# Closer to Perfection

Feed Management, November 1992

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IF a feed manufacturer mixes feed longer than necessary to achieve a practically "perfect" mix, he is wasting labor and energy and reducing the production capacity of the facility. On the other hand, if the mix of ingredients is incomplete, animal production and customer satisfaction may be adversely affected (Behnke 1991).

An improperly functioning mixing system can be corrected by either replacing or rebuilding the mixer or changing batch sizes, mixing times, or microingredient addition locations. Further, as mixers wear they require both maintenance and periodic testing (Wicker and Poole, 1991). If test results are satisfactory, the feed manufacturer may decide that mixing time can be reduced, either immediately or when feed demand increases.

## Nutrient Dispersion

Table 1. Comparison of various nutrients and commercial markers for use in determining mixer performance

| Sample Number (1): | Protein (%) | Calcium (%) | Fat (%) | Salt (%) | Manganese (ppm) | Marker (2) (ppm) |
|---|---|---|---|---|---|---|
| 1 | 15.5 | 4.25 | 2.81 | 0.81 | 56.8 | 380 |
| 2 | 15.4 | 4.37 | 2.60 | 0.75 | 57.0 | 323 |
| 3 | 15.0 | 3.41 | 3.02 | 0.61 | 46.0 | 391 |
| 4 | 15.2 | 4.33 | 2.70 | 0.76 | 57.0 | 459 |
| 5 | 15.6 | 3.81 | 2.74 | 0.68 | 50.0 | 336 |
| 6 | 15.3 | 4.33 | 2.54 | 0.80 | 62.1 | 399 |
| Average: | 15.3 | 4.08 | 2.74 | 0.74 | 54.8 | 381 |
| SD (3) | 0.22 | 0.39 | 0.17 | 0.077 | 5.8 | 48.8 |
| CV (4) | 1.4% | 9.6% | 6.2% | 10.4% | 10.6% | 12.8% |

(1) - Samples obtained after three minute mix
(2) - Commercial marker: MT-Blue, Microtracer™
(3) - Standard deviation.
(4) - Coefficient of variation.

## Marker Use

Table 2. Marker distribution as influenced by addition site and mixing time.
Mixer Site

**Blue Marker**

| Mixing Time | North End | South End | Discharge |
|---|---|---|---|
| 1.5 minutes | 11 | 216 | 115 |
| 3.0 minutes | 54 | 194 | 122 |
| 4.5 minutes | 70 | 217 | 82 |

**Red Marker**

| Mixing Time | North End | South End | Discharge |
|---|---|---|---|
| 1.5 minutes | 91 | 3 | 36 |
| 3.0 minutes | 86 | 8 | 68 |
| 4.5 minutes | 78 | 17 | 84 |

Blue marker: Microtracer, F-Blue added at south end of a newly installed two-ton, fully charged paddle mixer.
Red marker: Microtracer, F-Red added at north end of a newly installed two-ton, fully charged paddle mixer.

**Marker Design and Sampling Strategy:**

A mixer maintenance program is necessary to consistently produce uniformly mixed livestock and poultry feeds and optimize mill capacity. For a maintenance program to be effective, it must include a mixer efficiency test. All mixer testing regimens involve the addition of a marker, or tracer, to the unmixed ingredients, sampling the marked feed after mixing, analyzing the samples for the marker's concentration, and interpreting the results of such analyses.

A marker must meet several criteria to be used in a mixer testing program. The ideal marker should be effective when added at a "micro" concentration and not be native to the other feed ingredients. Also, the assay should be simple and inexpensive. It is important that mixer test data be available as quickly as possible. Of course, the ideal marker can not be toxic or alter the color or flavor of the feed. Also, the assay for the marker must be of known reproducibility.

Feed manufacturers frequently use micronutrients as markers to test mixer efficiency. These include vitamins, trace minerals, amino acids, drugs and commercial tracer products. Manufacturers assume if the micronutrient is uniformly distributed in the feed, macronutrients, such as protein and fat, will also be uniformly distributed. This is a much safer assumption to make than the converse, that distribution of a macro-ingredient would be indicative of practically "perfect" micro-ingredient dispersion.

Data from an actual feed mill test are presented in Table 1 includes results for analysis of macro-ingredients protein and fat and for calcium, manganese, salt, and a colored iron tracer. The protein results consistently yielded coefficients of variation of less than 3%-far lower than the 10% accepted as an industry standard (Wilcox, Feed Additive Compendium 1981). As the marker became less concentrated in the diet and more unique to a single source, its variability in the samples became greater. In the case of the salt, manganese, and colored iron particles, it was obvious that the mixing system was not operating properly.

The requirement for marker "uniqueness" becomes obvious when one considers that if all ingredients in a feed contained the same concentration of a given analyte, then analysis of

multiple samples from the feed would inevitably yield data typical of a "perfect" mix even if no mixing had occurred.

The requirement for known reproducibility of the marker assay is critical in permitting an objective evaluation of test results. This will be discussed at greater length later in this paper.

Feed manufacturers must consider the following when adding a marker to test mixing completeness:

**Location of Addition:**

An ingredient added at the center of a mixer may mix more uniformly and quickly than an ingredient added at an end of a mixer (Table 2). If the objective is to validate existing procedures, the marker should usually be added as a premix ingredient where the premix is normally added. In certain special cases, the location of tracer addition must be " special" as in evaluating proposed production changes or when evaluating horizontal paddle mixers. Such mixers often do not move feed from one end of the mixer to the opposite end. To test such mixers, one should add two tracers, one at each end, then take samples from each end for analysis and evaluation.

**Time of Addition:**

If the objective is to validate existing procedures, the marker should be added as a premix ingredient when the premix is normally added. If colored iron particles are used as markers, two or more different colors may be added to a mix at different times yielding information for two or more mixing times from one test batch.

**Form of Addition:**

The marker should be added as a premix ingredient rather than as a "hand add" dropped directly into the mix unless such "hand add" addition is routine.

The following must be considered in sampling the test batch of feed:

**Sample Size:**

Samples should be of adequate size to allow retesting if unusual or unexpected results are found from the initial analysis-usually 0.25-0.5 lb. samples are adequate.

**"Grab" Versus Composite Samples:**

Samples must be "grab" not composites. Composite samples may accurately reflect the proper formulation of the mix but they do not yield information on the quality of its mixing. Do not homogenize grab samples prior to analysis. Sub-samples taken from grab samples should be no larger than the amount of feed consumed by a single animal at a single feeding. However, extremely small sub-samples may be impractical as some assays, such as for vitamins or drugs, which may require large amounts of sample.

**Sampling Location:**

To eliminate error from residual feed from previous batches, it is recommended that samples be taken from within the mixer. If this is not possible, samples should be taken as near the mixer as practical either from the surge bin or the screw conveyor leaving the surge bin.

Some feed manufacturers prefer to sample finished feed at loadout. Their logic is that mixing may occur after the feed leaves the mixer. We have never yet encountered a feed badly mixed when tested at the mixer properly mixed at loadout. Some mixes may separate during conveying but this is a different problem.

**Number of Samples:**

Ideally, one should sample the entire batch. But practically, if one samples from within the mixer one should take at least three samples-one from each end of the mixer and one from the middle. If one samples from a screw conveyor leaving the surge bin, one should take at least 10 samples. As the number of samples increases, the data will be more reliable. The number of samples assayed depends mainly upon how critical it is to be right (or not wrong) and the cost of the assay.

**Analyzing the "Marker":**

Just as selection of the marker is essential to the success of the mixer test, there are certain criteria which must be met in the assay of the marker. Reproducibility of the assay is critical in permitting an objective evaluation of results. The advantages of low cost and quick availability of results are obvious.

A more difficult question to answer is: Is it preferable to analyze a few samples very precisely or many samples less precisely?

Regarding colored iron markers, it is preferable to analyze many samples with less precision. If one takes 10 samples from a "perfect" mix and counts 100 marker particles per sample, one can expect from Poisson distribution a standard of 10 and a coefficient of variation (CV) of 10%. If one takes only one sample and counts 1000 marker particles, one expects a standard deviation of 31 and a CV of 3.1 %. While this CV is certainly more precise, it provides information on only one location in the mixer. If one summed the results for the analysis of the 10 samples, one would have a CV of 3.1 % but also have information for ten sampling locations.

**Evaluating the Results:**

Having an assay of known reproducibility permits an objective evaluation of test results.

As an example, if a feed manufacturer tests for methionine and can achieve reproducible results of 4% CV from a set of samples of known composition, and then finds a CV of 10% from a set of samples, he may have a statistically significant basis for considering these samples to evidence an incomplete mix. If he finds a CV of 20% from a group of samples, he can be nearly certain the mix is not complete (Wicker and Poole), Variability is simply far greater than is expected from a completely mixed feed.

Also, many feed manufacturers use of a 10% CV as a standard for determining completeness of a mix-a CV greater than 10% is indicative of an incomplete mix. The

use of an arbitrary value may be incorrect because it does not take the CV of the assay into account. For example, a feed manufacturer uses an antibiotic as a test marker. The assay of this antibiotic has a CV of 25%. If he analyzes a set of samples and finds a CV of 25%, he can say that he has an almost "perfect" mix. While the results might be more variable than he might like, the results are far more meaningful than a set of protein results for a feed concentrate formulated to contain 40% protein.

The use of colored iron particles as markers for testing mixing is advantageous as they can be expected to distribute in feeds following a Poisson distribution. Test results can then be objectively compared to what one would expect from a complete "perfect" mix.

Also, in evaluating mixer test data, a feed manufacturer should confirm that average assay results match the expected concentrations of the marker. If assay results are low, the tracer may have degraded during mixing or was removed from the mix. In some cases, fat or molasses, built up on the sideways of the mixer trapped the marker.

An unsatisfactory mixer test may be indicative of problems beyond worn paddles or too insufficient mixing time. Incomplete mixing can be due to overloading or failure of automated micro-ingredient addition systems to add the marker as specified. The so-called problem of over-mixing may simply reflect poor mixer design.

It is reasonable to assume that a properly manufactured feed is one that is completely mixed. Further, it is reasonable to assume that one should test mixers at least when they are installed and thereafter periodically, possibly once each six months. This is also necessary to assure the public the best food supply possible recognizing that illegal drug residues can occur if medications are not mixed uniformly.

**References:**

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Feed Management, November 1992, pg 8-20.
Edited: July 19, 2013 ZE