Managing Mixing Wagons for Performance and Health

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Tremendous strides have been made in improving the quality of the rations formulated for dairy cattle. In the recently released ***Nutrient Requirements of Dairy Cattle*** (NRC, 2001), effort was spent on predicting dry matter intake (**DMI**) of dairy cattle so that diets can be formulated to meet the nutritional needs at various production levels. Yet, DMI and production response to formulated rations continue to vary from herd to herd and within herd. Thus we must address the question "What are the consequences of various on-farm mixing procedures and bunk management on dry matter intake?"

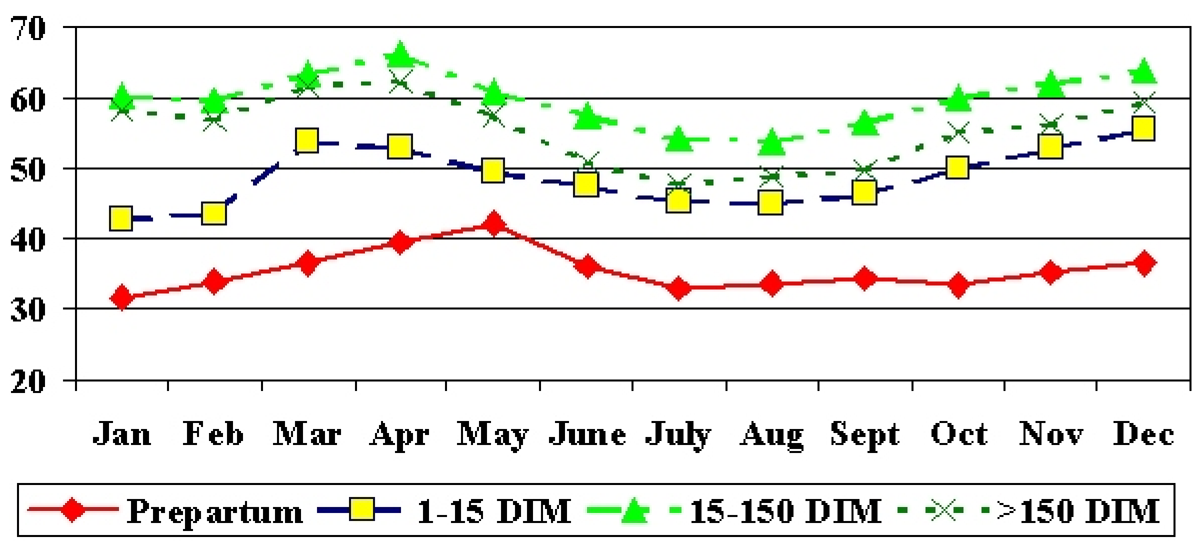
Bunk management has received considerable emphasis over the years. Some of the key elements of feedbunk management which have been identified include:

- Provide ample bunk space per cow
- Keep fresh feed in front of cows at all times
- Monitor feed refusals
- Clean feed bunks regularly
- Minimize feed bunk competition
- Provide plenty of clean, fresh water

Despite addressing these issues on many farms, predicted DMI may not correspond to actual DMI. The current NRC (2001) equation to predict DMI includes only animal factors: fat corrected milk, body weight and week of lactation. The equation does not include temperature or humidity adjustments to account for heat stress periods, relying instead upon the use of lower milk production inputs. Although this methodology may work for lactating animals, DMI for prepartum cows may be over estimated during periods of heat stress.

Today's mixer wagons allow us to capture data so that actual DMI can be recorded and used in subsequent ration formulation. Figure 1 illustrates the changes in actual DMI observed over the course of a year for animals in four different physiological states located in a Central Texas herd. Tracking DMI changes from year to year provides a customized prediction tool so that rations can be formulated in anticipation of expected changes in DMI in an

Figure 1: Seasonal changes in DMI with physiological state



attempt to minimize climatic impacts on nutrient intake. This is particularly critical in adjusting nutrient density in rations formulated to meet the needs of non-lactating animals.

Fiber Needs

Sometimes rumen function is compromised by the way rations are delivered, preventing attainment of maximum DMI. To maintain rumen function and health, NRC (2001) recommends that dairy rations contain a minimum of 25% neutral detergent fiber (**NDF**) with 19% of dietary DM originating from forage NDF. Adjustments to the guidelines are recommended based on the effectiveness of that fiber at stimulating cud chewing, salivation and rumen movement.

The effects of insufficient effective fiber in dairy rations include:

- Acidosis (subacute or acute)
- Erratic dry matter intakes
- Decreased milk yields
- Lowered milk fat production
- Health problems (laminitis, ketosis, displaced abomasum)

Allen (1996) identified eight factors which could be used to adjust the optimal level of NDF needed in early lactation rations to maximize energy intake. These factors included: forage particle size, quantity of NDF from by-products, frequency of concentrate feeding, starch digestibility, use of buffers, rate of fiber digestibility and passage, addition of fat and variability of forage dry matter and quality.

Most of these factors can be readily evaluated. However, the determination of forage particle size has been a tedious task. As a result of the increased interest in evaluating ration particle size to assess the adequacy of fiber in high producing dairy rations, the Nasco Forage Particle Separator was designed at The Pennsylvania State University to physically separate a feed sample into three portions: particles greater than 0.75 inches, between 0.31 and 0.75 inches, and those smaller than 0.31 inches. Based on their analysis of total mixed rations they recommended 6-10% of particles should remain on the upper sieve, 30-50% should be on the middle sieve and 40-60% on the bottom pan.

We began analyzing TMRs and found that virtually every Texas TMR exceeded Penn State's recommended long particle size (Table 1; Rippel et al., 1998). Based on the amount of long fiber (i.e. particle size) in these rations, little acidosis would be expected, yet acidosis continues to be a problem. Furthermore, these samples were taken during the summer, when the typical ration is higher in concentrate to compensate for the effects of reduced DMI. The difference may be the forage base and how it is stored. Texas silage-based rations are predominantly wheatlage although some corn and sorghum silages are fed as well. Alfalfa hay is used, not alfalfa haylage. Some rations have coastal bermuda grass or sorghum/sudan hay. In addition, silage and haylage are typically stored in bunker rather than upright silos. Possin et al. (1994) reported that mean particle length and the percent of the sample retained on the upper screens was greater in forages from bunker compared to upright silos, primarily due to unloader constraints.

Not only did Texas rations exceed the recommended long forage particle length, they differed substantially from the TMR averages reported by Penn State researchers (Table 1). The major differences were more long particles on screen 1 and less of the TMR on the bottom pan. We have not tested as many rations as the Penn State researchers; however, based on these results and additional rations evaluated since, producers feeding TMRs using different forages from those in the Northeast region must be cautious in using the Penn State Separator guidelines.

Particle Size as a Tool

Besides assessing the adequacy of fiber in high producing dairy rations, particle size provides another method to evaluate key components of bunk management which might impact rumen function and prevent attainment of maximum DMI. Namely:

- Is a uniform ration delivered to each group?
- Is over mixing occurring?
- What is the optimal loading sequence?
- Does the available ration change over time?
- How do feed refusals differ from the feed delivered?

Table 1. Comparison of particle size of Texas farms and those in the northeast.

Ration	n	>0.75 inches	0.31-0.75 inches	<0.31 inches
Silage TMR	7	18.4	42.7	38.7
Hay TMR	12	22.2	31.8	45.9
TMR[a]	367	6.1	35.5	58.4

[a] Lammers et al., 1996.

Table 2. Ration Uniformity by C.V. ranges and interpretations.

C.V.	Screen 1	Screen 2	Screen 3	Interpretation[a]
< 10 %	4.7	38.0	47.9	Desirable
10-20 %	38.0	57.0	38.0	Needs improvement
> 20%	57.0	4.7	14.0	Cause for concern

[a] Recommendation from Behnke, 1996.

Ration Uniformity

There is very little published data on the effects of nutrient uniformity on animal performance. What work has been done focused on non-ruminants. Thus there are few benchmarks for using this technique with dairy rations. If mixing is poor enough to alter nutrient intake of certain individuals, performance may be altered. The animals receiving excess nutrients will be inefficient in feed conversion. In extreme cases, such as with urea inclusion, this situation may even become toxic. Conversely, animals receiving rations deficient in nutrients will have performance compromised. Feed intake and body size influences susceptibility to ration imbalances in that smaller animals consuming smaller meals are more likely to be influenced by improper ration mixing than are larger animals consuming more dry matter. The influence of DMI on nutrient consumption is most noted in transition and fresh cows with lower levels of intake, and perhaps it is with this group that ration uniformity is of most importance.

Behnke (1996) has recommended we use the statistical calculation coefficient of variation (C.V.) as a measure of ration uniformity. In Table 2 the percent of herds in our study (Rippel et al., 1998) within the C.V. ranges and their interpretations as evaluated with Behnke's (1996) recommendations are shown. If we evaluate only screen three, the majority of the herds were within an acceptable variance range. This, coupled with chloride ion analysis we conducted, suggested that the concentrate portion of the rations were mixed adequately. But the high percent of herds with greater than 20% variation for screen one, indicated the forage portion of the ration was not being mixed adequately with the concentrate.

Uniformity Check Procedures: To determine whether the forage in the ration delivered is uniform, take a minimum of five samples (ten would be better), evenly spaced along the entire length of the bunk where the mixer wagon discharges. Next use the Penn State Particle Size Separator to sort each sample. Determine the average percent on each screen. Look at the variation from the average. Statistically compute the coefficient of variation by using the formula:

$$CV = (s/\bar{x})\ 100 = \frac{100\sqrt{s^2}}{\bar{x}}$$

where $S = \sqrt{S^2}$

and $S^2 = [\sum_{1}^{n} (x_i - \bar{x})^2] / n\text{-}1$

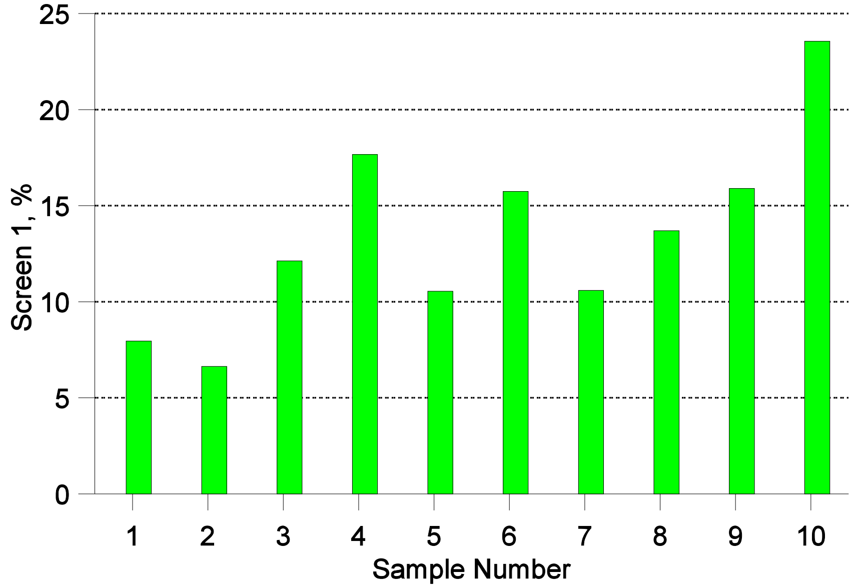


Figure 2: Sample ration with a mean on the top sieve = 15.7% and CV = 55.22%

This statistical method results in one number which can be used to decide if too much variation in the total mixed ration exists. Use Behnke's recommendations to characterize the variation in the herd's ration.

One example herd is shown in figure 2. This herd had a CV of 55.2% on screen 1. Although the average particle size for the 10 samples was adequate based on the Penn State recommendations, some individual animals did not receive sufficient long fiber. In this herd, those cows had no opportunity to eat the longer fiber at another meal because 5 different pens of cattle were fed from the same load of feed in the same order.

Evaluating Particle Size Reduction

One of the reasons we evaluated Texas TMRs was to determine if over mixing resulted in particle size reduction and whether either a vertical or horizontal mixer wagon caused more degradation. We identified ten dairies using vertical-type mixer wagons and ten dairies using horizontal mixers. Each dairy mixed their feed using their standard mixing procedures. We placed ten sample containers at equal distances down the feed bunk and then unloaded the mixer wagon. Next, an identical ration was over mixed by mixing the load for an additional 15 minutes.

After analyzing the samples we could not make any generalizations as to whether over-mixing by 15 minutes affected particle size or if one type of mixer reduced particle size more than another. On individual dairies it did appear that over mixing reduced particle size. In figure 3, the results from one dairy, feeding an alfalfa hay-based ration, are shown.

In a Wisconsin survey of 49 herds, TMR rations were grouped based on whether the ration was mixed over or under 15 minutes for their standard mixing procedures (Possin et al., 1994). Using the Wisconsin Forage Particle Size Separator 7.6% of the ration was on the top two screens (>1.5 inches long) in rations mixed less than 15 minutes, while only 4.8% was on the top two screens in rations mixed more than 15 minutes. The herds were also categorized based on incidence of laminitis. Herds with a high-incidence had 3.5% of the particles on the top screens, while herds with a low incidence had 7.9%. In addition, herds with a higher incidence of laminitis had 42.9% of the ration dry matter from forage compared to 49.5% in the herds with reduced laminitis.

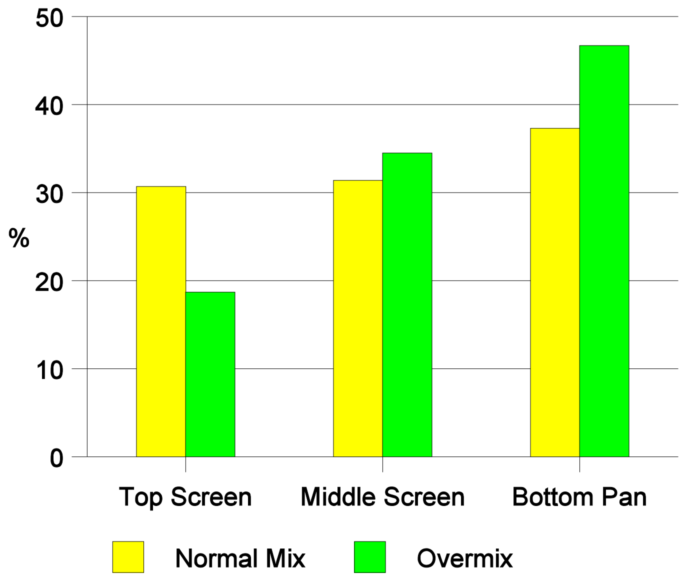


Figure 3: Effect of over mixing by 15 minutes in an example alfalfa hay based TMR.

In 2000, we collected samples from 10 herds and conducted both particle size and wet chemistry analysis on those samples to evaluate whether their was a relationship between variability in the composition of the diets delivered between various nutrients and particle size. Table 3 illustrates the mean, range for various nutrients evaluated and correlation of the nutrient CVs with the particle size CV in the analysis. In this sample, the variation in particle size does explain some of the variation found in various nutrients, while very little in others.

Although not the original purpose of this trial, one item of particular interest is the amount of phosphorus in these rations. As nutrient management becomes more critical on these farms, feeding nutrients above requirements will become less acceptable. Since these samples were taken and results shared with individual producers, feeding phosphorus above requirements has been curtailed.

Loading Sequence

Several ingredient properties can influence mixing: particle size, particle shape, density, hygroscopicity, static charge, and adhesiveness (Behnke, 1996). From this list, particle size, shape, and density appear to have the greatest impact on mix uniformity. The addition of forage and the level of forage inclusion in dairy rations presents a unique challenge to determining adequate mixing times. The differences in forage and concentrate particle size alone present a problem. Differences in particle density between ingredients add another consideration. On a dry matter basis, corn silage and haylage are fairly equal in bulk density (kg/m^3); however, on an as-fed basis, corn silage tends to have a 33% greater bulk density than haylage. In addition, mineral density can be two to three times that of grain and protein, making it difficult to maintain a random distribution.

As a general rule, lighter and larger particles tend to move upward while the smaller, more dense particles gravitate downward. Traditionally it has been recommended to load larger particle size ingredients first (forage) and heavier, smaller particles last. However, with the use of individual commodities and rations containing many ingredients with a large variation in size, shape, and density, determination of loading sequence has become a method of trial and error on many farms.

Table 3: Correlation of the particle size CV to the CV for various nutrients.

Particle Size	$\bar{X}$	Range	Correlation $CV_{top} : CV_{nutrient}$
Top, %	20.6	3.0 - 35.6	
Middle, %	37.5	17.7 - 51.0	
Bottom %	41.9	30.7 - 58.4	
Nutrient Analysis			
Moisture, %	44.6	37.8 - 48.7	.42
CP, %	17.8	16.4 - 19.5	.45
ADF, %	27.4	23.3 - 29.9	-.44
NDF, %	40.3	35.8 - 45.4	-.08
Ca, %	.71	.37 - .99	.26
P, %	.62	.50 - .78	.51
Mg, %	.33	.25 - .42	.06
K, %	1.64	1.21 - 1.95	.41
Na, %	.44	.24 - .66	.49
Zn, ppm	97.7	73.2 - 124.4	.17
Cu	33.8	16 - 80.8	-.22
Mn, ppm	79.7	57.3 - 108.8	.56
% Cl ion	.51	.39 - .66	.11

In an attempt to reduce the variation in ration uniformity in one herd we changed the mixing order. The producer had already changed to chopping the hay to increase uniformity. The ration consisted of wheatlage, alfalfa, and various concentrate components. In this particular herd with a horizontal mixer, loading the wheatlage first followed by the concentrate and chopped hay resulted in the most uniform ration mix based on forage particle size. While reversing the order resulted in the highest variation (Figure 4). Furthermore, the average particle length was longer when the chopped alfalfa was added last.

Adjusting Particle Size for Feed Refusals

On occasion, initial particle size evaluation indicates that adequate long fiber is being provided in the TMR, yet acidosis continues to be a problem in the herd. This is the time to evaluate what the cows are refusing and reevaluate the amount of long fiber provided based upon a value adjusted for refusals. Example 1 illustrates how to make adjustments for feed refusals.

As this example demonstrates, a ration which appeared to have sufficient long fiber when initially fed, actually had inadequate amounts of fiber consumed as a result of sorting by the cattle.

Example 1: Adjusting Forage Particle Size Measurements for Feed Refusals.

Step 1: Determine the percent of long fiber in the initial TMR.

A 2,000 kg batch had 12% on screen 1, 40% on screen 2 and 48% on the bottom pan

Step 2: Determine the percent of long fiber in the feed refusals.

In the 200 kg of refusals 50% was on screen 1, 28% was on screen 2 and 7% was on screen 3.

Step 3: Adjust the percent on each screen/pan by the refusals.

	kg originally	kg refused	kg consumed	% as consumed
Screen 1	240	100	140	7.8
Screen 2	800	56	744	41.3
Bottom Pan	960	44	916	50.9
Total	2000	200	1800	

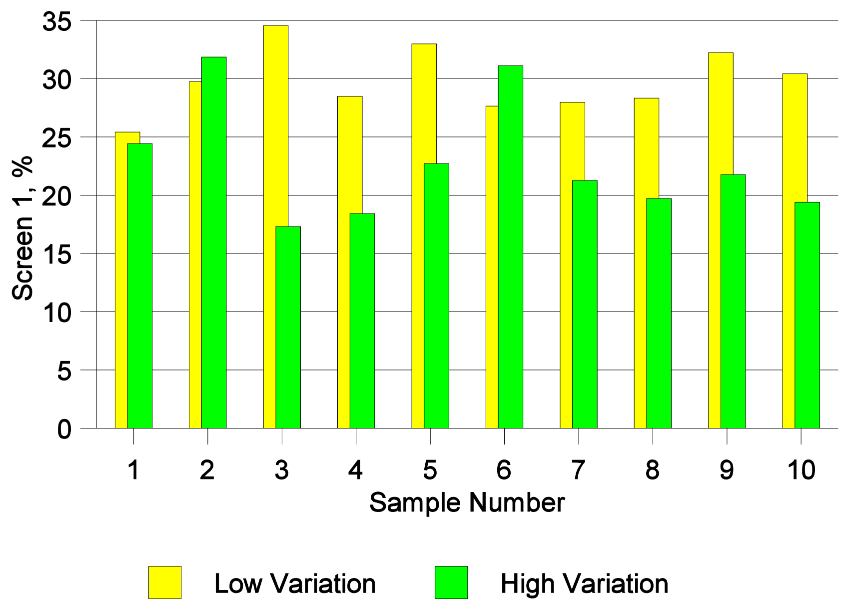


Figure 4: Effect of changing mixing order and hay processing on variation in particle size.

Ration Changes in Bunk

Evaluating the ration when initially distributed may be insufficient. Martin et al. (2000) reported on the changes found in the feed remaining in the bunk with time after delivery. A well-managed herd feeding a one-group TMR was used to evaluate the effect of selective consumption by dairy cows on particle length available over time. Feed was pushed up at 6 hour intervals and the remaining ration was sampled for particle size analysis. The percent of particles on the top screen increased from 9.3% at the time of initial distribution of the ration to 58.7% after 23.5 hours in the bunk. Thus during the first 12 hours after distribution, cows consumed very little of the fiber portion of the ration, increasing their risk for acidosis.

Martin et al. (2000) suggested four factors were important to minimize sorting:

- Keep ration dry matter between 46 and 52%.
- Restrict dry hay usage to <4 lbs/head.
- Maintain consistent particle size in the ration.
- Process corn silage to minimize the effects of husks and cobs in the TMR.

Although these recommendations may be practical for silage and haylage based rations, many of the rations fed in the South and Southwest are hay based. Thus it is not feasible to restrict the dry hay used. With hay based rations, adding additional water to the ration may minimize sorting as might pre-chopping. Another key component is delivering a uniform mix as discussed previously.

Many larger herds are fed multiple times per day, which may reduce the impact of sorting. Some herd owners elect to start discharging the mixer wagon at a different location during each feeding in a day which may compensate for the lack of uniformity in the mix. Since the number of times per day cows are fed varies depending upon group size, number of different rations being fed, size of the mixer wagon, seasonal impacts, owner preferences, etc. it is critical to conduct evaluations in light of these variables.

Conclusions

Managing mixer wagons is an integral part of feed management on today's large dairy. Data collected electronically can be used to calculate actual DMI to improve ration formulation. Particle size evaluation of delivered feed can be a tool to improve feed bunk management.

From our work and that of others, it is evident that many factors can affect the particle size in the mixed ration, such as:

- condition of mixer,
- amount of feed mixed at one time,
- loading order,
- type of feed, and
- particle length prior to mixing.

Forage particle size evaluation can indicate when a ration contains insufficient forage particle length to maintain proper rumen function. However, the interpretation of particle length depends upon the type of forage included in the ration. In addition, the results from particle size evaluation can help determine optimal loading sequences and mixing time for individual dairies so that both adequate forage particle length and ration uniformity can be maintained.

When using particle size evaluation on a herd, take a minimum of five samples, evenly spaced along the entire discharge of the mixing wagon. Maintain a log of results from the farm. Then use the information to evaluate how uniform the ration is delivered over time, determine if pre-processing hay is needed and monitor the condition of the mixer. By continually monitoring the herd, a baseline for particle size can be established and used for comparison when metabolic or production problems arise.

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References

Allen, M. 1996. Fiber requirements for dairy cattle: How low can you go? In Proceedings of the 1996 Mid-South Ruminant Nutrition Conference. p.12.

Behnke, K.C. 1996. Mixing and nutrient uniformity issues in ruminant diets. *In:* Mid-South Ruminant Nutrition Conference Proceedings, p. 6.

Heinrichs, J. 1996. Evaluating forages and TMRs using the Penn State Particle Size Separator. Penn State Cooperative Extension Service. DAS 96-20.

Lammers, B., J. Heinrichs and D. Buckmaster. 1996. Method helps in determination of forage, TMR particle size requirements for cattle. Feedstuffs 68(41):14.

Lammers, B., J. Heinrichs, R.T. Ward and D.R. Buckmaster. 1996. Forage and TMR particle size distribution used by farmers in the northeast. J. Dairy Sci. 79(Suppl.1):153.

Martin, R., L. Armentano, and C. Leonardi. 2000. Feed sorting and acidosis: Is there a link? Hoard's Dairyman 145:625.

National Research Council. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. ed. Natl. Acad. Press Washington, D.C.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. 7th rev. ed. Natl. Acad. Press Washington, D.C.

Possin, I.R., C. DeCorte, R.D. Shaver, and R.T. Schuler. 1994. Survey of forage particle length and metabolic disorders on commercial dairies. University of Wisconsin-Madison.

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 Northcentral Texas. The Professional Animal Scientist 14:44.