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

Authors:
Gary R. Parker, University of Kentucky
Gary Cromwell, University of Kentucky
Virgil W. Hays, University of Kentucky
James McKean, Iowa State University
Reviewers:
Bruce and Kimberly Esham, Millsboro, Delaware
Bridgitte Franzen, Lincoln, Illinois
E.T. Kornegay, Virginia Polytechnic Institute and State University
Beth Lautner, Des Moines, Iowa
Dean Zimmerman, Iowa State University

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Feed additives are non-nutritive compounds added to swine diets for the purpose of enhancing animal performance. Those used in swine diets include antibacterial agents, anthelmintics, direct fed microbials (probiotics), organic acids, copper sulfate, flavoring agents, pellet binders and antioxidants. Of these, antibacterials and anthelmintics are the major ones added to swine feeds. Some of them have been used extensively in the United States over the last 40 years.

Antibacterial Agents

Antibacterials (antibiotics and chemotherapeutics) are medications added to swine feeds to improve health and performance. A list of compounds and levels approved for specific purposes such as growth promotion, prevention of disease, and treatment of a specific disease are included in the Feed Additive Compendium[1]. The medications and levels used are approved by the Food and Drug Administration (FDA). It is the FDA's responsibility to determine that products intended for animal use are safe, effective, and properly labeled, and that food derived from treated animals is safe to eat.

Antibiotics are compounds produced by bacteria or molds that inhibit the growth of other microorganisms. Chemotherapeutics are chemically synthesized compounds that inhibit the growth of certain microorganisms. They may be used alone or in conjunction with antibiotics for the purposes of enhancing growth and feed efficiency, or for disease control in swine. It is generally accepted that the beneficial effects of these compounds result from alteration of the bacterial population primarily within the animal's digestive tract. The actual mechanism by which antibacterials exert the growth promoting effect in the absence of clinical disease situations has remained elusive throughout the 40-plus-year history of feeding these compounds. A number of possible mechanisms have been suggested, each of which may contribute to the observed responses:

Metabolic Effect. The metabolic effect implies that antibacterial agents improve performance through a direct effect on the metabolic processes in the animal. This is not a reasonable explanation, however, for the antibacterials which are not absorbed from the intestinal tract, unless the metabolic effects are at the intestinal cell level and possibly involved in the nutrient absorption processes.

Nutritional Effect. Certain bacteria that inhabit the intestinal tract synthesize vitamins and amino acids essential to the host, while others compete with the animal for essential nutrients. Shifts in bacterial populations due to the feeding of antibacterials may result in a greater availability of nutrients to the host animal. Also, antibacterials have been shown to reduce the thickness of the intestinal wall, potentially resulting in greater absorption of nutrients. In addition, antibacterials reduce the total mass of the gut, so less nutrients are needed for the rapid turnover and high energy demands of these body tissues.

Disease Control Effect. Greater responses in young vs. older pigs, in unsanitary vs. clean environments, under production vs. experimental conditions, and in normal vs. germ-free animals all point to disease control as being the primary explanation for improved performance by pigs fed diets supplemented with antibacterials[2,3]. Antibacterials suppress those bacteria in the intestinal tract that cause subclinical or nonspecific disease. Chronic stimulation of the immune system to fight these organisms may result in reduced feed intake and repartitioning of protein and energy sources away from lean growth. Control of these subclinical diseases allows the animal to perform up to or near its genetic potential.

The response to antibacterials seems to be as large today as it was in earlier time periods. Hays (1977)[2] and Zimmerman (1986)[3] summarized the studies on the effects of antibacterials on pig performance during the periods of 1950 to 1977 and 1977 to 1985, respectively. The data in Table 1 compare the average percentage improvements resulting from antibacterial usage in the two time periods. The improvements in rate of gain and efficiency of feed utilization are similar for the two periods. Antibiotics and chemotherapeutics remain the most consistently effective feed additives for improving animal performance.

Table 1. Improvements in performance of pigs fed antibacterials during the years of 1950-1985.

		Improvement, %	
Years	Periods[a]	Daily gain	Feed/gain
1950-1977[b]	Starter	16.1	6.9
	Grower-finisher	4.0	2.1
1978-1985[c]	Starter	15.0	6.5
	Grower-finisher	3.6	2.4

[a]Starter period from about 15 to 55 lb. and grower-finisher from 55 to 200 lb. body weight.
[b]Hays (1977); 15,689 pigs.
[c]Zimmerman (1986); 10,083 pigs.

Table 2. Withdrawal time for antibacterials in swine feeds.[a]

Additive	Withdrawal time before slaughter, days
Bacitracin, methylene disalicylate	none
Bacitracin, zinc	none
Bambermycins	none
Chlortetracycline	none
Oxytetracycline	none[b]
Penicillin	none
Tylosin	none
Virginiamycin	none
Apramycin	28
Arsanilic acid or Sodium Arsanilate	5
Carbadox	70
Chlortetracycline/ sulfamethazine/penicillin	15
Chlortetracycline/sulfathiazole/penicillin	7
Colimix	21
Lincomycin	6
Neomycin/oxytetracycline	5[c]
Roxarsone	5
Tiamulin	2
Tylosin/sulfamethazine	15

[a]Feed Additive Compendium, 1994.
[b]At 500 g/ton use level, withdraw 5 days before slaughter.
[c]Withdraw from feed 20 days before slaughter when neomycin base level is 140 g/ton and 5 days before slaughter when neomycin base level is below 140 g/ton.

There are several individual antibacterial agents and combinations approved for use in swine diets. The more common additives and their withdrawal times are listed in Table 2. Selection of a specific feed additive and the level necessary for optimal response vary depending on several factors including: the stage of growth, with percentage response being less as the pig increases in age; disease incidence within the herd; antibacterial spectrum of additive used; the cleanliness and comfort of the environment; and required withdrawal time.

Usage level of an additive or combination of additives must comply with FDA approvals and the manufacturer's directions. The FDA classifies additives into those that have a high degree of human safety requiring no withdrawal time and those with a higher potential risk for residue in edible tissue. The latter have specific withdrawal times before slaughter (Table 2). Producers must use medications responsibly in their feeding program. They must know the approved use levels and withdrawal periods of the compounds they use. Extra-label usage (higher than approved FDA levels or unapproved combinations) of feed additives is not permissible.

Antibacterials are not as commonly used with breeding animals as in diets for growing pigs. Research has shown antibacterials to be effective during certain critical stages of the reproductive cycle, such as at the time of breeding. A summary of nine research trials shows that a high level (0.5 to 1.0 gram/sow/day) of an absorbable antibiotic (such as one of the tetracyclines) fed before and at the time of breeding improved farrowing rate by 7% to 10% and litter size by 0.4 to 0.5 pig/litter at the subsequent farrowing[4] (Table 3). Generally, benefits from antibacterials in gestation diets other than during the breeding period are minimal. Antimicrobial agents are thought to be beneficial at farrowing and during early lactation because the sow and her pigs are more vulnerable to stress at this time. The data in Table 4 suggest that weaning weights and pig survival are increased slightly when these agents are included

Table 3. Effects of antibacterials at breeding on reproductive performance of sows.[a]

	Control	Antibacterial[b]
Farrowing rate, %[c]	75.4	82.1
Live pigs/litter	10.0	10.4

[a]Cromwell (1991); Data on 1,931 sows, 9 experiments, 1962-1987.
[b]In most cases, 0.5-1.0 gram/sow/day prior to and after breeding.
[c]Percent of sows bred that farrowed.

Table 4. Antibacterial agents in the prefarrowing and lactation diet for sows.[a]

	Control	Antibacterial[b]
Pigs born alive/litter	10.3	10.6
Pigs weaned/litter	8.2	8.6
Survival, %	84.9	87.1
Weaning weight, lb.	10.24	10.35

[a]Cromwell (1991); Summary of 11 experiments, 2,105 litters.
[b]Tetracyclines, chlortetracycline-sulfamethazine-penicillin, tylosin or copper sulfate fed from 3-5 days prepartum through 7-12 days of lactation.

in the prefarrowing and lactation diet[4].

Copper Compounds (sulfate, carbonate or amino acid complexes)

Elemental copper is a required nutrient for normal pig growth and well-being. It is routinely added to swine diets at the rate of 6 to 11 ppm to meet this nutritional requirement. Copper possesses antibacterial and antifungal properties, and it is an effective growth promotant when fed at concentrations of 100 to 250 ppm (.8 to 2 lb of hydrated copper sulfate/ton of feed) in the diet [5,6]. The addition of 250 ppm copper to swine diets improves performance of weanling and growing-finishing swine as illustrated in Table 5. In young pigs, the combination of copper and growth promotant antibiotics results in a greater growth response than the feeding of copper or antibiotics alone[4,7] (Table 6).

Copper, when fed in excess of 250 ppm for an extended period of time, is toxic. The severity of the toxicity is related to the level fed, the duration of feeding, and the chemical form of the copper. Furthermore, copper toxicity is increased if the diet is low in zinc and iron. Therefore, producers should check with their feed manufacturer about the concentrations of copper, iron, and zinc present in commercial feeds or mineral mixes before adding copper to feeds. Drawbacks to copper supplementation include increased corrosion of metal equipment, increased dirtiness of pigs and their surroundings, decreased bacterial degradation of manure in lagoons, and environmental contamination.

Direct-fed Microbials or Probiotics

Probiotics are mixtures of living bacteria and/or yeasts that are fed with the intention of establishing a desirable microflora to compete with deleterious bacteria within the small and large intestine. Numerous microbial products are available for inclusion in swine feeds[8], such as *Lactobacillus species, Bacillus subtilis, Streptococcus faecium* and *Saccharomyces cerevisiae*. The current theory for activity is that these organisms, through competitive inhibition or modification of intestinal pH, favor the development of desirable health promoting microorganisms that theoretically improve weight gain and feed efficiency. To be effective, the microorganisms should be established as normal inhabitants of the intestinal tract of healthy animals. They must be acid- and bile-tolerant to survive passage through the stomach and to become established in the small intestine.

It also has been suggested that the beneficial actions of direct fed microbials (competitive inhibition) include changing the enteric flora and reduction of *E. coli*, synthesizing lactate with subsequent reduction in intestinal pH, adhering to or colonizing in the digestive tract, producing antibiotic substances, and reducing toxic amines and ammonia levels in the gastrointestinal tract and blood[9].

Table 5. Effect of copper sulfate on performance of weanling and growing-finishing pigs.

	Copper, ppm[a]		Improvement
Growth stage	**0**	**250**	**%**
Starting period (15 to 30 lb)[b]			
Daily gain, lb	.51	.62	21.6
Feed/gain	2.04	1.86	9.7
Growing period (40 to 123 lb)[b]			
Daily gain, lb	1.47	1.56	6.1
Feed/gain	2.80	2.70	3.7
Growing-finishing period (40 to 205 lb)[c]			
Daily gain, lb	1.56	1.6	4.2
Feed/gain	3.18	3.10	2.5

[a]Does not include copper in trace mineral mix.
[b]Cromwell et al., 1988. Summary of 12, 28-day experiments with 482 pigs weaned at 28 days of age, 44 replications of 4 to 8 pigs/pen, conducted at the University of Kentucky from 1978 to 1983.
[c]Cromwell et al., 1988. Summary of 18 experiments, 84 replications of four pigs per treatment, conducted at the University of Kentucky from 1970 to 1980.

Table 6. Effects of single and combined additions of copper and antibacterials on performance of weanling pigs.[a]

	Additive			
	None	**Copper[b]**	**Antibacterial[c]**	**Both**
Daily gain, lb	.46	.57	.55	.62
Feed/gain	1.98	1.87	1.81	1.75
Survival, %	95	100	93	98

[a]Two trials involving 256 pigs from 4 to 8 weeks of age (15 to 30 lb)
[b]250 ppm copper as copper sulfate.
[c]55 ppm chlortetracycline in one experiment, 27 ppm of virginiamycin in a second experiment.

Although probiotics have been commercialized and used to some extent for more than 45 years, the documented evidence of their therapeutic and nutritional value is still quite variable. Some of the possible reasons for the variability of results are poor viability of microbial cultures in the feed or in storage, strain differences of probiotic cultures, dose level and frequency of feeding the culture, drug and feed ingredient interactions which neutralize viable probiotic colonies, composition of diet (lactose in diet favors colonization by certain probiotics), and lack of systematic investigation by researchers.

Previously, research information on probiotics was not required to substantiate therapeutic or growth promotional claims. However, on June 2, 1988, the FDA published a compliance statement on direct-fed microbial products. Under the new guidelines, a direct-fed microbial product that is labeled/promoted with any therapeutic or growth promotional claims is considered a new animal drug. Before a drug can be sold with therapeutic and/or growth claims, the FDA requires a completed new animal drug application (NADA) which includes validation of safety and effectiveness for claimed results. The intent of this regulation is to minimize misleading or deceptive advertising for therapeutic and growth promoting claims for microbial products. **To date (March, 1994) no direct-fed microbial products have cleared the FDA review process.**

Organic Acids

Of the several organic acids available for use in feeds, fumaric acid and citric acid are most commonly used. Improvements in gain and feed efficiency in weanling pigs have resulted from including organic acids in the diet. The exact mode of action is not known, but it has been rationalized from several positions:

- Acidification of the diet may decrease stomach pH and increase pepsin activity (required for protein digestion),
- Reduced stomach pH may decrease the rate of stomach emptying, thus increasing time for protein digestion in the stomach,
- Reduction in stomach pH may reduce the proliferation of coliforms and other pathogens in the upper gastrointestinal tract, and
- Organic acids may serve as preservatives to reduce deterioration of feed quality.

The effects on performance of organic acid additions to diets vary with age of pigs, the amount of milk by-products or other ingredients in the diet, and the presence or absence of antibacterials. At the present time, the optimal inclusion rate seems to be between 2% to 3% of the diet; at these inclusion rates it is generally difficult to show an economic benefit from using organic acids.

Anthelmintics (Dewormers)

Swine are susceptible to infection by numerous species of internal parasites (See PIH-44, *Internal Parasites*). These parasites vary widely in structure, size, shape, habits, life cycle, and extent of injury to swine. The pork producer has available a wide array of anthelmintics that are very effective in controlling several parasite species.

Some anthelmintics are more effective than others for certain species of internal parasites. Producers should be aware of the parasite spectrum and efficacy data of each anthelmintic to be utilized. Anthelmintics may be added to swine feed for limited periods to kill (purge) immature and mature parasite stages in growing/finishing swine and in the breeding herd. This type of deworming program usually removes the immediate parasite burden, but it needs to be repeated (frequency of treatment depends on species of worm and intensity of exposure) for effective control. Continuous feeding of some anthelmintic products reduces parasitism throughout the feeding period. Currently, two dewormers (pyrantel tartrate and hygromycin) are approved for continuous inclusion in the diet. These anthelmintics reduce the immediate parasite burden and help prevent the problem from recurring for those parasites for which they have activity. Withdrawal periods for the feed additive anthelmintics are listed in Table 7.

Table 7. Withdrawal time for anthelmintics in swine feeds.[a]

Chemical name	Withdrawal time before slaughter, days
Dichlorvos	none
Fenbendazole	none
Hygromycin B	15
Ivermectin	5
Levamisole Hydrochloride	3
Pyrantel Tartrate	1
Thiabendazole	30

[a]Feed Additive Compendium (1993).

Other Additives

Flavors are sometimes added to diets to enhance the aroma or taste of the feed. Most research data suggest flavors are of limited benefit unless one is attempting to mask off-odors or off-flavors in feeds.

Enzymes are sometimes included in feeds for the purpose of assisting in the digestive process. Most research indicates very little benefit from enzyme supplementation. Exceptions to this include the enzymes beta-glucanase and phytase. Beta-glucanase has been shown in certain instances to benefit the utilization of barley that is rich in beta-glucans, a complex carbohydrate that interferes with the pig's ability to efficiently digest and utilize the nutrients in this grain. Phytase enhances the availability of organic phosphates, the major form of phosphorus in plant materials. The use of phytase reduces the amount of supplemental inorganic phosphorus needed in diets to meet the pig's requirement.

Antioxidants often are included in feeds that are high in fat. They reduce oxidative rancidity in feeds, especially in hot weather, and reduce oxidative losses of essential vitamins.

Frequently pellet binders are added to improve the pelleting process and increase the cohesiveness of the pellets, thus reducing disintegrated pellets or fines in the feed mix. Also, several of the clays that are used as pellet binders are effective in binding aflatoxins in mold corn.[10] Inclusion of these clays in the diet is a common practice when feeding aflatoxin-contaminated grain to pigs.

Proper Use of Feed Additives by Producers

Producers should follow directions for feed additive usage as provided by the manufacturer (See PIH 86, *Management to Prevent Drug Residue Problems in Pork*). Thoughtful use of these compounds to maximize profits, while preventing residues and reducing consumer concern, is important. Participation in the Pork Quality Assurance Program[11] of the National Pork Producers Council is helpful in managing the use of feed additives.

Efficacy claims, approved usage concentrations in feed, and withdrawal times are regulated by the FDA. USDA-FSIS (United States Department of Agriculture Food Safety and Inspection Service) routinely monitors for residues in pork carcasses at packing plants. Every pork producer must take precautions to abide by FDA required pre-slaughter withdrawal times for feed additives and other medications. Disregarding these regulations could result in a sizable monetary loss to individual producers from condemnations due to tissue residues and to the pork industry from withdrawal of approval for certain effective feed additives. In addition, adverse publicity associated with residues can reduce consumer demand for pork products.

In using medicated feeds (antibacterials, anthelmintics, etc.) the producer should:

1. Read the feed tag to assure the additive is being fed at approved concentrations and for valid reasons.

2. Comply with the proper withdrawal times to avoid residues, thereby ensuring safe, wholesome pork.

3. Prevent drugs and/or medicated feeds from contaminating other medicated or nonmedicated feeds in mixers and feed handling equipment, through appropriate clean out and sequencing procedures.

4. Avoid giving additional medications to animals on medicated feed without professional advice. One compound may interfere with the effectiveness or clearance rate of another drug.

5. Use only those medications approved for swine and only for the appropriate purpose and appropriate stage of production.

Summary

Feed additives available to producers include antibacterial agents, anthelmintics, organic acids, and direct-fed microbials, and to a lesser extent, flavors, enzymes, antioxidants, and pellet binders. Current research has shown that antibacterials and copper compounds provide the most consistent improvements in growth rate and feed efficiency.

To maximize returns, producers should obtain professional help to develop a specific feed additive program based on their unit's needs. A well planned program can help prevent management errors associated with withdrawal times and make it easier to execute specific disease prevention and treatment programs. Practice good feeding, sanitation, disease control and management techniques. Also, seek and utilize the services of a practicing veterinarian and an animal nutritionist to formulate effective medication and feed programs.

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