What Can Be Learned From TMR Audits?

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▪ Take Home Messages

- Good silage face management and feed centre organization are keys to reducing waste on dairies.
- Reducing variation in silages improves consistency among loads of TMRs.
- Following the 10 mixing basics reduces variation in TMRs.
- Increasing access to feed by all cows at all times will improve health and production.

▪ Introduction

Feed costs represent the largest portion of the cost to produce milk. Much effort has been spent on making sure the cow gets the most out of the feed by feeding highly digestible forages, well processed grains, and commodities that provide available levels of amino acids, minerals and vitamins. Often, the performance of the cows does not match what the nutritionist has formulated for on paper. Reasons for this can vary, but can include improper knowledge of actual dry matter intakes, poor cow comfort leading to excessive maintenance energy costs not accounted for in the ration software and finally, improper mixing of the total mixed ration (TMR). Sova et al. (2014) showed a negative association between the coefficient of variation (CV) in NE_L content of the ration fed and average test-day milk yield. The data were collected from 22 farms for 7 consecutive days during summer and winter months. They also showed a negative association between the CV of long forage particles and average test-day milk yield. As the CV of these components increased (more variation) the average test-day milk decreased. Various methods of testing mixer efficiency have been developed using salt (Groesbeck et al., 2004; Harner et al., 1995) or drugs such as Rumensin® (Biermann, 2008). Others have used these methods to test the effects of mix time after the last added ingredient (Biermann, 2008; Groesbeck et al., 2004; Harner et al., 1995), and loading sequence (Biermann, 2008; Groesbeck et al., 2004). However, these methods require collecting and sending the samples to a lab for analysis and then waiting for the results. A faster and lower cost method was needed to do an on-farm evaluation of TMR consistency.

▪ TMR Audit

The TMR Audit® evaluates feed-out management of haylage and corn silage piles so that variation in moisture and nutrients are reduced prior to loading into the TMR mixer (Oelberg and Stone, 2014). The audit also evaluates feed center organization, use of on-farm premixes and TMR loading sequences and timing. Making slight changes in the TMR loading and mixing routine can lead to significant improvements in fuel and labor efficiency and mixer performance, and reduced feed waste. Much attention is paid to how and when feed is delivered to the pens. Finally, the TMR Audit also uses time-lapse cameras positioned over the feed bunks to evaluate cows' access to feed and feed push up schedules.

▪ Managing Forage Feedout to Improve TMR Consistency

Feed out management of stored wet feeds is critical to ensuring high quality and consistent loads of TMR. Critical control points are as follows:

1. Remove at least 6 and 12 inches off the silage face per day during cold and warm weather, respectively, to avoid excessive secondary fermentation, heating and spoilage of the silage by wild yeast, aerobic bacteria and molds.
2. Uncover enough silage to feed out for several days depending on weather conditions. Caution is needed to keep workers at a safe distance from the edge of the face.
3. Remove any moldy or spoiled silage before facing the silage.
4. Face the silage into a windrow and then push and lift the faced silage into a pile with a payloader or skid-steer loader. This action improves consistency of the silage before it is placed into loads of TMR (Oelberg and Stone, 2014). It is highly recommended to take 10 samples from this pile and place into a pail, blend the samples and take a sub-sample for moisture and nutrient analysis.
5. Make sure there is a minimal amount of loose silage remaining when feeding is complete.

▪ The Ten Factors Causing TMR Variation

A key goal of the TMR Audit is to help reduce variation of the major ingredients. The next part of the audit is to evaluate the TMR mixing process. There are 10 factors in the TMR loading and mixing process that can contribute to TMR variation individually or in combination. Each of these will be discussed in detail.

They are:

1. Worn mixer augers, kicker plates and knives
2. Un-level mixers
3. Mix time after the last added ingredient
4. Loading position on the mixer box
5. Load size
6. Hay quality and processing
7. Loading sequence
8. Liquid distribution
9. Vertical mixer auger speed
10. Forage restrictor settings on vertical mixers

Worn Mixer Augers, Kicker (Deflector) Plates and Knives

TMR particle size consistency as well as moisture and nutrient consistency along the feed bunk (TMR mix quality) can decrease significantly with worn blades, kicker plates and augers (Oelberg and Stone, 2014). Mixers are factory set with specific agitator clearances of 0.3 to 0.9 cm (Zinn, 2004). As these clearances increase due to wear, mixer efficiency is impaired (Zinn, 2004). The easiest way to evaluate wear on augers is to look for feed under horizontal augers or reels and to look for the feed ring inside vertical mixers. The mixing efficiency on vertical auger mixers depends on the condition of the edge on the auger flighting and on the condition of the kicker plate, shoe or deflector. The edge of the flighting should not have rounded corners. The degree and speed of wear on the augers, kicker plates and knives depends on the size of the herd and the amounts of hay, baleage or straw fed. Routine replacement of blades, kicker plates and augers are required to keep TMRs consistent. Augers with no knives attached can be used to make very consistent TMRs if the hay and straw are pre-ground.

Un-level Mixers

Un-level mixers cause migration of the heaviest and most dense materials in the TMR to the lowest section of the mixer wagon. Figure 1 shows a shaker box analysis of ten samples taken from a triple–auger vertical that was parked in a ramp that was too short causing the grain-concentrate portion of the TMR to migrate to the back of the mixer box. Notice how the levels in the bottom screen increase from sample 1 (front) to sample 10 (back) and the opposite trend can be observed for the middle screen which would have less dense feedstuffs such as haylage and corn silage and small particles of hay. This is a very typical pattern in the Penn State shaker box analysis for both un-level mixer boxes and for improper loading position on vertical wagons. A discussion on loading position on mixer boxes will occur in the next section.

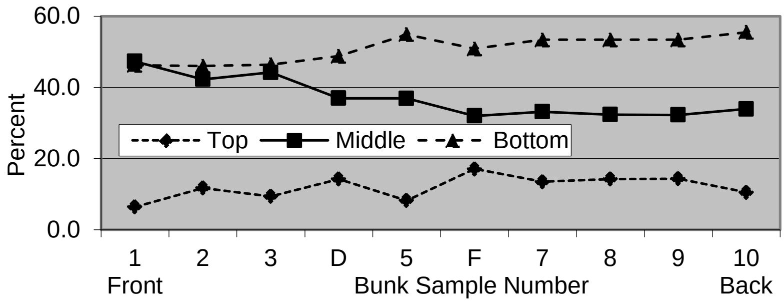


Figure 1. Influence of un-level mixer box on TMR particle size distribution on the Penn State shaker box screens.

Loading Position on the Mixer Box

Loading position on the mixer box refers to the location on the mixer box where the feeder is dumping ingredients in. Improper loading position on the mixer box will create a poorly mixed TMR (Oelberg and Stone, 2014). Figure 2 shows the influence of loading liquid in the front versus the middle of a dual-auger vertical mixer on the levels of TMR in the middle and bottom screens of the Penn State Particle Separator. The liquid was a whey product that bound the small feed particles in the bottom screen to the larger particles in the middle screen at the front of the wagon. Then there is a continued increase in the amount of material in the bottom screen as you progress to the back of the wagon. The opposite trend is seen for the middle screen. The mixer was moved ahead 4 feet so that the liquid whey could be loaded between both augers or in the center of the mixer box. This resulted in a very consistent TMR shown by the dotted lines. Figure 3 shows the influence of loading a liquid protein supplement in the back of a dual-auger vertical wagon on moisture and protein levels in the TMR. Both moisture and protein increase linearly as you move from front to back of the wagon. This resulted in a very inconsistent TMR along the feed bunk. Because cows are quite territorial within the pen, not all cows will get the same nutrition nor will they get the same effective particle size. This leads to differences in rumen health and digestion, rumination patterns and manure consistency among cows within the pen fed this ration. Most dual-auger and triple auger vertical wagons move feed back and forth in the wagon, but it takes time. These results show that feed dumped in either end of these wagons does not get completely mixed during routine mixing. If mixing time is increased so that the TMR is completely mixed then there is increased risk of decreasing effective particle size in the TMR. The increased mixing time would also increase fuel and labor cost. It is best to load the mixers at the proper position.

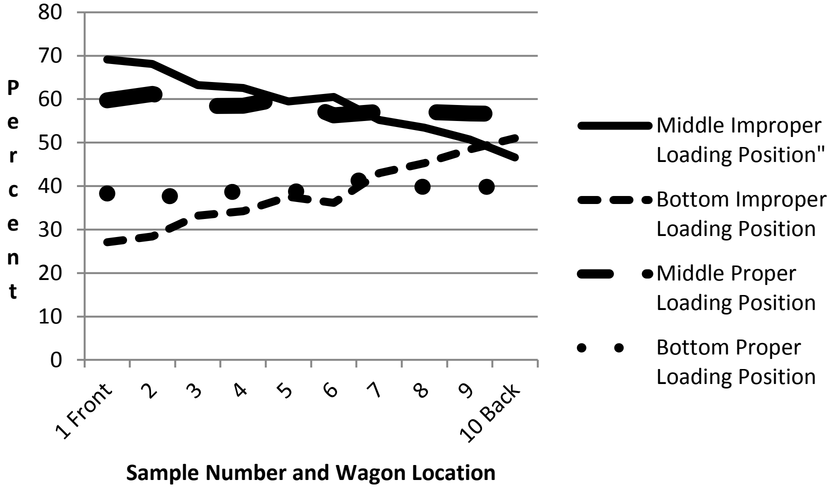


Figure 2. The influence of loading liquid whey in the front vs. center of a dual-auger vertical mixer on levels of TMR in the middle and bottom screens of the Penn State shaker box.

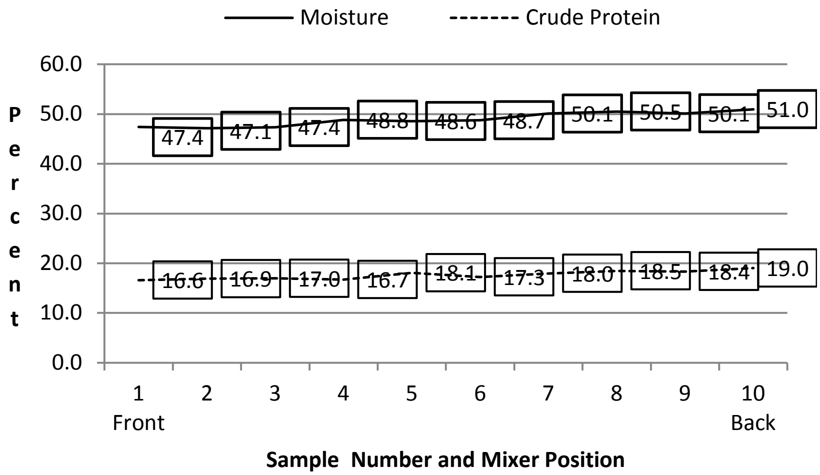


Figure 3. The influence of loading a liquid protein supplement in the back of a dual-auger wagon on moisture and crude protein levels in the TMR.

Mix Time After the Last Added Ingredient

Several authors have cited mixing time as a critical element to get consistent mixes (Behnke, 2005; Bierman, 2008; Groesbeck et al., 2004; Harner et al., 1995). Groesbeck et al. (2004) showed that the amount of mix time after the last ingredient was added to a swine diet in a horizontal ribbon mixer was important in reducing the variation in the concentration of salt (Groesbeck et al., 2004). One of the most common mistakes in TMR mixing is lack of mix time after the last added ingredient (usually corn silage or liquid supplement) (Oelberg and Stone, 2014). Often times the corn silage at the top of the load does not get mixed and is delivered towards the end of the load as pure corn silage. This is even more prevalent as mixer boxes are over-filled. Suggested mix times after the last ingredient with tractors/trucks at nearly full power (1700 to 2000 rpm engine speed) are 2 to 5 minutes. Inadequate mix times resulted in an inconsistent TMR (Table 1). Increasing mix time after the last added ingredient from 3.5 to 5 minutes in a 4-auger horizontal mixer decreased coefficients of variation and improved TMR consistency.

Table 1. Influence of mix time after the last added ingredient, load size and forage restrictor setting on TMR mix quality percent coefficient of variation, CV %).

	Penn State Particle Separator Results for Each Screen					
	Top	Middle	Bottom	Top	Middle	Bottom
Mix time	3.5 Minutes			5 Minutes		
CV, %	18.52	3.11	4.81	8.15	2.12	2.56
Load size	Over-filled			Normal Filled		
CV, %	31.58	7.39	5.22	19.35	2.72	2.58
Forage restrictor	All the way in			Half way in		
CV, %	28.12	6.78	6.66	8.86	1.82	1.72

Load Size

Over-filling

Over-filling the load capacity can occur on all types of mixer wagons resulting in poor mix quality of the TMR (Oelberg and Stone, 2014). It is a very common mistake in TMR mixing on many dairies and feedlots. Overfilling occurs for several reasons:

- Under sizing the mixer box for the dairy.
- Inaccurate pen counts.

- Changes in forage moisture levels, i.e., drier silages take up more space.
- Too large of an increase in bunk calls where the mixer box is already at full capacity.

Reducing the load size in a 4-auger mixer by 5000 pounds decreased the coefficient of variation (Table 1) of the average levels of TMR in all 3 trays of the Penn State Particle Separator and improved TMR mix quality.

Under Filling Vertical Mixers

Under filling of vertical mixers occurs when the TMR does not reach the top of the augers so that all of the ingredients are pushed off the augers and mixed. This happens often on many dairies that are mixing for small pens such as close-up dry and fresh pens (Oelberg and Stone, 2014).

Forage Restrictor Settings

Most brands of vertical mixer have forage restrictors mounted on the side of the mixer box. The forage restrictors, when properly set, improve hay processing without impeding TMR mix quality. If the forage restrictors are moved too far into the mixer box, mixing can be impeded resulting in a poorly mixed TMR (Table 1).

Hay Quality and Processing

Poor hay quality and inadequate processing make TMRs very inconsistent and can affect both variation and level of milk components in a herd (Figure 4).

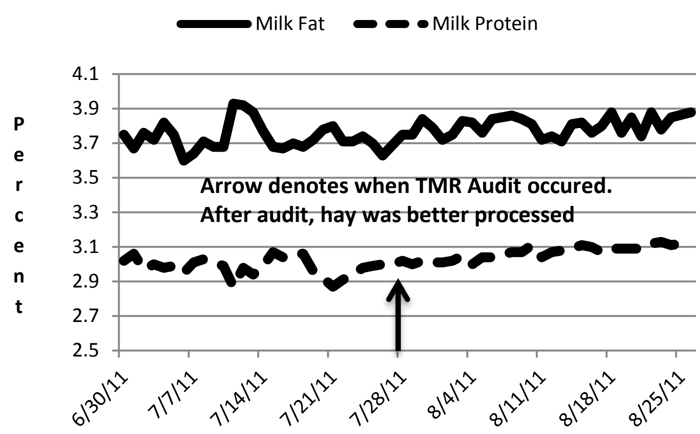


Figure 4. Milk fat and protein levels in the bulk tank before and after hay was better processed.

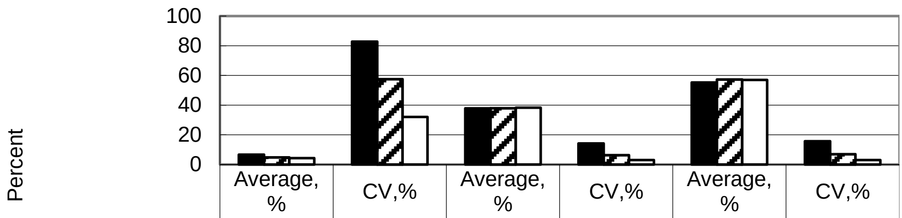
Loading Sequence

Several authors have addressed loading sequence as a factor contributing to TMR mix quality (Barmore, 2005; Behnke, 2005; Biermann, 2008; Oelberg and Stone, 2014; Zinn, 2004). The loading sequence will depend on:

- Mixer wagon type (auger-reel versus 4-auger or vertical).
- Ingredient type (density, particle size and shape and moisture level and flow ability) (Behnke, 2005).
- Inclusion level (Zinn, 2004).
- Convenience of loading based on where ingredients are stored at the feed center and time available to the feeder (not the most ideal situation on many dairies).

Generally, lower density and large particle feeds are loaded first, followed by dry more dense feeds followed by wet feeds and liquid last. Of the dry, more dense feeds, the lower-inclusion level feeds are added first so that they can be blended properly (Zinn, 2004). Use the ratio of 50:1 to blend lower inclusion dry feeds such as rumen by-pass fats and vitamin/mineral premixes. For example, if 50 kg of rumen by-pass fat is being added, then the load size should be no more than 2500 kg. The mixer should be running to allow the lower inclusion feed to mix.

TMR mix quality was improved dramatically by increasing mix time after the last added ingredient from 2 to 4 minutes and then changing mix order to further improve the mix quality (Figure 5).



	Top: Average, %	Top: CV,%	Middle: Average, %	Middle: CV,%	Bottom: Average, %	Bottom: CV,%
Mixing Time	6.7	82.8	37.9	14.2	55.4	15.7
Loading Sequence	4.7	57.4	38.0	6.2	57.3	7.0
Normal	4.4	32.2	38.4	3.1	57.1	3.0

Figure 5. Influencing of mixing time after the last added ingredient and loading sequence on TMR variation.

Liquid Distribution

Liquids such as water, whey and cane molasses are routinely added to TMR to add moisture or sugar, or are used as a carrier for micro ingredients. Another important reason liquids are added to the TMR is to help reduce sorting by cattle. The liquids, especially cane molasses and liquid whey, are sticky and they help bind the smaller particles to the larger forage particles. As a result, the levels of on the bottom pan of the Penn State shaker box will shift to the middle and top screens by as much 5 to 7 percentage units depending on type and level of liquid added directly to the TMR.

It is best to add the liquid last to the TMR to prevent any balling or clumping of the drier ingredients (Behnke, 2005; Biermann, 2008; Zinn, 2004). There are 2 challenges of adding liquid directly to the TMR; time and distribution. Depending on the amount of liquid added to the TMR and the sizes of the pumps and pipes to load the liquid, the amount of time it takes to add liquid can range from 2 to 10 minutes per load and sometimes even longer. This can create a bottleneck in getting cattle fed on time for larger operations. Many dairy operations are adding the liquid to the on-farm commodity blend (Oelberg and Stone, 2014). Improper distribution of the liquid can make the TMR very inconsistent along the feed bunk (Oelberg and Stone, 2014). Figure 6 is an example of how liquid should be added to a TMR or to an on-farm commodity blend.

Figure 6. Example of how liquid is added to a TMR

Vertical Mixer Auger Speed

The influence vertical auger speed has on TMR mix quality and apparent improvement in dairy cattle performance has been documented in a case study (Oelberg and Stone, 2014). Improved milk and energy-corrected milk (Figure 7) along with improved milk urea nitrogen (MUN) levels (Figure 8) were associated with improved TMR mix quality after vertical auger speed was increased with proper engine speed and mixer gear box setting.

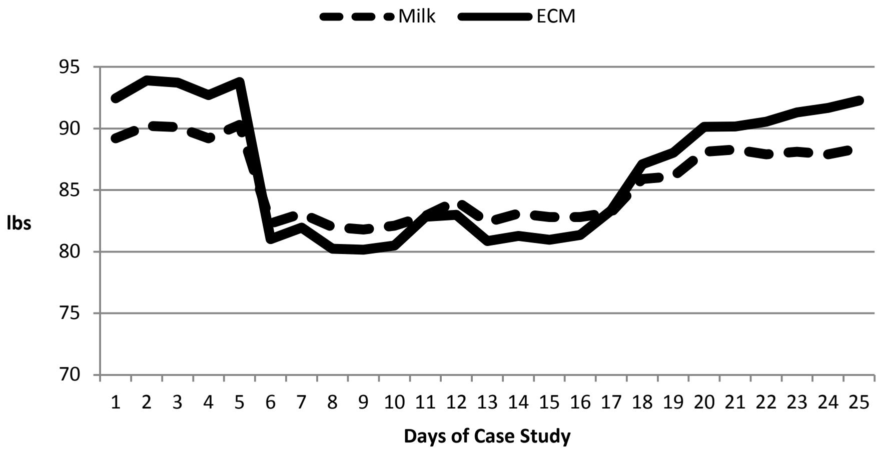


Figure 7. Influence of vertical mixer auger speed on TMR mix quality and milk production.

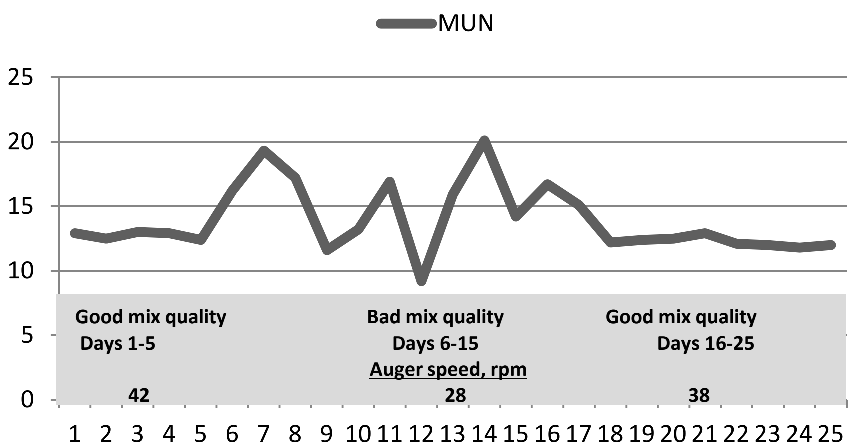


Figure 8. Influence of vertical mixer auger speed on TMR mix quality and milk urea nitrogen.

▪ What do Time-lapse Cameras Above Feed Bunks Tell us?

Time-lapse cameras used for game hunting have been very effective tools to monitor TMR levels along feed bunks. Cameras are mounted on a feed line support post at one end of the pen for several days or more. Photos are taken every 5 seconds and saved on a 32 gb SD card. Events such as feed delivery, feed push up, feed push out, and cow movement to and from the parlor are documented. The following have been observed:

- There are cows eating or looking for feed at all hours of the day and night.
- Cows are territorial within the pen. If their area of the bunk is empty, they generally will not go to another area where there is feed due to social dominance issues.
- Cows often cannot reach feed or there is no feed for 4 to 7 hours during late evening and early morning.
- Cows returning from the parlor will aggressively eat if feed is pushed up.
- Labor for feed push up during evening and early morning is a limiting factor on many dairies.

▪ Summary

An on-farm system to test TMR consistency along the feed bunk and to evaluate mixer performance has been developed. Implementation of this system has improved TMR consistency on many dairies in North America, China, Europe and Central Asia. The standard for TMR particle size consistency determined on 10 samples is a CV of 2.5% or less for the average levels on middle and bottom screens of the Penn State Particle Separator. Time-lapse game cameras are an effective tool to monitor feed access by dairy cows.

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