SAFE Guidance on Testing Mixer Efficiency

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What is a Mixer Study?

A mixer study is the chemical analysis of 10 samples from a single batch of formula feed to evaluate uniformity of a feed mixture. The main objective of mixing feed is to ensure each animal receives all formulated nutrients and medications at the correct rate each day. Inconsistency in formula feeds due to poor mixer efficiency can negatively impact animal performance.

Mixer evaluation is also a requirement for medicated feed mills under the Code of Federal Regulations (CFR), Title 21, Part 225.30 (b) for a licensed feed mill and Part 225.130 for a non-licensed feed mill. Routine testing of mixer efficiency is an important aspect of feed manufacturing which should be included within a firm's food safety plan and quality assurance plan.

Study Design

The first step in conducting a mixer study is to design a plan to adequately test the mixer capability.

What to Sample:

Select a formula feed which contains at least one micro-ingredient, which is defined as an ingredient that comprises 0.5% or less of the feed[1] such as drug, mineral, and vitamin ingredients. The selected nutrient or chemical which will be analyzed should come from a single ingredient source. Examples of micro-ingredients to test include drugs, minerals such as zinc and copper, and amino acids.

In some cases, it may be beneficial to test additional chemicals/nutrients which represent minor and/or major ingredients. For example, in some formula feeds limestone (calcium carbonate) may be a minor ingredient and a good candidate for analysis because it is the sole source of calcium and differences in the density and/or particle size present a good challenge to feed mixing. Crude protein may be a good analysis in formula feeds which include urea or other sources of non-protein nitrogen as the main source of protein. Testing for crude protein may also be appropriate when the main source of protein is a single high protein ingredient, or in pellet and grain mixes which have a concentrated protein pellet. If a very high fat ingredient is used in the mix, then crude fat may be appropriate as well. Although some protein and/or fat is provided by other ingredients, the high concentration in certain ingredients (or a pellet) can help identify inconsistencies in mixing. However, confirming good consistency of major ingredients through testing crude protein or crude fat does not necessarily prove good

consistency in relation to micro and minor ingredients. It is best to consider the nutritional composition of every ingredient in the mix, as well as physical characteristics, when selecting the best analytes for your mixer study.

There may be laboratory assay limitations for certain ingredients depending on the concentration of ingredient in the formulation, or generally. For example, accuracy of detection for a mineral may decline when present below a certain level, or variability may be generally high for a given analytical method. Such limitations in laboratory capability may compromise results, and therefore should be understood when planning what to sample in your mixer study.

Another technique to evaluate uniformity is to add an analytical tracer to the feed, such as colored iron particles, and evaluate the results with methods provided by the tracer manufacturer.

Where to Sample:

Representative samples should be obtained as near the mixer discharge as possible, at equally spaced time intervals throughout a single batch of feed. Utilize an opening that can safely be opened and is as close to the mixer as possible.

Some facilities perform mixing by other means such as layering. The same concepts of mixer study sampling can be applied to nearly any manufacturing process. However, it is important that sampling occur as near to the mixing step as possible to test the effectiveness of that process. While sampling at load-out will test final consistency of the product, it does not determine effectiveness of a single processing step because the feed continues to mix during subsequent processing, conveyance and storage steps.

Likewise, it is common that problematic conveyance and/or storage after the mixer may lead to unmixing of the feed and poor consistency in the final product, regardless of satisfactory mixer study results. Therefore, conducting subsequent ‘mixer study’ sampling techniques at various points in the manufacturing process can be important in investigating the root cause of consistency issues.

A mixer study should be conducted for each mixer at a facility, at least once annually.

When to Sample:

Sampling can begin after the last ingredient has been added and the total dry and wet mixing time has been completed. Decide on a time interval that will allow you to obtain a minimum of 10 evenly spaced samples throughout a single batch of feed. A ‘batch’ of feed is an individual run of the mixer’s capacity.

SAFE Guidance on Testing Mixer Efficiency

A mixer study should be conducted initially upon installation of new equipment, when a new drug or concentrated ingredient is going to be used, as part of troubleshooting, and at least once annually.

How to Sample:

You will need 10 sample bags and label them with the name and formula of the feed, the date, and a number (1-10) so that the samples can be distinguished after being taken. Collect samples beginning with bag 1 and moving on until you have finished with bag number 10. A single stream-cut or scoop per sample is acceptable.

Analysis of Mixer Study Data

The measure of uniformity used to analyze mixer study results is the coefficient of variation (CV). As the level of a chosen ingredient or nutrient varies in each formula the standard deviation will also vary, making it difficult to compare the results of various nutrients. The percent CV is mathematically calculated as the standard deviation divided by the average, multiplied by 100, making it independent of the actual values or mean of the dataset. This allows for all ingredient or nutrient value variability to be comparable to a common standard.

Table 1. Example results of a mixer study. The coefficient of variation (CV) is equal to the standard deviation divided by the average, multiplied by 100. For crude protein; 1.2 standard deviation ÷ 17.8 average = 0.067 (multiplied by 100 equals 6.7% CV).

SAMPLE ID	CRUDE PROTEIN (%)	CALCIUM (%)	COPPER (PPM)
1	18.40	4.87	9.75
2	18.90	4.56	9.44
3	18.80	5.36	9.93
4	19.00	5.8	12.60
5	17.30	4.14	11.00
6	17.00	2.99	8.91
7	18.00	3.26	9.37
8	18.90	4.38	9.68
9	16.50	1.98	8.11
10	15.50	1.93	10.30
AVERAGE	**17.8**	**3.9**	**9.9**
STANDARD DEVIATION	**1.2**	**1.3**	**1.2**
COEFFICIENT OF VARIATION (CV)	**6.7**	**34.2**	**12.3**

SAFE Guidance on Testing Mixer Efficiency

Interpretation of Results and Corrective Actions

A non-uniform distribution of ingredients especially minerals, vitamins, and medications can negatively impact animal performance and health. The industry standard for excellent mixer efficiency is a CV less than 10% (Table 2). A higher CV suggests improvements may be needed, such as inspection of equipment and increased mixing time. A CV of over 20% is considered poor mix uniformity and suggests a re-evaluation of the mixing system is needed.

Table 2. Interpretation and corrective action of mixer studies[1].

CV	Rating	Corrective Action
<10%	Excellent	None
10-15%	Good	Increase mixing time by 25 to 30 percent.
15-20%	Fair	Increase mixing time by 50 percent; look for worn equipment; overfilling; or sequence of ingredient addition.
>20%	Poor	Possibly combination of all of the above. Re-evaluate mixing system.

In the event of fair to poor mixer study results, follow-up and additional sampling will be needed to investigate the cause of the issue. In addition to the CV, results of a mixer study may reveal other quality concerns, such as an average analysis off-specification of the intended formulation.

Poor mix uniformity may be attributed to many factors, including, but not limited to:

- inadequate mixing time
- operating beyond designed limits
- operating with worn, altered or broken equipment
- buildup in equipment

Uniformity issues also may be caused by a process rather than the mixer itself, such as:

- sequence of ingredient addition
- batching procedures
- conveyance after mixing

Uniformity issues may also be due to properties of the ingredients themselves, such as:

- particle size
- particle shape
- particle density

SAFE Guidance on Testing Mixer Efficiency

Diversity in the physical characteristics of feed ingredients is a common problem in feed mix uniformity[2]. Feed ingredients with similar particle size and density tend to blend easily. Consistent particle size in the formulation is critical, and likely more important than density. Formulations with variable particle size are prone to un-mixing during conveyance and storage. It is especially important to use a carrier, or combination of carriers (millrun, rice bran, almond shell, limestone), in concentrated formula feeds which has suitable particle size and density to maintain consistent distribution of the various minerals, vitamins, and drugs.

Additional Resources

1.) Herrman, T. and K. Behnke. 1994. Testing mixer performance. MH1172. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Bulletin, Manhattan, KS: Kansas State University. Download here: https://bookstore.ksre.ksu.edu/pubs/testing-mixer-performance_MF3393.pdf

2.) A Guide to Feed Mixing. R.A. Zinn. University of California, Davis. Download here: https://animalscience.ucdavis.edu/sites/g/files/dgvnsk446/files/faculty/zinn/pdf/04.pdf