Pork Industry Handbook: Feed Processing for Swine
Michigan State University
Cooperative Extension Service

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Approximately 65% to70% of the total cost of producing a market hog can be attributed to feed. As such, it is desirable for the pork producer to find the most economical feeding method to achieve the lowest cost per unit gain.

Feeding and processing methods should be evaluated both individually and collectively as to their potential to improve the economics of pork production. Nutrient availability and balance are important in diet formulation and are dependent not only on the feedstuff but may be altered by processing methods. Diets based strictly on least-cost formulations do not always result in the lowest cost of production. Quality control is an essential component of any feed manufacturing process. A sound quality control program assures the producer that the feed consumed by pigs contains the expected concentration of nutrients. This fact sheet deals with feedstuff ingredients, specific nutrient limitations, the physical forms of these feedstuffs, and various aspects of a quality control program. All are essential to maximizing profits in the hog industry.

Why Study Feeds?

Producers should understand the various processing techniques and associated feeding problems to make a system usable for their operation. For example, feedstuffs may be more acceptable to the pig in one physical form than another, thus improving feed intake. The digestibility of the nutrients within each feedstuff may be improved if the surface area is increased to allow greater exposure to digestive enzymatic activity, thus enhancing nutrient availability. In other cases, altered feed surface areas may reduce diet acceptance. Processing could lower the availability of nutrients in grains, such as the destruction of vitamins; but in other cases, it could increase their use by the pig. Although the results of a laboratory-conducted nutrient analysis of a feedstuff may not be changed, the digestibility and availability of nutrients may be enhanced or hindered by various processing methods. Great care and accuracy can be involved in formulating swine diets, but this effort is wasted if similar accuracy is not an integral part of the feed manufacturing process. Surveys conducted by various researchers indicate that over 30% of swine diets manufactured on the farm do not meet intended nutrient targets. Nutrient analyses coupled with an understanding of the effects of feed-processing and attention to quality control of the final feed are essential to ensure optimal performance of pigs.

Free-Choice vs. Complete Feeds

In free-choice feeding, different components of the diet, such as grain and supplemental protein fortified with vitamins and minerals, are provided in separate compartments of a self-feeder. This compartmentalization allows the pig to eat as much of each component as desired. Thus the pig makes the choice in balancing the diet.

While free-choice feeding offers greater simplicity for pork producers, more supervision is usually required to ensure an adequate intake of all nutrients for optimal performance than with a complete mixed feed. Overeating or undereating of the protein-mineral-vitamin supplement may occur if the grain or supplement varies in acceptability to the pig. Generally, when feedstuffs are of poor quality (e.g., molds, extreme dryness, etc.), a depression in intake is observed and a corresponding increase in the consumption of the other components results. Maintaining quality is more important with grain, as grain varies more in quality than most processed supplement sources. Supplement intake sometimes can be controlled by keeping the number of feeder holes containing the supplement low, but adequate, relative to those containing grain.

The free-choice system usually produces a slower rate of gain than a system using a completely mixed diet, especially

Table 1. Effects of processing feedstuffs on pig performance.

Processing method	Type of grain	Growth rate	Change in feed intake	Feed conversion	Comments
Grinding	Corn	Improved 3-5%	No effect	Improved 3-5%	Medium screen (1/4 to 3/8 in.). Generally most acceptable
	Grain sorghum	Improved	No effect	Improved	Too fine of grind can reduce palatability.
Pelleting	Corn, Grain sorghum	Improved 3-6%	Reduced 1-3%	Improved 5-8%	
	Barley, Oats, Alfalfa, Wheat bran	Improved 3-6%	Reduced 1-3%	Improved 7-10%	Greater improvement with higher fiber materials.
Paste	Corn	Improved 10-15%	Increased 10-15%	No change	Feed:water ratio of 1.2 to 1.5:1. Advantage with G-F pigs but not weanlings.
Liquid	Corn	Improved	Increased	Improved	Water:feed ratio of 2:1. Advantages with limit-fed systems. Full-fed levels fail to improve performance.
Roasting	Corn	No change	No change	Slightly improved	Processing cost greater than improvement return.
	Soybeans	No change	Decreased	Improved 4-6%	Necessary for adequate performance except in gestating sows. Comparisons made with soybean meal.
Steam flaking	Corn, Grain sorghum	No change	No change	No change	
Micronizing	Corn,Grain sorghum	No change	No change	Variable	Availability of amino acids may be reduced.
Extruding	Wheat, Grain sorghum	No change	No change	No change	
	Soybeans	No change	Decreased	Improved 4-6%	Comparison made with soybean meal—necessary for adequate performance, except in gestating sows.

with younger pigs to 100 lb body weight. If free-choice feeding is not properly monitored, poor feed efficiency easily can occur.

Increased demand for "high lean gain genetics" and increased pressure to reduce nitrogen in manure due to overfeeding protein has renewed interest in free-choice feeding programs. Modern free-choice programs might be described more accurately as self-selection programs. In this program, two complete diets (one with a high and one with a low protein concentration) are offered to pigs simultaneously. Pigs are allowed to determine the protein concentration of their final diet by the amount of each diet they consume.

Self-selection programs are a relatively new concept in the U.S. Results of initial studies in the U.S. indicate pigs overconsume protein with self-selection programs. This observation negates one of the important advantages of self-selection programs — reduction of nitrogen in swine manure. Additional research will determine if self-selection programs are practical for commercial pork production.

Complete mixed feeds or those with the proper balance of nutrients mixed and supplied in one batch are the most common methods of feeding pigs. Complete mixed swine feeds are generally more satisfactory for most operations.

Limit-fed gestating sows will perform equally well when fed their diet components (grain and supplement) separately or as a completely mixed feed once daily in individual stalls. It is advisable to feed the supplement at the time the grain is fed to ensure an adequate intake and balance of nutrients.

Grinding

Most feeds are processed in some way before distribution and consumption (Table 1). For example, some grinding and/or rolling is necessary in completely mixed diets to prevent ingredient sorting by the pig and to break the hard grain kernel into smaller particles of uniform size. The degree of grinding varies from finely to coarsely ground material.

Grinding feedstuffs can be accomplished with a hammer mill or roller mill. The advantages of a hammer mill over a roller mill include higher speed of grinding and greater mill throughput. However, a hammer mill has a greater power requirement compared with a roller mill to achieve a given particle size. Roller mills produce greater uniformity of particle size than do hammermills especially when processing wheat or grain sorghum. The choice of one mill type over another depends on the feed processing needs of the swine unit and the feed materials used.

Passage rate of feedstuffs through the digestive system of pigs is slightly faster with finely ground feeds. Normally, feedstuffs which have passed through a 1/8 to 3/16-in. screen or smaller are considered to be finely ground. The screen size and area through which the feed is passed, along with hammer tip speed, will determine the fineness of grind in a hammer mill. A more accurate method of describing fineness of grind relies on measurement of average particle size. Particle size is determined by passing the feedstuff through a series of sieves with progressively smaller openings. Feed with particle sizes ranging from 600 to 800 microns is considered finely ground. Finely ground feed is more subject to wind losses when filling the feeders and to "bridging" problems in self-feeders and bulk bins than is coarsely ground feed. Excessively dusty conditions inside swine facilities can be largely attributed to finely ground feed. Feeding finely ground feed also increases the incidence of gastric ulcers. Fine grinding of some grains, such as wheat and grain sorghum, may result in a product with a powdery or floury texture, reducing their acceptability to the pig. The primary advantage associated with small particle size as compared with larger particle size is a consistent improvement in feed efficiency of pigs fed finely ground feed. The financial gain realized from improved feed efficiency must be weighed against the increased power and time required to achieve the smaller particle sizes.

A medium-textured feed, ground through a 1/4 to 3/8 in. screen with an average particle size of 800 to 900 microns, seems most suitable for complete mixing of dietary ingredients because it eliminates the problems associated with finely ground grain and achieves acceptable pig performance. Generally, a medium grind improves feed efficiency over a coarsely ground feed (greater than 1000 microns) with little, if any, improvement in rate of gain.

With high-moisture grain, maximal performance can be obtained by feeding the grain either rolled or coarsely ground. Care should be taken that the high-moisture grain does not become moldy. It should be fed the same day it is prepared, or it must be treated with an organic acid or another mold inhibitor at the time of processing to prevent spoilage. Acid-treated high-moisture corn can be ground or rolled and mixed in a complete feed with satisfactory results. One should be aware, however, that the acid contact with metal feeding equipment hastens deterioration unless some protective coating is applied to the metal. Wooden or concrete feeding equipment can be used effectively with acid-treated grains (see PIH-73, "High-Moisture Grains for Swine" for more details).

Pelleting

Pelleting is used extensively in commercially prepared rations. Pelleted feeds are initially ground fine or medium, then steam conditioned and formed into a pellet by extrusion through a die. Steam in the pelleting process increases pellet durability and produces less starch damage in the grain. Pellets can be made of different lengths, diameters and degrees of hardness. The kind and quantity of ingredients in a diet can influence the hardness of the pellet. Diets containing wheat or wheat by-products usually result in a hard pellet. Young pigs generally prefer a pelleted over a meal diet if given a choice of the two forms of feed, but they do not like an extremely hard pellet. Few consumption differences occur between pelleted and non-pelleted feeds when fed separately and when pigs are not given a choice.

Often, reground, pelleted feeds improve feed conversion over an unpelleted meal diet. This fact suggests that energy digestibility is enhanced by the pelleting process, owing to a partial gelatinization of starch (rupture of starch molecule), thus making it more susceptible to enzymatic digestion. Pelleting high-fiber diets increases digestible energy by 10% to 15%. No improvement in protein digestibility by pelleting has been observed.

Various studies on the effect of pelleting indicate that growth rate and feed efficiency of pigs are improved by pelleting the diet along with a slight reduction in feed consumption. The decreased feed intake may be partially attributed to a lowered amount of feed wastage compared to a meal diet. This improvement is generally associated more with dietary formulations containing more fiber than with diets based on corn-soybean meal.

Other advantages of pelleted diets are:

- Reduced dustiness
- Reduced storage space
- Reduced feed wastage
- Less wind loss
- Less "settling out" of fine particles during transportation
- Reduced sorting of diet ingredients and particles

However, disadvantages of pelleting include:

- Increased cost
- Reduced acceptance of hard pellets by the young pig
- Fine grinding requirement of cereal grains before pelleting
- Difficulty in pelleting high fat diets (greater than 6% fat)
- Possible occurrence of spoilage if improper cooling of pellets occurs

In general, the more expensive a diet is, the more economical it is to offer the diet to pigs as a pellet.

Paste Feeding

The development of a feed-water mixture (paste) feeding system for growing-finishing swine results in improved performance. Paste-fed swine consistently show increases of 10% to 15% in growth rate and feed intake but no improvement has been noted for feed efficiency.

The paste is formed by mixing one part dry diet with 1.2 to 1.5 parts water by weight. This paste mixture is then pumped and piped to a specially constructed feeder which is timed to release the paste to the pigs when the trough sections are emptied. The feeder is not, however, commercially available. Because of the high water content of the diet and its use of special equipment, it is essential that where freezing temperatures occur, the system be used only in temperature controlled facilities.

Although this paste system results in improved performance of growing-finishing swine, no benefits occur with weanling pigs.

Liquid Feeds

There are several commercial systems available to provide liquid-feed mixtures for all phases of pork production (i.e., gestating and lactating sows, early weaned pigs and growing-finishing hogs). Various liquid feeders operate differently, but the principle of providing feed is similar. The feed and water are combined either before delivery or at the trough. Pigs may be either limit- or full-fed. The ratio of feed to water desired by the pork producer can be adjusted by the setting of the equipment controls.

Although water is provided in the mixture at the trough, continual access to additional water is essential. Some producers find it desirable, however, to limit the access to the waterer during the initial phase to encourage feed consumption. Pigs adapt readily to the liquid feeding system with few problems. The use of liquid-feed mixtures reduces dust accumulation in buildings, and feed wastage is minimized when the equipment is properly adjusted.

Pig response to liquid feeding systems is inconsistent. When growing-finishing hogs are limit-fed, weight gain and feed efficiency improve with liquid feeding as compared to feeding a dry diet. However, when pigs are full-fed, pig performance is similar, regardless of the type of feeding system.

Heating Feed Ingredients and Feeds

Cereal grains and many feed by-products are not normally heat processed before mixing into swine diets, except to prepare them for safe long-term storage. Because of their high moisture content, some feed ingredients, such as alfalfa, distillers grains, whey, and meat meal must be dried when used in swine feeds.

Other feed sources, however, must be heat-treated to be effectively used by swine. Soybeans are an excellent example. The major objectives in the processing of soybeans for use by swine are (1) to destroy the trypsin inhibitors, (2) to inactivate the toxic hemagglutinin, and (3) to increase the nutrient availability. Attempts to achieve these objectives employ a wide range of processing conditions. The primary factors involved are cooking temperature and time, moisture content of the seeds, particle size, such as whole vs. flaked, and equipment used to process the beans.

Soybeans are processed initially to remove the oil for other uses with the resulting meal then being heated to improve its quality. Heating time, temperature and moisture level must be regulated closely to attain maximum product quality. In general, longer heating time is required with low temperatures. The nutritive value of soybean meal has been improved when the length of heating is increased from 4 to 15 min. at 250°F (121°C). However, when heating time is increased beyond 15 minutes at this temperature, there is a rather drastic decline in the nutritional value of the meal. Overheating of soybean meal destroys some of its vitamins and reduces the availability of the amino acids. The regulation of the water content during the heating process can partially prevent the damaging effects of overheating. Moisture is added in the form of steam after the oil extraction and before the toasting of solvent processed soybean meal. The added moisture aids in quick distribution of heat during toasting, thereby minimizing heat damage.

Full-Fat, Heat-Processed Soybeans

Research has established that properly heated, full-fat soybeans are a good feed source for swine. Heat-treatment can occur in roasters or extruders, and may involve the whole or ground soybean seed. Growing and finishing pigs are able to use the protein in the full-fat beans nearly as efficiently as the protein in soybean meal. However, the oil in full-fat soybeans is not used efficiently unless the processing method involves rupturing of fat cells in the soybean. Carcasses of pigs fed heat-treated, full-fat soybeans tend to be softer with a higher percentage of unsaturated fatty acids. These differences are small, however, unless an unusually high amount of oil is fed. Feeding a diet without full-fat, heat processed soybeans one month before marketing results in firmer carcass fat.

Full-fat, heated soybeans are lower in protein and carbohydrates and higher in fat than solvent-extracted soybean meal (Table 2). Because of this lower protein concentration, additional quantities of heat-treated soybeans must be added to swine diets to provide equivalent amounts of protein (amino acids) provided by the soybean meal (Table 3). Full-fat soybeans contain 18 times more fat than soybean meal. This fat or oil is 2.25 times as concentrated in energy as the carbohydrate or starch from corn. Because this oil can be used by pigs as a source of energy, the energy level of diets using full-fat, heated soybeans is higher than diets using commercial soybean meal (Table 3). Because of this greater energy concentration, there is a 4% to 6% improvement in feed conversion when feeding heat-treated, full-fat soybeans compared to soybean meal.

Table 2. Comparative nutritive values of full-fat soybeans and solvent extracted soybean meal.

Content	Full-fat soybeans	Soybean meal
Crude protein, percent	37.0	44.0
Crude fat, percent	18.0	1.0
Carbohydrate, percent	30.0	40.0

Table 3. Diets comparing soybean meal and heat-treated soybeans.

Ingredients	Soybean meal	Heat-treated, full-fat soybeans
Corn	1650	1520
Soybean meal, 44%	300	—
Soybeans, heat-treated	—	430
Min-Vit. premix	50	50
Total	2000	2000
Percent protein	14.0	14.8
Metabolizable energy, Kcal./lb.	1432	1478

The protein (amino acid) needs of the pig are related directly to the amount of energy in the diet. Pigs fed higher energy-containing diets will not consume as much feed. Hence, with higher levels of dietary energy provided from the full-fat soybeans, additional protein must be supplied to keep the protein:calorie ratio at an optimal level. Therefore, diets containing full-fat soybeans must contain more protein than comparable diets using soybean meal. An example of a diet using soybean meal and full-fat, heated soybeans is presented in Table 3.

Pig performance achieved with soybean meal or heated soybeans depends on the quality of the beans initially used and upon proper processing techniques used in their preparation. Commercially processed soybean meal is checked periodically for product quality, whereas it is more difficult for pork producers and small processors to evaluate the quality of their heated, full-fat soybeans.

On-the-farm heat-processing methods include roasting (tumble roaster, fluidized bed roaster), dry cooking (infrared and microwave), and extruding of ground soybeans. The extrusion method generates friction (i.e., heat) by forcing the soybeans through a restricting die under high pressure. For optimal quality, roasted soybeans should be heated for 3 to 5 minutes at an exit temperature of 240 to 260°F (115°C to 127°C). Extruded soybeans should have an exit temperature of 280°F (138°C) to achieve maximal pig performance.

The merits of using full-fat heat-treated soybeans in farm mixing situations versus commercially prepared soybean meal depends upon several factors. As a fat source, full-fat soybeans could represent a viable alternative to other sources of fat such as tallow, choice white grease, dry fat, etc. Thus, the decision must be in relation to cost savings. Home-grown soybeans may be grown and used on the farm or purchased at harvest when they are normally lower in cost. However, this process must outweigh the disadvantages, which include increased storage bin capacity, equipment to heat-process the beans, energy costs of cooking, shrink, and available labor. Normally, the feeding value of the added fat in swine diets containing full-fat soybeans is offset by the energy cost of processing the soybeans. Dietary cost advantages vary from year to year and by locality.

Heat-Processed Grains

The introduction of units designed primarily for heating soybeans stimulated interest in the use of such units for processing feed grains. No consistent improvement has been shown in performance with pigs fed diets containing heat-processed corn. No differences occur in carcasses as a result of feeding roasted corn.

Extruding Grains

The extruding process has been used to process corn, grain sorghum and wheat for pig diets. Little research has compared the nutritional value of extruded corn with ground corn. Extruding does not improve either rate or efficiency of gain among pigs fed either grain sorghum or wheat as a grain source. Extruding improves the digestibility of both energy and protein in extruded grain sorghum.

Steam Flaking—Micronizing

Steam flaking involves heating grain to approximately 200°F (93°C) in a steam chamber for 20 minutes followed by flattening the feed through rollers. Micronizing consists of heating grain to 300°F (149°C) 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 availability.

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 while reducing the amount of feed necessary per unit of gain. 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. Thus, diets containing grain processed at high temperatures may need additional lysine supplementation to achieve similar performance.

Drying Grain for Storage

It is a common practice to dry corn with artificial heat to a moisture content low enough for safe storage. Corn dried at normal temperatures supports gains and feed efficiencies in pigs similar to those obtained with field-dried corn. Research indicates that air temperatures up to 230°F (110°C) for drying corn to a moisture content of 12% to 15% have no detrimental effect on pig performance. Drying temperature does not affect the content of carotene (vitamin A precursor), riboflavin or niacin, but pantothenic acid and thiamin may be decreased. If, during the harvesting and/or handling process, the grain kernel is cracked and then dried, nutrient destruction is enhanced. This destruction is particularly true for carotene and vitamin E. In addition, cracking the seed coat due to high temperature drying, or damage during handling increases the opportunities for mold growth and potential mycotoxin production (see PIH-129, "Mycotoxins and Swine Performance"). Stress cracking of corn occurs primarily due to rapid cooling. Stress cracked corn is more susceptible to breakage which increases the amount of fines in the grain and may reduce the success of the grinding operation in achieving a uniform particle size.

Proper Feed Manufacturing Procedures

Many pork producers choose to manufacture all or a large part of the feed for their pigs. When choosing to manufacture feed on the farm, the producer assumes responsibility for ensuring the quality of that final feed. Errors in feed manufacture resulting in poor pig performance or over-supply of costly nutrients increase a pork producer's cost of production. Because feed costs usually represent 65% to 70% of the total cost of producing a pig, it makes good business sense for pork producers to ensure that pigs receive feed that has been properly formulated using good quality ingredients, and manufactured using proper processing practices.

Formulations

Accurate formulation is essential to producing swine diets that satisfy nutrient requirements of the pig. Nutrient concentrations of feed ingredients vary substantially from average values published in nutrient composition tables. For example, low-yielding drought-stressed corn usually has a higher protein concentration than that published in nutrient composition tables. In contrast, high-yielding corn may have a lower protein concentration when compared with "average" values in published tables. The most accurate formulations result when laboratory analyses of ingredients are available. Generally, lysine content of grain increases as the protein content of the grain increases. However, increases in lysine and protein are not proportional such that lysine content of grain cannot be accurately predicted from crude protein content. Lysine analysis is most valuable for diets with a high proportion of grain such as finisher diets. In high-grain diets, a large portion of the total dietary lysine comes from grain. As diets become more complex and/or contain a lower proportion of grain, lysine analysis of the grain becomes less critical. Pork producers should seek the help of trained professionals if they are not comfortable with the calculations involved in the formulation process.

Mixing directions from feed tags or special formulations should be followed exactly! Deviation from these mixing directions alters nutrient content of the final feed and may compromise pig performance. Use supplements and premixes formulated specifically for swine. Do not use a trace mineral premix designed for other species in a swine diet. Do not mix premixes and supplements from different suppliers. For example, do not use company A's supplement with company B's booster pack. Products from different companies are not always made to go together in a diet.

Adding Ingredients

There are two types of feed mills—continuous flow (volumetric or meter mills) and batch. Continuous flow mills add ingredients based on volume. This procedure assumes that each ingredient has a constant bulk density. When bulk density of ingredients changes, the mill still adds a given volume of material, but that volume no longer contains the proper weight of ingredient. Therefore, calibration of continuous flow mills is critical and should be checked, and adjusted if necessary, for all diets at least once a month and every time a new batch of ingredient is purchased. Consult PIH-94, "Calibrating Meter-Type Feed Mills" for more details about this process.

With batch processing, each ingredient is added individually to the mixer on a weight basis. On many farms, this system consists of a portable grinder-mixer. Greater accuracy in feed manufacturing is possible when ingredients are added by weight rather than volume. **The only substitute for a scale is another scale.**

Make a list of ingredient names and amounts used in each swine diet, then check off each ingredient as it is added to the mixer. This helps guard against forgetting an ingredient or adding one ingredient twice. Ingredients added in very small amounts (less than 1% to 2% of diet) are difficult to mix evenly throughout a batch of feed. These ingredients should be premixed with some of the cereal grain and added in amounts of not less than 40 pounds per ton. A clean concrete mixer or horizontal ribbon mixer works well for premixing.

The order that ingredients are added to portable grinder mixers or stationary vertical mixers influences mixing time required to disperse all ingredients evenly throughout the feed. Add at least one-half of the grain first, followed by all premixed ingredients. Next add all the protein source and finish by adding the remaining grain. A good rule of thumb for on-farm mixing is to mix feed 15 minutes from the time the last ingredient is added. Particle segregation or "unmixing" of feed will not occur if particle size of ingredients is uniform. Do not overfill mixers. Efficiency of mixing is reduced when mixers are too full. For other types of mixers or when in doubt about mixing times, consult the manufacturer's directions.

Sequencing of Batches

Every effort should be made to guard against drug carryover from medicated to non-medicated feeds. One source of carryover occurs because electrostatic charges cause medicated feed particles to cling to the inside of the mixer. Another source of drug carryover is residual medicated feed that remains in discharge augers and the bottom of the mixer after unloading. Proper sequencing of batches minimizes unwanted drug carryover from medicated to non-medicated feed. Mix medicated feeds first, followed by non-medicated sow feed, which flushes residual medicated feed out of the mixer. Non-medicated finishing feed should be mixed last. If proper sequencing is not possible, the mixer should be flushed with ground corn and cleaned thoroughly by hand to remove drug residues. This ground corn can be saved for use in the next batch of medicated feed that is mixed.

The National Pork Producers Council in collaboration with many professionals in universities and industry has developed the Pork Quality Assurance (PQA) program. This home-study program is designed to instruct producers in practices that will permit continued use of medications while minimizing chances of drug residues in pork carcasses. To ensure the continued success of the U.S. swine industry, every pork producer should be enrolled in PQA. Contact your local or state pork producer organization for more information.

Quality Control Programs

Every quality control program should include periodic laboratory analyses of ingredients and feed. Success of a quality control program hinges on collection of representative samples for laboratory analysis. Great care should be taken to ensure samples are representative of material under inspection so that laboratory results reflect the nutrient content of the ingredient or feed being sampled. The easiest way to obtain representative samples is to collect numerous samples from a running stream of material, mix the samples and subsample the total amount collected for a laboratory analysis. When a running stream is not available, bulk lots should be sampled with a sampling probe. Six to eight probe samples should be collected around the outside edge of the structure and two or three in the center of the structure for a total of eight to ten samples that are then mixed and sub-sampled. For bagged material, collect a one-pound sample with a probe from 10% to 15% of the bags in the shipment. Mix samples and subsample for laboratory analysis. Retain a portion of the subsample in a freezer for possible later analysis. Some suggested analyses for individual ingredients and complete feeds are listed in Table 4.

Each new batch of grain should be sampled for laboratory analysis because grains tend to be variable in nutrient content. Diets then can be formulated based on nutrient content of grain. Soybean meal does not have to be sampled quite so often because processors are bound by law to meet a guaranteed analysis on feed tags. It is still a good idea to sample soybean meal occasionally. If protein content does not meet tag guarantees, then the producer is eligible for a rebate. Soybean meal also should be analyzed for calcium content. Sometimes a calcium source is added to soybean meal to enhance flowability, resulting in calcium levels higher than normally found in soybean meal.

If premixes are purchased from a reputable company, it is not necessary to routinely send samples for laboratory analysis. Laboratory analyses for vitamins and trace minerals are rather expensive. Reputable companies pay close attention to the

Table 4. Suggested analyses for individual ingredients and complete feeds.

Item	Suggested Analyses
Ingredients:	
Grain	Moisture
	Lysine (crude protein)*
Soybean meal	Moisture
	Crude protein
	Calcium, Phosphorus
Complete diets:	
Grain-soybean meal-premixes combined	Moisture
	Lysine (crude protein)*
	Calcium
	Phosphorus
	One trace mineral (e.g. zinc or iron)
	Particle size
Grain-supplement combined	Moisture
	Lysine (crude protein)*
	Particle size

*While crude protein analysis is quick and inexpensive, it cannot be used to predict lysine concentration accurately. See text for explanation.

quality control aspects of manufacturing premixes. Nonetheless, it is a good idea to sample each shipment of premixes and store samples in a freezer for later analysis, if needed. If problems with pig performance that may be caused by the premix develop, a sample is available for laboratory analysis.

At the very minimum, final feeds should be sampled and analyzed quarterly. Preferably, a laboratory analysis of finished feed should be conducted every two months. Frequent analysis of final feed will help producers determine if the feed being offered to pigs contains the desired nutrient concentration. Laboratory analyses are the first step in troubleshooting feed manufacturing problems.

Quite often, feed suppliers use synthetic amino acids, particularly lysine, to reduce the proportion of soybean meal needed in a complete diet. In this situation, crude protein concentration of the final diet will be lower than expected. Consequently, a more accurate evaluation of the nutritional value of a diet is possible by analyzing for lysine instead of crude protein. Lysine analysis is more expensive than crude protein analysis.

Interpreting results of a lab analysis can be confusing. The first principle to remember is that lab results can be variable. Labs make mistakes from time to time and there is an expected normal variation in the results of laboratory analyses. An acceptable variation in laboratory analyses is presented in Table 5. If lab analysis of a final feed indicates a particular nutrient concentration is outside the range of acceptable variation, then another sample should be submitted for analysis. Major changes in feeding programs should not be made based on results from one feed sample. If a second analysis of the same feed indicates nutrient concentrations are outside the acceptable range, then it is likely that an error in formulation, mixing or sampling occurred. Producers may need to consult a nutritionist to help in troubleshooting their feed manufacturing process.

Several commercial labs are available for analysis of feed samples. Often, suppliers of feed ingredients will offer lab services to their customers. Contact your local Extension educator, state Extension specialist, or feed dealer for names and addresses of commercial labs. It is best to call a laboratory before submitting a feed sample to inquire about cost, sample size needed, type of analyses available and turn-around time. Use the same laboratory for all feed analyses because there is more consistency within a single laboratory than there is between laboratories.

Table 5. Acceptable variation in laboratory analyses*.

Nutrient	Variation	Calculated level	Normal range
Crude protein	4%	16%	15.4 to 16.6%
Lysine	10%	.70%	.63 to .77%
Calcium	20%	.65%	.52 to .78%
Phosphorus	10%	.50%	.45 to .55%
Trace minerals (zinc or iron)	20%	100 ppm	80-120 ppm

*Adapted from 1993 Official Publication of Association of American Feed Control Officials.

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