Effective Outcomes of TMR Audits

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Abstract

Total mixed rations **(TMR)** are formulated to contain a combination of feedstuffs that provide the right balance of nutrients in every bite consumed. Poorly mixed TMR negatively impact animal performance and health. A system has been developed to monitor how well the feedstuffs are blended and delivered to the feed bunk. This system is called the TMR Audit (Oelberg and Stone, 2014). There are 10 factors in the TMR mixing process that can create variation in the TMR before it is delivered to the feed bunk. Additionally, time-lapse cameras can be utilized to evaluate animal access to the TMR and feed push routines. The desired outcomes of a TMR Audit are: 1) reduced variation in feed ingredients and TMR, 2) improved feeding efficiency, 3) reduced feed waste, and 4) improved feed bunk management.

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. Oftentimes the performance of the cows does not match predicted performance from ration formulation software. Reasons for this can vary but can include improper knowledge of actual dry matter intakes, poor cow comfort leading to excessive maintenance costs not accounted for in the ration software, and finally, improper mixing of the TMR. Sova et al. (2014) showed a negative association between fed ration coefficient of variation **(CV)** in NEL 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 (Harner et al., 1995; Groesbeck et al., 2004) or a drug such as Rumensin® (Biermann, 2008). Others, have used these methods to test the effects of mix time after the last added ingredient (Harner et al., 1995; Groesbeck et al., 2004; Biermann, 2008), or loading sequence (Groesbeck et al., 2004; Biermann, 2008). However, these methods require collecting and sending the samples to a lab for analysis and then one must wait 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 forages so that variation in moisture and

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nutrients are reduced prior to loading into the TMR (Oelberg and Stone, 2014). The audit also evaluates feed center organization, use of on-farm premixesn 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, 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. This manuscript will focus on the 10 mixing factors that cause variation in TMR particle size.

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. Mix time after the last added ingredient,
3. Unlevel mixers,
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, and
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 consistencies 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. Often, mixing problems become obvious if one simply looks at a full load of feed being mixed. 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 TMR consistent.

Mix Time After the Last Added Ingredient

Several authors have cited mixing time as a critical element to get consistent mixes (Harner et al., 1995; Groesbeck et al., 2004; Behnke, 2005; Biermann, 2008). 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. One of the most common mistakes in TMR mixing is the lack of mix time after the last added ingredient (usually corn silage or liquid supplement) (Oelberg and Stone, 2014). Oftentimes, 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 3 to 5 minutes. Inadequate mix times resulted in an inconsistent TMR (Table 1). Increasing mix time from 3.5 to 5 minutes in a 4-auger horizontal mixer reduced the CV for particles retained on each screen and the pan of the Penn State Particle Separator **(PSPS)**.

Unlevel Mixers

Unlevel 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 PSPS analysis of 10 samples taken from a triple–auger vertical mixer that was parked on 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 amount in the bottom screen increased 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 PSPS analysis for both unlevel mixer boxes and for improper loading position on vertical wagons. A discussion on loading position on mixer boxes will occur in the next section.

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. 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 PSPS. The liquid was a whey product that bound the small feed particles in the pan to the larger particles in the middle screen at the front of the wagon. Then, there was a continued increase in the amount of material in the pan as you progress to the back of the wagon. The opposite trend was 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, neither will 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's best to load the mixers at the proper position.

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). This is a very common mistake in TMR mixing on many dairy farms and feedlots. Overfilling occurs for several reasons:

- Under sizing the mixer box for the dairy farm,
- Inaccurate pen counts,
- Changes in forage moisture levels or types, i.e. drier silages take up more space, and haylage is bulkier than corn silage, and
- 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 lb decreased the CV (Table 2) of the average levels of TMR in all 3 trays of the PSPS 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 dairy farms that are mixing for small pens, such as close-up dry and fresh pens (Oelberg and Stone, 2014). Running the vertical augers at a higher RPM can help small loads to mix.

Hay Quality and Processing

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

Loading Sequence

Several authors have addressed loading sequence as a factor contributing to TMR mix quality (Barmore, 2002; 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, moisture level, and flowability) (Behnke, 2005),
- Inclusion level (Zinn, 2004), and
- 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 dairy farms).

Generally, lower density and large particle feeds are loaded first, followed by dry more dense feeds followed by wet feeds, and last with liquid. 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. Example, if 50 lb of rumen by-pass fat is being added, then the load size should be no more than 2500 lb. 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).

Liquid Distribution

Liquids, such as water, whey, and cane molasses, are routinely added to the TMR to add moisture, 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 amount on the pan of the PSPS can 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 (Zinn, 2004; Behnke, 2005; Biermann, 2008). 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.

Vertical Mixer Auger Speed

The influence vertical auger speed 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 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.

Forage Restrictor Settings

Most brands of vertical mixers 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 3).

Conclusions

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 dairy farms across the U.S. The standard for TMR particle size consistency determined on 10 samples is to have a CV of 2.5% or less for particles retained on the middle screen and pan of the PSPS.

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Table 1. Influence of mix time after the last added ingredient on TMR mix quality (CV = coefficient of variation).

	Penn State Shaker Box Results (% of sample)					
	3.5 Minutes			5 Minutes		
Bunk Sample #	Top	Middle	Bottom	Top	Middle	Bottom
1 Front	10.9	38.2	50.8	14.9	38.8	46.3
2	8.6	38.8	52.6	12.6	41.5	45.9
3	11.6	38.4	50.0	12.5	40.0	47.5
4	15.6	37.8	46.7	14.3	39.3	46.5
5	13.9	39.1	47.0	13.1	39.8	47.1
6	10.8	38.2	51.0	11.7	39.5	48.8
7	9.2	39.1	51.7	12.6	38.8	48.6
8	12.2	41.7	46.0	12.4	38.7	48.9
9	14.1	38.1	47.7	13.0	40.2	46.9
10 Back	11.6	37.3	51.1	11.4	39.3	49.3
Average, %	11.8	38.7	49.5	12.8	39.6	47.6
CV, %	18.52	3.11	4.81	8.15	2.12	2.56

Table 2. Influence of load size in a 4-auger horizontal mixer on TMR mix quality (CV = coefficient of variation).

	Penn State Shaker Box Results (% of sample)					
	Over-filled			Normal Filled		
Bunk Sample #	Top	Middle	Bottom	Top	Middle	Bottom
1 Front	4.9	45.9	49.2	5.6	44.8	49.6
2	2.9	46.3	50.7	6.0	46.0	48.0
3	2.3	44.2	53.5	4.7	46.2	49.1
4	3.8	44.0	52.2	7.4	45.9	46.7
5	4.8	43.8	51.4	5.5	44.5	50.0
6	3.4	47.7	48.9	8.8	42.8	48.5
7	4.3	44.6	51.1	7.0	46.5	46.5
8	3.8	44.2	51.9	8.1	44.1	47.8
9	7.0	37.3	55.7	7.2	43.9	48.9
10 Back	3.6	38.8	57.6	5.9	44.1	50.0
Average, %	4.1	43.7	52.2	6.6	44.9	48.5
CV, %	31.58	7.39	5.22	19.35	2.72	2.58

Table 3. Influence of forage restrictor setting on TMR mix quality (CV = coefficient of variation).

Sample Position	Forage restrictors set all the way in			Forage restrictors set half way in		
	Top	Middle	Bottom	Top	Middle	Bottom
1 Front	4.6	45.4	50.0	6.2	41.6	52.2
2	3.9	45.2	51.0	5.3	41.3	53.4
3	6.0	43.5	50.5	5.4	40.3	54.3
4	4.2	44.2	51.6	6.2	40.5	53.3
5	3.5	46.1	50.3	4.8	41.8	53.4
6	4.8	42.0	53.2	5.1	39.8	55.2
7	2.9	40.0	57.1	5.4	40.1	54.5
8	3.8	41.7	54.5	5.2	41.6	53.2
9	3.8	38.3	57.9	5.1	40.2	54.8
10 Back	1.8	38.3	59.9	5.0	40.4	54.6
Average, %	3.9	42.5	53.6	5.4	40.8	53.9
CV, %	28.12	6.78	6.66	8.86	1.82	1.72

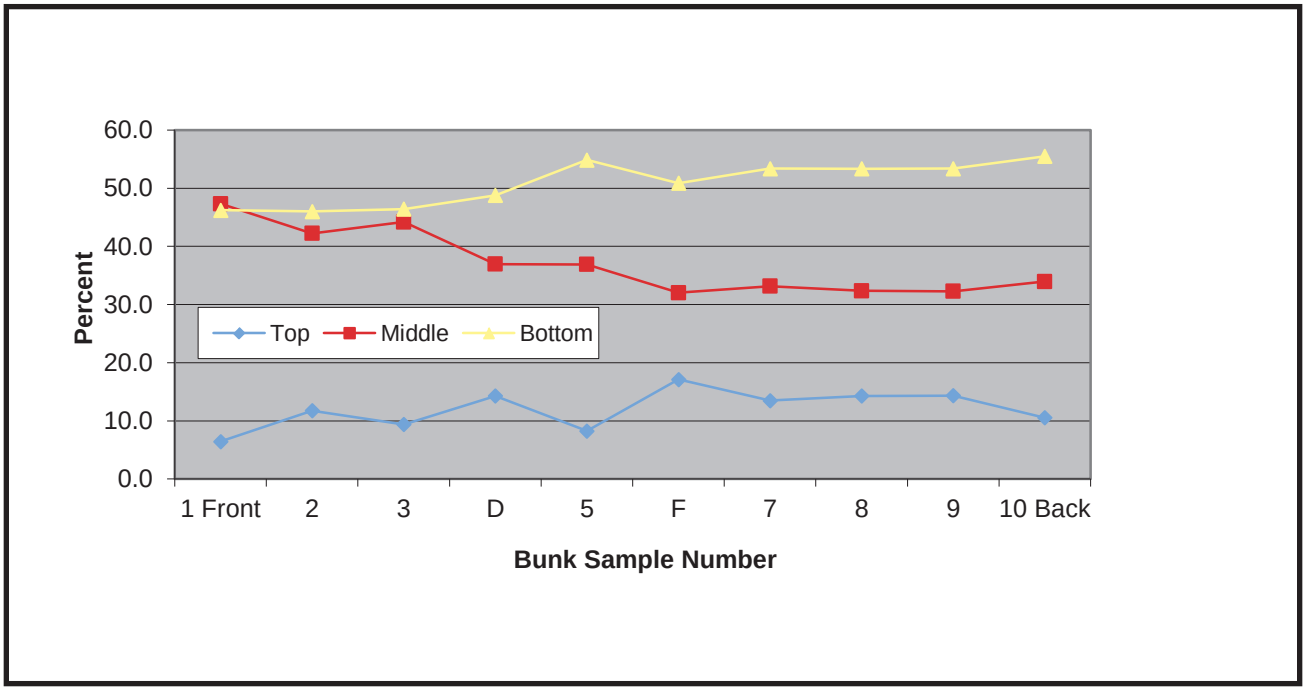


Figure 1. Influence of un-level mixer box on TMR particle size distribution on the Penn State Shaker box screens.

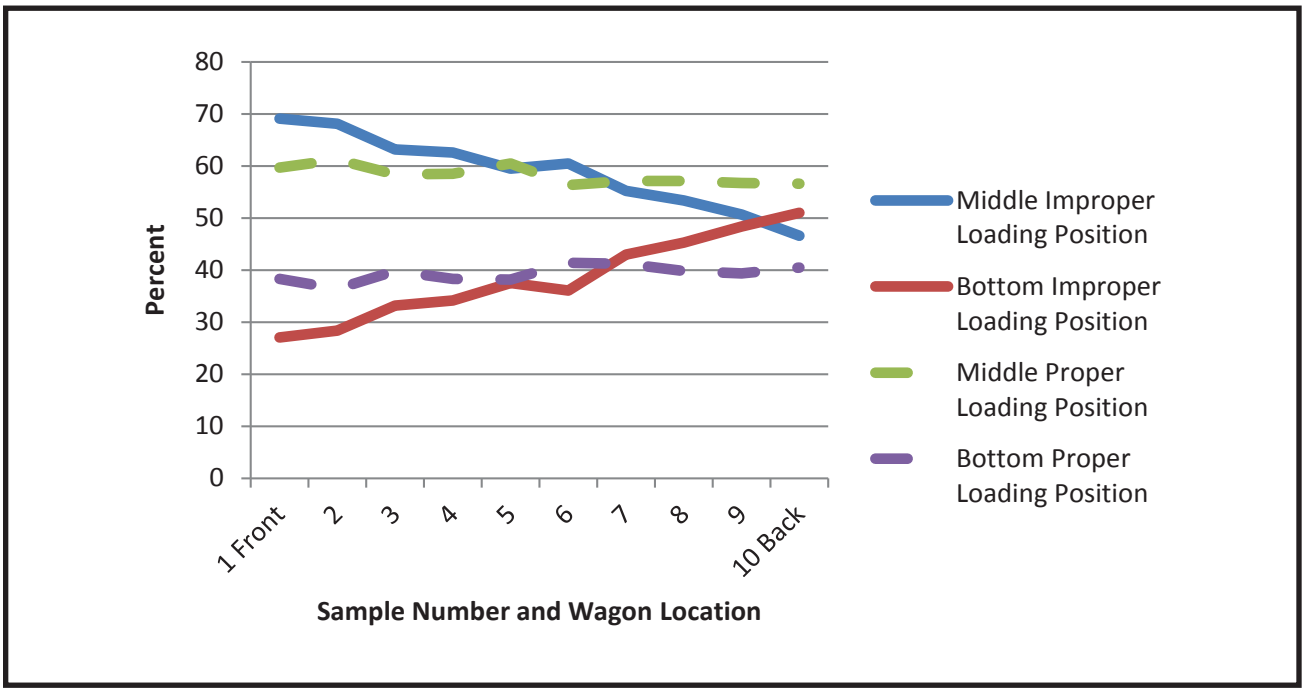


Figure 2. The influence of loading liquid whey in the front vs. center of a dual-auger vertical mixer on levels of TMR in the middle and bottom screens of the Penn State shaker box.

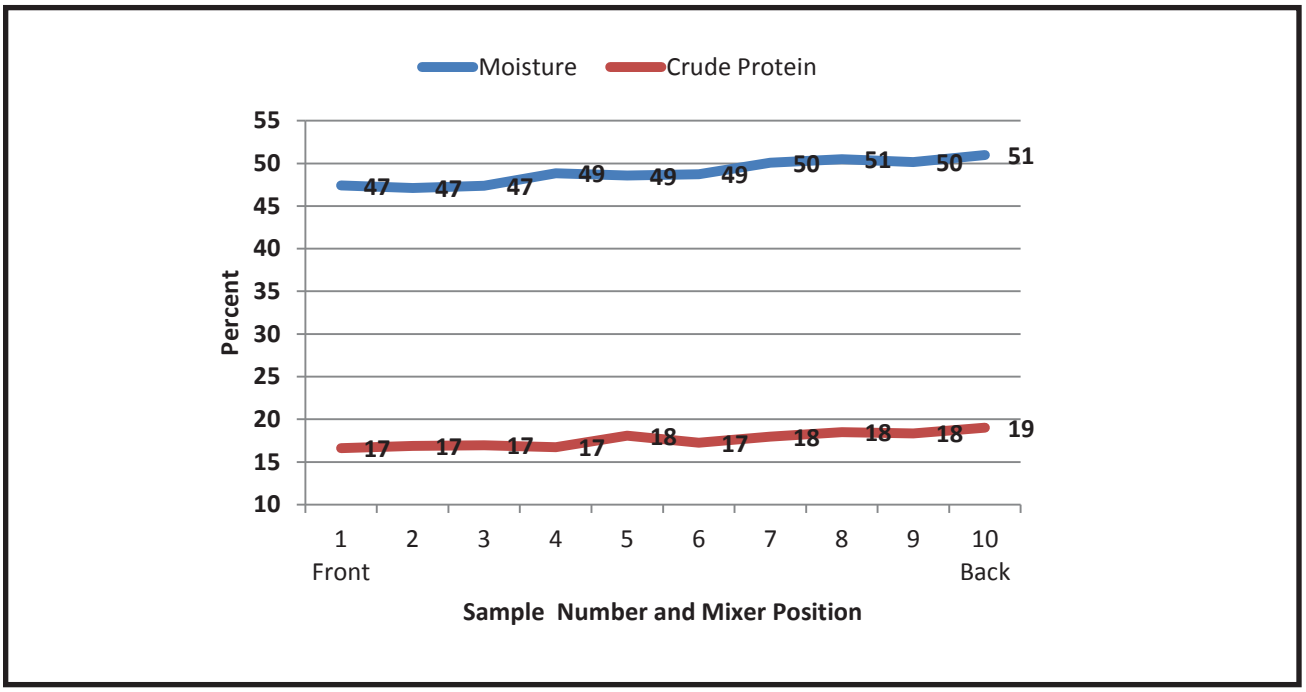


Figure 3. The influence of loading a liquid protein supplement in the back of a dual-auger wagon on moisture and crude protein levels in the TMR.

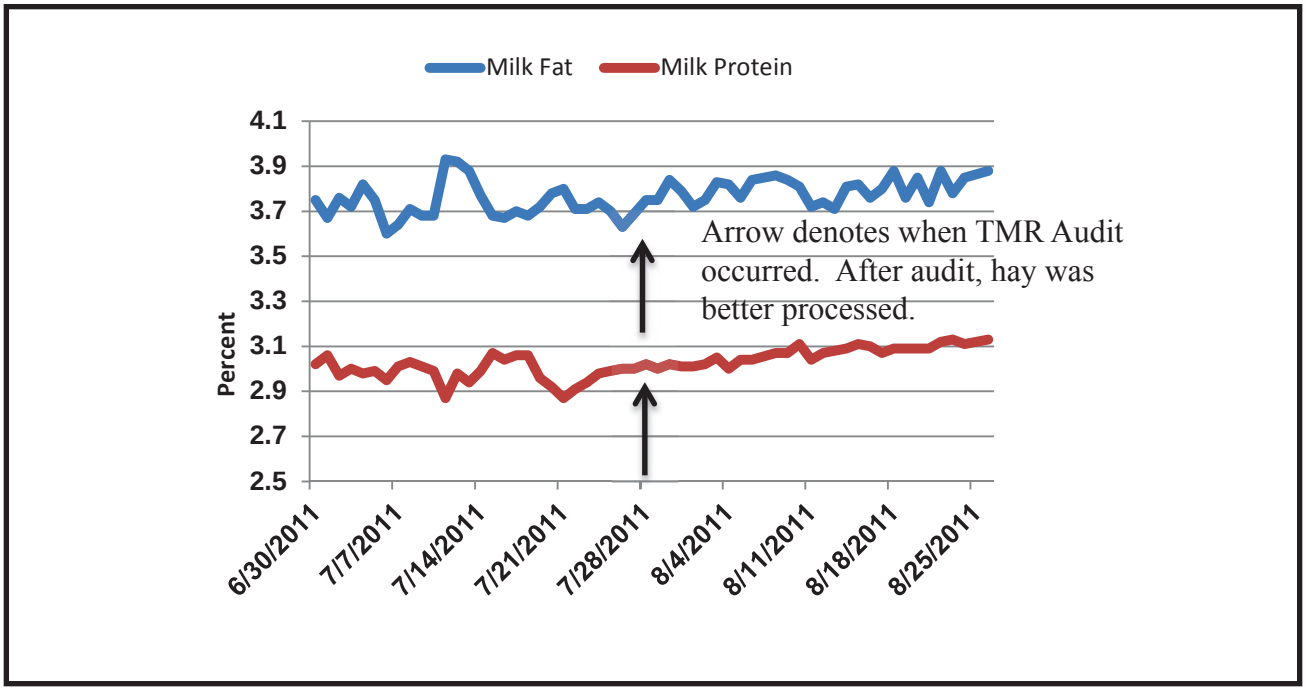
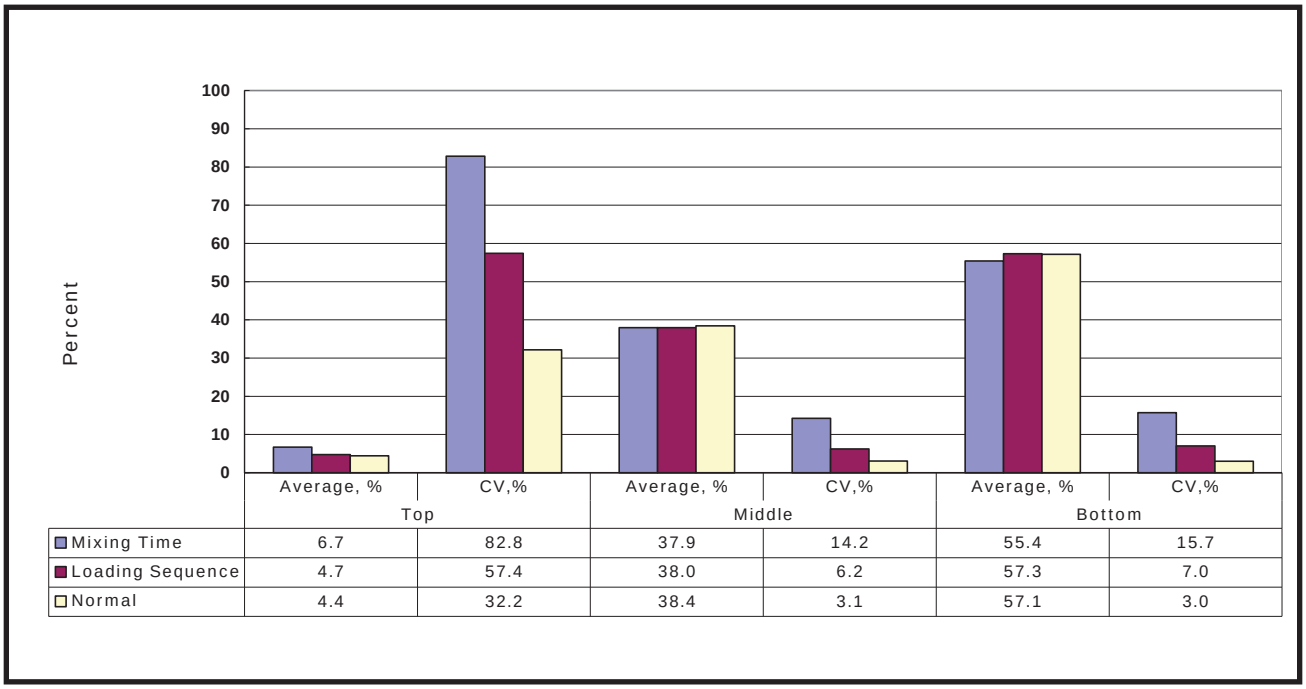


Figure 4. Milk fat and protein concentrations in the bulk tank before and after hay was better processed.



	Top		Middle		Bottom	
	Average, %	CV,%	Average, %	CV,%	Average, %	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 (CV = coefficient of variation).

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

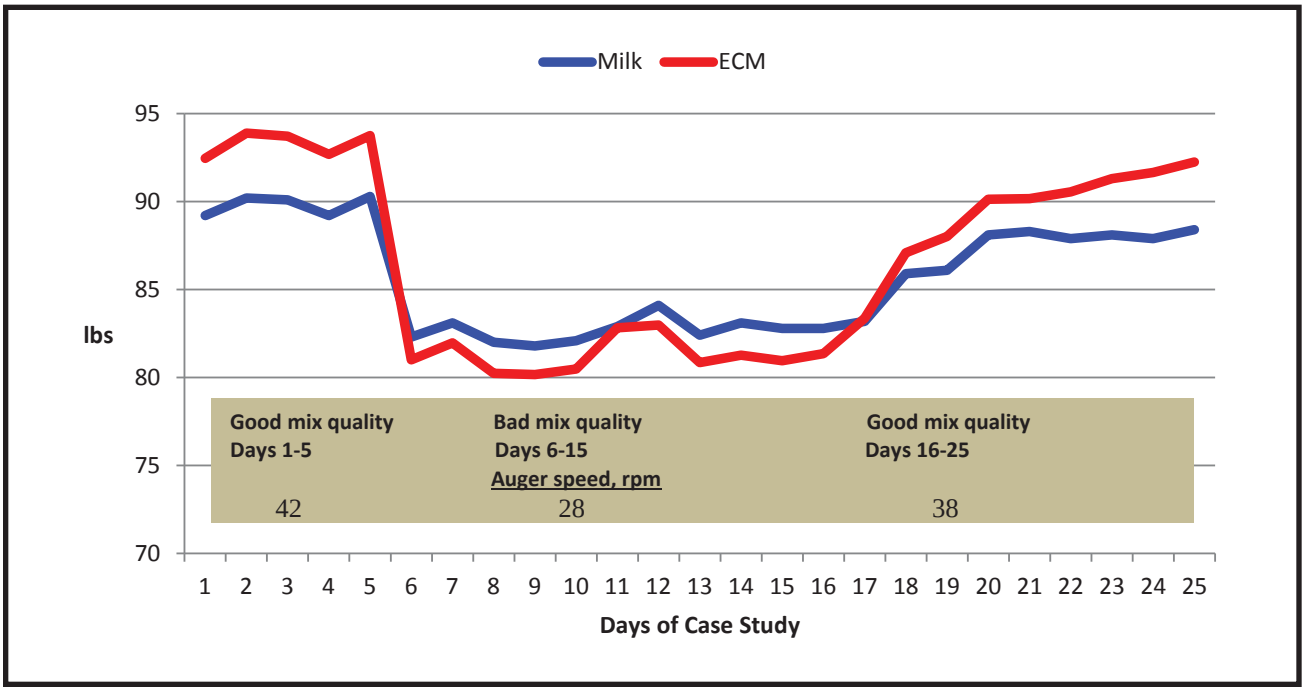


Figure 7. Influence of vertical mixer auger speed on TMR mix quality and milk production.

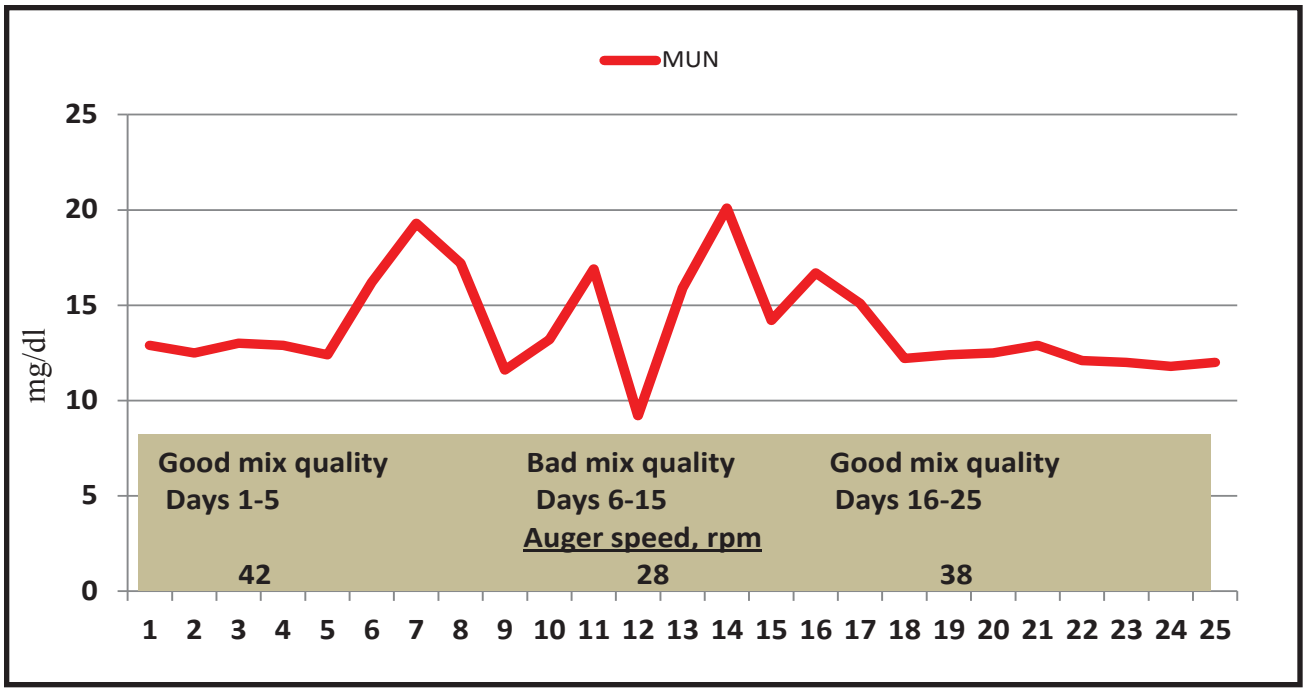


Figure 8. Influence of vertical mixer auger speed on TMR mix quality and milk urea nitrogen (MUN).