

Batching and Mixing

Nutritionists formulate diets based on the assumption that the pig will receive all the nutrients needed for maintenance and growth each time they go to the feeder. Factors influencing ingredient distribution in feed include how ingredients are stored after receiving, order of ingredient addition, scale accuracy, ingredient characteristics, mixer type and mixing time.

Ingredient Storage

Key factors affecting grain storage include condensation, weather, moisture movement, hot spots, insects, and moisture differences. Optimal growth conditions for insects and spoilage organisms is 70 to 90°F where insects are likely dormant from 50 to 70°F (Fields et al. 2012). Removal of foreign material by sending grain or corn through a screener prior to storage can help mitigate problems with grain storage. Adjustments may need to be made for allowable shrink.

Bulk

For bulk ingredient storage, bins should be properly labeled on a production board or in the computer automation system. Ingredient bins should be visually inspected prior to changing the bin to a different ingredient. Additionally, slide gates and scale hopper gates should be checked biannually by watching for scale weight fluctuation after weighing an ingredient. This is to ensure gates are closing properly and positive shut-off is achieved.

Bagged

For bagged ingredient storage, bags should be kept in original packaging with lot numbers for traceability and identification of products. Ingredient bags should be stored in a separate area for feed ingredients. Drugs in mixing areas should be properly identified, stored, handled, and controlled to maintain their integrity. This includes inventory of drug through reconciliation.

Liquid

Liquid ingredients should be stored in original containers or liquid tanks and provided heat until use if specified by supplier. The storage temperature of liquid fat should be monitored and maintained to prevent solidification, often target storage temperature is between 120 and 140°F. Lower ambient temperatures will require more energy to heat the fat to a usable temperature where higher temperatures can contribute to fat rancidity. Liquid molasses should be stored between 70 and 90°F. Storage at higher temperatures can result in caramelization or charring reducing nutritional value and damaging the system. Liquid fat should be used as quickly as possible to uphold fat quality, therefore inventory should not exceed a monthly need. Liquid tanks and equipment should be kept clean and inspected when tanks become empty to prevent ingredient spoilage.

Batching

Under-addition of ingredients can lead to poor animal performance while over-addition of ingredients can lead to deviation in inventory, diluted nutrients and added cost.

Scale resolution

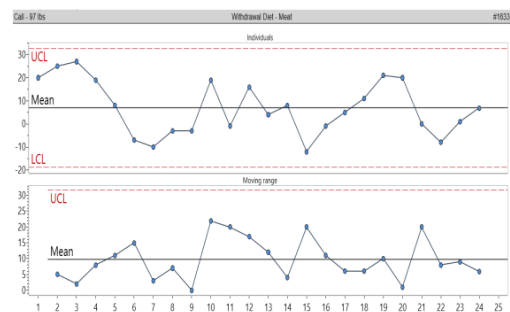
Keeping scales within specification limits of the required quantities is key to getting precise diets in front of the pig. Time, screw conveyor diameters, and the use of variable frequency drives (VFD) at multiple speeds determine the accuracy of ingredient addition (Stark and Jones, 2015). Deviations from specification should not exceed 1% for ingredients with greater than 5 lb inclusion and 2% for ingredients less than 5 lb. Under no circumstance should the overage or shortage of one ingredient be corrected when adding the next ingredient. Smaller ingredient inclusions like concentrated enzymes, vitamins and minerals

require greater scale resolution, finer control of equipment, and a higher degree of accuracy during weighing. This proposes a challenge when trying to weigh ingredients to the nearest 0.01 lbs (Stark, 2016). Additionally, ingredient free fall can occur where ingredients fall into the scale after conveying turns off, yet ingredients are still being added. Therefore, routine scale checks are critical to ensure accurate weighing. Operators should review each batching report for ingredient discrepancy before shipment of complete feed to compare formulated and actual ingredient addition. Each report should include time and date, formula name and number, ingredient names, ingredient lot numbers (if applicable), ingredient quantities, theoretical and actual weight of ingredients added, where feed was stored, and operator identification. Records should be kept for 1 year after production, 2 years if VFD. Additionally, batching equipment should be sized appropriately to meet a system's needs.

Data in batching systems

Collecting system data over time can be a management tool used to create change and maintain processes and equipment. Using statistical process control (SPC) analysis can help with the predictability of the batching system (Figure 1). This automation system can provide increased production rate, tracing and tracking of lots, data collection, process monitoring, inventory tracking, regulatory compliance, and product integrity. These benefits can be seen through system reports of equipment motor loads, operator efficiency, bearing temperatures, inventory variance, processing rates and alarms. Interpreting weekly and monthly SPC control charts and histograms will save time and money long term.

Figure 1. Example of SPC control chart to visualize actual and theoretical addition of ingredients.



Order of ingredients

The order of addition of ingredients into the mixer from bins, totes or hand-add stations is important to establish a uniform mix. For example, ingredients of smaller inclusions could fall between the tub and ribbons or paddles and not be fully mixed into the batch. It is for that reason that ingredients need to be added to the mixer in order from largest to smallest as major, minor, micro, then liquid. Major ingredients include those of the highest inclusion in the batch typically greater than 20% of the diet. For example, corn, soybean meal, dried distiller's grain with solubles and wheat. Minor ingredients include approximately 10 to 20% of batch inclusion. Examples typically include limestone, mono- or dicalcium phosphate. Micro ingredients are often less than 10% of the diet. Examples of these include vitamins, trace minerals, amino acids, and other feed additives. Ingredients with inclusions of 1% or less can be a hand addition. Liquid ingredient, such as molasses or fat, should be sprayed on after the pre-determined dry mix time for dry ingredients.

Mixer ingredient discharge location

The location of discharge of micro-ingredients should also be considered to prevent discharge into dead zones, or areas of the mixer where mixer paddles or ribbons do not reach. The size of the batch of feed should never exceed the volume which the mixer is designed. However, the ingredient density must be considered since it can influence the uniformity of the mix. Commonly,

high byproduct diets will decrease the density of the diet and therefore the batch size should decrease.

As a general guideline, ribbons should always be visible (Stark, 2016). Material buildup on the shaft, paddles or ribbons is a key indication that ribbons, paddles and ribbons are not functioning properly.

Mixing

The overall goal of mixing is to create a uniform mix in the minimum amount of time. Evaluating and monitoring mixer performance is critical to ensure distribution of ingredients.

Mixer type and time

The type of mixer used to mix ingredients greatly influences the time needed to create a uniform mix (Table 1; Froetscher, 2005). There are two considerations when evaluating mixer performance, mixing time and surface area of internal mixing parts (Figures 2, 3, 4, 5; Turlington, 2005). In general, the more surface area the feed encounters the more opportunity to mix feed therefore requiring less mixing time. Mixer ribbons and paddles should be inspected monthly to minimize build up from ingredient adhesion. While these recommendations certainly serve as a reference and starting point, it is strongly advised to conduct a minimum of biannual to annual mixer uniformity tests.

Table 1. Common mix times by mixer type ¹			
Mixer type	Mix time, min		
	Dry Mix	Wet Mix	Total
Paddle	3.0	3.0	6.0
Double shaft, double paddle	0.5	1.0	1.5
Ribbon	2.0	3.0	5.0
Double ribbon	1.0 to 2.0	2.0 to 3.0	3.0 to 5.0
Double shaft, double ribbon	0.75 to 1	2.0	2.75 to 3.0

¹Froetsschner, 2005; adapted from Saensukjaroenphon, 2016

Figure 2. Mixing zones of a vertical mixer (modified from Wilcox and Unruh 1986, Saensukjaroenphon 2016)

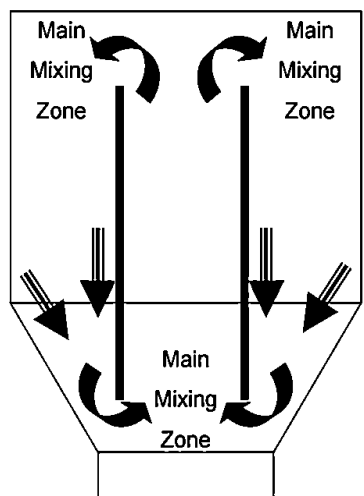


Figure 3. Feed flow and mixing zones of a double ribbon mixer (modified from Wilcox and Unruh 1986, Saensukjaroenphon 2016).

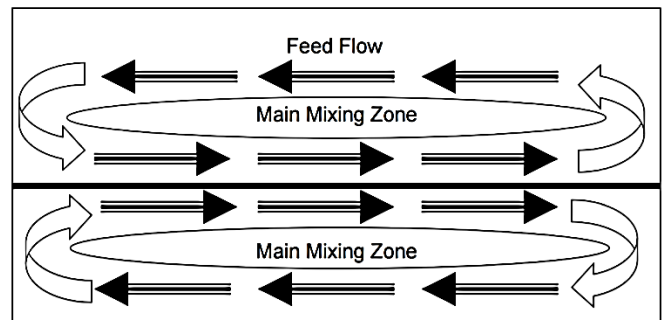


Figure 4. Feed flow and mixing zones of a paddle mixer (modified from Wilcox and Unruh 1986, Saensukjaroenphon 2016).

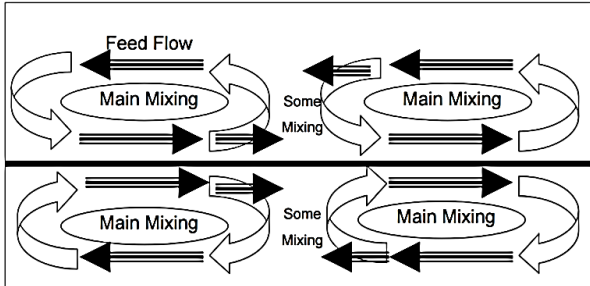


Figure 5. Mixing zone of a drum mixer (modified from Wilcox and Unruh 1986, Saensukjaroenphon 2016).



Mixer uniformity test

For precision formulation to be successful, a uniform mix must be determined by the coefficient of variation (CV). Procedures for testing mixer uniformity can be found in “MF3393 Testing Mixer Performance – Kansas State University”. A mixer uniformity test is often done by using a single source tracer (i.e. salt, trace minerals, or iron filings) as the indicator. Ten samples should be pulled in order from mixer discharge or sack off with a probe and the tracer analyzed to be tested for uniformity. The CV can be calculated by $CV\% = (\text{standard deviation} / \text{mean}) \times 100\%$. Any changes in mixing should be validated by mixer uniformity (Stark and Saensukjaroenphon 2017). Mixer uniformity CVs should be done annually, if not biannually, for validation or when there are major changes in ingredient characteristics. Testing the mix of specific ingredient is possible but should be done by the ingredient company of the ingredient in question.

- The feed industry standard is a CV of less than 10% (Herrman and Behnke 1994). If results are between 10 and 15%, it is considered a good mix and mixing time should be increased by approximately 25%. With results 15 to 20%, mixer time should be increased by 50% and mixer wear and ingredient propriety should be addressed (Table 2). Any results greater than 20% are considered poor and should be evaluated.

Table 2. Interpretation and corrective actions for mixer testing ¹		
Percent CV	Rating	Corrective actions
<10 %	Excellent	None
10 to 15%	Good	Increase mixing time by 25 to 30%
15 to 20%	Fair	Increase mixing time by 50%, Inspect for worn equipment Check ingredient addition Overfilling
>20%	Poor	Possible combination of all the above Consult extension personnel or feed equipment manufacturer

¹ From Herrman and Behnke, 1994

Ingredient characteristics influencing uniformity

Characteristics of ingredients greatly influence mixing capabilities. The particle shape and size; spherical, square, flat can separate during the handling process. Dense particles may settle out during conveying and movement throughout the feed mill. Static charge between particles can cause ingredients to adhere to equipment. Hygroscopicity, or ability of an ingredient to absorb water, such as some vitamins or feed additives, will influence mixing. Additionally, ingredient adhesiveness such as fats or molasses that can build up on mixer equipment making weekly mixer inspection critical and should be physically cleaned, as necessary. Additionally, all lock out tag out (LOTO) procedures should be followed from established SOPs.

Feed Sequencing and Flushing

To prevent drug carryover during mixing, the mixer should be subjected to effective cleanout procedures. The cGMP regulations require medicated feed manufacturers to use one or more of the approved cleanout procedures, such as cleaning, sequencing, and/or flushing to prevent unsafe contamination by drug carryover (Food and Drug Administration, Department of Health and Human Services, 1976). The most effective option is utilizing a complete cleanout procedure of the mixer. However, it is massively time-consuming and requires down time. Therefore, sequencing and flushing are often used in the feed industry.

Sequencing

Batch sequencing is the pre-defined succession of feed manufacturing to prevent contamination of subsequent batches. This is usually done in high production facilities where they have enough production volume and pre-defined weekly production schedule. The goal is to minimize drug carryover into subsequent batches of feed. To achieve this, feeds with the same drug should be manufactured in sequence from highest to lowest inclusion. When manufacturing feeds with drug inclusion, for integrated mills, manufacture the

nursery diet likely containing the drug followed by sow, grower, then finisher feed. Cull sows should not be fed from this sequence. For commercial mills, make sure that batches following the sequence are non-medicated feed of the same species (Rickert et al. 2010).

- When considering batch sequencing for pathogen control, manufacture feeds from highest to lowest risk, starting with multiplication units followed by sow farms, nursery, clean grow finish, then dirty grow finish.

Flushing

Another option to reduce feed contamination is using a grain ingredient to flush out medication or pathogen residues. When implementing flushing procedures, it is recommended to use flush size of 5 to 10% of the mixer's total capacity for normal mixing times (Martinez et al. 2018). Flush material can then be used as rework in future medicated diets of the same drug. Bin or container should be labeled as flush rework including the flush ingredient, medication flush may contain, lot number, and target animal. Flush for medicated feed should be used in feed containing the same medication for the same species. Herrman et al. (1995) evaluated drug carryover from the mixer to sack off and found the greatest amount of drug carryover was in the conveyer leg followed by sack off. Additionally, chemically treated flushes including rice hulls or other abrasive ingredients can be used to provide a reduction in viral particles (Gebhardt et al. 2018).

Summary

In conclusion, batching and mixing can be the most time-consuming steps of the feed manufacturing process. Continuous evaluation of data from system processes such as batching automation is key for feed mill performance improvements. Accurate weighing of ingredients is the most critical step in precision feeding, therefore scales need to be within established accepted tolerances for each ingredient. Consistent evaluation of mixer performance and

taking steps to decrease medicated feed residue and pathogen mitigation will provide the best and safest finished feed quality. While complete mixer cleanout is best, strategic sequencing and flushing can be effective alternatives when downtime is not an option.

Additional resources

MF3393 Testing Mixer Performance – Kansas State University

- <https://bookstore.ksre.ksu.edu/pubs/MF3393.pdf>

KSU Mixer Uniformity Calculator

- https://www.grains.k-state.edu/research/AnimalFeedandPetFood/feed_science_research_extension/index.html

References

- Fields, P., Subramanyam, B., & Hulasare, R. (2012). Extreme Temperatures. In D. W. Hagstrum, T. W. Phillips, & G. W. Cuperus (Authors), *Stored product protection* (pp. 179-190). Kansas State University, Manhattan, KS. doi:<https://bookstore.ksre.ksu.edu/pubs/S156.pdf>
- Froetschner, J. R. 2005. Mixing: A detailed look at the factors that influence mix uniformity. Parsippany, NJ.
- Gebhardt, Jordan T., Roger A Cochrane, Jason C Woodworth, Cassandra K Jones, Megan C Niederwerder, Mary B Muckey, Charles R Stark, Mike D Tokach, Joel M DeRouchey, Robert D Goodband, Jianfa Bai, Philip C Gauger, Qi Chen, Jianqiang Zhang, Rodger G Main, Steve S Dritz, Evaluation of the effects of flushing feed manufacturing equipment with chemically treated rice hulls on porcine epidemic diarrhea virus cross-contamination during feed manufacturing, *Journal of Animal Science*, Volume 96, Issue 10, October 2018, Pages 4149–4158, <https://doi.org/10.1093/jas/sky295>
- Herrman, T. and K. Behnke. 1994. Testing mixer performance. MF-1172. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Bulletin, Manhattan, KS: Kansas State University.
- Herrman, T; Behnke, Keith C.; and Loughin, T (1995) "Mixing and clean-out properties of sulfamethazine and carbadox in swine feed," *Kansas Agricultural Experiment Station Research Reports*: Vol. 0: Iss. 10. <https://doi.org/10.4148/2378-5977.6451>
- Martin, S. 2005. Mixing. Feed Manufacturing Technology V. Pages. 137-141 ed. E. K. Schofield and American Feed Industry Association, Arlington, VA: American Feed Industry Association.
- Martinez, A., C.K. Jones, C.R. Stark, L.J. McKinney, K.C. Behnke, and C.B. Paulk. Evaluating flushing procedures to prevent nicarbazin carryover during medicated feed manufacturing, *Animal Feed Science and Technology*, Volume 242, 2018, Pages 1-7, ISSN 0377-8401, <https://doi.org/10.1016/j.anifeeds.2018.04.017>.
- Richert, B. T. and J. M. DeRouchey, C.R. Stark, and L. McKinney. 2010. Swine Feed Processing and Manufacturing Fact Sheet. National Swine Nutrition Guide, Manhattan, KS: Kansas State University.
- Saensukjaroenphon, M. 2016. The effect of ingredient properties, liquid system and mix time on uniformity of mix and testing of uniformity of mix. M.S. Thesis, Kansas State University, Manhattan.
- Stark, C. R. 2014. Feed processing technology to improve feed efficiency in pigs and poultry. *Recent Advances in Animal Nutrition 2014*. P. C. Garnsworthy and J. Wiseman. Ed. Context Products Ltd.
- Stark, C. R. and C. K. Jones. 2015. Feed processing to improve animal performance. Canada Eastern Animal Nutrition Conference. Quebec, Canada.
- Stark, C. R. 2016. Feed processing to improve swine and poultry performance. The 5th Global Feed and Food Congress, Antalya, Turkey.

Stark, C. R. and M. Saensukjaroenphon, Testing Mixer Performance, Kansas State University, September 2017.

Turlington, H. 2005. Premixing. Feed Manufacturing Technology V. Pages. 310-316 ed. E. K. Schofield and American Feed Industry Association, Arlington, VA: American Feed Industry Association.

Wilcox, R. and D. Unruh. 1986. Feed manufacturing problems-feed mixing times and feed mixers. Bulletin MF-829, Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan, KS: Kansas State University.