Swine Feed Processing and Manufacturing

Introduction

All cereal grains fed to swine need to be processed to reduce the particle size by cracking, grinding, rolling, extruding, expanding, or other method before being mixed with other ingredients and fed as a complete diet. Processing improves the utilization of grain nutrients primarily through improved digestibility. Cereal grains with hard seed coats (grain sorghum, barley, and triticale) have the greatest improvements in digestibility due to processing, but even processing corn has economic benefits and is routinely done for swine [1,2]. Pelleting is a cost-effective technology that can improve feed efficiency, decrease diet segregation, increase bulk density, reduce dustiness, improve feed handling characteristics and reduce issues with feed bridging. However, other feed processing technologies may have limited value in swine diets. Proper feed mixing and diet sequencing is also important to maintain pig performance and minimize concerns about potential antibiotic residues.

Objectives

Discuss feed processing and management considerations for the swine operation:

- Effects of particle size
- Grain grinding options
- Pelleting and other feed processing options
- Feed mixing and batching sequences

Grain particle size

Grinding cereal grains is effective in improving feed utilization and decreasing dry matter (DM), nitrogen (N) and phosphorus (P) excretion. By reducing the particle size (Figure 1), the surface area of the grain particles is increased allowing for greater interaction with digestive enzymes. Generally, when particle size is reduced from 1000 microns to 400 microns swine feed efficiency is improved by an average of 1.3% for every 100 microns reduction in particle size [3,4]. This reduction in particle size also improves DM and N digestibility by approximately 5 to 6 percentage units. As particle size is reduced from 1000 microns to 700 microns, DM and N excretion are reduced by 20 and 24%, respectively in grow-finish pigs [3]. In lactating sows, as particle size was reduced from 1200 to 400 microns in size, energy digestibility improved linearly from 83.8% to 90.0% and DM and N excretion are decreased by 21% and 31%, respectively [5,6]. Grinding grain is a simple process but an effective way to increase nutrient utilization and reduce nutrient excretion of DM and N, with minimal cost to the producer. However, the cost of grinding increases and mill throughput decreases as particle size decreases (Table 1) [3]. The costs of reducing particle size and the mill throughput have improved due to recent changes in the engineering design of grinders and their improved efficiency of particle size reduction. Current estimations suggest modern grinding equipment can reduce grain particle size for an additional $0.05/ton of grain for every 100 microns reduction in
particle size between 800 and 400 microns [7]. These changes in design allow modern feed processing systems to reduce grain particle sizes to near 500 microns when they are pelleting the diet to improve pellet durability and maximize feed efficiency [7].

There are many factors that can affect the actual particle size of the grain and this can be part of the reason why particle size can change over time with little or no adjustment to the grinder. Grain kernel size, hardness, moisture content and fiber content, feeding rate into the grinder, mechanical factors such as hammer tip speed, hammer and screen wear, screen opening, roller speed and number of corrugations can all influence particle size. If particle size of the grain in meal feed is too fine (below 600 microns) then bridging can occur in the bulk feed bin or feeder (Figure 2). Additionally, as particle size is reduced below 600-700 microns the incidence of stomach ulcers will increase in nursery pigs [4], grow-finish pigs [3,8,9,10], and lactating sows [5,6]. It is thought that the increase in stomach ulcers with fine grinding is related to the increased fluidity of the stomach contents and increased pepsin and digestive acids, creating increased contact time with the sensitive esophageal region of the stomach [4]. Additionally, fine particle size is associated with increased incidents of feed bridging (Figure 2) and out-of-feed events in the barn. These out-of-feed events can reduce pig feed intake and growth performance and create additional stress that may cause ulcers in pigs.

Considering improvements in feed efficiency, processing costs, incidence of gastric ulcers, and potential for bridging, the recommended average grain particle size is between 650 and 750 microns in mash diets. Producers should evaluate increased electrical costs, mill throughput (Table 1), feed flow ability, and potentially increased ulcers if they chose to grind to a finer micron size. As a rule of thumb, if there are whole or half kernels in your feed, it is probably not ground fine enough, and you may be losing 5 to 8 percent in feed efficiency. Research shows that for every 100 microns over 700 microns, producers lose 1.2-1.4% in feed efficiency and will cost the producer 7-10 lb of additional feed per pig to market weight. Depending on the amount of grain ground in the mill, particle size should be monitored from a daily to monthly basis. If whole kernels or even half kernels are noticed, these can be indicators of a hole in a screen or rolls that are not in parallel alignment. [1]

### Table 1. Effect of corn particle size on mill energy costs and throughput

<table>
<thead>
<tr>
<th>Item,</th>
<th>1000</th>
<th>800</th>
<th>600</th>
<th>400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milling energy, kilowatt hours/ton</td>
<td>2.42</td>
<td>2.78</td>
<td>3.46</td>
<td>7.35</td>
</tr>
<tr>
<td>Milling production, tons/hr</td>
<td>3*</td>
<td>3</td>
<td>2.85</td>
<td>1.43</td>
</tr>
</tbody>
</table>

* Milling production was limited by capacity of exit auger. Wondra et al., 1995 [3]

**Hammermill versus Roller mill**

The two most popular grain processing options in the U.S. are using a hammermill or roller mill (Figure 3 and 4). Both grain processing methods produce acceptable products for swine diet formulation. However, there are differences between the mills in processing capacities, efficiency, and maintenance. Hammermills are effective grinding a wide range of feed stuffs and capable of producing a wide range of particle sizes. However, hammermills can be noisy, dusty, and generate heat during the grinding process [11]. Roller mills can produce 15-40% more pounds of ground grain for the same energy input compared to hammermills [7, 8,11]. This difference between mill types becomes less pronounced as the particle size gets finer and falls below 700 microns [7,8]. Additionally, roller mills generate less noise and dust, and...
provide a more uniform particle size/grind, which may provide a slight improvement in digestibility (due to less large particles) and feed flowability (due to less fines and an irregular particle shape) [4,11]. A more uniform particle size should have better feed flow through augers, bins, and feeders. The problem with feed bridging in bins and feeders can be significant, especially when considering the potential impact of out-of-feed events. Therefore, a roller mill may be a better alternative to a hammermill for swine feed processing [1]. However, roller mills require more vigilance to maintain a gap width that will produce the targeted particle size. Roll gap width will change as rolls wear and grain qualities change. Hammermills will require less monitoring by comparison. It can be more difficult to grind small grain seeds such as grain sorghum using a roller mill if the correct set up and corrugations are not utilized because the rollers cannot be set close enough to properly process the grain. Roller mills will also have more costly maintenance than a hammermill [11].

For processing grain with a hammermill, screen size will vary based on the type of grain and hammermill operating parameters (ie. hammermill tip speed, feeding rate etc.). Generally, corn and wheat can be processed through a hammermill equipped with a 5/32 or 3/16-inch screen, whereas an 1/8-inch screen is recommended for processing milo, barley, and oats. By using these screens with the respective grain, an approximate 700 micron particle size should be achieved [1].

When using a roller mill, three criteria are essential in producing a 700 micron particle size. First, the rolls should be moving with a differential drive of one roll moving 50 to 75 percent faster (ie.1.5:1 ratio) than the other to produce a shearing action that will help “cut” the kernel rather than crush it. Second, the rolls should have corrugations to help slice the grain, with desired corrugations per inch of roll being 8 to 10 for corn, 10 to 12 for wheat, barley, and oats, and 12 to 14 for sorghum on the bottom pair of rolls. Third, the corrugations should have a 1 to 1.5-inch spiral to increase shearing potential and reduce fines. In addition, it is generally easier to produce feed with a 700 micron particle size with a double high roller mill (two pairs of rollers in sequence stacked above each other) compared to a single pair roller mill because each set of rollers is doing only half of the reduction compared to a single set of rollers working to do the full reduction in one pass [1,7,11].

The condition of hammermill screens and roller mill rolls are critical in maintaining grinding efficiency and optimum particle size. Rolls, screens, and hammers need to be checked at least weekly for wear and replaced if damaged. Hammers can be reversed or replaced if they become worn and should be maintained on a production schedule to extend their life. Magnets and scalpers are very important to remove any metal objects from the grain and increase the longevity of hammers, screens and rolls [1].

**Pelleting**

Pelleting can decrease diet segregation, increase bulk density, reduce dustiness, improve feed handling characteristics and reduce issues with feed bridging [4]. Pelleting of diets (Figure 5) is an effective way to improve feed efficiency in all phases of swine production. However, pelleting of diets will not likely increase feed intake or gain during most production phases. During the nursery phase when typically very fine ingredients are fed, a slight increase in feed intake may be observed when the diet is pelleted, with a pronounced improvement in feed efficiency. Generally a 6 to 7% improvement in feed efficiency is observed with pelleted diets compared to the meal form in most phases of production [4]. The improved
feed efficiency is due to several factors. The first is a slight reduction in feed wastage. The second is a slight improvement in digestibility of the diet due to the steam heat of the pelleting process gelatinizes some of the starch and opens up the starch and protein matrixes of the diet to more digestive enzyme hydrolysis. A side benefit to pelleting the diet is a 10 to 20% reduction in dry matter and nitrogen excretion caused by the reduced feed wastage and improved feed efficiency and digestibility [4]. The pig seems to be able to utilize multiple pellet diameters with similar growth performance [4]. It is generally accepted that excellent nursery pig performance can be achieved with an 1/8-3/16 inch diameter pellet and grow-finish pigs and sows can effectively utilize a 3/16-3/8 inch diameter pellets. The pelleting process must be done correctly to create a high quality pellet. When the percentage of pellet fines increase to between 20-40% at the feeder, the benefits of pelleting are lost (ie. equal feed efficiency to a meal diet) and the expense of pelleting is no longer of value to the swine producer [4].

Other Processing Technologies

Extrusion has been primarily used in pet foods and aquaculture diets [4]. However, there is value in using extrusion for processing whole soybeans for the swine producer. Extrusion processing involves the application of heat, pressure, and/or steam to an ingredient or diet. Research has shown that moist extruded soy protein concentrate or soybean meal, as well as dry extruded whole soybeans are excellent protein sources for baby pigs[12]. Because of volume, tonnage, and processing costs, extrusion of complete feeds is usually not economically justified based on performance of pigs fed extruded complete feeds. If properly heated, extruded whole soybeans can replace a portion or all of the soybean meal in swine diets while increasing the diet energy level due to its increased fat content. Extruded soybeans should have an exit temperature of 280°F to achieve maximal pig performance.

Roasting can also be used to process home-grown soybeans. This can be an alternative method for adding fat to swine diets. However, roasting temperature and times must be checked to ensure adequate processing. The added cost of the extruded or roasted products must be the ultimate consideration in determining the feasibility of use in swine diets [1]. For optimal quality, roasted soybeans should be heated for 3 to 5 minutes at an exit temperature of 240 to 260°F.

Expanding (high-shear conditioning) converts mechanical energy into frictional energy to modify or cook certain components of the diet. If this process is used, it would typically be performed prior to and in conjunction with pelleting. Current data suggests there are limited improvements in growth performance of pigs fed expanded diets. However, the most consistent improvements associated with expanders are in the areas of pellet quality, pellet throughput, and improved microbiological control of the complete feed [1].

Steam flaking involves heating grain to approximately 200°F in a steam chamber for 20 minutes followed by flattening the feed through rollers. Micronizing consists of heating grain to 300°F for 20 seconds before being rolled and converted into flakes. The dry heat used is supplied by infrared radiation. The micronizing process ruptures the cell wall and causes partial gelatinization of the starch, which increases its digestibility.

The steam flaking of grains generally has not improved growth rate or feed efficiency of pigs. However, micronizing certain hard-shelled grains, such as grain sorghum, may improve growth rates and feed efficiency. No consistent improvement in pig performance has been noted by micronizing corn. High temperatures frequently used to process grains quickly may in fact result in a lowered availability of lysine and other amino acids, possibly due to a Maillard reaction. Thus, diets containing grain processed at high temperatures may need additional lysine supplementation to achieve similar performance.
Mixing

There are numerous types of feed mixers used to process swine diets with the vertical screw, horizontal paddle, and horizontal ribbon being 3 of the most common. Mixing time for the diet will vary with the type of mixer, its load as a percentage of maximum, and the state of repair of the mixing equipment [13]. An acceptable mix of the diet would be considered when variation between samples is less than 10% [13]. Generally, horizontal mixers will require less time to achieve a uniform mix. A horizontal mixer in excellent shape will typically reach 10% variation by 3 to 4 minutes and a typical single screw vertical mixer will require 8 to 12 minutes to reach a uniform mix after the last ingredient is added [4]. If the mixer has a large amount of wear on its ribs or screws or if the mixer is filled above the rated capacity, the time needed to reach an acceptable mix will be greatly extended or variation may never be reduced below 20-30% [1,4]. There is a direct relationship between RPM of the mixer and time required to mix a diet, with the faster the RPM the sooner 10% variation is achieved. If feed is under-mixed, this will be more of a problem for young pigs because they eat only a little amount of feed. Larger pigs, however, by virtue of their greater feed intake, may be less susceptible to marginally mixed feed [1,4].

The correct sequencing of ingredients will help in maintaining good quality diets being manufactured. One good sequence is; 1) to add 1/3-1/2 of the grain, 2) add the vitamin and trace mineral premixes and ingredients with a low inclusion rate (whey etc.), 3) add the protein sources, 4) add the remaining grain, 5) mix 2-3 min., 6) add any supplemental liquids and fat sources, and 7) final mixing for 2-3 minutes [1,2]. These mix times are only an example and will vary based on mixer type and condition.

Batching sequence is extremely important to prevent drug residue problems. Many of the vertical screw mixers (portable grinder mixers) will have 20 to 40 lbs of residual feed in the bottom of the mixers. This residual feed is the source of most contamination problems. Ideally, a producer should remove the clean out plate on the bottom of the mixer after every medicated diet and remove the residual feed. However many of these ports are not easily accessible so the contamination problem is often handled through a correct batching sequence. After mixing feeds that contain withdrawal medications the next diet in the feed manufacturing sequence should be for gestating or lactating sows or other animals not intended for market in the near future. To avoid residue problems with market animals, never follow diets with high antibiotic levels (like nursery diets) with a finishing pig diet [2,14].

Vitamin Stability

Purchasing a properly fortified vitamin premix is only part of the job in providing the correct amount of vitamins to the pig. Vitamin stability varies greatly among vitamins, depending on conditions they are exposed to and storage time. Moisture, visible and ultraviolet light, heat, and interaction with certain trace minerals are the most common factors that reduce vitamin stability. Vitamin premixes should be stored in a cool, dark, and dry place. The more stable vitamins (e.g. riboflavin, niacin) have potency losses of less than 1% per month. However, less stable vitamins (eg. thiamine, K-menadione) may have losses of 4 to 6% per month in vitamin premixes alone but as high as 15 to 30% per month when mixed with trace mineral premixes. Pelleting of diets will further reduce the stable vitamins by 2-6% activity and the less stable vitamins by another 10-25% activity. Total activity loss for menadione that is manufactured with a trace mineral premix and then pelleted could be as high as 55%. If choline or trace minerals are mixed with vitamins in the premix, storage time should be less than 2 months [15].

Grain Storage

Grain quality is a critical part of swine nutrition. Grain will make up 40 to 90% of every diet on the farm and maintaining it in excellent condition is critical. Good grain storage starts with a good quality grain at harvest. There are steps that producers can take to ensure properly stored grain is available for their livestock. At harvest grains need to be dried to 14% moisture for long term storage (1 year) and no more than 16% moisture for winter storage. Grain temperatures during drying should not exceed 180°F (air temperatures of 220-240°F) or there will be some browning, evidence of decreased lysine availability (Maillard reaction), increased splitting and fines, and reduced dry matter. Also, dried grain needs to have proper cool down before storage. Producers are encouraged to measure temperatures in the top one foot of the grain in the bin to make sure that the cooling fans have ran long enough to cool the entire depth of
Storage and mixing of fat

Fat rancidity is the major concern with feed grade oils/fats. The main cause of lipid rancidity is oxidative in nature and is caused by the exposure of the fat to heat, light, and/or minerals, which creates free radicals. These free radicals will tie up vitamins (vitamin E) and reduce palatability. To check the quality of the fat; moisture, impurities, and unsaponifiables (MIU) as well as the free fatty acids should be analyzed. Acceptable levels are: not less than 85% fatty acids, not more than 6% unsaponifiable matter and 1% insoluble matter. Fat should not be stored at temperatures above 140°F, with 120°F being most ideal. Fat additions should occur last in the mixing sequence. It is best to mix the whole diet for a few minutes and then add the fat to the diet and mix again for 2-3 minutes [1,2].

Antioxidants extend the time period before rancidity of the oil starts. The addition of antioxidants to the diet should be based on the fat quality and quantity used in the diets. If the fat quality was excellent to start with and the diets will not be stored for more than 2 months, there would be no need to add an antioxidant. However, if the diets use a marginal quality oil (e.g. restaurant grease) then the use of antioxidant (e.g. ethoxyquine, BHA, BHT etc.) would be well worth the small investment [1,2]. Often antioxidants are added by the fat supplier to ensure there are no rancidity issues with their products. This supplier information needs to be known to prevent the unnecessary expenses of adding antioxidants twice.

References

Frequently asked Questions

What is the optimum particle size?

Considering improvements in feed efficiency, processing costs, incidence of gastric ulcers, and potential for bridging, the recommended average grain particle size is 650-750 microns. Finer grinding (600 microns) of high-fiber feed ingredients may be required to improve their feeding value.

Should I use a roller or hammermill?

Either mill, if properly adjusted, is capable of producing the desired particle size. However, there are advantages and disadvantages that must be considered for each mill. Hammermills cost less up front and can quickly change from grinding one grain to another ingredient by simply changing screens. However, a hammermill requires more energy than a roller mill and produces a higher percentage of fines and dust. A roller mill requires 15-40% less energy to produce a 700 micron particle size than a hammermill, but if grain types are to be changed frequently, the roller mill will need to be adjusted for each grain. A roller mill will produce grain with a more uniform particle size (less fines and large particles) than a hammermill. The more uniform the particle, the better feed will flow through augers, bins, and feeders.

Can I over-mix my feed?

There is a common misconception that feed, if mixed too long, can become “unmixed.” Research has shown that once a feed is properly mixed it does not begin to separate and become “unmixed” even after extended mixing times.