Evaluating Particle Size in Texas TMRs

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INTRODUCTION

With the genetic potential of today's dairy animals, early lactation rations require high levels of energy for peak performance. Formulating diets to contain adequate energy for high milk production often results in rations with high levels of grain; combine this with the lower intakes of early lactation cows, and there is little room left in the diet for fiber. Furthermore, when rations include processed forages and by-product feeds, the physical nature of the fiber may be altered, reducing its ability to stimulate rumination and saliva flow. The effects of inadequate fiber in lactation rations are exhibited as acidosis (subacute or acute), erratic dry matter intakes, decreased milk yields, lowered milk fat production, and health problems (laminitis, ketosis, displaced abomasum). Laminitis is acknowledged as the primary contributor to lameness in dairy cattle and can cost the dairy producer as much as $627/case in delayed reproduction, body weight loss, and decreased milk production (Shearer, 1996). The incidence of laminitis in confinement operations is thought to average 35% and, while there are several causes of laminitis, lactic acidosis appears the primary culprit (personal communication, J.K. Shearer).

The potential for these productive losses has precipitated the feed industry's interest in developing an on-farm assessment of ration fiber effectiveness in sustaining high levels of performance while maintaining rumen health. Particle size evaluation is one attempt to identify the proportion of the ration which is effective in stimulating cud chewing and buffer production from those which are rapidly or moderately digestible. Particle size distribution and mix uniformity should be evaluated concurrently, since the ultimate goal is to have a uniformly mixed ration with as little particle destruction as possible. With the diversity of feedstuffs and mixers available, defining the process of mixing on a specific operation is currently more of an art than science.

The mixer functions to uniformly distribute ration ingredients into a final product that serves the intended purpose. For dairy rations, the final intended purpose is evaluated using a combination of several measures, such as level of milk production, milk composition (butterfat and protein content), rumen function, and general herd health. Many times, these factors are antagonistic, i.e. the case of milk production and rumen function in the fresh or high producing cow. Nutritionists continually strive to reach an acceptable balance between the energy and fiber components in the rations of fresh and high producing dairy cows. Ration formulation is the initial factor in achieving optimum performance, but feed management has a significant impact on ration performance as well. In many cases, feeding management overrides or masks the true potential of the ration. Nutritionists often refer to three rations on the farm: *the ration formulated on paper, the ration offered to the cow, and the ration consumed by the cow*. This phrase was traditionally thought of in terms of nutrient uniformity; however, we must now think about it in physical respects as well.

There are many steps between the ration on paper and the ration consumed by the cow that can cause differences. These include scale accuracy of loading ingredients, mixer design, loading sequence of ingredients, and mixing time. There are several types of feed mixers available for commercial dairying and a crude breakdown of these would be by design: horizontal and vertical mixers. Within these categories, there is a range of types including horizontal ribbon and paddle mixers, vertical screw mixers, drum mixers, and mobile mixing boxes. The management of the chosen type affects the final ration presentation as much as the decision between a horizontal and vertical mixer. Maintenance schedules for mixers are critical, as worn or broken mixing components prohibit the mixer from functioning uniformly. Nor can mixer cleaning be overlooked, as build-up of wet feedstuffs can impair mixer function and inhibit uniform distribution of micronutrients.

Given optimum mixer performance, mixing time may influence the final ration considerably. Manufacturer's recommended mixing times range from 3-6 minutes. The question then arises: is the mixer running while loading and does this time count? With larger mixes and a variety of separate commodities, it is possible for ingredient loading to take 15-20 minutes. Should the mixer be active while loading? If this is the case, then total mixing time will now be greater than 20 minutes. Additionally, physical form of dry hay may alter mixer strategy and processing of long forage may require additional time prior to addition of other feeds. In a survey of actual mixing times in Wisconsin, the average mixing time was 16 minutes, with a range between 2-60 minutes (Possin et al., 1994). Appropriate mixing time required to achieve uniformity can only be determined through testing with the specific ingredients to be used. While striving to achieve a uniform nutrient mix, the concern with over-mixing is the physical breakdown of fiber particles.

Particle Size

Literature reports of cow response to effective fiber (particle size, forage level) led to an interest in developing a diagnostic tool to evaluate effective fiber on-farm. As a result, particle size separators have been developed to measure particle size distribution in feeds. These tools consist of a series of stacked screens designed to separate out a ration sample into various particle sizes. The intention of this process is to have a visual, quantitative assessment of particle distribution as it will occur in the rumen. Some commercial laboratories offer particle size separation analysis as part of their available services. There are also separators available for on-farm demonstration analysis, such as the Nasco Forage Particle Separator (C19524N; Fort Atkinson, WI). This tool was designed at Pennsylvania State University for particle separation of feeds into three groups: particles greater than .75" , between .31 and .75", and those smaller than .31" (Heinrichs, 1996). The top screen (retaining particles greater than .75") identifies those particles that remain in the rumen mat and stimulate cud chewing and saliva production; the middle screen (particles between .31 and .75") represents the portion of the total mixed ration (TMR) that is moderately digestible; while the bottom pan (particles smaller than .31") represents particles that are rapidly digestible and/or may be removed from the rumen in the fluid outflow (Lammers et al., 1996). Use of the separator is fairly simple and can be used on-farm to monitor changes in forage harvesting procedures or feed mixing schemes. Table 1 gives the Pennsylvania recommendations for forages and TMR's. However, it is important to remember that many of the forages used in the Pennsylvania area are quite different than those used in Texas.

Table 1: Recommended forage and total mixed ration particle sizes for the Nasco/Penn State Forage Particle Separator[1].

Sieve	Corn silage	Haylage	TMR
Upper sieve[2] (>.75")	2-4% if not sole forage 10-15% if chopped/rolled	10-15% in sealed silo 15-25% bunker silo, wetter mixture	6-10% or more 3-6% focus on TNDF and FNDF
Middle sieve[2] (.75-.31")	40-50%	30-40%	30-50%
Bottom pan[2] (<.31")	40-50%	40-50%	40-60%

[1]Heinrichs, 1996
[2]Portion remaining on the screen.

Ration Uniformity

The importance of ration uniformity is perhaps better accepted in meat animal production (feedlot, swine, and poultry) than it is in dairy cattle production; thus on farm tests to evaluate mix uniformity have been developed with high grain diets. Due to the inclusion of forages, dairy rations present a different degree of difficulty in assessing uniform mixing as forage type and inclusion level can affect marker analysis. Methods that have been investigated for determination of ration uniformity include assays for a selected nutrient or ion concentration and the use of markers. The traditional chemical assay included a chemical, quantitative measurement of a selected nutrient (CP, NDF, etc.). The limitation to these assays tend to be the cost and time for analysis. One marker that has been used is iron filings. The limitations to this method with TMRs may be practical use with rations containing heavy, wet feeds. Quantab® (Environmental Test Systems, Inc., Elkhart, Indiana) is a method for determining the chloride ion concentration of solutions. This method is relatively fast (10-15 minutes), requires minimal lab equipment (hot water, filter paper, measuring device, and paper cups), and is relatively inexpensive.

Due to the diversity of particle sizes between ingredients used in dairy rations, collecting a sample representative of the total mixed ration can be difficult. Care must be taken when collecting traditional *grab samples* to ensure representative samples. Behnke (1996) described a more accurate sampling technique involving plastic sheets placed in the feed lane and then using a quartering technique to reduce the sample size to a workable size. Other questions remain what size sample accurately represents an entire mixer? How many samples are necessary to represent the entire mixer? Does the sample taken from the initial mixer represent the ration being eaten by the cows? How should the initial sample be adjusted for feed refusals?

Assuming accurate sampling techniques and proper marker choice, interpreting results is the next challenge. Research at Kansas State University reports the mean, standard deviation, and coefficient of variation as indicators of mixing tests for high concentrate diets. Use of coefficients of variation has been more widespread as a number to identify the distribution of values and condense them into one measure of the mix uniformity.

Ration quality management procedures, such as particle size assessment and ration uniformity checks, may be used to track ration consistency and ward off sudden outbreaks of metabolic or health problems in the herd. To date, little work has been done on rations outside the Northeast; thus extrapolation of their results to Texas rations may or may not be correct.

The objectives of this study were to: (1) evaluate the effect of mixer type on particle size reduction over time, (2) accumulate information regarding average particle size of various total mixed rations fed in Texas, and (3) test the use of the chloride ion concentration as an indicator of uniformity in dairy rations.

Additional tests were conducted on the effects of altering mixing order in a herd with high variation in its total mixed ration and whether adding feeds containing high moisture levels, such as wet brewer's grain, would alter interpretation of results.

METHODOLOGY

Twenty dairies in north central Texas utilizing a TMR were blocked according to mixer-feeder type, ten vertical and ten horizontal. Feed samples were collected under two mixing schemes. First, ten - 6.5 liter samples were collected from a feed batch mixed according to typical individual on-farm practices. Sampling containers were placed at equal intervals along the length of the feed bunk in order to sample from beginning to end of mixer unloading. Second, an additional ten - 6.5 liter samples were collected in the same manner from an identical ration mixed 15 minutes past normal mixing time. Samples were frozen until analyzed for particle size and salt content.

Particle size was determined using the Nasco Forage Particle Separator. Due to separation during transport and storage, thawed samples were manually remixed and a representative portion (approximately 3/4 of the sample) was placed into the top screen of the separator. The remaining portion was refrozen for later analysis of chloride ion concentration. On a flat surface, the separator was shaken 5 times horizontally in one direction and then rotated one-quarter turn; a shake being an arms-length forward and back. This was repeated eight times until the separator had been turned a total of two full rotations, insuring thorough separation with minimal shaking.

The portion of the sample remaining in each screen was weighed on a Sunbeam Digital Deluxe Scale (Nasco, WA12267N) accurate to 1 g. The percent of sample in each screen was determined. The comparison of normal mixing and normal plus 15 minutes additional mixing was made to determine the effect of standard/over-mixing on particle size.

Salt content was determined in duplicate using Quantab® Chloride Titrators (Environmental Test Systems, Inc., Elkhart, IN). Samples were thawed, remixed, and 100 g placed into a plastic container. Nine hundred milliliters of boiling water was poured into each container. The samples were stirred vigorously for 30 sec, allowed to rest 1 min, and then stirred an additional 30 sec. After the sample cooled to room temperature a small amount of the liquid was drained into a plastic cup with a titrator strip. Chloride ion concentration was determined after complete saturation of the test strip according to manufacturer's instructions.

After completion of the collection and analysis of the twenty samples, the herd exhibiting the highest coefficient of variation was selected for further testing. When this herd was originally tested, they were using unchopped alfalfa hay, wheatlage and various concentrates. To evaluate what mixing order would result in the most uniform ration mixing, based on forage particle size, four different mixing orders were evaluated. The orders were: 1) wheatlage, alfalfa, and concentrate (W-A-C); 2) alfalfa, wheatlage, and concentrate (A-W-C); 3) alfalfa, concentrate, and wheatlage (A-C-W); and 4) wheatlage, concentrate, and alfalfa (W-C-A). Ten samples were collected per mix and separated using the Nasco Forage Particle Size Separator, as previously described.

Although none of the rations in the original trial had a high inclusion rate of wet brewer's grain, a herd with 40 lbs (as fed basis) of wet brewer's grain in the ration was identified and sampled. Ten samples were taken as previously described. One half was separated (as fed) and the other half was dried in a 55°C oven prior to separation. Particle size distribution was determined for each subsample.

To evaluate grab sampling as an effective method for sampling for chloride ion concentration, ten samples were taken from one dairy under the normal mixing procedure. The samples were divided into three portions: one proportional to the particle size distribution, one ground sample, and one grab sample. Each portion was then analyzed for chloride ion concentration as previously described.

Statistics

Results were analyzed using LOTUS and SAS. Coefficients of variation (CV) for individual farms were calculated in LOTUS using the formula:

$$CV = \frac{\text{standard deviation (samples 1-10)}}{\text{mean (samples 1-10)}} \times 100$$

The effect of mixing time on particle size distribution for individual dairies was determined using the SAS paired t-test:

$$t = \frac{(\chi_1 - \chi_2)}{\sqrt{s^2(1/n_1 + 1/n_2)}}$$

where: χ_1 is the sample mean for normal mixing time,
χ_2 is the sample mean for 15 additional minutes mixing time ,
s^2 is the pooled variance, and
n is the number of samples.

Remaining particle size distribution and chloride ion content results were analyzed using the following model in SAS:

$$Y_{ijk} = \mu + T_i + M_j + F_k + E_{(ijk)}$$

where: μ is the overall mean,
T_i is the effect of mixing time,
M_j is the effect of mixer type,
F_k is the effect of feed type, and
$E_{(ijk)}$ is the experimental error.

RESULTS AND DISCUSSION

Particle Size Distribution

The over-all main effect was the combination of mixer and ration type and was defined in the model as dairy. Due to the large variation among each set of ten samples taken at each

Table 2: Effects of mixing time on particle size distribution.

Ration base	Mixing Time	% Screen 1	% Screen 2	% Screen 3
Silage	Normal	17.8[a]	48.0	34.0[b]
	+15 min	12.9[b]	46.0	41.0[a]
Hay	Normal	30.7[c]	31.4[b]	37.3[d]
	+15 min	18.7[d]	34.5[a]	46.7[c]

[a,b] Means in the same column with different superscripts differ (p<.05).
[c,d] Means in the same column with different superscripts differ (p<.001).

dairy (CV range 3.0 to 55.2%), no generalizations can be made as to whether over-mixing affected particle size distribution or if one type of mixer caused more particle size reduction than another. In comparing the results of normal mixing time versus over-mixing by 15 minutes, there was no significant difference between treatment groups in this study.

Although there was no statistical significance detected, it appeared that on some individual dairies over-mixing did affect particle distribution of the final TMR (Table 2). While similar changes were not observed at all dairies, it is important to note that many factors such as condition of mixer, amount of feed mixed at one time, loading order, and particle length before mixing may contribute to particle size of the final ration. The effects of forage level and particle size on DMI and rumen function has been studied by several groups (Beauchemin et al., 1994; Grant et al., 1990a; Grant et al., 1990b; Okine et al., 1994; and Woodford and Murphy, 1988). Reducing forage particle size has been shown to improve the dry matter intake (DMI) potential of forage diets (Campling et al., 1966), especially with poor quality forages. Woodford and Murphy (1988) evaluated the effect of particle size on DMI and milk production by feeding a control (40% alfalfa haylage) or two levels of alfalfa pellet (30% of forage or 70% of forage). These investigators reported a 5% increase in milk production (over control) when 30% of the forage supply was in pelleted form, while intakes remained similar between these two diets. However, as inclusion of the pellet increased from 30 to 70% of the forage, both DMI and milk production decreased.

In addition to its effect on DMI, forage also plays a key role in proper rumen function, as adequate particle size in the ration appears necessary to avoid milk fat depression. Cows require fiber and forage to stimulate chewing activity and saliva production, both necessary to maintain proper ruminal pH and a healthy rumen. Grant et al. (1990a) examined the effect of particle size of dry hay on chewing activity and milk fat production by including a finely (0.6-cm screen) or coarsely (7.6-in screen) chopped hay into the ration of cows 3 week postpartum. These investigators reported that DMI and milk production were not affected by particle size of hay and that NDF intake, expressed as a percentage of body weight, was similar between diets (1.2%). However, reduced forage particle size was associated with depressed ruminal pH, decreased acetate:propionate ratios, and lower milk fat synthesis (Table 3). These effects were further supported in a subsequent trial with alfalfa haylage (Grant et al., 1990b). Beauchemin et al. (1994) compared diets at two levels of forage fiber (35% and 65%) and chop length of forage (5 mm and 10 mm theoretical chop length) within each level of forage. This group reported cows fed diets containing 65% forage fiber produced more milk when the theoretical chop length (TCL) of the forage was reduced (5 mm). Conversely, with low forage fiber (35%), cows produced more milk on coarser particle size forage (10 mm). Milk fat production was substantially higher for cows fed the higher forage fiber diet (65%) and fat synthesis also tended to increase with coarser chop length.

The average and standard deviation for the particle size distribution under normal mixing conditions for the Texas farms feeding either an alfalfa or silage based ration is depicted in Table 4, as well as the comparable figures from Lammers et al. (1996). It is important to note that although there was a much larger sample population from

Table 3: Effects of forage particle size on rumen conditions and milk fat synthesis[1].

	(Treatment[2])		
Rumen parameter	**Fine**	**Medium**	**Coarse**
pH	5.40[c]	5.80[b]	6.25[a]
Acetate:propionate ratio	2.08[c]	3.20[b]	3.89[a]
Milk fat synthesis, %	3.2[c]	3.5[b]	3.8[a]

[1]Grant et al., 1990a.
[2]Represents the grind of hay. Fine = hay ground through a .24" screen; Medium = 1:1 mix of fine and coarse ground hay; Coarse = hay ground through a 3" screen.
[a,b,c]Means in the same row with different superscripts differ (P<.05).

dairies in the northeast, standard deviations on screens 2 and 3 were similar for all three TMRs. Particle size distributions were quite different for Texas rations versus Northeast rations, suggesting that recommendations for northeastern TMRs may not be applicable to those in the south due to feeding differences.

Additional Ration Evaluation

Effect of loading sequence on TMR consistency. Within a single dairy, the effect of loading order was determined. Although when initially sampled this herd was using all unchopped hay, when we returned to try to reduce the variation they had switched to a mix of chopped and unchopped hay. In several instances, altering order in which ingredients were placed into the mixer affected particle length and the associated variance. Loading order A-C-W illustrates this (Table 5). When alfalfa hay was added first, the particle length was decreased the greatest. Although the associated variance with order A-C-W was the highest, this might be expected depending on hay quality, moisture content, and amount included in ration. It was observed that on a daily basis that the amount of baled alfalfa versus chopped alfalfa was not consistent. A higher proportion of chopped alfalfa., with a more uniform particle length, could affect ration uniformity, possible explaining the lower variance for screen 1 associated with order W-C-A. 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. With respect to particle size, the addition of forage and the

Table 4: Comparison of TMR particle size between Texas and the Northeastern US.

		Screen 1		Screen 2		Screen 3	
Ration	**n**	**%**	**S.D.**	**%**	**S.D.**	**%**	**S.D.**
Texas TMRs							
Silage-based	7	18.4	12.4	42.7	11.1	38.7	10.5
Hay-based	12	22.2	9.7	31.8	9.6	45.9	8.9
Northeast TMRs[1]	367	6.1	4.5	35.5	10.1	58.4	11.5

[1] Lammers et al., 1996.

Table 5: Effect of loading order on particle size distribution.

Order[1]	Screen 1	CV	Screen 2	CV	Screen 3	CV
W-A-C	28.7[a]	17.4	35.3	7.7	35.8[b]	13.7
A-W-C	29.1[a]	19.6	32.9	12.4	37.9[a,b]	12.4
A-C-W	22.8[b]	22.0	36.2	9.4	40.9[a]	5.9
W-C-A	29.7[a]	9.3	33.6	10.8	36.5[b]	9.4

[1] W=wheatlage, A=alfalfa hay, C=concentrate.

[a,b] Means in the same column with different superscripts differ (P<.10).

level of forage inclusion in dairy rations presents a unique challenge to targeting adequate mixing times. The differences in forage and concentrate particle size alone presents a challenge. Differences in particle density between ingredients adds 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 (Kammel et al., 1995). 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. Differences seen in particle size distribution due to varying the loading sequence from an individual ration in this study further supports the importance of daily on farm quality control.

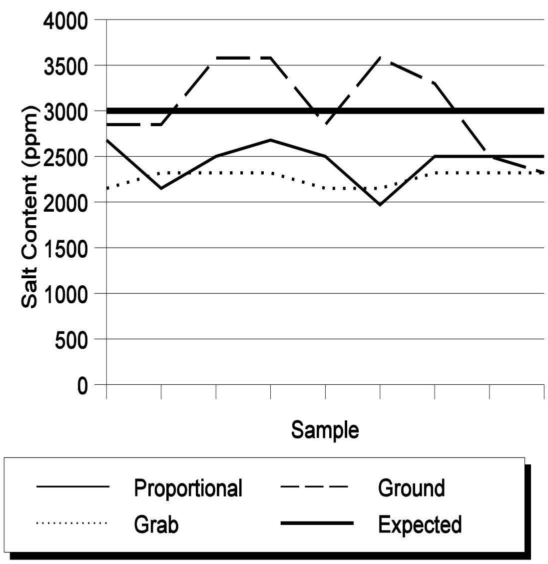
Impact of ration moisture on particle size assessment. To evaluate what effect moisture content of the ration may have on the percent of particles found in each screen, a dairy using 40 lbs. (as fed) of wet brewers grain per day per cow was identified. Samples were taken and sieved as either wet or dry (Table 6). It was originally presumed that high moisture feeds would falsely increase the amount of particles found in the bottom pan. However, it was determined that high moisture feeds tend to clump small particles, preventing them from sifting to the bottom pan and misrepresenting the amount of longer particles. The variance decreased dramatically with drying. Much of this could be attributed to the fact that variation in moisture content of component ingredients was not a factor after drying as the small particles consistently sifted to the bottom pan. For this reason, rations with marginal effective fiber and high moisture content feeds may need further analysis.

Table 6: Effect of ration moisture on particle distribution.

Treatment[1]	Screen 1	CV	Screen 2	CV	Screen 3	CV
As Fed	22.6	22.8	25.2	10.7	52.1	8.9
Dried	15.6	16.6	18.2	6.8	66.1	2.9

[1] Treatment significant at p<.001.

Figure 1: Salt content of grab, ground, and proportional to particle size distribution samples as compared with the expected salt content of dairy rations (.5%).



Ration Uniformity Evaluation. Ration uniformity was tested through particle size evaluation as well as chloride ion concentration. As with particle size reduction, the effect of mixer and mixing time on chloride ion concentration was not statistically significant. Based on recommendations of Behnke (1996), the Quantab® analysis was chosen for these studies; however these recommendations are based on feedlot and monogastric diets containing as much as 90% or more concentrate. Chloride ion concentration within each dairy varied to a much lesser degree (average of 10% variation) than particle size. In this study, ten samples were taken for sample analysis. To evaluate whether ten is the appropriate number of samples necessary for accurate uniformity analysis, all ten samples, even samples, and odd samples were compared for variance uniformity. The proportion in each screen and its variance was unaffected by sample within mixing time, suggesting it is possible to collect only five samples, rather than ten. It is not recommended to take less than five samples, since decisions based on fewer samples could be misrepresentative of the true uniformity.

Salt is associated with the concentrate portion of the ration, and therefore tests the uniformity of it and not the uniform mixing of concentrates with forages. Because of the large inclusion of forage in dairy rations, it may be inappropriate to use this test to determine uniformity of the total ration. In addition, the accuracy of the chloride ion test is also affected by high acidity, which would be found with silage, thus raising question as to the appropriateness of this test for dairy rations including fermented feeds. Additionally, grab sampling of dairy rations may not be adequate for analyzing salt content, because the concentrate easily separates from the forage portion (Figure 1). In our study, salt content of the ground and proportional samples were consistent with the percent of particles in the bottom pan (most likely to contain salt), again demonstrating that this test may be inappropriate for assessing adequate mixing of dairy rations containing forage levels of 40% or greater.

Table 7 identifies the percent of herds in this study within a CV range and the respective interpretations based on literature recommendations (Behnke, 1996). These recommendations were that rations be evaluated for uniformity using a CV, where a CV of <10% was desirable, a CV of 10-20% needed improvement, and a CV greater than 20% was cause for concern. If only the bottom pan was evaluated, the majority of the herds (80%) are within an acceptable variance range. This suggests that the concentrate portion of the rations are being mixed adequately, but as seen by the high percent of herds (57%) with greater than 20% variation for screen 1, the forage portion of the ration is not being mixed adequately with the concentrate.

There is very little published data on the effects of nutrient uniformity on animal performance. What little work that has been done has focused on the monogastric species (McCoy et al., 1994; Stark et al., 1991; and Traylor et al., 1994), thus there are few benchmarks for using this technique with dairy rations. With respect to nutrient levels, 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

Table 7. Percent of study herds within particle size CV ranges and interpretations.

CV	Screen 1, %	Screen 2, %	Screen 3, %	Interpretation[1]
< 10 %	4.7	38.1	47.9	Desirable
10-20 %	38.1	57.2	38.1	Needs improvement
> 20%	57.2	4.7	14.0	Cause for concern

[1] Recommendation from Behnke, 1996.

urea inclusion, this situation may even become toxic. On the other side, 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 may be most critical in transition and fresh cows with lower levels of intake, and perhaps it is with this group that ration uniformity is of most importance.

SUMMARY

The objectives of this trial were to gather information about Texas TMRs and to evaluate potential changes in particle size and ration uniformity over mixing times, utilizing both vertical and horizontal mixers. Further testing included evaluation of loading sequence on final TMR consistency and addition of feeds with high moisture content on accurate particle size assessment.

Particle Size Data

Comparative Texas information against Northeast recommendations. Although sample numbers vary, average particle size distribution for the Texas rations sampled differ greatly from those reported in Northeast rations. Particle retention on screen 1 (particles greater than 1.5") for Texas TMRs averaged 20.3%, as compared to those reported from Northeast TMRs of 6.1%; concurrently, average particle retention in the bottom pan (less than .31") was 42.3% for Texas rations versus 58.4% for Northeast rations.

Impact of mixing time on particle size changes. Due to the large variation among each set of ten samples taken at each dairy, no statistical conclusions can be made as to whether over-mixing affected particle size distribution or if one type of mixer caused more particle size reduction than the other. However, raw averages showed some interesting numerical trends; including a 33% decrease in particle size retention on screen 1, with a corresponding increase of 22.8% in particle size retention in the bottom pan.

Impact of ingredient loading sequence on TMR quality. In several instances, altering the order in which ingredients were placed into the mixer affected particle length and the associated variance. The impact of this variable was investigated on the individual dairy having the highest coefficient of variation by altering ingredient loading sequence of wheatlage, alfalfa, and concentrate. With the addition of alfalfa hay first, particle length was decreased the greatest (40.9% retention in the bottom pan compared to 36.2% when alfalfa hay was included in the second or third order). Although the associated variance with this order was the highest, this might be expected depending on hay quality, moisture content, and amount included in ration. While not enough treatment repetitions have been taken to date to evaluate the statistical continuance of this effect over a large number of samples, the numerical changes demonstrate the importance of daily ration quality control.

Impact of ration moisture on particle size assessment. Diets containing high moisture contents (water addition, inclusion of wet brewers grains, etc.) need careful consideration when evaluating particle size. Results from our data suggest that particle sieving of wet rations may tend to over-estimate particle length and distribution. When these diets were dried prior to sieving, particle size distribution shifted downward with average particle retention on screens 1 and 2 decreasing by 29% and a concomitant increase in the sample size retained in the bottom pan by 27%. Additionally, CV analysis of screen variance decreased by 43.7%.

Ration uniformity

As with particle size, the effects of mixer and amount of time mixed on ration uniformity were not statistically significant. The results of the Quantab® analysis showed variation in samples within herd. Comparison of the CV ranges for the bottom pan suggests that the majority of the herds were getting the concentrate portion of the ration mixed adequately. However, the high percentage of herds with greater than 20% variation for screen 1 would suggest the forage portion of the ration was not being mixed adequately with the concentrate. The use of this analysis in dairy rations is currently limited as the accuracy of the chloride ion test is affected by high acids, such as in silage and other fermented feeds.

APPLICATION

Results from this study suggest that Northeast recommendations on particle size analysis may not be directly applicable to rations containing southern forages. However, variation between farms due to the wide range of ration management practices makes it difficult to draw general, widespread conclusion. Field logistics such as loading sequence of ingredients, large inclusions of wet ingredients, and sample collection may contribute to potential error in ration evaluation. Particle analysis in dairy rations needs to be weighed against other information about individual feeding management practices and, most importantly, responses from the cows due to changes. Additional information is needed to further identify changes in particle size and ration uniformity in response to commercial feeding practices.

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