

# MIXING AND UNIFORMITY ISSUES IN RUMINANT DIETS

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The basic premise used by all nutritionists when formulating rations is that each aliquot (mouthful) of the diet is balanced with respect to the known nutrient requirement of the target animal. The diet must contain the necessary nutrients to support maintenance, growth, production, and health. Feed additives should be present to provide the appropriate level of protection from disease and other maladies. In all cases, the levels must be controlled so as to be neither deficient nor toxic. The question that must be addressed is how well do current feed manufacturing techniques provide that level of nutrient uniformity assumed by the nutritionist?

The purposes of this paper are to provide a discussion of the current situation, guidance as to how feed uniformity can be measured, and a brief discussion as to how animal performance can be affected if uniformity is not obtained and maintained.

## THE CURRENT SITUATION

The basic objective of any feed mixing operation is to create a uniform, random mixture of the solid and liquid ingredients in the ration. The equipment used is, at least in theory, designed to accomplish that objective, without nutrient destruction, in a minimum amount of time. A uniform, random mixture can only be obtained if there is no favored direction of movement by individual particles and if there are no selective forces (i.e. centrifugal forces) that come into play. In bulk solids mixing, it is logical that motion must be introduced so that particles are displaced relative to one another. That is a complex way of saying that if ingredients are layered one on top of another and no motion takes place, mixing will not occur. However, if the container is rolled, shaken, or vibrated, particle displacement will occur and random uniformity will eventually be obtained.

There are obviously many factors that influence mixing and feed uniformity. They can be divided into ingredient characteristics and machine characteristics. For the time being, only bulk solids will be discussed--liquids present special circumstances.

## Ingredient Properties

The following is a list of ingredient properties that can influence mixing:

- particle size,
- particle shape,
- density,
- hygroscopicity,
- static charging, and
- adhesiveness.

Of this list, the most important are particle size, shape, and density. If these three factors can be controlled, most feed uniformity problems are solved. For example, large and small particles typically do not mix well and are subject to directional influence in nearly any type of mechanical mixer.

Another example might be a mixture of grains, proteins, and minerals. The minerals often have a density two to three times greater than the grains and protein meals and are difficult to hold in a uniform, random distribution.

Some ingredients, particularly vitamins, are subject to static charging and may cling to non-grounded metal such as reels, tubs, and spouting. It is imperative that all equipment, including portable machines, be grounded to drain off static charges.

## Equipment Properties

The range of equipment used to mix feed is at least as diverse as the ingredients. There

have been many attempts to reduce mixing concepts to a series of engineering equations thus facilitating equipment design from a theoretical approach. The fact is, most contemporary mixing equipment, including horizontal ribbon and paddle mixers, vertical screw mixers, drum mixers, and mobile mixing boxes, have simply evolved from historically successful designs without benefit of theoretical input. For example, most horizontal mixers have a length approximately three times their diameter and have a rotational tip speed of 250-300 rpm regardless of the diameter. The inside ribbon is usually 2.5 times the thickness of the outside ribbon to balance the directional forces applied due to ribbon diameter.

Given this discussion, it is easy to appreciate the complexity of the mixing operation in any production facility. Yet, this seems to be an area of little concern to most feed manufacturers -- commercial or farm. As regulatory pressures for additive uniformity increase and as the need for providing uniform nutrient density to genetically superior livestock become necessary, it will be in the best interest of all feed manufacturers to ensure nutrient uniformity through testing.

#### Current and Future Aspects

To focus on the regulatory aspect of uniformity, the following excerpt is taken from the 1990 FDA Regulatory Guidelines (FDA, 1990).

*Equipment (225.30) - All equipment used in the manufacture of medicated feed shall have the capacity and capability to produce a homogeneous medicated feed of the intended potency. The capability of the mixing equipment should be demonstrated upon installation and periodically as needed to ensure proper adjustments during operation. Written documentation of the adequacy of the equipment should be available for FDA review.*

It is obvious that the regulation is subject to individual interpretation, but it is apparent that FDA is moving rapidly toward a program of

equipment validation when dealing with feed additives. In the area of nutrient uniformity, AAFCO (1992) has indicated that the Analytical Variation Program (AV) used by most state authorities is provided to "allow only for the inherent variability in sampling and laboratory analysis. Manufacturing variations are not included in the AV values." In other words, absolute uniformity is expected.

In January of 1990, the Degussa Corp. introduced a program to monitor uniformity of feeds manufactured by customers using their amino acid and other products (Wicker and Poole, 1991). Their results would indicate that only about half of the feeds tested would be of satisfactory uniformity (coefficient of variation [CV] < 10%). About 30% had a CV of 10-20% and the remaining 20% of the feed samples had a CV of > 30%. It is not known precisely at what level of uniformity animal performance will be affected, but one can certainly assume that, at a CV of greater than 20%, performance would be decreased.

The samples tested in this study were generally from large, centrally controlled feed mills. To gain a perspective on how well farm feed manufacturers do, Stark et al. (1991) conducted a study similar to that of Wicker and Poole except using salt as the tracer rather than synthetic amino acids. The results tend to parallel the Degussa report with about 42% of the samples having a CV of < 10%, 46% between a CV of 10% and 20%, and 12% having a CV of > 20%.

It is apparent that, at least in a significant portion of feed produced, nutrient uniformity criteria is not being met. As regulatory authorities move toward required equipment validation, it is imperative that the feed and livestock industries come to agreement as to what levels of nutrient uniformity is needed and how that uniformity is to be measured. There currently exists a standard (ASAE Standards, 1990) for testing solids-mixing equipment for animal feeds; however, the procedure is complicated and a great deal of the data gathered is meaningless to both regulators and to animal performance.

In order to help clarify the requirements for a procedure to be used for uniformity testing, the following criteria are offered:

1. The assayed item should be a common ingredient or nutrient that is usually in the formula or can be added without risk.
2. The cost for each assay should be minimal (< \$2.00 each).
3. The assay procedure should be simple, fast, accurate, precise, and able to be done on site.
4. The assay should present no safety hazard to personnel or animals.
5. The assayed item should be supplied from a single source.
6. Sample size required should be reasonable but large enough to reduce or eliminate sampling error.
7. The target mix uniformity (CV) should be approximately two (2) times the proven analytical variation for the assay selected but in no case exceed 10%.
8. The statistical procedures required should be easily understood and performed.

As the reader can imagine, there is no *perfect* procedure available. At present, assays that have been used include:

a) Chemical Assay - Drug, Vitamin, Amino Acid, etc.

Quantitative chemical analyses are usually very accurate. They are, however, often quite expensive. Drug tests often involve microbiological techniques and require long periods of time for results making them impractical for routine mixer tests. These tests could be used periodically for checking and for standardization.

There are some qualitative tests that can be used to check for the presence or absence of some vitamins, drugs, or antibiotics. These *spot tests* are colorimetric in nature and can only be used as guidelines and are not intended to be quantitative determination.

b) Colored Iron Filings

A sufficient amount of iron filings, colored with a water soluble dye, is added to the mix to result in sixteen to twenty-five counts (particles) per sample, with the sample size ranging between 50 to 100 grams. The filings are separated from the feed by a magnet on to filter paper. The paper is then sprayed with water and the colored spots are counted. Variation from the expected number is calculated to determine mixer performance.

c) Chloride Ion Test

The Quantab® (Environmental Test Systems, Inc., Elkhart, Indiana) is a method of determining the chloride ion concentration of a solution. Salt from the feed samples is extracted in hot water. The titrators consist of a thin strip laminated with a capillary column impregnated with silver dichromate. The column is a reddish-brown color. When the strips are placed in an aqueous salt solution, fluid will rise in the column. The salt reacts with the silver dichromate to produce a white color change in the column. When the indicator across the top turns blue, the reaction is completed. Chloride ion concentration is calculated and variation from the expected concentration is used to determine mixer performance.

This method is relatively fast (10-15 minutes). It can be done in the plant and does not require elaborate equipment. One must have hot water, filter paper, a graduated cylinder, and paper cups. The cost is about \$25 for 50 tests.

We have been testing a device using a specific ion electrode to determine salt content. The device, manufactured by the Omnion Company (Rockland, Massachusetts), uses a sodium ion electrode to determine Na<sup>+</sup> and reads out directly in percent salt. The technique appears to be quite accurate and reliable. The equipment requires a significant up-front investment but the variable cost per assay is then relatively low.

## Result Interpretation and Statistical Evaluation of Mixing Tests

The mean, standard deviation, and coefficient of variation can be used to interpret the results of the mixing test. In very simple terms, they help measure the distribution of values and express the values as one number (CV). In order to interpret the results of a test, the precision of the assay procedure itself should be known. For instance, the coefficient of variation of the Quantab® method is about 5%; therefore, if the result of the mixer analysis is 10% or less, we assume that a *good* mix has been achieved. The same criteria applies for other procedures.

One can also use these procedures to isolate points of segregation in the feed mill. For example, if one has a CV of 8% at the mixer and a CV of 18% after a transfer conveyor, there is a problem between the mixer and that point.

## VALUE OF NUTRIENT UNIFORMITY

If a diet is consumed that is deficient in a critical nutrient, animal performance will be lower than expected. Nutrients or additives supplied in excess of requirements will be wasted, add unnecessary cost to the diet, and, in extreme cases, can even be toxic to the animal. For example, urea is a common ingredient in dairy and, in particular, beef rations. Nearly everyone is either aware of or has been personally involved in situations where urea toxicity has occurred - usually because of poor feed manufacturing practices.

Pharmaceutical companies are required to spend millions of dollars proving that a compound is effective at a particular dosage rate. If, because of poor manufacturing techniques, a lower dosage is fed to a group of animals, efficacy is lost. Higher levels seldom provide additional response or protection and, in some instances, can produce harmful effects that can affect herd performance far into the future.

### Relationship of Meal Size and Uniformity

It is intuitive that there must be a relationship between the size of a meal consumed and the effect of uniformity on performance. Several studies done at K-State have shown that

non-ruminant animal performance can be dramatically affected by nutrient uniformity (McCoy et al, 1994; Stark et al., 1991; and Traylor et al., 1994). These studies indicated that the youngest animals consuming the smallest meal size were most affected.

Because ruminants tend to consume relatively large amounts of feed in multiple meals, the effects of a poorly mixed ration may not be as apparent. However, in instances where cattle, both dairy and beef, are being pushed to near their genetic potential and where we are processing grains to obtain maximum rates of fermentation, it is feasible and, perhaps, likely that rumen disfunction might occur simply due to a poorly mixed ration. Maladies such as bloat, acidosis, rumenitis, and laminitis can be the result of poor mixing practices.

There is very little published data on the affects of nutrient uniformity on animal performance and essentially none specific to ruminant nutrition. Commercial feedyard operators and dairies using total mixed rations (TMR) are certainly aware that good mixing practices are desirable. However, there are few benchmarks by which to set or judge standards. Historically, the commercial and integrated industries have set a 10% coefficient of variation as a target. As mentioned earlier, of nearly 100 commercial and integrated feed manufacturers sampled, nearly 50% had a CV above 10% and 1 in 5 had CV's in excess of 20% (Wicker and Poole, 1991). These plants, of course, are manufacturing grain-soy based feeds where the physical properties of ingredients are well controlled and more sophisticated mixing equipment is the norm. In a smaller study of on-farm swine feed manufacturers, Herrman and McClure (1995) found a mixing CV average of 13% with a range of 4 to 34%. One can easily visualize non-uniformity in a TMR or feedyard ration that contains a coarse forage, flaked grain, and a meal type supplement mixed in a typical auger box mixer.

### Sampling

Perhaps the most challenging aspect of measuring uniformity in a ruminant ration is obtaining a representative sample and maintaining analytical precision to the point a judgement can be made. Feedlot and TMR rations are comprised

of ingredients that vary widely in particle size, shape, density, texture, adhesiveness, and moisture content. As the roughage content of a ration increases, sampling problems are increased.

Often times, the worst sampling technique, the *top of the bunk grab sample*, is used by feed or additive reps as a matter of convenience. When analytical results then indicate a serious nutrient or drug deficiency or overage, panic sets in and the finger pointing begins. If more thought were given to sampling, many problems would disappear. The following is a suggested technique that should result in good representative feed samples for uniformity testing:

1. Lay large, unopened garbage bags or large plastic sheets crossways across the bunk at random intervals over the distance to be covered by a single delivery vehicle.
2. Using normal delivery practices, fill the bunks making sure that the delivery chute passes over the plastic sheets.
3. Collect each sheet with its feed intact in order, making sure to maintain location identity. Lay sheet with sample on a flat surface.
4. Using a *quartering* technique, reduce the large sample to a more satisfactory sample size of 1 to 2 pounds.
5. Place each sample in a clean, uniquely numbered, one-quart plastic bag and seal. If the rations contain high moisture or wet flaked grains, silage, or other wet ingredients, the samples should be refrigerated as soon as possible.

There are numerous other sampling techniques that can produce satisfactory results, however, any technique used must result in a representative sample to be valid.

As previously described, there are many *tracers* that can be used to evaluate uniformity. In the case of the Quantab® test for salt (chloride ion), the actual procedure calls for a 10 g sample and 90 ml of distilled water. Common sense should indicate that, in a typical TMR or feedlot ration, a representative 10 g sample would be

impossible. In actual practice, it is only the relationship of the sample weight to the water that matters; therefore, it is feasible to use a one-pound sample and nine pounds of water. After solubilizing the salt, a small aliquot of the water can be assayed for chloride and salt content determined. If a good scale is used, the precision of the test is not compromised.

### Uniformity Target

In the absence of regulatory targets, we must rely on judgement and economics to set standards. Simply put, the objective of any feeder should be to maintain consistent feed intake by cattle. Supplying a balanced and uniform feed is critical to maintaining intake; therefore, ration uniformity should be a high priority to every feeder. Mixing a uniform ration is not difficult but does require careful attention to equipment selection, operation, maintenance, and management. Control of ration uniformity will enable the feeder to minimize nutrient overages, make better management decisions, and optimize animal performance.

### Factors That Contribute to Non-Uniformity

1. **Ingredient Characteristics** - The most critical physical properties are size, shape, and density. The greater the differences between ingredients, the more difficult uniformity is to obtain and maintain.
2. **Insufficient Mix Time** - If given sufficient time, most mixers will produce uniformity. Appropriate mix time can be determined only through testing. This is the most common cause of poor nutrient uniformity.
3. **Mixer Overload** - If a mixer is loaded beyond its usable capacity, areas within the mixer will become essentially stationary and mixing will simply not occur.
4. **Worn or Broken Mixing Components** - If augers, paddles, or ribbons are broken, missing, or simply worn out, the mixer cannot perform its function.

5. **Ingredient Build-Up** - A build-up of molasses and fines on agitator members will, in effect, change the design of the mixer. This usually results in reduced mixer performance and can result in drug carryover.
6. **Improper Sequence of Addition** - As a general rule, light and larger particles tend to move upward while small and dense particles tend to migrate downward in a feed mass. It is usually advisable to load larger particle size ingredients first (forage) and heavy, smaller particles last; however, only through testing can the optimum sequence of addition be established.

### IMPLICATIONS AND CONCLUSIONS

- A. Feed additives and nutrient uniformity are far too important to leave to chance.
  - Everyone involved in the feeding operation should realize the importance and consequences.
- B. Testing for nutrient uniformity and mixer performance should become a routine activity at every feed manufacturing facility - commercial or farm.
- C. In nutrient uniformity targets.
  - \* A coefficient of variation of less than 10% is both desirable *and* obtainable.
  - \* A coefficient of variation between 10 and 25% indicates opportunities for improvement.
  - \* A coefficient of variation greater than 25% should be cause for concern.

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