EFFECTS OF SALT PARTICLE SIZE AND SAMPLE PREPARATION ON RESULTS OF MIXER-EFFICIENCY TESTING

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Summary

Two experiments were conducted to evaluate the effects of using salt with different particle sizes and of using different sample-preparation methods on mixer-efficiency testing (time required to achieve a coefficient of variation (CV) of 10% or less among 10 feed samples). A 3000-lb capacity horizontal ribbon mixer was used to mix batches of feed. Ten samples were collected at eight times during mixing (0.0, 0.5, 1.0, 2.0, 3.5, 5.5, 8.0, and 10.5 min) after all ingredients were added from pre-determined locations in the mixer. Coefficient of variation was used to measure mixer efficiency by analysis for chloride concentration in each sample with Quantab® chloride titrators. In Exp. 1, four 3000-lb batches of feed were prepared, two with 440-micron salt and two with 730-micron salt. Samples were analyzed as collected (unground; approximately 700 microns) or were ground with a coffee grinder (ground; approximately 400 microns). A salt particle size × sample preparation × mixing time interaction (P<0.001) was observed, but a CV of 10% or less was never achieved, indicating inadequate mixing. In Exp. 2, all samples were collected from 2000-lb batches of feed made in the 3000-lb-capacity mixer. Four different salt particle sizes (440, 730, 1999, and 3000 micron) were used, and each set of samples collected was also analyzed as unground or ground. A salt particle size × sample preparation × mixing time interaction (P<0.04) was observed. As salt particle size decreased and mixing time increased, there was a decrease in CV. Grinding samples before analysis decreased CV, compared with that of the unground samples, but to a greater extent with coarse salt than with fine salt. The batch mixed with 440-micron salt and the batch mixed with 730-micron salt (ground) reached a CV of less than 10%, indicating a uniform mixture. No other treatments reached a CV of 10% or less. When the mixer was filled to the rated capacity we were unable to achieve an acceptable CV for mixer efficiency; therefore, it is important to test mixers at various fill levels. Our study also showed that it is important to use a fine mixing salt when testing mixers for mixer efficiency.

(Key Words: Mixer Efficiency, Particle Size, Pigs, Salt.)

Introduction

The purpose of mixing a livestock diet is to distribute all ingredients and nutrients throughout the entire batch of feed to achieve a uniform mixture. A uniform mixture will supply the animal with a balanced diet, ensure proper nutrient consumption, and maximize animal performance. Testing uniformity with-in batches of feed is commonly termed mixer-efficiency testing. Briefly, mixer-efficiency

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testing consists of obtaining multiple samples from a batch of feed, analyzing for the selected ingredient, and evaluating the within-batch variability. The results for mixer-efficiency testing are often reported as a coefficient of variation (CV), which is the standard deviation divided by the mean. Standard guidelines for evaluating CV are: A CV of less than 10% is considered excellent; a CV of 10 to 15% is considered good mixing that may be an indicator that increased mix time is needed, and a CV greater than 15% warrants finding a cause of the poor mixing efficiency. The selected ingredient or tracer should have low analytic variability, and the analysis should be relatively inexpensive to perform, because multiple samples need to be analyzed to characterize within-batch variability. Salt is the most common ingredient used to evaluate mixer efficiency. But a variety of particle sizes of salt are used in swine diets. Because only a small subsample of feed is tested for each feed sample, we hypothesize that a larger particle size of salt may increase analytic variability. This would artificially increase the CV in a well-mixed diet. One method to reduce analytic variability in samples with variability in particle size is to finely grind the sample. Therefore, the objective of our study was to determine whether salt particle size or sample-preparation method influence the mixing time required to achieve a CV of less than 10%.

Procedures

Both experiments were conducted at the Kansas State University Animal Sciences and Industry Feed Mill in a 3000-lb-capacity, horizontal, double-ribbon paddle mixer (DS30, Davis & Sons Manufacturing Company, Bonner Springs, KS). A basal diet was used to collect all samples. The diet contained 67.3% sorghum (680 microns), 30% soybean meal (700 microns), 1.0% limestone (180 microns), 0.9% monocalcium phosphate (540 microns), 0.15% L–Lysine HCl (680 microns), 0.15% trace mineral premix (320 microns), 0.15% vitamin premix (300 microns) and 0.35% salt. For each batch of feed made, ten samples were collected at eight mixing times (0.0, 0.5, 1.0, 2.0, 3.5, 5.5, 8.0, and 10.5 min), resulting in a total of 80 samples per batch. All ten samples were collected from pre-determined locations in the mixer, by using a grain probe. Samples were placed into pre-labeled sample bags. Coefficient of variation (CV) was used to measure mixer efficiency, and was determined by analysis for dietary chloride concentration with a standard analytic test kit (Quantab® chloride titrators; Environmental Test System, Elkhart, IN). Ten g of the collected sample was weighed into a 120-mL sample cup. Ninety mL of 100°C distilled water was added to the sample cup. The sample was stirred for 30 s, let stand for 60 s, and stirred for an additional 30 s. A folded, circular, fast-flow 12.5-cm filter paper (Quantitative Q8, Pittsburg, PA) was placed into the 120-mL sample container, and the Quantab® chloride titrator was placed inside of the filter paper. Solution was allowed to completely saturate the wick of the titrator. The reaction was completed when the yellow wick turned completely black. The titrator was removed from the solution, read, and recorded. Coefficient of variation was then calculated for each batch and replicate. All data were analyzed by using PROC MIXED in SAS 8.1 (SAS Inst. Inc., Cary, NC).

Experiment 1. The objective was to evaluate the effects of two salt particle sizes (440 and 730 microns) and of grinding the test sample on mixer efficiency (time required to achieve a CV of 10% or less, among 10 feed samples). All samples in Exp. 1 were collected from 3000-lb batches of feed in a 3000-lb-capacity mixer. Four batches of feed were made, two for each particle size of salt. Each batch of feed collected also was analyzed as collected (unground) and analyzed after being ground in a coffee grinder (Model 168940, General Electric).

Experiment 2. The objective was to further evaluate the effects of salt with different particle sizes and of using different sample-preparation methods on mixer efficiency. All samples in Exp. 2 were collected from 2000-lb batches of feed, mixed in the 3000-lb-capacity mixer used in Exp. 1. We evaluated salt with four different particle sizes (440, 730, 1999, and 3000 microns). Eight batches of feed were made, two for each salt particle size. Similar to Exp. 1, in Exp. 2 each batch of feed collected was also analyzed as collected (unground) and analyzed after being ground to approximately 400 microns in a coffee grinder.

Results and Discussion

Experiment 1. A salt particle size × sample preparation × mixing time interaction ($P < 0.001$) was observed (Figure 1). For the first 2.0 min of mixing, the coefficient of variation dropped rapidly, with ground samples mixed with 730-micron salt having a lower CV than the unground samples, and no difference in sample preparation in the samples mixed with 440-micron salt. Also, as time increased, there was an improvement in mixing performance, but a CV of 10% or less was never achieved. Because a CV of 10% or less was not achieved, it is possible that the mixer was overfilled when filled at the rated capacity (3000 lb); therefore, we used 2000-lb batches in Exp. 2.

Experiment 2. A salt particle size × sample preparation × mixing time interaction ($P<0.04$) was observed (Figure 2). As salt particle size decreased and mixing time increased, there was a decrease in CV. When samples were ground before Quantab® analysis, there was a decrease in CV, and differences between ground and unground smaples became less when smaller-particle salt was used. Similar to Exp. 1, in Exp. 2 the CV of samples mixed with the 440-micron salt showed no improvement with grinding. Unlike Exp. 1, in Exp. 2 the samples mixed with the 440- and 730-micron salt reached a CV of less than 10% when ground, indicating a uniform mixture. No other treatments reached a CV of 10% or less.

Mixer-efficiency evaluation of mixers should be conducted on a regular basis. Every mixer is variable in mixing time and, as it ages, mixing time may have to be altered to ensure that adequate mixing is occurring. There are several methods that can be used to test mixer efficiency. Quantab® chloride titrators were used in Exp.1 and 2 because the assay is simple to conduct and inexpensive. Previous research with Quantab® analysis has also shown that the Quantab® assay is comparable to both a salt-meter test and laboratory analysis and is less expensive to perform.

The salt with a particle size of 440 microns mixed to a CV of less than 10% in 2.0 min in the 2000-lb batch, and never achieved an adequate CV when the mixer was filled to the rated capacity of 3000 lb. This suggests that filling the tested mixer at rated capacity inhibits the mixing action and increases the time needed to adequately mix. Previous research also has indicated that many mixers do not operate efficiently when filled to the rated capacity.

The particle size of ingredients can affect the time needed to adequately mix feed to a uniform end point. Salt with particle sizes of 440 and 730 microns was used in both experiments. In Exp. 2, it was demonstrated that, as the particle size of salt increased, the time needed to achieve a uniform mixture increased. With ingredients being variable in size and shape, ingredient selection becomes more important. The particle sizes and shapes of all ingredients should be similar to ensure proper dispersal throughout the feed.

Experiments 1 and 2 demonstrated that when samples are analyzed as collected (unground), the CV may be overestimated by the analysis, compared with that of the samples analyzed after grinding to a uniform particle size. Although the results from samples mixed with 440-micron salt were very similar between the as-collected (unground) and ground samples, the decrease in CV to 10% or less indicates that a fine mixing salt should be used when mixer-efficiency analysis is being conducted. The fine mixing salt will provide the most accurate CV. If a coarse salt is used in mixer efficiency testing, grinding the sample to a uniform particle size before analysis will give a better indication of the performance of the mixer, but using a fine mixing salt will still generate more accurate results.

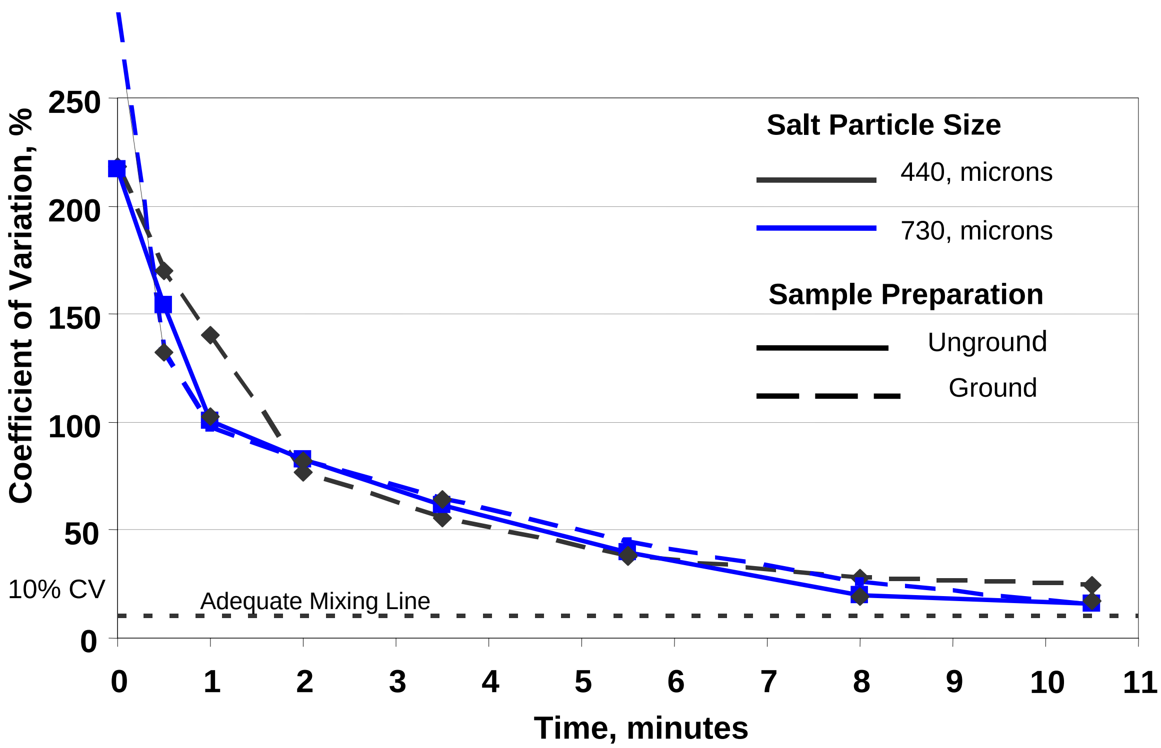

Figure 1. There was a Salt Particle Size × Sample Preparation × Mixing Time Interaction (P<0.001) Observed. For the first 2.0 min of mixing, the coefficient of variation dropped rapidly. Grinding the samples mixed with 730-micron salt resulted in a lower CV than the unground samples had, no difference among the samples mixed with 440-micron salt. A CV of 10% or less was never achieved in Exp. 1, indicating that we were unable to achieve a uniform mixture.

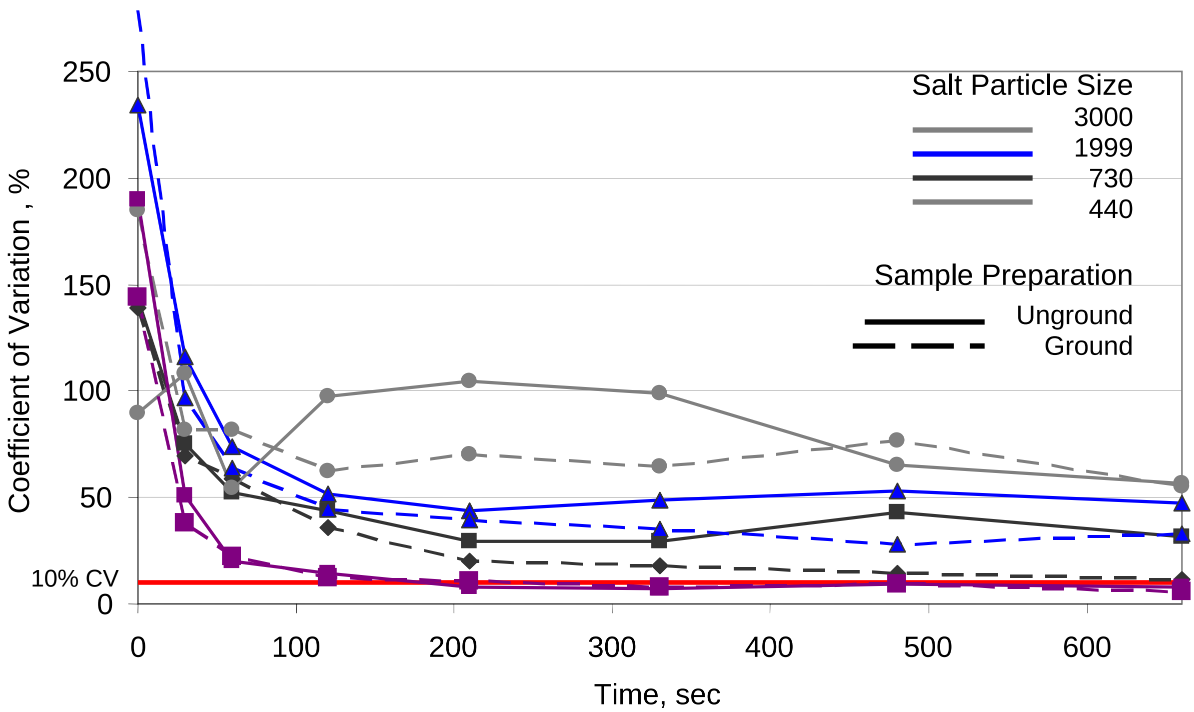

Figure 2: There was a Salt Particle Size × Sample Preparation × Mixing Time Interaction (P<0.04) Observed. As salt particle size decreased and mixing time increased, there was a decrease in CV. When samples were ground before Quantab® analysis, there was a decrease in CV. The samples mixed with 440-micron salt showed no improvement with grinding. The samples mixed with 730-micron salt (ground) and the 440-micron salt (ground and unground) reached a CV of less than 10%, indicating a uniform mixture. No other treatments reached a CV of 10% or less.