Introduction
Ration mixing and feed delivery are two of many important processes in cattle feeding operations. Based on experience, one would assume that poor mixing translates into poor animal performance. Unfortunately, limited information exists which demonstrates the impact of mixing on fed cattle performance. Crossbred heifers fed a silage-based diet gained 9 percent faster and 14 percent more efficiently when fed a mixed vs. an unmixed ration. Imposing a 20 percent variation in weekly protein supplement inclusion rates decreased daily gain by 8 percent and increased feed conversion by 5 percent when compared to steers receiving a similar diet with no variation in supplement inclusion rate. Limited information exists where marginal mixing is related to cattle performance. Nevertheless, the above information supports the long-standing theory that providing rations that are more uniform will equate to improved animal performance.

Assessing ration uniformity
Assessing ration uniformity is a relatively simple process. Normally, a “marker” is added into the ration at a set amount. The marker can be a normal component of the ration (i.e., protein, calcium, non-protein nitrogen or salt) or a substance added specifically to measure ration uniformity such as colored iron filings or dyes. Ideally, the marker should be a unique component that can be accurately and inexpensively measured. Following the collection and analysis of a series of samples, a coefficient of variation (CV) is calculated. A CV is a statistical measure used to describe the variation that occurs within a set of observations. Coefficient of variation is calculated by expressing the standard deviation of a set of numbers as a percentage of its mean [i.e., (standard deviation/mean)*100]. As CVs become smaller, the ration is more uniform because there is less variability. It generally is accepted that CVs less than 10 percent represent acceptable mixing, whereas CVs greater than 20 percent are cause for concern.

Several reports have been published documenting the variability of feed mixers in commercial operations. Of nearly 100 commercial feed mixers tested, approximately 51 percent had mixing CVs less than 10 percent and 19 percent of the mixers had CVs greater than 20 percent. Results from 153 mixing studies conducted in commercial feedlots indicated the average CV was 9.5 percent. Of these, 66 percent were found to have a CV below 10 percent and 31 percent had a CV between 10 percent and 20 percent.

Factors affecting ration uniformity
Improper mixing time
Individual mixers vary widely with respect to optimal mixing times. One study determined that inadequate mixing time is the primary reason for poor mixing results. Another study demonstrated that approximately four minutes of mix time were required in a horizontal ribbon mixer to obtain a CV below 10 percent (Figure 1). Similarly, results obtained from a stationary paddle mixer within a commercial feedyard demonstrated that longer mixing times improve feed additive distribution and increase the likelihood of acceptable assay results (Table 1). However, in most commercial feedyards, mixing times often are minimized to preserve the integrity of the flaked grains and to maximize feedmill production. Consequently, feedlot rations may tend to be slightly undermixed. The manufacturer of the feed mixer should be contacted to determine the appropriate mixing time.

It generally is accepted that CVs less than 10 percent represent acceptable mixing, whereas CVs greater than 20 percent are cause for concern.

Only 3 percent showed poor mixing characteristics with CVs greater than 20 percent. This would indicate that most commercial feedyards do an acceptable job of manufacturing feed. When results from mixing studies report less than optimum results, there are several areas that should be investigated to determine the cause of poor results.
Mixer overload

Another critical error that can occur during feed mixing is overloading the capacity of the mixer. Overloading a mixer beyond its effective capability causes problems by creating “dead spots” of stationary feedstuffs that are not incorporated uniformly into the ration. One study demonstrated that when a mixer was loaded beyond its capacity, additional mixing time would not reduce variation (Table 2). Similar results have been observed with respect to feed additive distribution at commercial feedyards. In a specific example, when a feed mixer truck was overloaded with feed, distribution of Rumensin® was poor (Figure 2). Upon discharge, the majority of Rumensin was located in the front half of the load while little Rumensin was found near the back. When the truck was filled to the appropriate level and then mixed, Rumensin was distributed evenly throughout the feed truck.

Table 1. Hypothetical effect of mixing time on ration coefficient of variation, assay results and percent of feed additive assays within tolerance using a stationary paddle mixer in a commercial feedyard

<table>
<thead>
<tr>
<th>Mixing time, seconds</th>
<th>Ration CV</th>
<th>Average assay result, % of claim</th>
<th>Percent assays within tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>12</td>
<td>69.1</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>19</td>
<td>93.9</td>
<td>90</td>
</tr>
<tr>
<td>55</td>
<td>6</td>
<td>99.1</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 2. Potential effect of overloading a feed truck mixer on Rumensin assay results

Table 2. Effect of batch size and mixing time in a 5-ton mixer on lysine and methionine variation

<table>
<thead>
<tr>
<th>Batch size, tons</th>
<th>Mixing time, minutes</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Methionine</td>
</tr>
<tr>
<td>5</td>
<td>2.0</td>
<td>34.6</td>
</tr>
<tr>
<td>5</td>
<td>2.5</td>
<td>5.0</td>
</tr>
<tr>
<td>5</td>
<td>3.0</td>
<td>2.6</td>
</tr>
<tr>
<td>6</td>
<td>2.0</td>
<td>34.9</td>
</tr>
<tr>
<td>6</td>
<td>2.5</td>
<td>31.4</td>
</tr>
<tr>
<td>6</td>
<td>3.0</td>
<td>29.8</td>
</tr>
</tbody>
</table>

Worn, broken or improperly adjusted equipment

Often, little attention is given to the fact that worn, broken or improperly adjusted equipment affects ration uniformity. When mixing equipment is worn or broken, the efficiency of mixing is decreased. One study compared different mixer wagons to determine the optimal length of time required to mix a silage-based grower ration and a whole-shell-corn-based finisher ration. Results demonstrated that an auger mixer in poor condition required eight minutes to mix either the grower or finisher ration, whereas an auger mixer in good condition required two minutes and four minutes to adequately mix the grower and finisher rations, respectively.

Ingredient buildup on mixers

Because of the high use of fat, molasses and/or liquid supplements in feedlot rations, buildup on augers, mixer shells and doors is possible. This buildup will decrease the efficiency of the mixer. One study reported results from a series of mixer studies conducted at a commercial feedmill where ingredient buildup within the mixer was present. Within four batches of feed where ingredient buildup was present, the mixer CVs were 5, 36, 24 and 14 percent. The ionophore concentrations of the four batches were 92, 80, 133 and 88 percent of theory, respectively. Following cleaning, mixer CVs on four batches of feed were 92, 80, 133 and 88 percent of theory, respectively. Every operation should have a standard operating procedure (SOP) in place to properly clean feed mixing equipment.

Weighing errors

Weighing errors can also create problems with ration uniformity. The capability to weigh accurately and precisely varies among feedyards. One study found that as the amount of the ingredient required became a larger percentage of the batch size, the ability to repeatedly weigh accurately and precisely improved. With smaller ingredient inclusion rates (i.e., protein supplements, fat and molasses), greater variability was observed. The study concluded that within feedmill operations where large scales are used for small ingredient inclusion rates, scale resolution might be needed. The addition of more scales, particularly liquid scales, and the use of variable speed motors, were noted as means to enhance weighing accuracy. It also is important to note that weighing errors typically are more pronounced in situations where front-end loaders are used to add ingredients directly to a feed truck mixer.

Improper sequencing of ingredients

Proper sequencing of ingredients also may affect ration uniformity. Making simple changes in the order of ingredient inclusion may improve ration uniformity. For example, the addition of molasses, fat and/or liquid supplements immediately following grain addition may provide for a more uniform distribution within the mix rather than adding these ingredients last, after roughages have been added to the mix. The manufacturer of the feed mixer should be contacted to determine if a specific ingredient sequence order is recommended.
**Ration heterogeneity issues**
Segregation within a ration may occur when one or more of the ingredients separate from the remainder of the ration. Ration segregation may occur at a number of locations during the feed manufacturing process. Segregation may occur in the mixer, the surge bin, the auger or elevator, the storage bin and/or in the feed truck. Typically, the physical characteristics of feedstuffs affect ration uniformity. Particle size and shape, particle density, electrostatic charge, hygroscopicity and flowability of ingredients have the potential to impact ration uniformity. Of these, particle size is considered to be the most important factor. To overcome the tendencies for feedlot rations to separate, molasses or fat is often added.

**Variation in ingredient composition**
Ration analyses may deviate from their formula specifications because of unexpected deviations in the content of ingredients. Routine testing of incoming feed ingredients may be more helpful in establishing nutrient values than using textbook values. If questions arise based on results of complete feed drug assays, the drug levels in the supplement may need to be checked for deviations. If the drug is added to the complete ration via a feed ingredient machine, proper machine calibration may need to be investigated. If further investigation into the cause of deviations in the drug level is required, the drug manufacturer should be contacted and provided with the lot number of the product to help determine the release assay potency of the lot.

**Improper sampling**
Improper sampling can create a misperception of poor mixing. Improper sampling can be attributed to both timing of sampling and the technique used. For example, animals often sort feed once it has been delivered to the bunk. For this reason, it is recommended that all samples be obtained immediately after feed delivery and before cattle have had an opportunity to come in contact with the feed. When samples are taken, it is recommended that samples be taken from below the crown of the feed within the feedbunk using a small garden scoop. When conducting ration uniformity studies, approximately five individual samples should be taken at equally spaced intervals along the feedbunk upon discharge from the delivery truck.

**Analytical error**
Variation is an inherent factor in any analytical process. Variation also may exist in analytical processes between laboratories. Therefore, it is recommended that one laboratory be used to help minimize this variation. Nevertheless, because of the sensitivity of most analytical processes, the amount of analytical error is usually small.

**Summary**
Proper evaluation of feed mixers is important to help maximize animal performance and to minimize potential adverse effects from feeding poorly mixed rations. When results from analytical tests are more variable than expected, a thorough evaluation of the mixing procedure is warranted.

Consumption by unapproved species or feeding undiluted may be toxic or fatal. Do not feed to veal calves. The label contains complete use information, including cautions and warnings. Always read, understand and follow the label and use directions.

**Rumensin: Cattle fed in confinement for slaughter**
**For improved feed efficiency:** Feed 5 to 40 g/ton of monensin (90% DM basis) continuously in a complete feed to provide 50 to 480 mg/hd/d.
**For the prevention and control of coccidiosis:** Feed 10 to 40 g/ton of monensin (90% DM basis) continuously to provide 0.14 to 0.42 mg/lb of body weight/d of monensin up to a maximum of 480 mg/hd/d.


