Department of Grain Science and Industry

Portable Grinder-Mixers

Tim Herrman
Extension State Leader
Grain Science and Industry

Joseph P. Harner III
Extension Agricultural Engineer
Biological and Agricultural Engineering

Processing feed on-farm using a portable grinder-mixer provides an affordable and flexible manufacturing system for producers with small to intermediate size operations (50 to 400 farrow to finish sows). The portable grinder-mixer differs from a stationary mill in several important areas during feed processing. These differences will be considered by examining five functions or cost centers in a feed manufacturing operation including:

- batching or proportioning
- grinding
- mixing
- delivery
- system clean-out

The purpose of this bulletin is to provide information pertaining to feed processing that will improve operating efficiency, feed quality, and regulatory compliance. Proper feed processing techniques also will reduce the chance of violative tissue residue in market animals.

Batching

The batching process involves proportioning the ingredients specified in a feed ration. Unlike the stationary mill, which conveys ingredients to the mixer, the portable grind and mix system moves to the ingredients. Hence, the farm layout with regard to grain bins, soybean meal hoppers, and other bulk/bagged ingredient storage can greatly influence proportioning efficiency. Design of bulk and bagged storage areas are described in Kansas State University Extension bulletins MF-2039 and MF-2040, respectively.

Grain is typically transferred from a corrugated steel bin to the portable grinder-mixer by a screw auger. A recent study of Kansas on-farm feed processors revealed that farmers spent between 5 to 27 minutes conveying 2 tons of grain to the portable grinder-mixer. Table 1 provides the amount of time required to transfer 2 tons of grain from a bin using different sized augers and motors. The auger should be sized at 80 to 90 percent of the grinder capacity. Grinding capacity of portable units is such that grain augers should not exceed an 6 inch diameter.

Sequencing feed batches to avoid drug carryover should be practiced by the on-farm feed manufacturer. The degree of detail will depend on the number of species the farmer is feeding and the category drug(s) that are used.

Producers manufacturing feed for a single species, in which a category II drug (one that requires a withdrawal time, see MF-2042 and 2043) is fed to young animals, should generally mix feed in the following order: nursery ration containing the withdrawal drug, sow feed, grower, and finishing ration. Place cull sows in the finishing pen prior to sending them to market if this sequence is followed. When using a sequencing pattern to avoid cross-contamination, it is imperative that feed production records are kept and detailed enough to denote the last batch/ration. Otherwise, the sequencing pattern could be violated by the next individual who uses the portable grinder-mixer.

Table 1. *Time requirements for grain transfer (2 tons) for various diameter, 20 foot long augers and horsepower motors. Assumes auger is at a 35° incline and at full capacity.*

Auger Diameter (inches)	Motor Horsepower	Time (minutes)
4	2	9.0
6	4	3.3
8*	5	2.3
10	7	1.5
12	8	1.1

*Auger 8 inches or larger in diameter may exceed the capacity of the grinder and cause plugging or handling problems.

A sequencing procedure cannot always be followed, thus, alternative methods must be in place to avoid cross-contamination of feed that may lead to violative tissue residue. Two other FDA approved options include flushing the mixer with ground grain or cleaning the mixer. These options are described below in the delivery and clean out sections of this bulletin.

Scale accuracy and the proper use of scales during the batching process determines both the feed's nutritional composition and maximum economic benefit of the feed. The Food and Drug Administration's (FDA) good manufacturing practices (**GMPs**) highlight the importance of proper weighing of feed ingredients. These regulations stipulate scales and liquid metering devices shall be accurate and of suitable size, design, construction, precision, and accuracy for their intended purposes.

A proper understanding of weighing feed ingredients necessitates a discussion of three important concepts: **precision**, **bias**, and **accuracy**. These concepts are most readily discussed in terms of "inaccuracy" or the amount of error that occurs between measured values and the true value.

Figure 1 depicts the type of error that can occur during the batching process by illustrating these concepts as the target pattern of three shooters. The first target pattern depicts a precise but biased result, therefore it was inaccurate. This example is similar to feed manufacturers who consistently overfill their bagged product by several pounds (e.g. each 50 pound sack of product weighs between 52.5 pounds and 53.5 pounds).

The second shooter was unbiased but the pattern of shot was imprecise and, therefore, inaccurate. In this case, suppose a feed mill sold product that averaged 50 pounds, however, the sacks ranged in weight from 48 pounds to 53 pounds. Although the company provided, on average, the amount of feed specified on the label, the lack of precision between bags could result in a product recall.

The third shooter achieved a pattern that was precise and contained little bias; therefore this shooter was accurate. Suppose this target represents the feed manufacturer who sold 50 pound sacks of feed that averaged 50.3 pounds and the product ranged in weight between 50.1 to 50.5 pounds. This manufacturer met the label requirements while not giving away excessive product.

The **economic implications** of precision, bias, and accuracy are significant. Suppose feed is being over fortified with protein due to a precise but inaccurate scale. For example, over-fortifying the feed protein content by 0.5 percent is equivalent to adding an extra 22 pounds of 44 percent soybean meal per ton of feed.

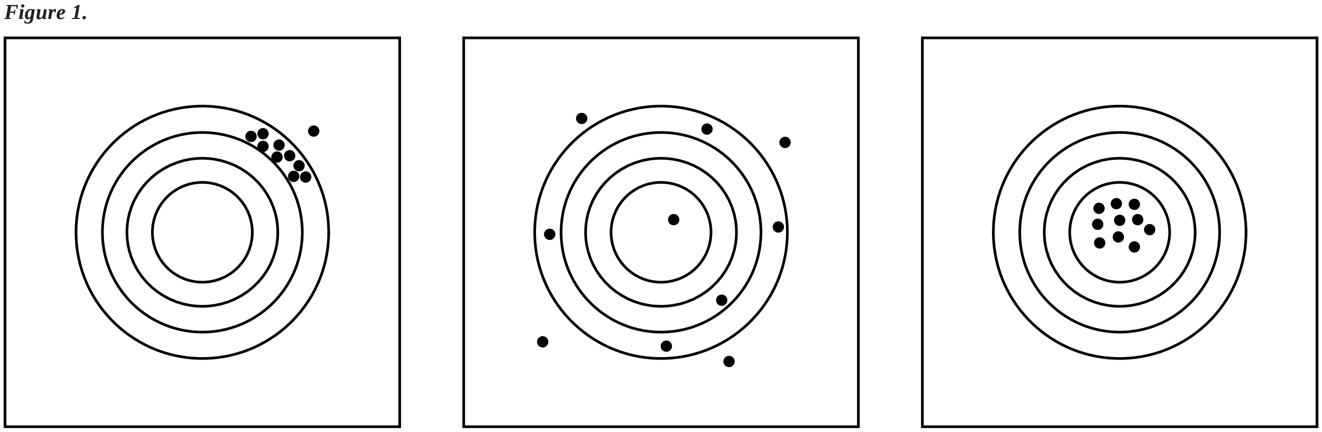
$$2{,}000 \text{ pounds} \times 0.005 \div 0.44 = 22.7 \text{ pounds}$$

If the price spread between corn and soybean meal averages 4.5 cents per pound, the cost of this weight error is $1 per ton. Calculating this weighing error over a 200 sow operation will result in an average cost of $1,850 per year. Under formulating can diminish the effectiveness of the ingredient and also waste money.

The **sensitivity** of a scale is defined by its response to relatively small changes of load. The sensitivity requirement of a scale is determined by the amount of ingredients that are weighed. In other words, scales for microingredients (less than 1 percent of the batch weight) must be more sensitive than scales for major ingredients. Most microingredients are formulated into premixes, basemixes, or supplements so on-farm feed processors can proportion these ingredients without needing highly sensitive weighing equipment.

In general, if weighing ingredients between 1 and

Figure 1.



A. First Shooter *B. Second Shooter* *C. Third Shooter*

10 pounds, the scale should be sensitive to 0.1 pounds; for ingredients between 10 and 100 pounds, the scale should be sensitive to 1 pound; etc. Routinely check the accuracy of the scale by testing it with a known weight. Checking the accuracy of the scale on a portable grinder-mixer can be as simple as stepping on the equipment and weighing yourself.

Purchasing the proper scale for weighing hand-add ingredients can be an expensive proposition. A top loading platform scale possesses the desired sensitivity, accuracy, and capacity for weighing most hand-add ingredients. A scale graduated in 0.5-pound increments for weighing up to 1,000 pounds costs between $500 and $600 and may be purchased from a scientific supply company. Many producers opt for a hanging scale since it is less expensive. This type of scale is less accurate compared to a platform scale and typically is not permitted for use in commercial trade.

Grinding

The grinding action in a portable feed processing unit involves a hammer mill that pulverizes the grain to a desired average particle size. An important first step in the grinding operation is to decide what particle size meets the desired objective(s) (e.g. feed use efficiency, feed processing efficiency, and feed handling and processing characteristics). The feed processor must decide on an acceptable compromise between these quality characteristics (see MF-2050) and then manage the factors described below to achieve that predetermined particle size average.

The reduction of grain into small particles using a hammer mill is determined by the number of hammers, hammer size, hammer wear, hammer tip speed, tractor horsepower, screen area, the diameter of the screen opening, grinding rate (rate at which grain is fed to the grinder), and grain quality (moisture, hardness, grain test weight/bulk density, grain type).

The hammer number and dimensions are usually determined by the manufacturer of the portable grinder-mixer. In a recent study of Kansas on-farm feed manufacturers, it was found that hammer thickness varied between 0.16 and 0.27 inches while hammer numbers for different models and manufacturers ranged between 36 and 66 hammers. Past studies at Kansas State University indicate that grinding efficiency increases with decreasing hammer thickness, whereas, only minor changes in particle size (granulation) occur when altering hammer thickness. A routine inspection of hammers (e.g. after every 200 tons or once a month) and rotating or replacing worn hammers provides the greatest management opportunity related to hammer condition.

Hammer tip speed has an inverse relationship with particle size (a faster hammer tip speed results in smaller particles). The hammer tip speed in a grinding system can be calculated by measuring the shaft speed with a tachometer. Multiply the number of revolutions per minute by the circumference of the hammer tip arc (Formula 1) to calculate speed in feet per minute.

Formula 1.

$$\text{tip speed in feet} = \frac{2\pi r \times \text{shaft rpm}}{12}$$

Where:
$\pi = 3.14$
r = inches diameter from shaft center to hammer tip
shaft rpm measured with a tachometer

In a recent study, Kansas State University faculty found that hammer tip speed ranged between 13,000 and 22,000 feet per minute between portable grinder-mixer units. The power take-off gearing ratio and belt drives to the hammer mill shaft offer little or no management opportunity with respect to controlling hammer tip speed. The tractor engine rpm can be manipulated to control hammer speed. Refer to your portable grinder-mixer operating manual for instructions on maximum and minimum cylinder speed.

Tractor horsepower influences grinding capacity and efficiency. In most instances, on-farm feed manufacturers do not select the tractor size or horsepower based on grinding efficiency; consequently, power sources are often greater than the job requirement for grinding grain. Although a tractor with an 80 horsepower engine (or less) is sufficient to operate a portable grinder-mixer, the expense of operating a larger tractor may not be any greater (see MF-2034).

Screen size opening and screen area are positively related to grinding efficiency, production rate, and particle size (the larger the screen opening or screen area the greater the grinding efficiency, production rate and larger particle size). Most portable grinding systems possess half screens (screens that cover half the hammer's rotational arc). Screen size opening and screen condition are two variables which the on-farm feed processor can control.

A single recommendation for screen size opening to achieve a desired particle size is not possible for all the reasons listed above. A recent study of portable grinders in Kansas revealed that one brand containing 66 hammers could pulverize sorghum below an 800 micron average particle size using a screen with $^{3}/_{16}$-inch openings. The grinding rates in these mills did not exceed 400 pounds per minute.

Portable grinders with fewer hammers may require a smaller screen size opening than those described above to reduce the sorghum below an average particle size of 800 microns. A $^{5}/_{32}$- or $^{3}/_{16}$-inch screen opening diameter should be sufficient to reduce corn particle size below 800 microns.

Screen wear also is a determining factor in particle size reduction. Rounded edges around the opening or an increase in the hole diameter leads to larger average particle size. Inspect screens at the same time that you inspect the hammers.

Some grains will reduce more easily than others because of their structure and composition. Studies conducted at Kansas State University indicate that grain-size-reduction efficiency decreases in the following order: sorghum, corn, and oats. As grain moisture increases, grain-size-reduction efficiency decreases.

Routine evaluation of the ground grain or feed particle size will assist the on-farm feed manufacturer to better manage the grinding process. This service may be performed by your ingredient supplier, veterinarian, or Cooperative Extension Service. Directions on how to perform your own particle size evaluation are described in bulletin MF-2051 from Kansas State University's Cooperative Extension Service.

Mixing

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 FDA good manufacturing practices.

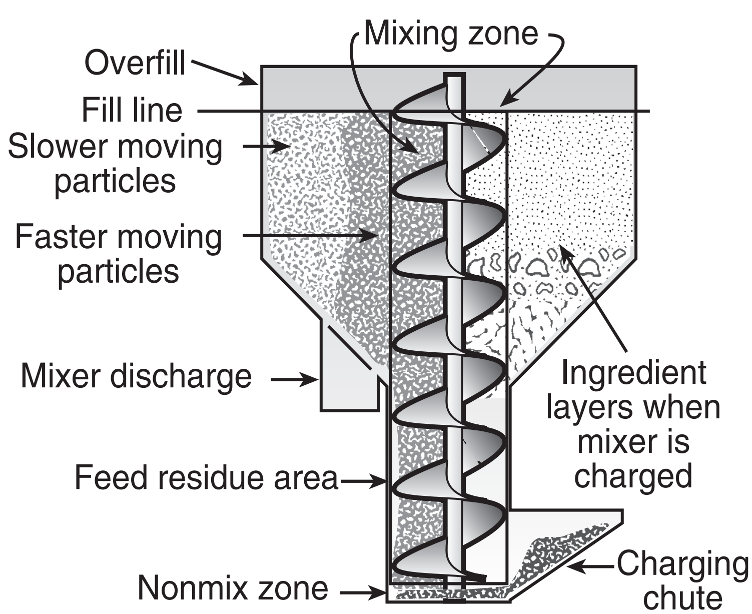
Portable feed processing systems are equipped with a vertical mixer. Mixing is performed by continuously subdividing the material with a screw auger located in the center of the mixer. The auger draws material from all directions at the base of the mixer (Figure 2). Feed ingredients mix as they are conveyed upward inside the chamber surrounding the auger. Once the feed material reaches the top of the mixer it is distributed across the feed batch using a slinger (see Figure 3).

The sequence of addition into the mixer determines mixing efficiency. Since mixing is performed by repeated subdividing, addition of microingredients (basemix, premix, or medication) early in the batching process will improve mixing efficiency (decrease mixing time). An ideal sequence of ingredient addition is as follows: add half of the soybean meal, add basemix and medication, add the rest of the soybean meal, and grind grain. This sequence offers several advantages. Addition of the soybean meal before medication prevents accumulation of drug and basemix in dead spots that may be present in the mixer, while adding soybean meal following these microingredients serves to flush the charging chute. Addition of grain last permits mixing to occur during the grinding process.

In a portable system, it may be possible to mix feed as it is delivered to the bulk feed bins. The proper sequence of ingredient addition during batching and mixing during transit may be sufficient to produce a uniform feed.

On-farm feed processors should test their mixer upon purchase and on an annual basis thereafter. Mixer performance testing will enable you to decide on the optimal mixing time. As equipment begins to wear out, additional mixing time may be necessary to achieve the desired distribution of ingredients. Proce-

Figure 2.



dures for testing mixer performance are described in Kansas State University Extension bulletin MF-1172. Many veterinarians and feed ingredients suppliers provide this service.

Delivery

In a recent study of swine farms in north central Kansas, it was found that the average delivery time was 4 minutes per ton of feed. This includes travel to and from the bulk feeder, setup, and discharge of feed into the feeder.

Several critical steps in feed delivery include: 1) ensuring the feed is delivered to the correct feeder, 2) avoiding spillage during feed transfer, 3) fastening the bulk feeder door to avoid weather damage after feed is discharged, 4) performing this operation safely (e.g. avoiding contact with power lines by the feed conveying auger), and 5) emptying the mixer completely during delivery to avoid cross-contamination.

Number your bulk feeders or draw a map of the farm layout that clearly identifies the feeder and pen (building) it serves. Although you may know the correct feeder to deliver a particular ration, new employees may not know this system.

Flushing the mixer with ground grain following discharge will assist the feed processor avoid cross-contamination. This practice is the preferred (most common) method used to prevent cross-contamination between feed batches in stationary mills.

Flushing a portable system poses several difficulties, since it would either require transporting several hundred pounds of ground grain (in sacks) to the bulk feeder or storing ground grain in a covered container near the bulk feeder. Flushing procedures include the following:

- add 300 pounds (or 5 percent of mixer capacity) of ground grain to the mixer through the charging chute (note: to compensate for the addition of 300 pounds of grain used to flush the mixer, deduct that amount from the feed ration),
- run the mixer for 30 to 60 seconds before discharge,
- discharge the flush material into the bulk feeder containing the feed most recently mixed.

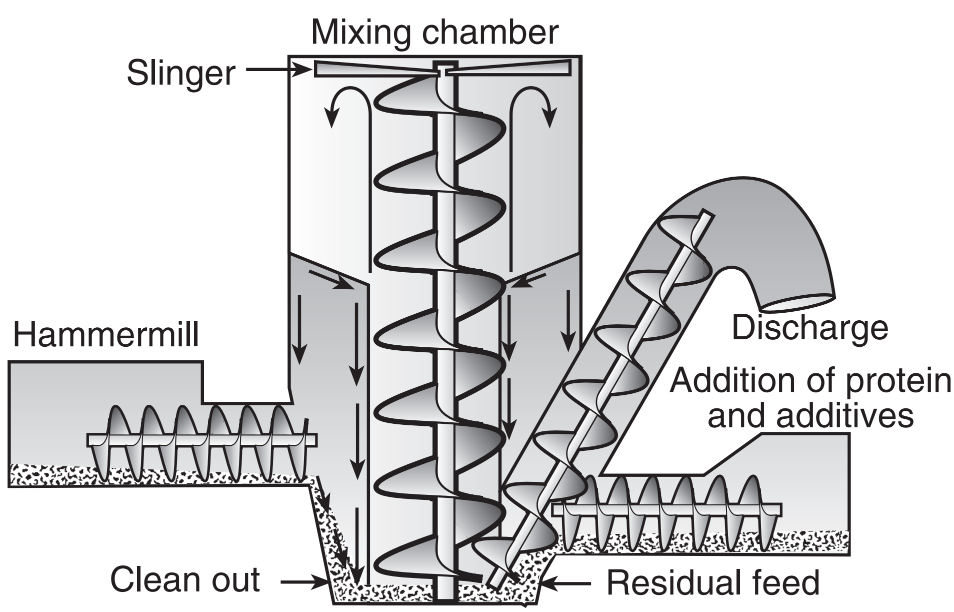
A simpler option may involve cleaning the mixer by discharging carryover feed out the bottom port in the vertical mixer (see Figure 3). Some portable systems do not contain clean out ports; in this instance flushing may be essential.

Clean out

Mixer clean out assists on-farm feed processors avoid cross-contamination when they manufacture feed that includes a drug requiring a withdrawal time. Cleaning also may improve mixer performance if material buildup occurs on the mixing auger.

A recent study of portable on-farm feed processing systems in Kansas revealed that the average feed carryover following mixer discharge was 39 pounds or 0.74 percent. The range in carryover material was from 3 to 80 pounds. Twenty pounds of feed containing sulfamethazine can contaminate 2,000 pounds of feed in the subsequent batch which is enough to cause violative residues in market animals.

Figure 3.



A small hatch (door) may be found near the bottom of most portable mixers (Figure 3). To clean out carryover material, place a tarp underneath the mixer, open the hatch, and run the mixer for a minute. The material collected on the tarp can be saved in five gallon buckets and reused when making the next batch of feed that contains the particular drug. This practice is only recommended when manufacturing feed containing a withdrawal drug (or changing species) and it is not possible to follow a batching sequence describe above. Clearly label the buckets containing the leftover feed so it is not inadvertently added to the wrong feed ration.

Cleaning your mixer to avoid contamination of medicated or non-medicated feed is a requirement of the good manufacturing practices. Buildup of material on the mixing apparatus, particularly when a liquid ingredient is used, reduces mixer performance. Unfortunately, portable grinder-mixers are designed in such a manner that physically entering the mixer to scrape off residue in the mixing auger is very difficult. In view of this problem, it is recommended that the use of liquid ingredients be avoided.

Conclusion

Quality feed can be manufactured using a portable grinder-mixer. Proper equipment maintenance and management of the five cost centers described above can help to ensure success. Proper management includes following the good manufacturing practices.

This, and other information, is available from the Department of Grain Science at www.oznet.ksu.edu/grsiext, or by contacting Tim Herrman, Extension State Leader
E-mail: tjh@wheat.ksu.edu
Telephone: (785) 532-4080

References

Colijn, Hendrik. 1995. *Weighing and Proportioning of Bulk Solids.* Tran Tech publications. Clausthal Germany.

MF-1172. 2002. *Testing Mixer Performance.* Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS.

MF-2039. 1995. *Bulk Ingredient Storage*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS.

MF-2040. 1995. *Bagged Ingredient Storage*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS.

MF-2042. 2002. *Medicated Feed Additives for Swine*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS.

MF-2043. 2002. *Medicated Feed Additives for Cattle*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS.

MF-2050. 1995. *The Effects of Diet Particle Size on Animal Performance*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS.

MF-2051. 2002. *Evaluating Particle Size*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Manhattan, KS.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-2054 August 1995