K-STATE Kansas State University

Testing Mixer Performance

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The objective of the mixing process is to produce feed in which nutrients and medication are uniformly distributed. Well-mixed feed enhances animal performance and is an essential step in complying with Food and Drug Administration (FDA) Current Good Manufacturing Practices regulations (Title 21 C.F.R. 225.30,130).

A satisfactory mixing process produces a uniform feed in a minimum time with a minimum cost of overhead, power, and labor. Some variation between samples should be expected, but an ideal mixture would be one with minimal variation in composition (Lindley). Measuring the variation in finished feed is the *crux* of mixer testing.

A number of factors that determine mixer performance are considered below. Understanding how these factors affect the mixing process is essential when interpreting the results of a mixer test.

Factors that Determine Mixer Performance

Several factors determine the dispersion of ingredients in a feed. These factors include ingredient particle size and shape, ingredient density and static charge, sequence of ingredient addition, amount of ingredients mixed, mixer design, mixing time, cleanliness of the mixer, and wear or maintenance of the mixer. Feed manufacturers can control most of these variables through equipment maintenance and operation described below.

Particle size of grain ingredients is controlled through the grinding operation. Coarsely ground grain (a large particle size) can have a detrimental effect on a batch of feed's mixing properties. For example, ground grain with a particle size of 1,200-1,500 microns reduces the likelihood of uniform incorporation of micro-ingredients compared to grain ground to an average particle size of 700 microns. A large particle size variation between grain and micro-ingredients also can result in increased segregation after mixing.

The **sequence of ingredient addition** also determines ingredient dispersion in the mixing process. Mixers may have dead spots, where small amounts of ingredients may not be readily incorporated into the feed. This situation is aggravated when mixing ribbons, augers, or paddles become worn. Ground grain or soybean meal should be the first ingredient added into a horizontal mixer. Vertical mixers generally provide an optimal mix when micro-ingredients are added early in the matching process (e.g., during or after soybean meal, but prior to grain).

Buildup of material on ribbons, paddles, or augers can reduce mixer performance. The FDA Current Good Manufacturing Practices (**GMPs**), which pertain to production of medicated feed, require that equipment be maintained and cleaned (Title 21 C.F.R. 225.65, 165). Residual material on mixing parts can also lead to feed contamination (cross-contamination).

Overfilling or **under-filling** a mixer can lead to inadequate mixing. Overfilling a mixer can inhibit the mixing action of ingredients in horizontal mixers at the top of the mixer. Filling a mixer below 50 percent of its rated capacity may reduce mixing action and is not recommended.

The **mixing time** necessary to produce a homogenous distribution of feed ingredients should be measured for each mixer. Mixing time is a function of mixer design and the rotational speed of the ribbon, paddle, or auger. The best way to establish the appropriate mix time is to conduct a mixer performance test.

Mixer Performance Testing

Mixer performance testing consists of two parts: sampling and sample analysis. Procedures for sampling mixers, analyzing samples, and interpreting results are described below.

Sample Collection

The first step in mixer testing involves collecting representative feed samples. This process depends on the type (horizontal versus vertical) and design of the mixer.

For example, it is difficult to collect a representative sample directly from a vertical mixer using a grain probe, hence, collecting samples at evenly spaced intervals during mixer discharge is recommended.

Samples can be taken from the spout end of portable grinders/ mixers or near the discharge point for a stationary vertical mixer.

Horizontal mixers are usually accessible from the top which permits sample collection directly from the mixer using a grain probe.

Samples should be drawn from 10 predesignated locations or at even intervals during mixer discharge. Identify the location, or time sequence, by numbering the sampling bags; this step will help one interpret the data (see Figure 1).

Ten samples are advised; this recommendation is based on the statistical analysis procedures described in step 3 of **Sample Evaluation.** Mixer test results are less accurate when fewer samples (data points) are used.

If you are evaluating mixer performance using a micro-ingredient that requires an expensive laboratory assay, (e.g. drug), it may become necessary to make a trade off between the cost and accuracy of the test.

To select the optimum mixing time, feed samples must be collected at intervals over an extended period. For example, a horizontal mixer can be evaluated for optimal mixing time as follows: run the mixer for two minutes, stop the mixer and collect 10 representative samples from predetermined locations, run the mixer two more minutes, stop the mixer and collect ten samples from the same locations as the previous sampling. Repeat this process for ten minutes (five sampling times).

As mentioned above, it is difficult to collect samples directly from vertical mixers. In this instance, a sampling scheme will involve separate batches of feed that have different mixing times. It is important to perform this test using the same feed ration and same sequence of ingredient addition to the mixer.

Safety precautions must be followed when sampling a mixer. In every instance, use proper lockout, tag-out procedures (disengage power) before reaching into a mixer to collect a sample. Do not place your hands near moving augers when collecting samples during mixer discharge.

Sample Evaluation

Sample evaluation involves 1) selecting the micro-ingredient or tracer to test for feed uniformity; 2) assaying the samples for the specified ingredient level; 3) analyzing the data collected during samples analysis; and 4) interpreting the data.

Step 1: Selecting a Micro-ingredient

A micro-ingredient is defined as an ingredient that comprises 0.5 percent or less of the final feed. Testing mixer performance using a micro-ingredient will provide a better indication of feed uniformity, since micro-ingredients are typically more difficult to incorporate into a large batch of feed.

Salt is a commonly recommended micro-ingredient to test mixer performance. Salt is common in most feeds, it comes from only one source, and it is both inexpensive and easy to perform a salt assay. Physical characteristics that make salt an attractive ingredient for testing include the following: it is more dense than most feed ingredients, its shape is generally cubic rather than spherical, and it is smaller than most other particles. If the mixer will uniformly incorporate salt, those ingredients with more typical physical properties (shape and density) should pose no problem during mixing.

Step 2: Assaying Procedures

Assaying samples for salt content may be performed using several techniques. The sodium (Na^+) or chloride (Cl^-) ions from salt (NaCl) may be analyzed after mixing the feed sample in a water solution. “Quantab” (Environmental Test Systems, Elkart, Indiana)

Interpretation of Mixer Tests

Percent Coefficient of Variation	Rating	Corrective Action
<10%	Excellent	None
10-15%	Good	Increase mixing time by 25–30%
15-20%	Fair	Increase mixing time 50%, look for worn equipment, overfilling, or sequence of ingredient addition
>20%	Poor	Possible combination of all the above. Consult extension personal or feed equipment manufacturer.

chloride titrators measure the dissolved Cl^-, while the Omnion Sodium Analysis involves a meter with a specific sodium electrode that measures the Na^+ (Omnion, Inc., Rockland, Massachusetts).

Step 3: Data Analysis

The average salt concentration (mean) and variation between samples (standard deviation) are calculated to arrive at a single value described as the coefficient of variation (CV). A desirable CV for a well mixed feed, using the salt assay method, should be at or below 10 percent. Calculating the coefficient is performed using the following equation:

$$\%CV = \frac{s}{\bar{y}} \times 100$$

$$\bar{y} = \frac{\Sigma y_i}{n}$$

$$s = \sqrt{s^2}$$

$$s^2 = \frac{\Sigma(y_i^2) - n\bar{y}^2}{n-1}$$

where:

- %CV = percent coefficient of variation
- s = standard deviation
- s^2 = variance
- $\bar{y}$ = mean
- Σ = sum
- y_i = individual sample analysis results
- n = total number of samples

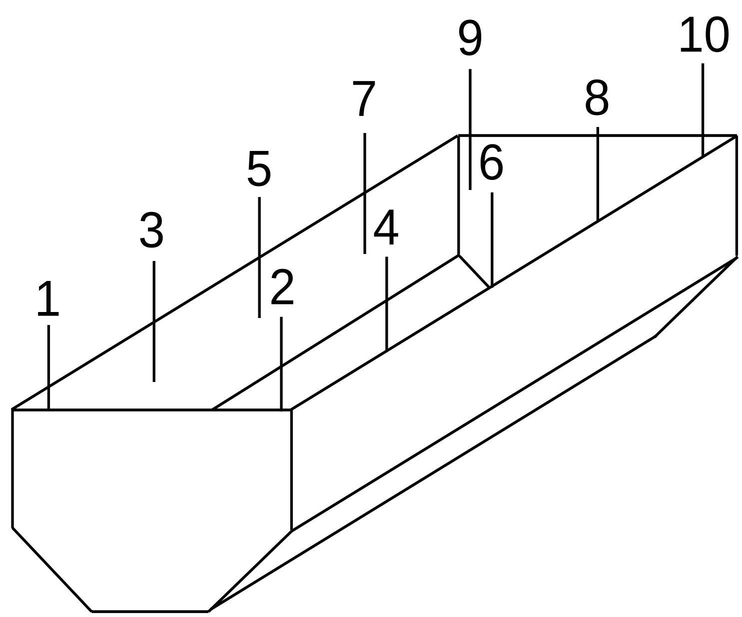

Figure 1. Sampling scheme used to evaluate mixing performance in a horizontal paddle mixer.

Inexpensive calculators are available that are programmed with a statistical function that automatically calculates the coefficient of variation or the standard deviation and mean.

Step 4: Interpreting the Results

A CV below 10 percent is considered a good mix. Variation in the assay procedure may be as high as 5 to 6 percent, indicating that the actual variation due to mixing is about 5 percent. If the CV is over 10 percent, increase the mix time and/or inspect the system for factors that caused the poor ingredient distribution (e.g., sequence of ingredient addition or particle size).

Example 1.

To illustrate the variation in salt concentration for a feed sample, consider the following example. Samples were taken from a horizontal paddle mixer with a 2-ton capacity using a 4-foot grain probe. Quantab titrators were used to measure the salt ion content with the following results:

Location	Salt (%)
1	0.24
2	0.51
3	0.55
4	0.42
5	0.59
6	0.55
7	0.59
8	0.59
9	0.64
10	0.55

Mean	0.523
Standard Deviation	0.1156
Coefficient of Variation	22.10%

The sampling scheme that was followed is illustrated in Figure 1. The lowest salt concentration was at location 1 (53 percent less than the mean concentration) and the highest salt concentration was at location 9 (23 percent greater than the mean concentration). Salt was added to the mixer as a premix after ground grain and soybean meal. The auger used to convey the premix discharged near the center of the mixer. Complete feed was discharged from the mixer end where samples 9 and 10 were drawn.

Results suggest that insufficient mixing action (or time) resulted in a low micro-ingredient distribution at one end of the mixer. Possible corrective action could include positioning the premix auger closer to sampling locations 1 and 2 (end opposite to the mixer discharge port) or increasing mixing time from 3 to 5 minutes.

A particle size evaluation revealed that ground milo was 1,150 microns. Adjusting the roller mill to reduce particle size below 800 microns should improve mixer performance and feed efficiency in this example.

Literature Cited

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Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-1172 October 1994