayne, IN. The Ohio State University, Columbus.Pg. 205-209.

Buckmaster, D.R., 1998. TMR mixer management. Proceedings Dairy Feeding Systems, Management, Components, and Nutrients Conference. Camp Hill, PA. NRAES-116. Pg. 109-119.

Buckmaster, D.R., and L.D. Muller. 1994. Uncertainty in nutritive measures of mixed livestock rations. J. Dairy Sci. 77:3716-3724.

Cameron, R.E.B., P.B. Dyk, T.H. Herdt, J.B. Kaneene, R. Miller, H.F. Bucholtz, J.S. Liesman, M.J. Vandehaar, and R.S. Emery. 1998. Dry cow diet, management, and energy balance as risk factors for displaced abomasums in high producing dairy herds. J. Dairy Sci. 81:132-139.

Dado, R. G., and M. S.nAllen, 1994. Variation in and relationships among feeding, chewing, and drinking variable for lactating dairy cows. J. Dairy Sci. 77:132-144.

Dickrell, J. 2001. Early-warning signs. Monitoring dry-matter efficiency can give you an early indication of potential problems ahead. In: Dairy Today. April. Pg. 32.

Fetrow, J. 2001. Making dairy management decisions in a financial context: Moving beyond "common sense" in dairy decision-making. Minnesota Dairy Herd Health Pre-Conference Seminar. May 22, 2001. University of Minnesota, St. Paul.

Hall, M.B. 2001. Troubleshooting rations: What the cows have to tell you. Available at: (http://www.animal.ufl.edu/hall/Manure99.htm).

Holmes. B.J. and R.E. Muck. 2000. Preventing silage storage losses. Available at: www.uwex.edu/ces/crops/teamforage.

Holmes, B.J. and R.E. Muck., 1999. Factors affecting bunker silo densities. Available at: www.uwex.edu/ces/crops/teamforage.

Hutjens, M.F. 2001a. Bunk management. Illini dairynet. Available at (http://dairynet.outreach.uiuc.edu).

Hutjens, M.F. 2001b. TMR/Feed bunk management. Illini dairynet. Available at (http://dairynet.outreach.uiuc.edu).

Hutjens, M.F. 2001c. Evaluating TMR Units. Illini dairynet. Available at (http://dairynet.outreach.uiuc.edu).

Kammel, D.W. 1999. Design, selection, and use of TMR mixers. Proceedings of 10th Annual Florida Ruminant Nutrition Symposium. Gainesville, FL.

Kammel, D.W., R.T. Schuler, and R.D. Shaver. 1995. Influence of mixer design on particle size. Pg. 271-297. Proceedings of Second National Alternative Feeds Symposium. St Louis, MO. University of Missouri, Columbia

Krohn, C.C. , and S.P. Kongaard. 1979. Effects of isolating first-lactation cows from older cows. Livestock Prod. Sci. 6:137-146.

Lammers, B.P., D.R. Buckmaster, and A.J. Heinrichs. 1996. A simple method for the analysis total mixed rations. J. Dairy Sci. 79(5):922-928.

Loerch, S.C. 2001. Feed Intake: Should the Cow be in Charge. Proceedings Tri-State Dairy Management Conference. Fort Wayne, IN.The Ohio State University, Columbus. pg. 101-105.

McFarland, D.F. 1998. Watering dairy cattle. Proceeding Dairy Feeding Systems, Management, Components, and Nutrients Conference. Camp Hill, PA. NRAES-116. Pg. 1-20

Menzi, W., and L.E. Chase. 1994. Feeding behavior of cows housed in free stall barns. Proceedings from: Dairy Systems for the 21st Century, American Society of Agricultural Engineers. Pg. 829-832.

Milton, T. 1998. Feed bunk and feed ingredient management: Perspectives from the beef feedlot industry. Proceedings Dairy Feeding Systems Management, Components, and Nutrients Conference. Camp Hill, PA. NRAES-116. pg. 222-229.

Peters, J. On-farm Moisture Testing of Corn Silage. University of WI Marshfield Soil and Forage Analysis Laboratory. Marshfield, WI. Available at: (http://www.uwex.edu/ces/crops/uwforage/CSMoistTest.htm)

Pritchard, R.H., 1998. Bunk management-Observations from research. Plains Nutrition Council Spring Conf. Texas A&M Research Extension. Pub. AREC 98-24. Pg. 68.

Rippel, C.M., E.R. Jordan, and S.R. Stokes. 1998. Evaluation of particle size distribution and ration uniformity in total mixed rations fed in North-central Texas. The Professional Animal Scientist 14:44-50.

Roenfeldt, S. 2000. Give her room to drink. Dairy Herd Management. May 2000. Pg. 28-31.

Salfer, J. 2001. Mixer match. Choose the right TMR mixer based on feed, batch size, and management. In: Dairy Today, June/July, 2001. Pg. 8.

Shaver, R.D. 2001a. Feed delivery and bunk management aspects of laminitis in dairy herds fed total mixed rations. Available at (www.wisc.edu/dairy-profit/dt.html).

Shaver, R.D. 2001b. Prevention of displaced abomasums. Proceedings of Tri-State Dairy Nutrition Conference. Fort Wayne, IN. The Ohio State University, Columbus. Pg. 35-44.

Shaver, R.D. 1998. Feeding systems and strategies for expanding dairies. Presented at 4-State Expansion Conference, March-April, 1998. New Ulm, MN and Madison, WI. Available at (www.wisc.edu/dairy-profit/dt.html).

Sutter, D. and R.D. Shaver. 2001. Evaluation of particle length reduction during silage removal using a bunker facer. University of WI-Madison.

Whitlock, L.A. 1999. Effect of level of top spoilage in the diet on feed intake, nutrient digestibilities, and ruminal metabolism in growing steers fed a whole-plant corn silage-based diet. M.S. thesis. Kansas State University, Manhattan, KS.

Table 1. Bunker silo densities from 168 Wisconsin bunkers[1].

Characteristic	Hay Crop Silage (87 silos)			Corn Silage (81 silos)		
	Average	Range	SD*	Average	Range	SD*
Dry matter, %	42	24-67	9.50	34	25-46	4.80
Wet density, lb/ft^3	37	13-61	10.90	43	23-60	8.30
Dry density, lb/ft^3	14.8	6.6-27.1	3.80	14.5	7.8-23.6	2.90
Particle size, inches	0.46	0.27-1.23	0.15	0.43	0.28-0.68	0.08

[1]Data taken frm Holmes and Muck (1999).
* SD = standard deviation.

Table 2. Particle size evaluation of silage removed with a de-facer.[1,2]

Farm	Forage	Bunker-Facer	Top or Coarse Fraction, %	Middle Fraction, %	Bottom or Fine Fraction, %
A	Alfalfa Silage	Valmetal	39.7	45.0	15.3
A	Alfalfa Silage	Hand	40.1	44.7	15.4
B	Corn Silage	Valmetal	10.6	74.2	15.2
B	Corn Silage	Hand	11.6	75.0	13.4
C	Alfalfa Silage	Valmetal	27.0	46.3	26.7
	Alfalfa Silage	Bunker Buster	31.8	41.9	26.2
	Alfalfa Silage	Bunker Claw	30.5	44.8	24.8
	Alfalfa Silage	Hand	30.9	45.1	24.0
D	Alfalfa Silage	Bunker Buster	43.2	40.3	16.6
	Alfalfa Silage	Bucket	48.2	42.6	9.3
	Alfalfa Silage	Hand	45.7	33.7	20.6
	Corn Silage	Bunker Buster	6.0	78.3	15.7
	Corn Silage	Bucket	11.2	74.3	14.5
	Corn Silage	Hand	7.6	77.4	15.0
SEM			1.6	1.3	1.1
Effects					
Farm			$P < 0.01$	NS	$P < 0.001$
Forage Type			$P < 0.001$	$P < 0.001$	NS
Sample Day			NS[1]	NS	NS
Facer System			NS	NS	NS
Interactions			NS	NS	NS

[1]Data taken from Sutter and Shaver (2001).
[2] NS = not significant and SEM = standard error of mean.

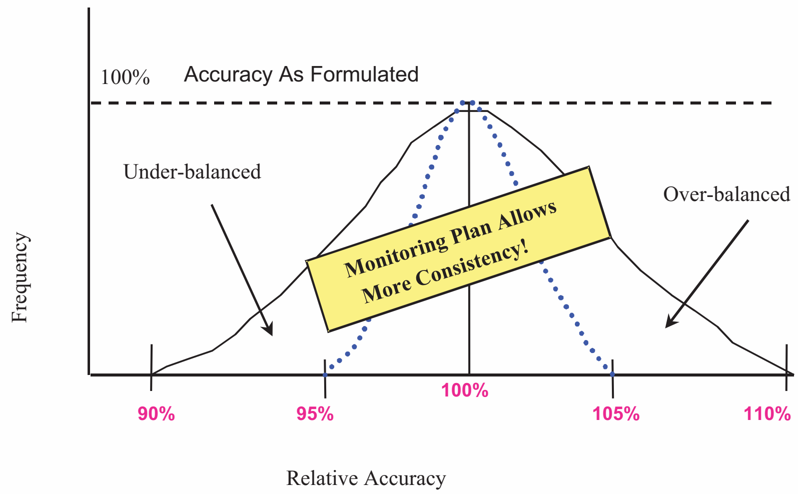

Figure 1. Relative accuracy of a delivered ration expressed as a percentage of formulated accuracy (assumed to be 100%).

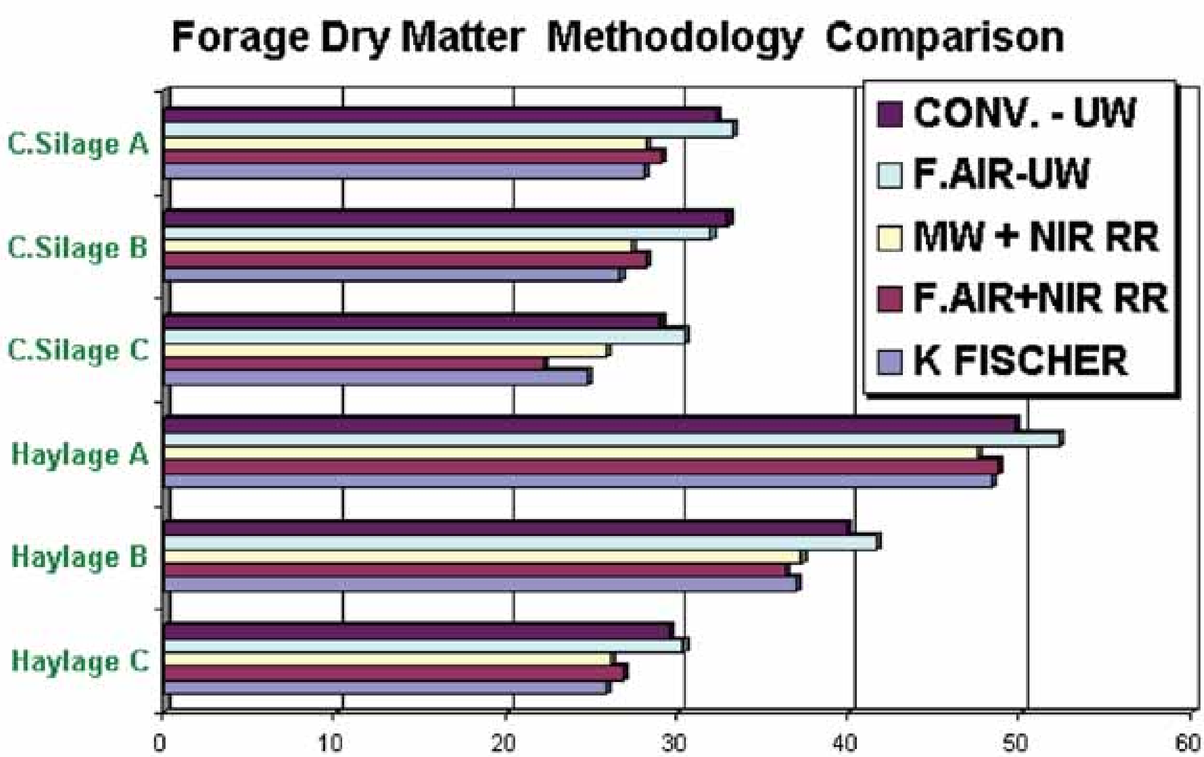

Figure 2. Comparison of different methods for determining forage DM (Barmore, 1997, unpublished). All values represent percentage of DM in forages; Conv-UW = Convection oven at 100°C for 8 hours, g. Oetzel, Univ. of Wisconsin, Madison; K. Fischer = Karl Fischer procedure, W. R. Windham, USDA Athens GA; F.Air-UW = forced-air oven (50°C for 24 hours) + near infrared reflectance (NIR), Rock River Laboratory, Watertown, WI; MW+NIR RR = microwave plus residual moisture by NIR (calibrated on Karl Fischer), Rocker River Laboratory, Watertown, WI; and F. Air + NIR RR = forced-air oven, 60°C for 48 hours, D. Combs, Univ. of Wisconsin-Madison.

Appendix I. Profile of nine Wisconsin, high producing herds during January 2002 (J. A. Barmore, unpublished).

Parameter	Herd 1	Herd 2	Herd 3	Herd 4	Herd 5
Breed	Holstein	Holstein	Holstein	Holstein	Holstein
Milking Cows	550	1532	240	375	830
Milking Frequency	3X	3X	3X	3X	3X
Milk, lb/cow/day	**97**	**87**	**102**	**88**	**90**
% First-Calf Heifers	36	25	33	?	?
% Holstein Cows	100	100	100	100	100
% Milk Fat	3.45	3.8	3.66	3.5	3.77
% Milk True Protein	3.03	3	2.98	2.9	2.95
Posilac Used	Yes	Yes	Yes	Yes	Yes
Posilac Start, DIM	85	65	70	75	>70
# Cows 1994	350	?	170	265	380
# Cows 1998	581	?	190	268	650
# FT Employees	14	30	4	7	8
# PT Employees	2	10	2	3	4
Facilities - Milking Cows					
Freestall Design	4-Row	6-Row	4-Row	4 & 6-Row	4 & 5-Row
Bedding Type	Deep Rice Hulls	Sand	Mattress	Mattress	Sand
Manger Design	Lock-ups	Post-n-Rail	Lock-ups	Lock-ups	Lock-ups
Lock-Up Time	3 hr/wk	?	0	1 hr/day	?
Fans	Holding Pen	Holding Pen	Holding Pen	Holding Pen	Holding Pen
	Freestalls	Freestalls	Freestalls	Freestalls	No
	Manger	No	Manger	Manger	Manger
Sprinklers	Yes	No	Yes	Yes	Yes
Waterers, #/pen	3	2	2	3	3 or 4
Waterer, inch/cow	3	?	?	1.75 - 2.9	2.7
Breezeway water	No	Yes	No	Yes	Yes
Bunk Space/cow	2 ft.	?	2 ft.	22.6 inches	22 inches
Bunk Access, hr/day	21.5	20	20	21	20
% High Pen Density	104	114	116	100	115
1st Calf Separate	Yes	Yes	Yes	Yes	Yes
% 1st Calf Density	104	114	116	109	117
Feed Storage & Ingredients					
Bagged Silage	Alfalfa, Cereals	No	No	Oats, Alf, Corn	Alf, Corn, Cereal
Bunkers	Corn Silage	Alf & Corn Silage	Alf & Corn Silage	Alf & Corn Silage	Alf & Corn Silage
Piles	No	No	Corn Silage	No	No
Upright Silo	HM Shell Corn	No	HM Shell Corn	Oatlage, HMSC	HMSC, Stalklage
Commodity Bays	Ingred. Blend	Chp Hay, SBM	Cottonseed	No	Mineral
		WCS, Gluten Fd			WCS, Gluten Fd
Upright Bins	No	Protein, Mineral	Protein Blend	Protein, Corn	SBM, Distillers
		Dry Corn		Gluten Fd, Bt Plp	
Liquid Fat/Molass.	No	Yes-Fat	No	No	Yes-Molasses
Water Added	No	No	No	No	No

Appendix I (continued).

Parameter	Herd 1	Herd 2	Herd 3	Herd 4	Herd 5
Milking Cows	550	1532	240	375	830
Milk, lb/cow/day	**97**	**87**	**102**	**88**	**90**
DM intake, lb/cow/day	54-56	60	63	53	58
Forage & Feeding Management					
Preblend (PB) Used	Yes	No	Yes	No	Yes
# Ingred. Preblend	6	0	?	0	5
Freq. Mixing PB	3x/week	0	1x/day	0	2x/week
Silage Removal	8"/day	12-16"/day	4-6"/day	4-6"/day	?
Silage De-facer	No	Yes	No	No	Yes
Purchased When	Considering	Fall 2001	None	None	Built 2000
Satisfaction, 1 to 5	None	4	None	None	5
Silage De-facer Satisfaction Rating: High = 5, Low = 1.					
Moisture Tester	Lab	Koster	Lab	Koster	Koster
Haylage	Weekly	Daily	with Changes	2x/week	1-2x/week
Corn Silage	Weekly	Daily	with Changes	2x/week	1x/week
TMR Rain Adjusted	Yes	Minimal	Feeder Est.	Yes	Yes
Monitoring/Record	EZ-feed	EZ-feed	Intake	Daily DMI/Refusal	EZ-feed
Bought/Satisfied	~3 yr/Good	~6 yr/Excellent	None	None	3 yr/Fair
Mixer & Mixing					
Mixer Type	4-auger	4-auger	vertical	4-auger	4-auger
Mixer Age	5 yr	2 yr	5 yr	6 yr	3 yr
# Batches/Day	5	15	6	10	8
Mixer Size, cu ft.	750	?	?	540	~900
Fill Level, % Struck	90	?	?	90	85
Hay in TMR, lb/cow/day	2-Fresh Cows	2-Transition Cows	2	0.75	No
Hay Source	Canada	WI	WI	WI	None
Hay Processed	No	Slicer	Vertical Mixer	Chopped	None
Target Refusal, %	5	2	1-2	Zero	3-5
Refusals Fed	Yes-Heifers	Yes-Low,Heifers	No	Yes-Heifers	Yes-Heifers
Fed When	9 months	Year-round	None	Year-round	~10 months
Refusal Recorded	Yes	Yes	No	Yes	Yes
Bunk Clean-Warm	Daily	Daily	2x	Daily	Daily
# Push-up/Day	4	6 to 8	None	7	5
Mix Time>Last Ing	5 min	3 min	5 min	40 revolutions	3.5 min
Load Time/Batch	20 min	15 min	45 min	30 min	20-25 min
Hay Sequence	1st out of 7	7th out of 11	3rd out of 5	8th out of 11	None
Haylage Sequence	2nd out of 7	8th out of 11	5th out of 5	9th out of 11	2nd out of 4
Corn Silage Seq.	7th out of 7	9th out of 11	4th out of 5	11th out of 11	4th out of 4
Feeding Frequency					
Summer Freq.	2x - every 12 hr	1x	1x	4x	2x
Winter Frequency	twice in 2 hrs	1x	1x	4x	2x

Appendix I (continued).

Parameter	Herd 6	Herd 7	Herd 8	Herd 9
Breed	Holstein	Holstein	Holstein	Holstein
Milking Cows	565	360	335	575
Milking Frequency	3X	3X	3X	3X
Milk, lb/cow/day	**95**	**98**	**93**	**90**
% First-Calf Heifers	36	28	29	38
% Holstein cows	100	100	98	100
% Milk Fat	3.6	3.71	3.62	3.9
% Milk True Protein	2.9	2.95	3.07	2.94
Posilac Used	Yes	Yes	Yes	Yes
Posilac Start, DIM	57	63	65	60
# Cows 1994	110	112	125	550
# Cows 1998	565	137	175	575
# FT Employees	10	7	5	14
# PT Employees	5	2	0	2
Facilities - Milking Cows				
Freestall Design	3 & 6-Row	6-Row	4-Row	3-Row
Bedding Type	Sand	Sand	Sand	Sand
Manger Design	Post-n-Rail	Lock-ups	Lock-ups	Post-n-Rail
Lock-Up Time	0	1	2	0
Fans	Holding Pen	Holding Pen	Holding Pen	Holding Pen
	Freestalls	Freestalls	Freestalls	Freestalls
	Manger	Manger	Manger	Manger
Sprinklers	No	Yes	Yes	Yes
Waterers, #/pen	2	3	2	2
Waterer, inch/cow	<2	4.3	?	1.3
Breezeway water	No	Yes	Yes	Yes
Bunk Space/cow	~15 in.	17.3 in.	20 in.	14.3 in.
Bunk Access hr/day	21	21	20	21
% High Pen Density	108	106	110	120
1st Calf Separate	Yes	Yes + 2nd Calf	Yes	Yes
% 1st Calf Density	123	106	110	123
Feed Storage & Ingredients				
Bagged Silage	Alfalfa, Corn Sil.	Alfalfa, Corn Sil.	Alfalfa, Corn Sil.	No
Bunkers	Corn Silage	No	No	Alf & Corn Silage
Piles	No	No	No	No
Upright Silo	HM Shell Corn	HM Shell Corn	HM Shell Corn	No
Commodity Bays	No	No	Cottonseed	WCS, Barley
			Beet Pulp, SBM	Protein, Hay
Upright Bins	Corn, Protein	Corn, Protein	No	EnerGII, Mineral
	Minerals	Minerals		
Liquid Fat/Molass.	Yes-Molasses	No	Yes-Molasses	Yes-Molasses
Water Added	No	No	No	No-Wet Brewers

Appendix I (continued).

Parameter	Herd 6	Herd 7	Herd 8	Herd 9
Milking Cows	565	360	335	575
Milk, lb/cow/day	**95**	**98**	**93**	**90**
DM intake, lb/cow/day	61-64	64	56	54
Forage & Feeding Management				
Preblend (PB)Used	No	No	Yes	No
# Ingred. Preblend	0	0	5	0
Freq. Mixing PB	0	0	1-2x/day	0
Silage Removal	6"/day	?	?	~3"/day
Silage De-facer	No	No	No	No
Purchased When	None	None	None	None
Satisfaction, 1 to 5	None	None	None	None
Silage De-facer Satisfaction Ratin: High = 5, Low = 1.				
Moisture Tester	Lab	Koster	Microwave	None
Haylage	bi-weekly	Weekly+	Weekly	6x/year
Corn Silage	bi-weekly	Weekly	bi-weekly	2x/year
TMR Rain Adjusted	None	No-Bags	Feeder Est.	Feeder Est.
Monitoring/Record	TMR-Tracker	TMR-Tracker	Intake	Daily DMI/Refusal
Bought/Satisfied	1.5 yr/Poor	~2 yr/Fair	None	None
Mixer & Mixing				
Mixer Type	Reel	4-auger	Reel	4-auger
Mixer Age	2 yr	4 yr	New	New
# Batches/Day	7	10	4	9
Mixer Size, cu ft.	?	630	450	630
Fill Level,% Struck	100	?	75	90
Hay in TMR, lb/cow/day	No-T.D. Fresh	Yes	No	Transition
Hay Source	WI	Western	None	WI
Hay Processed	No	Tub Gr-Consider	None	Tub Grinder
Target Refusal, %	4	3-5	5	1-3
Refusals Fed	Yes-Dry Cows	Yes-Heif/Steer	Yes-Heifers	Yes-Dry Cows
Fed When	Fresh Yr-round	Year-round	Year-round	Year-round
Refusal Recorded	No	Yes	No	Yes
Bunk Clean-Warm	Daily	Daily	Daily	Daily
# Push-up/Day	3	~6	6	5
Mix Time>Last Ing	3 min	5 min	3 min	6 min
Load Time/Batch	17 min	35 min	45 min	30 min
Hay Sequence	None	6th out of 9	None	None
Haylage Sequence	7th out of 8	8th out of 9	5th out of 5	2nd out of 6
Corn Silage Seq.	8th out of 8	9th out of 9	4th out of 5	6th out of 6
Feeding Frequency				
Summer Freq.	1x	1x	2x	1x
Winter Frequency	1x	1x	1x	1x