Minimizing the Use of Antibiotics in Pork Production

An antibiotic is any specific substance produced or derived from a bacteria or fungi that is capable of killing or inhibiting the growth of bacteria. An antimicrobial, on the other hand, is any substance, natural or manufactured, that destroys microbes or inhibits their growth. Therefore, an antibiotic is also an antimicrobial, whereas zinc oxide, for example, has antimicrobial properties but is not an antibiotic.

Antibiotics were first approved in 1951 by the Food and Drug Administration (FDA) as feed additives for farm animals. Since then a variety of antimicrobials has been used subtherapeutically for most pigs produced in the United States. According to the Swine 2000 Survey (USDA's Animal and Plant Health and Inspection Service), U.S. pork producers used antimicrobials for growth promotion in 83 percent of starter feeds and 88 percent of grower/finisher feeds. It was estimated that feed-grade antibiotics amount to less than 4 percent of total diet costs. Used properly, these products increase meat production approximately 15 percent each year and enable pork producers to provide safe, wholesome pork products to consumers at lower costs than would otherwise be possible (Hayes, *et al*., 2002). Antibiotic resistance is a global concern affecting humans and animals. Additionally the overuse and misuse in both food-producing animals and humans hastens the selection of resistant bacterial strains. Consequently a growing number of consumers would like to purchase meat from animals that have not been treated with antibiotics.

Antibiotics are part of a management regimen used to treat diseases, improve the efficiency of feed utilization and feed acceptance, or to be beneficial to the health or metabolism of the animal in some way. They typically are administered to pigs through the feed, water or by injection.

Feed additives can be divided into two broad categories, subtherapeutic (less than 200g/ton and for more than 14 days) and therapeutic (more than 200g/ton of feed for 14 days or less). Subtherapeutic antibiotics (STAs) are routinely fed to enhance growth rate and feed efficiency and to reduce the risk of an outbreak of some diseases. Therapeutic use of antimicrobials is for the treatment, control, and prevention of bacterial disease, i.e., to treat infected and sick animals. Therapeutic use should be taken under the advice of the herd veterinarian after an evaluation of the health concern and selection of appropriate therapy.

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Chart 1. Antibiotic feeding programs

Antibiotic Usage	Subtherapeutic Use		Treatment Use
	Birth to 40 lb	40 to 100 lb	
Conventional	√	√	√
No Subtherapeutic after 40 or 100 lb		√	√
No Subtherapeutic			√
No Antibiotics			

The concern about developing antibiotic-resistant organisms is causing the industry to examine the use of antibiotics to promote growth rate and efficiency. It is possible for all types and sizes of pig farms to produce consistent, high quality, healthy pork without the use of subtherapeutic antimicrobials. However, there will be a resulting increase in production costs.

Antibiotic Use Programs

Chart 1 defines four antibiotic use programs for pigs. The "Conventional" program allows complete usage of antibiotics for both subtherapeutic and treatment purposes, requiring only that producers follow label directions for appropriate withdrawal times before slaughter.

"No Subtherapeutic after 40 or 100 lb" allows the use of antibiotics in young pigs to enhance production and treat disease. Producers routinely using subtherapeutic feed additives will find minimal economic or performance value in feeding low levels to pigs weighing more than 100 lb, with removal of antibiotics at 40 lb a more restrictive program. Antibiotic removal at 100 lb allows at least a 60-day withdrawal and, because of the half-life of approved products, will result in a market hog that is completely free of detectable antibiotic residues.

"No Subtherapeutic" is a more rigorous program requiring higher management skills, especially with biosecurity issues and herd immunity development. It allows pigs that are treated for diseases (therapeutic) to be a part of the marketing program. This method may slow but will not eliminate the development of resistant bacteria. Removing subtherapeutic antibiotics from nursery diets could result in increased post-weaning diarrheas, uneven growth rates, and up to a 10 percent increase in nursery death loss. As in the "No Subtherapeutic after 40- or 100 lb" system, pigs not receiving antibiotics in the last 60 days before harvest will have no antibiotic residues.

Finally, "No Antibiotics" is a program to raise pigs for consumers preferring to purchase pork from pigs that have never been exposed to antibiotics. It makes pigs exposed to antibiotics for any reason ineligible for an antibiotic-free marketing program. This method has the highest loss risk for the producer because of production and health variability. Therefore, the product must command a higher market price to net an income similar to that received in any of the systems allowing antibiotic usage. Under welfare and ethical considerations, all sick animals must be treated and provisions made for their marketing through regular channels after appropriate withdrawal periods.

Before beginning a production program without the use of subtherapeutic or therapeutic antibiotics, the producer needs the following:

1) an understanding of biosecurity to prevent/reduce the introduction of new pathogens;
2) an understanding of environmental management to minimize stressors;
3) the ability to control pig flow to create uniform groups of pigs
4) adequate facilities to separate sick or injured pigs into isolated accommodations prior to medication and then market them outside the program (no antibiotic program only);
5) a staff dedicated to stockmanship, including observing pigs;
6) an absence of certain parasites and diseases, especially Postweaning Multi-Systemic Wasting Syndrome (PMWS), active Porcine Respiratory and Reproductive Syndrome (PRRS), swine dysentery, ileitis, and Progressive Atrophic Rhinitis; and

7) a marketing plan to capture potential added value and recoup higher production costs.

Production Health Issues

Any management strategy that reduces the introduction to or effect of pathogens on the production premises will reduce the dependence on antimicrobial agents. These strategies include:

1) maintaining stringent controls on cleanliness and sanitation, animals entering the farm, feed quality, and environmental conditions to prevent or reduce stress (including transportation);
2) eradicating specific diseases;
3) optimizing nutrition to enhance natural immunity;
4) breeding disease resistant animals; and
5) utilizing acceptable alternative growth promotants.

Before beginning a non-antibiotic production program the producer must decide on an initial health status by choosing from the following options:

1) minimizing pathogens entering the farm and minimizing the effects of current pathogens;
2) living with current pathogens if current health problems are acceptable; or if unacceptable,
3) partially depopulate and live with remaining pathogens; or
4) if the health status is intolerable, totally depopulate and repopulate the herd from a high health source.

Many disease conditions of pigs that are rendered subclinical with subtherapeutic feed additives can be controlled by other management strategies with acceptable economic consequences. Some of these diseases are mycoplasma-based Porcine Respiratory Disease Complex (PRDC), proliferative colitis, and pre- and post-weaning *Escherichia coli (E.coli)*. All producers should strive to eliminate external parasites (mange and lice). Reducing these stressors is especially important for pigs produced without antibiotics. Pork production techniques that separate pigs from their manure and the soil interfere with most parasitic life cycles. On many farms internal parasites are of minor economic importance. Internal parasites cannot be effectively eliminated from outdoor or bedded

production and pigs from these systems will require some internal parasite control. The use of parasiticides should be limited to those occasions when it is proven that internal parasite infestation is at a welfare or economic level. The use of slaughter checks, worm egg counts, and routine necropsies assist the attending veterinarian in choosing appropriate internal parasite control strategies.

Production Systems

Traditionally, herds that desired to produce pigs without STAs tended to be smaller, more extensive open-lot farrow-to-finish operations hoping to meet a niche market. However, production without antibiotics is applicable to both intensive confinement production as well as the more extensive production systems. In both situations the most important factors are monitoring and controlling pig flow. Many pork operations are striving to reduce production costs by reducing the use of subtherapeutic antibiotics in the feeding program.

The intensity (e.g., farrowing weekly or monthly) of the system selected will depend upon the amount of space available in each phase of production, allowing adequate time for all-in/all-out production and thorough cleaning and disinfection between each group. Production systems with access to soil or bedding commonly include one or two groups of sows farrowing twice per year or all-gilt systems farrowing once per year, whereas indoor systems include multiple groups with frequent farrowings. With either system, pig flow must be scheduled to keep different groups of farrowed pigs reasonably separated throughout the production system.

Grouping and segregating pigs by age for management and health reasons is essential. Groups of pigs of the same age are usually similar in size and can be handled as one group with similar feed and housing requirements. Segregating each group of pigs from older and younger pigs has health advantages. In particular, segregating weaned pigs from the sow herd may minimize transmission of bacteria and parasites between generations. Another strategy is to segregate groups of pigs through time, i.e., farrowing only once or twice per year that results in pigs of only one age on the farm at any time. This can be accomplished with an

all-gilt system, and, to a limited extent, with a group of sows farrowing twice per year.

A well-designed pig flow model that is strictly followed is essential for segregating different-age groups of pigs. All-in/all-out is the backbone of maintaining the health of a unit and this is achievable only through effective pig flow. It is highly desirable to keep the variation in weaning ages to no more than seven days. This will allow the producer to group pigs with common health issues until market.

Understanding gilt introduction protocols and adhering to female breeding requirements eliminates repetitive under-stocking and over-stocking. Failure to maintain a planned source of replacements, either through in-herd development or purchases, is a primary cause of unstable herd health and a major justification for the use of subtherapeutic antimicrobials.

Basic Management Skills

Stockmanship

Stockmanship is the skill of a person providing for the well being for animals under his or her care. Well-trained, dedicated, enthusiastic stockpeople are essential to the efficient running of a pig farm. The good stock person must be organized and allow sufficient time to observe the animals, and not spend most of their time maintaining the facilities. Excellent stockmanship is key to rearing pigs when minimizing the use of antibiotics.

Stockpersons who fail to modify the environment to minimize external stresses will likely have to use antibiotics to maintain the health and productivity of the pigs. Farms in the transition from routine use of antimicrobials have successfully implemented the following prerequisites: biosecurity measures, pig flow management, medicine controls, optimal animal environment, and high-quality stockmanship. Producers with buildings not designed for all-in/all-out pig flow and who do not employ strict management factors may have more difficulty adopting non-antibiotic production programs.

Effective and rational biosecurity measures

Pork producers whose operations have high health standards, including a biosecurity program restricting visitors, stray animals, and the introduction of new animals, and are all-in/all-out, have the best chances of success when adopting a non-STA program. They need to be aware of the sources of health threats (Table 1), which pathogens can be transmitted by these threats, and the relative risks for their farm. The number one threat to the health of pigs is any sick animal that is improperly treated. Adequate hospital areas and rules are vital to reducing clinical disease on farms.

Locating a new or isolation facility requires knowledge of diseases and how far they spread. For a reasonable measure of security, the recommended separation for PRRS is a minimum of one-half mile between the isolation unit and the main farm or from other animal units. Other pathogens such as Parvovirus are very stable, and successful destruction with disinfection is difficult because of this stability. It can be easily spread by aerosol over several miles, making elimination practically impossible.

Place fences around the farm boundary and lock building doors to prevent unauthorized entry. Exclude visitors, including truck drivers, from entering the facilities unless they wear provided boots and clothing. Exclude cats and dogs from the livestock areas, and maintain aggressive rodent and fly control plans. Reduce or eliminate the number of birds roosting in the barns. In some facilities this means covering openings with bird wire. In hoop buildings it might mean using bird wire on the lower cords. Additional bird scare tactics might need

Table 1. Biosecurity threats to a pig enterprise

Pig introduction
Other livestock
Dead stock disposal
Pig transportation
Closeness of neighboring units
Presence of a major road
Veterinarians and other advisors
Visitors (electricity and gas service)
Feed and water
Birds, rodents, cats, dogs, flies, and other wildlife
Bedding
Food products brought onto the farm
AI and embryo transfer
Clothing from another unit
Purchased second-hand equipment
New equipment
Staff or transport drivers owning their own livestock
Staff visiting packing plants, livestock shows, other units, etc.

to be employed.

Use weed control and gravel borders around the buildings to discourage rodents from approaching or entering. Rodent control must include appropriate placement of bait stations inside and outside of livestock buildings and removal of harborage areas within 300 feet. Clean up feed spills to reduce attractions for birds and rodents.

Pig Introduction

A major weakness of a farm's biosecurity net is the introduction of new breeding stock. Typically 90 percent of new pathogens come in with animals, including both the animals being delivered and the delivery system. A written introduction plan should be designed by the producer, veterinarian, and the seedstock source. Consider the use of artificial insemination, medicated early weaning, and embryo transfer for the introduction of new genetic stock.

If animals need to be purchased they should enter through a secure loading area and be placed in an isolation facility with separate manure handling and ventilation systems. The isolation caretaker ideally should not come into contact with the rest of the herd. If a separate caretaker is not available, the pigs in isolation should be cared for after all other livestock chores are finished. Do not allow clothes and boots worn in the isolation unit to come into contact with the production animals. After a suitable isolation period the pigs need to be tested for specified diseases before being introduced into the herd.

Prohibit the entry of transport vehicles for market pigs unless they are empty and have been cleaned and disinfected. Provide a secure loading area that prevents pigs from returning to the facility once they have been in contact with the truck. If it is necessary to load pigs onto a contaminated truck move the pigs to a neutral site with a farm trailer prior to loading.

New pathogens that enter a naive population may create an unstable health profile that will require treatment with antimicrobials. Detailed health plans should be written and implemented to reduce the risk of new breeding stock introducing new infectious agents.

Medicine program

A defined and audited medicine program that documents where medicines are used on the farm to vaccinate or treat diseased pigs is required. There are three major aspects of medicine control on farms:

1) Therapeutic antimicrobials must be used judicially and with the advice of the veterinarian who also should provide training in their use. It is unethical and a violation of animal welfare standards to not provide timely and effective treatment or, where treatment is not successful, timely euthanasia. Remove individually-treated pigs to an isolated hospital pen prior to antibiotic treatment because the antibiotic likely will appear in the manure and urine and could be consumed by untreated pigs. Removing the pigs also helps producers keep track of which pigs are still antibiotic-free and which ones have been treated. As an estimate, provide hospital space for 5 percent of the pigs in each stage of production. Hospital space should provide opportunities for individual animal care and for meeting thermal requirements of ill animals. If the facility is a naturally ventilated, cold facility (remodeled shed, small hoop structure, or old finishing floor) treated pigs should be provided with adequate bedding, particularly if not many pigs occupy the space. Groups of pigs can keep warm by huddling, but a solitary pig chills easily.
2) Vaccination is a reliable alternative to antimicrobials in the prevention and control of some diseases. A vaccine program should be part of the health plan and be reviewed quarterly with the farm's veterinarian.
3) For any medicine, including water and feed medications, to be effective, it should be stored following label instructions. Refrigerators need to be monitored with the use of a minimum-maximum thermometer. Nearly all live or modified live vaccines are deactivated upon freezing. Medicines, including feed additives, which don't require refrigeration are still vulnerable to degradation by excessive heat and sunlight.

Managing Pigs to Reduce Stress

STAs in swine feed are used to improve growth rate and control disease and are often used during times of stress. Strategies to minimize stress and thus minimize the need of STAs can be divided by stage of production. Two critical times in a pig's life are its first days after birth when it needs to consume colostrum and the first three days after weaning when it needs to adjust from a nursing schedule to dry feed.

Sow and litter

Provide a clean, disinfected area for farrowing. If farrowing stalls are over a shallow manure pit, the pit should be emptied between batches. Emptying a deep pit may not be practical between farrowings. Washing the sow and treating her for parasites before moving her to the farrowing area are parts of a good pre-farrowing strategy.

Piglets are born with essentially no antibody protection, and failure of the piglets to consume colostrum puts their survival at severe risk. Colostrum, the first milk secreted after farrowing, has high levels of antibodies that provide the major source of immunity during early life. Milk continues to provide antibodies throughout lactation but at reduced levels. Make sure all piglets nurse as soon as possible to get a healthy dose of the sow's antibodies via the colostrum. Limit cross-fostering to that which is necessary within 24 hours of farrowing. Attending farrowing is most advantageous to assure early nursing. Ensure that all pigs are actively nursing, usually once every one to two hours. After two weeks of age, sows and litters of similar age (less than a five-day age range) can be grouped. Possibilities include combining two or four litters by removing farrowing pen partitions or, alternatively, groups of 12 to 15 sows and litters may be combined in the pen that will become the nursery area. Risks include infected litters exposing others to their disease organisms, dominant nursing pigs, sows that limit lactation or "hide" from their litters, and potentially more crushed piglets.

During lactation, feed multiple times per day to encourage maximum sow feed intake using fresh feed and self-feeders, and allow for exercise and ample fresh, cool water. Cooling lactating sows during hot weather with drippers or air movement will encourage feed intake. Feed lactating sows so that the nursing pigs have access to the sow feed and learn to eat with the sow. If feed or water medications are used, all animals on the feed and water systems will no longer fit the criteria for antibiotic-free pigs.

Process pigs early to minimize stress. Carefully review the need for needle teeth clipping and if utilized it should be done along with castration within the first three to five days after birth. Disinfect equipment between litters. Pigs not exposed to soil must be provided with supplemental iron. Provide creep areas or feeders that allow the piglets, but not the sows, access to prestarter or starter diets. If the production schedule allows, piglet stress at weaning will be reduced by removing the sows from the farrowing stalls or pens and leaving the pigs there for three or four days, giving them time to adjust to dry feed. Weaning age will be determined by the planned pig flow schedule relative to the type of facility that will be used for a nursery.

Nursery and Growing-Finishing Pigs

Wean piglets into clean, disinfected pens. If shallow pits are used they should be emptied before putting pigs in the room. Emptying a deep pit may not be practical between groups and doing so would require very compelling reasons. Allowing more space (at least 3.5 ft^2 per pig up to 60 lb) in slatted pens and increasing the feeder space (3 in/pig) will reduce stress and may improve performance. If bedding is used it should be fresh and replaced or added to when it gets contaminated. Do not mix different age groups of pigs within the same environmental air space.

Minimize movement and mixing of pigs whenever possible. Do not remix the pigs as they move to the finisher. When not using STAs, allow more space per pig. Mixing and resorting activities stress the pigs, both by the movement as well as fighting to determine social dominance. Larger pens and group sizes are more likely to allow the pigs to express less aggressive behavior patterns. The stockperson should walk the pens daily to accustom the pigs to human contact. Observe the pigs carefully, particularly after changes in diets or weather.

Separating pigs from their manure will reduce the incidence of disease. Slatted floors are most effective for this purpose because pigs will have minimal opportunities to consume or come in contact with manure. Non-slatted floor facilities without bedding are difficult to keep clean and dry. Minimize drafts and temperature changes as much as possible.

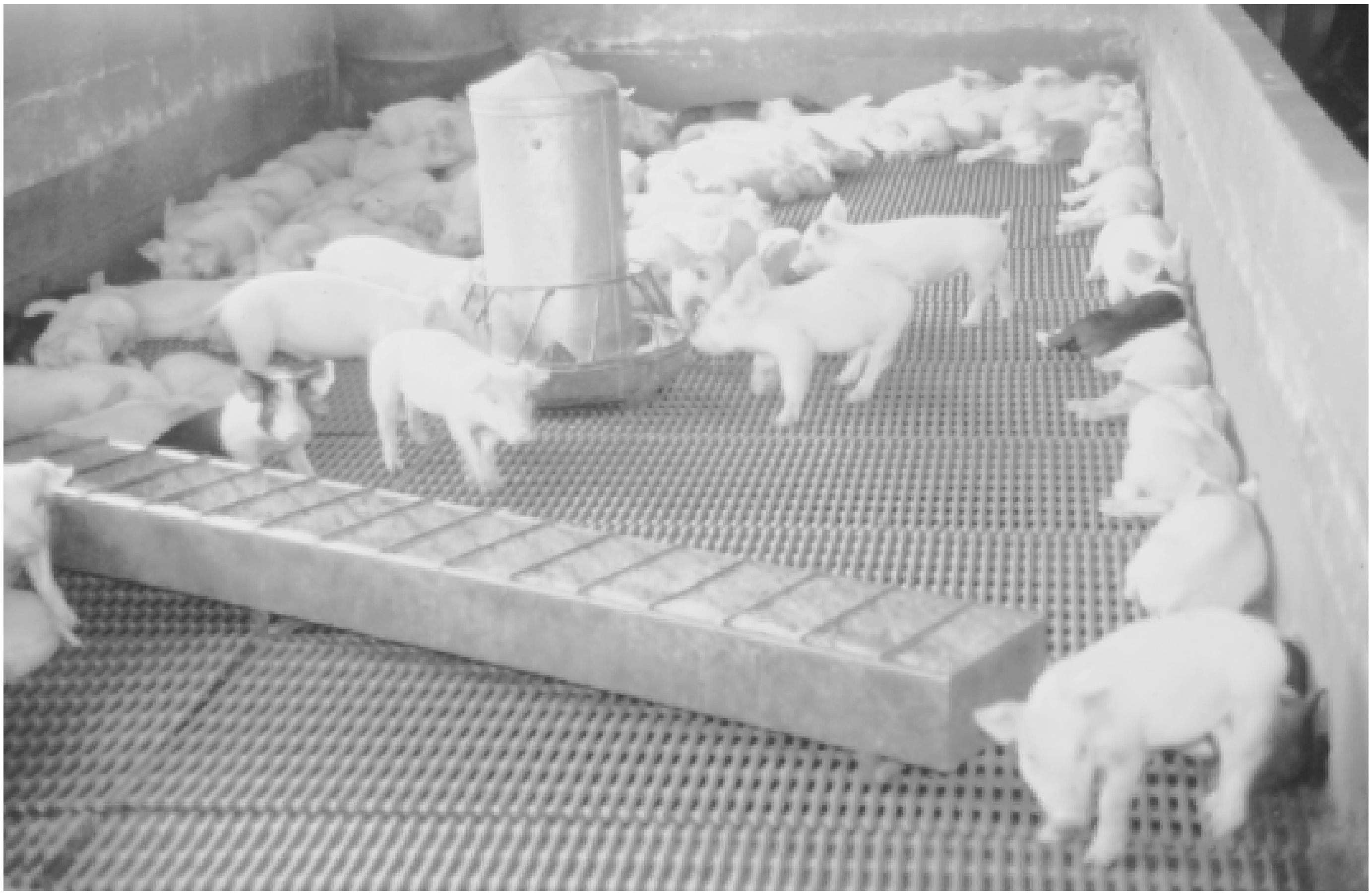
Using bedding to insulate the floor and keep sleeping areas dry will help pigs determine sleeping and dunging areas. The effectiveness of bedding in modifying the environment is dependent on the bedding quality that can be compromised if improperly harvested or stored. Removing bedding between groups of pigs and liming the ground before adding new bedding is recommended.

Environmental and Housing Issues

Environmental and housing requirements for pigs not fed medicated diets are the same as for those raised on farms utilizing antibiotics. The difference is that farms not utilizing antibiotics don't have antibiotics as a fall-back to prevent or treat diseases occurring as a result of environmental stresses without risk of losing those pigs to a premium market. Therefore, the production of pigs without subtherapeutic antimicrobials requires minimizing environmental stressors. These stressors can be divided into four major areas: water, feed, floor, and air. Failure to control these stressors will necessitate the use of subtherapeutic or therapeutic antibiotics to control performance failures.

The facility used for the production of non-antibiotic pigs should be sited and designed with maximum biosecurity in mind, because disease challenges could require medicating an animal and losing its marketing potential. Facilities should be constructed of easily disinfected materials. Confinement facilities that physically separate pigs from other domestic and wild animals will enhance biosecurity.

A hoop structure is an alternative housing for pigs, but biosecurity is at more risk because of the open structure and difficulty of disinfecting between groups of pigs. A concrete floor under the entire building will facilitate cleaning. Or in earthen-floor hoops, the building should be allowed to sit empty after clean-out until the floor is dry. During winter the soil under the bedding area must not be allowed to freeze, so clean bedding must be added for insulation after the manure pack is removed. Pasture and open lot production have greater biosecurity risks than confinement buildings but have the advantage of lower pig density.



Nutrition

Feed and ingredient management

Sow diets, particularly gestation diets, usually do not have added antibiotics. Most commercial prestarter, creep, and nursery diets for small pigs have added STAs. Grow-finish diets can readily be purchased without STAs. Therefore, if a producer wants to produce pigs with no STAs, special efforts will be required for the small pig diets. Custom diets, special arrangements, or mixing the diets on-farm are all possibilities. For assurance of antibiotic-free feed, ask custom mixers to sequence feed batches so that a non-antibiotic added diet precedes preparation of antibiotic-free feed. Delivery trucks also need to be flushed prior to loading non-antibiotic diets.

Feeding practices

High quality feed is always important, but becomes even more critical when a non-STA or no antibiotic program is implemented. The presence of molds, fungi, and resulting mycotoxins can have significant negative effects on the immune system and affect both feed intake and health of the pigs. Completely remove leftover feed from bulk bins and delivery lines between groups of pigs so stale or moldy feed is not left for the next group.

While feeding practices become more critical without the use of STAs, the nutrient requirements will be minimally affected. It becomes more important to ensure the diets meet all of the minimum nutrient requirements to prevent the occurrence of any deficiencies that would stress the pigs.

At weaning, piglets change from a liquid diet (milk) many times per day to *ad libitum* dry feed. Observe newly weaned piglets to ensure that they are consuming feed and water. Those weaned at less than three weeks of age will require more feed and water monitoring than older piglets that have consumed dry feed and water before weaning. Some may overeat and upset their digestive systems, resulting in fecal looseness that can be confused with infectious diarrheas. Four to six feedings per day of fresh diet will ensure adequate feed consumption in the critical first three days post-weaning.

Ingredients

Piglets weaned at less than 18 to 21 days will require a higher quality diet containing dried skim milk, dried whey, oat groats, and plasma proteins. Young pigs readily digest the milk protein and lactose in milk products. Pigs weaned at four to six weeks of age or later can be started immediately on a corn and soybean meal-based diet, which is much lower in cost.

Some feed ingredients have the ability to stimulate an immune response in piglets and will help reduce the occurrence of disease problems. The most common of these are the various spray dried plasma protein (SDPP) products available on the market. SDPP is produced from the blood of swine and cattle and contains about 78 percent crude protein. These proteins include immunoglobulins that retain functional activity as antibodies. When included at 4 to 7 percent of the diet for seven to 10 days post-weaning, SDPP stimulates feed intake and enhances performance.

Sources of dried skim milk, whey, plasma proteins, and other animal-based ingredients should be evaluated. Food (human) grade products are much lower in bacterial contamination than feed (animal) grade products. The influence of this contamination on the health status of the pigs is unknown. Producers for certain niche markets are not allowed to utilize animal byproducts such as plasma protein. Check your program parameters carefully to avoid these problems.

Generally Recognized as Safe (GRAS) compounds do not require FDA approval to be fed to livestock at levels higher than nutritional requirements, nor can health claims be made for them. These compounds often function either as antimicrobials or modifiers of intestinal microbial populations and may include the following products.

Zinc oxide supplemented in diets of newly weaned pigs at high levels (3000 ppm zinc as zinc oxide) has been shown to enhance growth and reduce the incidence of diarrhea. Other forms of zinc are not effective for this purpose. Supplemental zinc has been suggested as a way to help reduce *E. coli* scours in nursery pigs. This may, in part, explain the improved growth rate. Zinc works differently from antibiotics because effects of zinc and some antibiotics are additive.

While feeding zinc oxide at this high level does not appear to cause toxicity because of its reduced availability, feeding high levels of other forms of zinc, such as zinc carbonate or zinc sulfate, can result in toxicity.

Copper fed at 125 to 250 ppm (1 to 2 pounds of copper sulfate per ton) is recognized for its growth promotional properties, particularly for weaned pigs. Copper is routinely added as a required nutrient for normal pig growth to all swine diets at 6 to 11 ppm. As with zinc oxide, feeding a combination of copper and feed-grade antibiotics appears to be additive. Results vary on whether feeding high levels of copper and zinc together are additive.

When fed in excess of 250 to 500 ppm for an extended period of time, copper sulfate may be toxic. The severity of the toxicity is directly related to the level fed, and is increased if the diets are low in zinc and iron. Producers wishing to substitute copper for STAs should check with their feed manufacturer about the concentration of copper sulfate, iron, and zinc present in commercial feeds or premixes before indiscriminately adding copper sulfate to feed. Drawbacks to copper sulfate supplementation include increased corrosion of galvanized metal and decreased bacterial degradation of manure in lagoons. Environmental contamination, particularly where sheep have access to heavily fertilized soils, is another drawback. Use of copper and zinc has been identified as an environmental problem in the European Union where that use has increased.

Probiotics, or direct-fed microbials, are substances that contain desirable gastrointestinal microbial cultures and/or ingredients that may enhance the growth of desirable gastrointestinal microbes. While under normal conditions pathogenic organisms in the gut cannot grow and compete with the normal bacterial flora, during stresses the normal bacterial population may become upset. Probiotics may establish a desirable balance of gastrointestinal organisms and/or the substances that contribute toward the balance. The most common microorganisms included in probiotics are Lactobacillus species, *Bacillus subtilis* and *Streptococcus faecium* and yeast (*Saccharomyces cerevisiae*) or mixtures of these substances. The theory is that these organisms, through competitive inhibition or modification of intestinal pH, favor the development of desirable health promoting microorganisms. To be effective, the microorganisms should be established as normal inhabitants of the intestinal tract of healthy animals.

Although probiotics have been commercialized and used extensively for at least 30 years, documented evidence of their therapeutic and nutritional value still is quite variable. Possible reasons for the variability include the viability of microbial cultures, strain differences, dose level and frequency of feeding, and medicine interactions.

Botanical feeding research for pigs is very limited. Additions of Echinacea have been demonstrated to improve performance of nursery pigs weaned at 18 days of age. In the first three weeks post-weaning pigs fed additions of 2 or 3 percent Echinacea performed similarly to pigs fed carbadox. Similar tests with garlic, goldenseal, and peppermint showed no value when fed to nursery pigs. Commercial prices of botanicals vary widely from year to year.

Enzymes are essential for the digestion of proteins, carbohydrates, and lipids. However, commercial enzymes have not consistently demonstrated a positive response.

Organic acids, commonly referred to as acidifiers, have shown favorable effects in diets for pigs weaned at less than three to four weeks of age. Citric and fumaric acids have been the primary acidifiers tested. Similar responses may be obtained by use of fermented feeds after an effective starter culture has been established. Acidification may decrease stomach pH, increase pepsin activity (required for protein digestion), decrease the rate of stomach emptying (increasing time for protein digestion in the stomach), and reduce the proliferation of coliforms and other pathogens in the upper gastrointestinal tract. Young pigs have relatively immature digestive systems and do not digest the carbohydrates and proteins in plant-based diets as efficiently as the carbohydrate and proteins in milk. The exact mode of action is not known and research has shown the effects of organic acid additions to be quite variable. This variability may be attributed to 1) the age of pigs; 2) the amount of milk by-products in the diet; and 3) the presence or absence of antibiotics. Older weaned pigs are not as likely to benefit from the addition of organic acids.

Genetic Programs

The relationship between genetic potential and the farm environment in which the pigs are produced often is underestimated and will dictate the performance of the animals. Genetic changes will not solve performance problems if these problems are caused by the environment. This becomes part of the planning before beginning non-STA or no antibiotic production. Each farm is unique and the current breeding and genetics program must be evaluated to see if it is the right one for the farm environment and potential market. Don't change genetics without evaluating the farm's current production system and its goals.

Genetic strategies encompass pig health, pig durability, and pork quality. Some pigs have a genetic predisposition to be more susceptible or resistant to diseases. Production facilities and environments with outside breeding and gestation are more demanding and require sows with more durability to successfully reproduce. When the production system does not allow STA usage the management of the pigs will need to increase and the pigs will need to be more tolerant of environmental stresses.

Selection for high production often is accompanied by increases in stress and disease problems. There is vast genetic variation among animals for disease resistance, so even though heritability estimates are low, breeding for disease resistance is possible and justified. Genetics can control responses to infection by affecting the animal's ability to develop an immune response and the size of that response.

The value of pigs not fed or treated with antibiotics will be enhanced if they also have superior meat quality as well as efficient production characteristics. The genetic program has a great influence over both the production cost and market potential. Two factors influencing genetic decisions are the types of facilities under which the pigs are raised and the interaction of genetics with the requirements of the desired market.

The decision as to which population has the best genetic merit for any trait is a difficult one. The producer must consider diverse traits such as reproduction, feed conversion, lean gain, and meat quality. Berkshires and Durocs produced pork with the most desirable meat quality traits when various genetic populations were evaluated by the National Pork Producers Council's (NPPC) Genetic Evaluation (1995). When lean growth and feed conversion were considered along with meat quality, the Duroc-sired pigs were significantly superior to all other tested populations.

Designing a breeding program is not difficult. Select a crossbred female that will maximize reproduction in your system. The breeding and gestation facilities will dictate the type of sow. With crated breeding and gestation, where individual females are intensively managed and do not have to compete for feed or space, a white cross female (e.g., Landrace x Yorkshire) usually will maximize reproduction. Extensively raised females benefit from a partially colored ancestry because they are more durable under outdoor conditions. The boar line should be of a different breed than the crossbred females and should excel in meat quality, growth, muscle, and leanness with adequate structural soundness to successfully produce market pigs.

Within the breeds and lines evaluated by the NPPC, the genetic program required to maximize profit under the quality needs and environmental challenges that do not allow subtherapeutic antibiotic usage will likely have some Duroc and Berkshire genetics for meat quality and durability on the sire side. Landrace or Yorkshire genetics should be present on the sow side for mothering ability.

Economic Factors

Pork producers pursuing restricted antibiotic use production need an accurate knowledge of production costs as well as the value-added market return to ensure a long and profitable business. Producers need to evaluate the impact on production costs of raising pigs without the use of subtherapeutic antibiotics (non-STA) and with the use of subtherapeutic antibiotics (w/STA). The following analysis is a low investment outdoor pork production system, with production efficiencies adjusted to reflect the non-use of STAs. The systems are based on 100 sows and the market hogs are sold at 250 pounds. Results compare the economics of pork production in a low investment environment, including the economic impact of production differences such as death loss and feed efficiency. Producers are encouraged to utilize their own records to substitute values into the tables.

Table 2. Annual Facilities and Equipment Investment

Area	Non-STA		W/STA	
	Per Pig Space	Per Market Hog	Per Pig Space	Per Market Hog
Gestation*	$150.00	$1.14	$150.00	$1.00
Breeding*	$250.00	$1.90	$250.00	$1.67
Farrowing*	$265.00	$2.01	$265.00	$1.77
Finishing**	$60.50	$6.05	$55.00	$5.50
Miscellaneous**	$33.00	$3.30	$29.00	$2.90
Annual Depreciation	$18,953.00	$14.40	$19,235.00	$12.84
Interest (10% of facilities)	$9,477.00	$7.20	$9,617.00	$6.42
Total Facilities	$28,430.00	$21.60	$28,852.00	$19.26

* Per sow space
** Per finishing space

Facility and Breeding Herd Investments

Facility and equipment investments for the system are provided in Table 2. The facilities are the same for both systems with the exception of the finishing phase and provide costs per pig space as well as the annual cost per hog marketed. The facilities are expensed over a 10-year period. Even though both systems have the same total investment cost except for the finishing phase, the investment cost for the w/STA system was less per hog marketed due to the larger number marketed through that system. The finishing investment is higher for non-STA finishing space per pig space due to increased feeder space requirements. Finishing also differs because the w/STA system requires additional space per year due to the increase in pigs marketed per sow per year.

Investment levels were determined using new deep bedded and low cost facilities and equipment for both systems. Facilities were charged 10% interest on the average total investment [(annual depreciation x 10 / 2) x 0.1]. The facility investment level is high due to the use of new facility values. Total facility investment, expensed over 10 years, is $189,534 ($18,953/year) for the non-STA system and $192,351 ($19,235/year) for the w/STA system. Total facility and equipment annual investment is $28,430 for the non-STA system and $28,852 for the w/STA system.

Breeding herd investments are in Table 3. Each gilt costs $175 and each boar costs $750. Total investment is $14,613 but, when sow and boar costs are reduced by the respective cull revenues, the net annual investment cost is $5,256. Annual costs are calculated by dividing the number of sows by the number of years in service and then multiplying by the value of the sows. One-third of the sows and boars are culled per litter plus four percent death loss. One boar is allocated per 17 sows to ensure the tightest possible farrowing period. Boar numbers drop significantly with the use of artificial insemination (AI). AI would be approximately $10 per litter in semen cost plus an increase in labor requirements and costs for boar exposure and insemination pens. AI would eliminate the need of bringing in external animals, because all replacement females could be home-raised.

Expected Production Efficiency Changes

Production efficiency changes, as outlined by Hayes *et al*, (2002), are based on Swedish and Danish observations as subtherapeutic antibiotics were removed from their industries.

1) Weaning age increased by one week because early

Table 3. Annual Breeding Herd Investment

Item	Number	Value	Years in Service	Annual Costs
Sows	100	$175	1.5	$11,667
Boars	6	$750	2.0	$2,250
Sub total				$13,917
Interest	10%			$696
Total				$14,613

Breeding Herd Cull Revenue

	Number	Wt, lb	Revenue	Total Revenue
Sows	64	400	$0.35	$8,960
Boars	2.88	550	$0.25	$396
Total				$9,356
Breeding Herd Net				$5,256

weaning is facilitated upon STA usage.

2) Weaning weight for non-STA pigs was 7 pounds heavier due to weaning one week older.
3) Nursery feed efficiency was 1.77 for the non-STA and 1.63 for the w/STA system. (Holden and Jurgens, 1994)
4) Feed efficiency for the grow-finish (50 to 250 pounds) declined by 1.5 percent for the non-STA pigs.
5) Nursery mortality increased 1.5 percentage points for the non-STA system.
6) Grow-finish mortality increased 0.4 percentage points for the non-STA system.
7) Culled non-STA equals 3.6 percent of the pigs. The example budget assumes pigs are produced for an antibiotic-free market, treated pigs are culled from the herd at 100 pounds and sold for $0.25 per pound. If the use of therapeutic antibiotics is permitted the pigs could be marketed as non-STA pigs after the appropriate withdrawal period.
8) Pigs weaned per sow declined by one per year. This is a decrease of 0.1 litters per sow per year and 2 percent increased pre-wean mortality.
9) Net veterinary and therapeutic costs for the non-STA system increase by $0.25 per pig. This is an additional $1.47 in health costs compared with $1.22 for subtherapeutic antibiotics per pig in the w/STA system.

Table 4. Diet Costs [1]

Diet Phase [2]	Diet /Ton	Non-STA /lb	Antibiotic cost/ton	w/STA /lb
Nursery Diet (LC8-S3)	$254.71	$0.127	$10.00	$0.132
Grower Diet (LC25-S8)	$116.89	$0.058	$ 5.00	$0.061
Finisher Diet (LC25-S10)	$108.24	$0.054	$ 2.00	$0.055
Gestation Diet (LC26)	$101.89	$0.051	$ 0.00	$0.051
Lactation Diet (LC27)	$116.54	$0.058	$ 5.00	$0.061
Weighted Costs/ton or lb	$118.64	$0.059		$0.061

[1] Diet costs include $8/ton mixing and delivery cost.
[2] Holden *et al,* (1994). For example, LC8-S3 equals Table 8, Stage 3.

Feed is the largest cost item in pork production at about 60 percent of production costs. Feed is even more significant for non-STA production because the requirements per unit of gain will be higher. Table 4 estimates diet costs where the diets are the same with the exception of added antibiotics in the w/STA system. Total feed costs include an additional $8 per ton for processing and were calculated using $2/bu corn and $200/ton soybean meal. The average feed price was $0.0593/lb for the non-STA system and $0.0613/lb for the STA system (including the antibiotic cost.)

Table 5 shows feed usage and efficiency for each stage of production and the different efficiency assumptions.

Table 5. Feed Use and Cost by Production Stage and System

Stage	Number of Pigs	Pig Gain, lb	Feed/Gain	Feed, lb	Total Cost	Cost per Pig
Nursery Stage						
Non-STA	1479.6	28	1.77	73,330	$9,339	$7.10
W/STA	1592.5	35	1.63	90,852	$12,025	$8.03
Grower Stage						
Non-STA	1427.8	50	2.39	170,627	$9,972	$7.58
W/STA	1560.7	50	2.35	183,376	$11,175	$7.46
Finisher Stage						
Non-STA	1315.9	150	3.44	678,990	$36,748	$27.93
W/STA	1498.2	150	3.39	761,847	$41,994	$28.03
Gestation			Feed/sow/yr.			
Non-STA	100		1475	147,500	$7,514	$5.71
W/STA	100		1545	154,500	$7,871	$5.25
Lactation						
Non-STA	100		730	73,000	$4,254	$3.23
W/STA	100		615	61,500	$3,737	$2.49
Total						
Non-STA	1315.9	250	3.48	1,143,447	$67,827	$51.55
W/STA	1498.2	250	3.34	1,252,075	$76,803	$51.26

The lactation feed is lower for the w/STA system because the lactation is shortened by one week. The overall feed efficiency is 3.48 for the non-STA system and 3.34 for the w/STA system.

Table 6 summarizes pigs per litter and death loss for the various production phases for the systems. The w/STA system has an advantage of 1.82 pigs finished per sow per year. This impacts the facility, reproduction, and labor costs.

Table 6. Production Efficiency Information

Item	Non-STA	W/STA
Total Feed Efficiency	3.48	3.34
Pigs Born Live Per Litter	8.75	8.75
Pre Wean Mortality, %	11.0%	9.0%
Pigs Weaned/Litter	7.78	7.96
Nursery Mortality, %	3.50%	2.00%
Grow Finish Cull, %	3.60%	0.00%
Grow/Finish Mortality, %	4.40%	4.00%
Pig Finished/Litter	6.93	7.49
Litters/Sow/Yr.	1.90	2.00
Pigs Finished/Sow/Yr.	13.16	14.98

Production Costs

Table 7 summarizes total production costs and portrays a year-round outdoor farrowing system including a building and outdoor run for winter farrowing. Bedding reflects current hoop buildings from ISU with bedding costs added for farrowing. Labor is $10.00 per hour and 11 hours are required per litter. The breakeven production cost is $44.52/100 lb gain for the non-STA system compared with $42.36 for the w/STA system; a difference of $2.16/100 lb gain or $5.39 per 250 lb pig marketed.

This analysis indicates that it costs $2.16 per hundredweight ($5.39 per pig) more to produce pork through the non-use of subtherapeutic antibiotics than with the subtherapeutic use of antibiotics. There is a signifigant increase of non-antibiotic feed costs ($1.50), labor costs ($1.20), breeding herd costs ($0.49), and fixed costs ($2.35). The largest issue was the difference in pigs finished per sow. This resulted in differences in labor, fixed costs, breeding herd costs, and a portion of the feed costs.

Summary

A combination of producers and consumers would like the ability to produce and purchase pork from pigs that have reduced exposure to antibiotics. Producing pigs without using subtherapeutic antibiotics or feeding no antibiotics requires enhanced management skills. These include paying particular attention to alleviating stresses that weaken the pig's ability to fend off infections that

Table 7. Cost of Production

	Non-STA		W/STA		Added Non-STA Cost
Variable Costs	Total	Per Head	Total	Per Head	
Feed	$67,827	$51.55	$76,803	$51.26	$0.28
Health Costs	$6,546	$4.97	$5,250	$3.50	$1.47
Bedding	$6,579	$5.00	$7,491	$5.00	$0.00
Repairs	$1,895	$1.44	$1,924	$1.28	$0.16
Fuel/Utilities	$2,632	$2.00	$2,632	$1.76	$0.24
Sub Total	$85,479	$64.96	$94,099	$62.81	$2.15
Interest	$4,274	$3.25	$4,705	$3.14	$0.11
Labor	$20,900	$15.88	$22,000	$14.68	$1.20
Breeding Herd	$5,256	$3.99	$5,256	$3.51	$0.49
Marketing	$3,290	$2.50	$3,746	$2.50	$0.00
Total Variable	$119,199	$90.59	$129,805	$86.64	$3.95
Fixed costs	$28,430	$21.61	$28,852	$19.26	$2.35
Cull Revenue	–$1,184	–$0.90			–$0.90
Total	$146,445	$111.29	$158,658	$105.90	$5.39
Total Hogs Sold	1,316		1,498		
Total Wt Sold, lb	328,968		374,556		
Breakeven/cwt.	$44.52		$42.36		$2.16

often require the use of either therapeutic or subtherapeutic antibiotics.

Important issues to be considered range from biosecurity measures to the increased costs associated with the production of antibiotic-free pigs or pigs produced without the use of subtherapeutic antibiotics. Production of non-antibiotic pigs generally will have higher production costs than the non-STAs group because of the variability in growth rates and feed efficiencies, anticipated mortalities and sporadic disease episodes that require removal of pigs from the program. The projected additional cost of $5.39 per pig resulting from the non-use of STAs and higher costs for no-antibiotic pigs indicates the need to find an established market willing to pay a premium for each pig produced before production begins.

Consumer approval of pork production systems is a non-economic value not determined in this analysis. However, this publication's thesis is that a percentage of consumers are willing to pay a premium for pork produced with minimal or no use of antibiotics. Producers wishing to enter this market need to find interested consumers before making changes in their management systems.

The "Suggested reading" section lists additional sources of information and software programs that help define a breeding and pig movement schedule to allow the segregation of different groups of pigs.

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