The disposal of dead pigs: A review

W Morgan Morrow, BVSc MS, PhD; and Peter R Ferket, BSc, MS, PhD

Summary *— We explored options for disposing of dead pigs, including some recent technologies developed for the poultry industry. The methods, including trench burial, disposal pits, incineration, composting, as animal feed, extrusion, fluidized bed drying, flash dehydration, freezing, fermentation, and acid preservation are described. The relative advantages and disadvantages of each method, including cost, impact on the environment, and ability to destroy pathogens are compared.*

Increased public concern for the environment and resulting stricter regulations governing the disposal of dead pigs present a new challenge for the hog industry. The volume of dead pigs produced annually is daunting — a 1000-sow farrow-to-finish farm with:

- 7% mortality in the sow herd,
- 10% mortality in the neonatal phase,
- 5% mortality in the nursery phase,
- 1% mortality in the growing phase, and
- 1% mortality in the finishing herd

will produce approximately 20 tons (1.8×10^4 kg) of dead pigs in one year. In the past, these pigs have typically been either buried, incinerated, or taken for rendering. Unfortunately, these three disposal methods are now less acceptable or unavailable. Buried animals can contaminate ground water and smoke from burning animals will contaminate the air. Many rendering plants are closing, leaving fewer hog operations with that option. The industry's challenge is to find inexpensive, environmentally-friendly alternatives (that do not spread disease) for disposing of dead pigs.

The poultry industry has developed two techniques — composting and fermentation — that the swine industry can potentially use. However, all American states regulate the disposal of dead animals and state authorities must first approve these alternative techniques before they can be implemented in the field.

Disposal procedures: On-farm

Most pig carcasses are disposed of on-farm: they are buried in a trench or disposal pit, or burned. The major advantage of on-farm disposal is biosecurity. Outside collection trucks need not visit the farm nor must farm trucks risk contamination when visiting a rendering plant or central collection site.

Trench burial

Because trench burial is such a cheap and efficient disposal method, it is used extensively worldwide. Usually, a trench large enough to accommodate the carcasses is dug with a backhoe. Once buried, the pigs slowly decompose until after a few years they are unrecognizable. All major hog-producing states approve of trench burial. Some states specify a minimum depth of either 3 or 4 ft (0.9 or 1.2 m) and some specify a maximum depth of 6 or 8 feet (1.8 or 2.4 m). Also, some states mandate that the material covering the trench be from 30 to 48 in (0.76 to 1.2 m) deep. Hermel (*National Hog Farmer,* March 15, 1992; pp 34–42) reviewed state requirements governing the dimensions of the trench and their proximity to water supplies.

The major disadvantage of burial is that the carcasses can contaminate groundwater supplies, particularly in areas with light soil and a high water table. In colder areas it is difficult, if not impossible, to dig frozen ground during the winter months. Also, predators can uncover the carcasses, which is unsightly and a disease risk. Probably because it is such a basic disposal technique, there is no research documenting the relative advantages or disadvantages of trench burial.

Disposal pits

Although disposal pits are more common in the poultry industry than the swine industry, they have some advantages over other burial techniques. It is easy to build disposal pits that have solid walls and a solid top but with a permeable base so carcasses can be added continuously (Wineland MJ, 1990, *Proc Natl Poultry Waste Mgmt Symp,* pp 69–74). Although there is some aerobic activity on the top of the pile, decomposition is primarily accomplished by various microorganisms that anaerobically digest the polysaccarides, proteins, and fats of the carcass into substrates for methogenic

WMM, Department of Animal Science; PRF, Department of Poultry Science: North Carolina State University, Raleigh, North Carolina 27695

bacteria. This decomposition process produces methane, carbon dioxide, and other malodorous compounds, and depends on the successive interaction of a variety of organisms[1] that are temperature-, pH-, and oxygen-dependent. If the environment favors the growth of acid-forming bacteria, decomposition-inhibiting fermentation can occur (see Fermentation section). For poultry, Lomax and Malone (1988, *Proc Intl Summer Mtg of Am Soc of Ag Eng*) showed that decomposition was faster at 35°C than at 24°C, permitting higher loading rates.

Interestingly, a variety of insects are found in disposal pits. By consuming carcass flesh and burrowing through the surface of the skin, they increase the surface area accessible to microorganisms, thereby positively contributing to the decomposition process (Rives D, et al, 1992, *Proc Natl Poultry Waste Mgmt Symp,* pp 409-412). Provided the pit is rainproof, little water will leak from the base because the decomposition process produces little water. Unfortunately, anaerobic digestion can generate hydrogen sulphide in concentrations that can exceed human safety levels (Malone EW, 1988, *Proc Natl Poultry Waste Mgmt Symp,* pp 73-75). For a review of the construction and operation of on-site disposal pits for poultry read Sweeten and Thornberry (1984, *Proc 16th Ann Texas Broiler Symp*).

Incineration

Although incineration eliminates all pathogens, it is costly and produces pollution. Incinerators can be made from old low-pressure (LP) gas tanks for less than $1000 (Fig 1). A fully-insulated incinerator with afterburners to decrease pollution can be purchased for less than $2000. Converted LP gas tanks must often be replaced after 5 years; the purpose-built burners last much longer. Operation costs include the grates, which must be replaced every 2-3 years, and the oil or gas fuel. The 160-sow, farrow-to-finish demonstration farm at Rocky Mount, North Carolina averaged 844 gal (3200 L) fuel oil for each of the 8 years ending in 1990. At $1 per gal, the fuel oil alone would amount to $5.27 per sow per year.

Fig 1.— Incineration

All major hog-producing states permit the incineration of hogs but do not allow hogs to be burned in a field. Of all the methods of disposal, incineration generates the most public complaints and is therefore the least likely to remain an option (Murphy DW and Handwerker TS, 1988, *Proc Natl Poultry Waste Mgmt Symp,* pp 65-72).

Composting

The poultry industry, which has experienced increasing difficulty in disposing of its dead birds, has developed an alternative in composting (Fig 2). Composting uses waste products (such as dead pigs, straw, and poultry litter) and converts them into an odorless, inoffensive, generally pathogen-free product that can be used as a soil amendment or organic fertilizer. The process of composting carcasses is the same as that used to compost garden waste. A succession of mesophilic and thermophilic microorganisms, including bacteria, fungi, and actinomycetes, feed on the organic substrates to produce carbon dioxide, water, minerals, and a stabilized organic matter called humus. The speed and efficiency of this aerobic process depends on the temperature, nutrients, moisture, availability of oxygen, and particle size.

Fig 2.— Composting

Temperature

Because a compost pile contains a diversity of temperature-sensitive organisms, some decomposition occurs at virtually any temperature; however, the optimum temperature for microbial activity is < 55°C. (McKinley VL, et al. 1985. *Biocycle* 26:47-50.) Decomposition of pig carcasses slows considerably in winter but increases in the spring when temperatures rise. In North Carolina, our compost piles consistently reach temperatures > 55°C, which killed most of the *Salmonella,* and all of the *Erysipelas,* in broth cultures placed throughout the pile. Poultry compost piles routinely reach 70°C. The temperature can be controlled by adjusting aeration and moisture and covering the pile with an insulating layer of the carbon source (e.g. straw) each time pigs are added to the pile. The optimum temperature for the pile, then, must be a compromise between the temperature range that favors microbial activity and that which will result in the fastest decomposition (45°C–50°C) and the temperatures at which pathogens can be destroyed (> 55°C for *Salmonella,* some of the most heat-resistant pathogens).

Nutrients

Composting microorganisms need appropriate nutrients to work effectively. The most important are carbon and nitrogen. Phosphorous, sulfur, calcium, and trace quantities of other nutrients are required for cell growth. A carbon : nitrogen ratio between 20 : 1 and 35 : 1 is optimal. Above that range, decomposition slows. Below a ratio of 15 : 1, nitrogen is lost as ammonia, which reduces the value of the humus and creates an odor problem. Adjusting the components of the pile to get the correct ratio is the key to successful composting. The recipe we have used successfully is:

- 100 lb (45.4 kg) of dead pigs,
- 150 lb (68.0 kg) of turkey litter, and
- 10 lb (4.5 kg) of wheat straw.

Moisture

Since water is essential for nutrient solubilization and cell protoplasm, a moisture content below 20% can severely inhibit the decomposition process. Too much water will block air movement, causing the pile to become anaerobic. The optimum moisture level is 45%–55%. We have achieved this level by adding 4 gal (15 L) water to the above recipe.

Oxygen

Decomposition in the compost pile is fastest when aerobic conditions prevail throughout. In reality, aerobic conditions probably exist only at the periphery of the 6×4×5 ft (1.8×1.2× 1.5 m) piles we construct, which slows decomposition. Commercial composting operations for municipal waste can mechanically aerate their piles by periodically turning the piles, inserting perforated tubes, dropping the piles from floor to floor, or pumping air through them. Too much aeration can dehydrate the pile and waste heat so that the piles do not reach temperatures sufficient for proper decomposition (45°C) or pathogen destruction (> 55°C). In practice, the piles are turned 2–3 days after each temperature peak. This aerates the piles and restarts decomposition. It takes 2–5 days after turning for temperatures in the pile to peak again. Emulating the success of composting dead birds, we have found that it is sufficient to turn the pile three times.

Particle size

The smaller the particle size of the compost, the greater the surface area available to the microorganisms. However, some material must be large enough to provide structural support and to trap the oxygen needed for aerobic digestion. Murphy (1992, *Proc Natl Poultry Waste Mgmt Symp,* pp 33–40) has demonstrated that by cutting into and pulling apart the thorax, abdomen, and muscles, it is possible to compost pigs weighing up to 300 lb (136 kg). In practice, pig carcasses of less than 30 lb (14 kg) need not be cut open, and the straw that we have used provides carbon, structural support, and the necessary aeration.

The location, construction, operation, and precautions we used for composting dead pigs are similar to those required for poultry (as detailed in the publication "Composting Poultry Mortality in North Carolina" available from the North Carolina Cooperative Extension Service). The North Carolina State Veterinary office has authorized us to conduct experiments to tailor those requirements to the swine industry.

As feed for animals

In deference to the mink industry, the state of Minnesota permits the feeding of carcasses specifically to fur animals. The hazard of feeding dead pigs to livestock is well known to any farmer who has lost dogs and cats that had access to pigs that died of Aujeszky's disease (pseudorabies). However, some states allow producers to feed carcasses to animals (other than fur-bearing ones). One 2000-sow hog farmer in Pasco County, Florida is profitably feeding processed dead hogs and poultry to alligators that are slaughtered for their meat and hides.[2] Also, a hog farm in Singapore fed all its dead pigs to crocodiles that were slaughtered for the local leather industry.

Disposal procedures: Off farm

There are two main methods to dispose of pig carcasses off-farm:

- Taking them to a landfill: For routine use, or when supply exceeds disposal capacity, producers can sometimes take pig carcasses to a landfill. However, many municipal authorities now refuse pig carcasses even though state regulations permit their disposal in a landfill. Landfills can charge \$10–\$30 per ton (\$11–\$33 per tonne), which is cost prohibitive. Landfills raise the same concerns of groundwater contamination and predators as on-farm burial.
- Selling them to a rendering facility: Rendering was and is the best means for converting carcasses into a valued, biologically safe protein byproduct. Unfortunately, because world prices for fat, protein, and hides are depressed, fewer rendering facilities are in operation. Transporting carcasses can be prohibitively expensive if the rendering facility is too far away. Some counties have designated sites for the central pickup of carcasses. Central pickup and delivery to a rendering plant is an environmentally sound and efficient method for recycling pig and poultry

Table 1. — Advantages and disadvantages of extrusion processing.
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	Advantages	Disadvantages[1]
Protein	Denaturization; inactivation of growth inhibitors; breakdown of secondary bonds; formation of new bonds	Destruction of amino acids and cross-linking reactions of polymers with protein and carbohydrates
Starch	Improves digestibility by gelatinization and expansion; break down to simple "sweet" components	Hydrolysis of carbohydrates
Fat	Mixing; oil extraction; increase fat digestibility; encapsulation of oil; formation of fat and starch complex (1:10 ratio); improve stability by inactivation of lipolytic enzymes	Oxidation of lipids and flavor components
Fiber	Bulk density reduction; increase nutrient and fiber digestibility	Not applicable
Vitamins	Not applicable	Loss of vitamin activity, especially with A, D, E, C, B_1, B_6, pantothenate, biotin, and foliates
Minerals	Not applicable	Possibly phytate complex with zinc, magnesium, and phosphorous
Microorganisms	Destruction of bacteria, molds, fungi, yeast, and protozoa. Some extruders destroy viruses and mold spores	Not applicable
Toxic compounds	Destruction of glycoalkaloids; reduce gossypol toxicity; detoxify aflatoxin with the addition of 1.5% ammonium hydroxide; destruction of allergins	Not applicable
Palatability	Increased sweetness, unpleasant volatile flavor components flushed off during expansion; improved texture	Development of undesirable flavors by reaction products
Feed form	Versatility of feed density; texture and shape; improved mechanical durability of finished feed; no need for pellet binders, improve water stability	Not applicable

[1]Disadvantages are dependent upon the severity of the cooking process, which can be altered by dwell time, screw rotation, speed, and moisture.

carcasses. However, because the central site is visited by many producers, biosecurity is crucial and strict policies must be established and adhered to (Parsons J and Ferket PR, 1990, *Proc Poultry Serv Short Course*, pp 7–20). Construction costs can vary depending on the amount of work the site requires. Prices received for the carcasses also can vary considerably. Greene County in North Carolina profitably operates a site that accepts both poultry and livestock.

In addition to these off-farm disposal options, there are several off-farm disposal technologies that swine producers are using more and more frequently:

Extrusion

Extrusion is not a new technique for the food industry. It has been used to process human food for more than 50 years and it is the foundation of the pet food industry, producing 13 billion lb (5.9×10^6 kg) of product with a market value of $8 billion annually. High-quality feed products have been manufactured from:

- extruded whole chicken carcasses,[3]
- poultry offal and feathers (Blake JP, et al, 1990, Proc Midwest Poultry Fed Mtgs; Vandepopuliere JM, 1990, *Proc Natl Poultry Waste Mgmt Symp,* pp 64-67), and
- hatchery waste.[4]

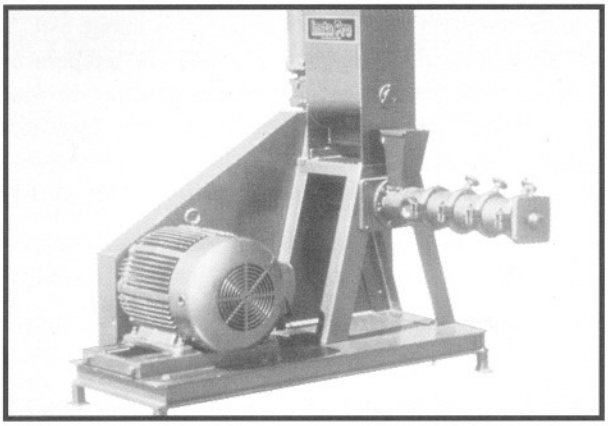

Fig 3.— Single-screw extruder

Material is fed into a raw material bin, then to a mixer, and finally into the extruder, which works by using friction to create heat, shear, and pressure. In the extruder, a screw (or screws) forces the material through a series of baffles where temperatures reach 115°C–155°C and pressure reaches 20-40 atmospheres (2.0×10^6–4.1×10^6 Pa) for about 30 seconds. The sudden decrease in pressure as the product leaves the extruder causes it to expand and lose 12%-15% of its moisture. The high temperatures and pressure associated with the extrusion process effectively inactivate bacteria, molds, and viruses (Reynolds D, 1990, *Proc Midwest Poultry Fed Mts*) (Table 1).

Single-screw systems (Fig 3) are most common in the industry, probably because they are about 50% cheaper (Hauck BW, 1990, *Proc 33rd Ann Pet Food Inst Conf*). However, double-screw systems are better able to cope with the high-moisture ingredients and would therefore be more appropriate for the disposal of dead pigs.

If extrusion is used to process carcasses it will probably be done centrally because of capital costs. However, if it can also be used to extrude full-fat soybeans and creep feed, individual farmers may be able to justify the cost.

Fluidized-bed drying and flash dehydration

Fluidized-bed roasting/drying technology was developed a few years ago for roasting full-fat soybeans. A centrifugal fan blows air over a natural gas or propane burner, heating the air to 300°F (150°C) and suspending the raw material in a turbulent windstorm of hot air. This technology is currently being tested for drying or heat-processing a variety of products, including:

- composted manure,
- leaf and grass compost,
- city sewer sludge,
- meat and fish processing waste,
- food processing waste, and
- ground poultry carcasses.

Flash dehydration (Fig 4) is similar to fluidized-bed drying, except that material flows along a channel of super-heated air instead of floating on a bed of hot air jets. Like fluidized-bed drying, flash dehydration can be used to dry many types of wet wastes, but it is most appropriate for drying large amounts of animal byproducts and offal. The current equipment can dry about 4 tons (3600 kg) of wet offal per

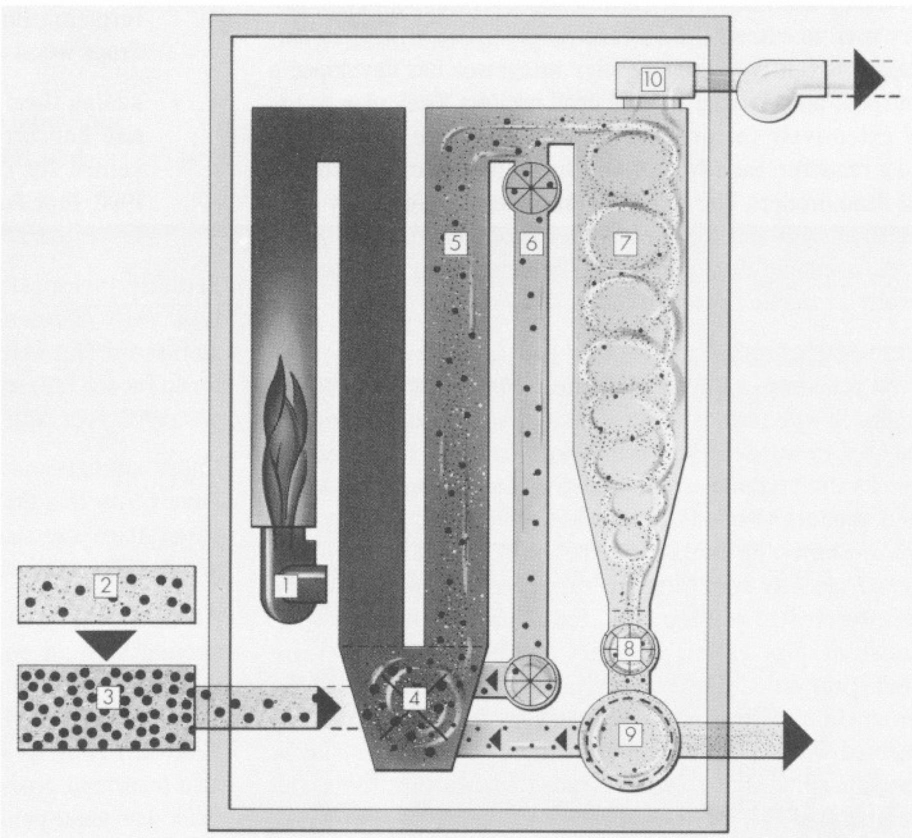

Fig 4.— A flash dehydrator. 1: oil or gas burner; 2: preheater; 3: fat press; 4: agitator; 5: drying tower; 6: classifier; 7: cyclone; 8: airlock; 9: rotary screen; 10: fan. Figure courtesy of Ziwex Recycling technology, North Carolina (Ziwag AG).

hour and it is very energy efficient compared to other drying methods. It can evaporate 500 gal (1900 L) of water per hour, using one part fuel to evaporate 12 parts of water. The high temperature and short dwell time causes little damage to protein quality. If sterilization of the product is required, it can be extruded and dehydrated to contain about 20% moisture. The cost to dehydrate turkey carcasses to 20% moisture is about $27 per ton ($30/1000 kg) of final product and $40 per ton ($44/1000 kg) if followed by extrusion (Nesbitt D, 1992, Ziwex Recycling Technology, USA, personal communication). These costs assume $1.10 per gal ($0.29/L) for fuel, $0.12 per kilowatt-hour (kWh) and $0.75 per ton ($0.83/1000 kg) maintenance. Neither flash dehydration nor fluidized-bed drying have yet been used to recycle pig carcasses, but both will probably be used in the future.

Storage techniques

The poultry industry is developing several intriguing technologies that enable carcasses to be stored on-farm until enough accumulate to make a trip to the renderer feasible. These techniques may be adapted for use in the swine industry.

Freezing

Freezing was one of the earliest methods the poultry industry used to extend the on-farm storage time of poultry carcasses. Recently, a large poultry integrator has developed a purpose-built freezer to hold dead broilers. They plan to use it extensively for preserving carcasses before taking them to a renderer. Each freezer will hold about 1 ton (0.9 tonne) of dead broilers. The company estimates the electricity costs at about $1.20 per day or $0.01 per pound ($0.02/kg) of carcass (assuming $0.08 per kWh). These units may soon be generally available for about $2000.

Fermentation

First proposed in 1984 by Dobbins (*Proc Natl Poultry Waste Mgmt Symp*), fermentation is an anaerobic process that can be used to store chicken and turkey carcasses for at least 25 weeks and produces a pathogen-free and nutrient-rich silage end product (Parsons and Ferket, 1990, *Proc Poultry Serv Short Course,* pp 7-20).[5] Sanders (1990, *Proc Env Sound Ag Conf*) recently conducted an extensive review on the subject. Fermented poultry offal, fed at up to 20% of growing-finishing pigs' ration, does not depress gains or increase feed : gain ratios.[6] Unfortunately, no one has documented the production efficiency of feeding hogs the silage from fermented whole birds or pigs. Fermented carcasses can also be used in mink or fox feed, extruded aquaculture feeds, and ruminant silage.

The bacteriocidal and virucidal activity of fermentation depends on the pH and prevailing temperature of the fermentation unit. A pH greater than the optimum 4.3-4.5 (Murphy DW, et al. 1990 *Proc Natl Poultry Mgmt Symp:* pp 56–63) can result in a secondary fermentation that spoils the silage. Viruses labile to low pH do not survive fermentation; inactivation occurs rapidly at 40°C, but more slowly at lower temperatures.[7] Most importantly, in fermented silage, Aujeszky's disease virus (pseudorabies virus) is rapidly inactivated at 20°C–30°C but survives 2 days at 10°C and 9 days at 5°C.[7] The optimum temperature for fermentation is about 35°C, but silage temperature usually matches ambient temperatures, indicating that Aujeszky's disease virus may not be inactivated in colder regions. Fermentation with *Lactobacillus acidophilus* destroys many bacteria including *Salmonella* spp,[8] *Salmonella typhimurium,*[9] and *Clostridium botulinum* type E.[10]

Typically, carcasses are prepared for fermentation by:

- grinding them to 1 in (2.5 cm) or smaller particles (the grinding aids in homogenizing the ingredients);
- mixing them with culture inoculant and a fermentable carbohydrate (CHO) source (for lactic fermentation, lactose, glucose, sucrose, whey, whey permeate, and molasses are all suitable as a CHO source; condensed brewers solubles are a particularly appropriate CHO source because they are a fermentation byproduct and silage pH rapidly drops when they are used); and then
- adding them to the fermentation container (any size noncorrosive container that is sealed and vented for carbon dioxide [Parsons and Ferket, 1990, *Proc Poultry Serv Short Course,* pp 7-20]; 55-gal drums are commonly used).

Recently, investigators varied the recipe to include a proteolytic yeast *(Hansenula montevideo)* instead of *Lactobacillus* for the inoculant and an out-dated, nondiet soft-drink syrup for the CHO source. The result was satisfactory (Malone GW. 1992. *Proc Natl Poultry Waste Mgmt Symp,* pp 49–55).

Under optimal conditions the pH of fresh carcasses is reduced from 6.5 to less than 4.5 within 48 hours. A properly prepared silage is semisolid, will keep for months, and is readily accepted for rendering.

Acid Preservation

Ground, split, or punctured dead broilers can be preserved on-farm at least 1 month in a 3.4% sulfuric acid solution at a cost of $0.10 per lb ($0.22/kg) carcass (Malone GW, 1988, *Proc Natl Poultry Waste Mgmt Symp,* pp 73-75). When this acid-preserved product is rendered, it has the same nutritive value as regular poultry-byproduct meal. Preserving dead pigs in sulfuric acid has not been tried, but it eventually may be an inexpensive on-farm method for storing carcasses. The safe handling of sulfuric acid stock solution is the primary concern.

The age of environmentalism began in the 1980s and will continue into the 21st century. The swine industry will continue to adopt those technologies that enable it to meet increasingly rigid environmental standards and those that it can use to increase the value of its waste products. It is time the swine industry stopped wasting money disposing of its waste and began converting these waste products into useful and valuable byproducts.

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