ORIGINAL RESEARCH

Composting as a suitable technique for managing swine mortalities

W.E. Morgan Morrow, BVSc, MS, PhD; Patrick O'Quinn; James Barker, PhD, PE; Gene Erickson, DVM, PhD; Karen Post, DVM, MS; Monte McCaw, DVM, PhD

Summary: *In an effort to recycle more of the waste generated from swine farms, producers have been looking for alternatives to the traditional methods for disposing of swine carcasses. From January 1992 through July 1994, we added 4622 kg (10,189 lb) of pig carcasses and afterbirth to seven compost piles. We built six piles in 2.5 m × 1.5 m concrete block pens of an idle hog growing barn. We built another pile, the fourth, in an isolation room because we included pseudorabies virus (PRV). The ratio, on a weight basis, of ingredients added was 1 part pig carcass, 0.1 part wheat straw (or 0.2 part peanut hulls), 1.5 part turkey cake, and 33 L of water per 100 kg of carcass. In two of those piles we included either* Salmonella *spp or* Erysipelothrix rhusiopathiae *in culture tubes. In the fourth pile we included sterile widemouth glass bottles containing scintillation vials with the tonsils of four pigs experimentally infected with pseudorabies virus (PRV). Four pigs similarly infected with PRV were securely wrapped in two plastic biohazard bags each and added to the pile. We monitored the temperatures of the piles and each for the presence of odor and flies. The composting process disintegrated most of the carcasses, including most of the bones, and reached temperatures sufficient to kill all of the* Erysipelothrix rhusiopathiae *and PRV and most of the* Salmonella. *There was little odor associated with the pile and few flies. Consequently, we consider composting to be a safe, efficient, and sustainable method for the disposal of swine carcasses.*

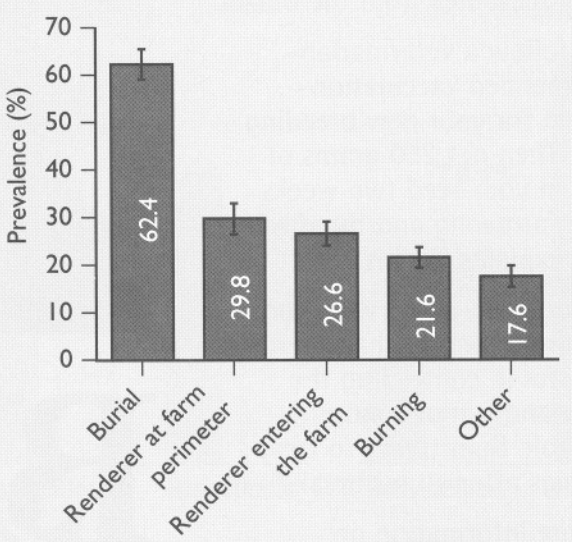
Every year more than 90,000 tons (81,646,200 kg) of dead pigs result from mortality in United States herds. Swine producers in the United States use various disposal techniques (Figure 1),[1] but are constrained in their choices by state regulations governing the disposal of swine mortalities. The public apparently fears that buried animals could contaminate groundwater and that emissions from incinerators could contaminate the air. All states allow dead pigs to be either buried, incinerated, or taken for rendering, and some states also allow swine carcasses to be fed to animals (e.g., Minnesota) or to be composted (e.g., Missouri).[2] Fewer swine farms now have the option of rendering swine carcasses because fewer than half of the approximately 800 plants operating in the 1970s are operating today.[3] Since most of the plants that had odor problems have closed, most of the public's concern with the rendering industry has been allayed. Farmers, however, are also concerned about the environment and, in addition, about the cost of disposing of mortalities. Consequently, they are searching for alternative processing methods that are inexpensive, environmentally safe, and that adhere to the stricter regulations governing waste disposal.

Many United States poultry farms compost their dead birds by combining a mixture of a carbon source (e.g., straw or peanut hulls), and a nitrogen source (e.g., poultry litter). The resulting product is an inoffensive, generally pathogen-free product with a non-offensive odor that can be used as a soil amendment or organic fertilizer.[4] Unfortunately, little work has been done to evaluate the efficiency of composting swine carcasses.[5] Studies in Maryland[6] have demonstrated composting to be effective for

WEMM, PO'Q: Department of Animal Science, Box 7621, North Carolina State University, Raleigh, North Carolina 27695-7621; JB: North Carolina State University, Department of Biological and Agricultural Engineering, Box 7625, Raleigh, North Carolina 27695-7625; GE, KP: Rollins Animal Disease Diagnostic Laboratory, North Carolina Department of Agriculture, Raleigh, North Carolina 27605; MMC: North Carolina State University, College of Veterinary Medicine, Box 8401, Raleigh, North Carolina 27695-8401.

This work was supported by a grant from the North Carolina Pork Producers Association and the North Carolina State University Agricultural Foundation.

Figure 1



Prevalence of methods of dead pig disposal. The percentages add up to more than 100% because some producers use more than one technique.

Table 1

The components and management of the compost piles

Pile	Carbon Source[1]	Size of Pigs	Pathogens Composted	Date Started and Days to Build pile	Days between turns
1	Wheat straw	Pigs < 13 kg, and afterbirth	*Salmonella*	January 23, 1992 112 d	50 d
2	Wheat straw	Pigs < 13 kg, and afterbirth	*Erysipelothrix*	June 9, 1992 123 d	106 d
3	Peanut hulls	Pigs < 13 kg, and afterbirth	None	March 23, 1993 149 d	only turned once
4	Peanut hulls	Pigs < 13 kg, and afterbirth	PRV	August 12, 1993 2 d	24 d
5	Peanut hulls	Sows	None	September 8, 1993 3 d	18 d and 33 d
6	Peanut hulls	Sows,Pigs < 13 kg, and afterbirth	None	September 29, 1993 41 d	64 d and 30 d
7	Peanut hulls	Pigs < 13 kg,and afterbirth	None	December 8, 1993 141 d	26 d and 15 d

[1] Nitrogen was always provided by 'turkey cake,' the hard layer of turkey manure and wood shavings that form on the top layer of the bedding.

composting swine carcasses up to 300 lb and in Missouri, Fulhage[7] composted swine carcasses in piles contained within round straw bales.

As in the compost piles built by home gardeners, successful composting of swine requires nutrients, water, and oxygen.[8] A carbon:nitrogen ratio between 20:1 and 35:1 is optimal.[8] Above that range (i.e., excess carbon), compost temperatures are not as high and decomposition slows. Below a ratio of 15:1 (i.e., not enough carbon), nitrogen is lost as ammonia, which reduces the value of the humus and increases the odor. Also, the smaller the size of particles in the compost, the greater the surface area available to the microorganism. However, the particles must be large enough to trap the oxygen needed for aerobic digestion.

The composting process is considered successful when the temperature of the pile is sufficient to maintain the growth of the microorganisms responsible for reducing the pig carcasses to humus. Because pigs often die from the effects of pathogenic organisms, composting should ideally eliminate or significantly reduce those organisms in the humus. Gotaas[9] compiled the thermal death points for some common pathogens and found that most, including *Salmonella* spp., die within 1 hour at 55°C or less.

Our objectives in this study were to determine whether:

- composting is a suitable method for the disposal of swine carcasses;
- wheat straw or peanut hulls are appropriate carbon sources;
- turkey cake (the hard layer of manure and wood shavings that forms on the top layer of the bedding) is an appropriate nitrogen source;
- the temperatures reached are high enough to destroy *Salmonella* spp., *Erysipelothrix rhusiopathiae*, and pseudorabies virus (PRV); and
- flies and odor from the compost pile are objectionable.

Materials and methods

From January 1992 through July 1994, dead pigs and afterbirth were added to six compost piles built in 2.5 m × 1.5 m (8 ft 3 inches × 5 ft) concrete-block open-front pens of an idle hog growing barn. The compost pile was contained at the front of the pen by a sheet of plywood. The barn is open-sided with a 1.3-cm wire mesh that would keep out birds but not flies. The layers of dead pigs were alternated with layers of turkey cake, and either wheat straw or unground peanut hulls until the pile was 0.9 m (3 ft) high (Table 1). For each kg of dead pigs, 1.5 kg (3.3 lb) of turkey cake, 0.1 kg (0.22 lb) of wheat straw, or 0.2 (0.44 lb) kg of peanut hulls, and water (33 L [8.75 gal] per 100 kg [220 lb] pigs) were added to the pile. This resulted in a C:N ratio of about 13:1. Most carcasses were added to the piles intact, i.e., without being cut. Sows were dismembered, their abdomens opened, and diaphragms punctured to expose their tissues.

To monitor the temperature of the piles, we placed six thermometers (ReoTemp Instrument Corporation, Model A36PF; or Fisher Scientific, Fisherbrand Expanded-Range Thermometers, Catalogue number 15-077-10 in each of compost piles 1, 2, and 3; and four each in compost piles 4, 5, 6, and 7. For piles 1 and 2, the thermometers were placed close to six wooden stakes that were placed upright in the piles equidistant from the sides and each other and used to attach the culture tubes. For the other piles the thermometers were placed equidistant from the sides and each other but we did not include the stakes. To avoid having to add to the compost piles daily, dead pigs were accumulated in a chiller and added to

the pile about every 2 weeks. However, pile 5 was built in 2 days because of the bulk of the sows added and mortalities accumulated in the chiller.

As dead pigs were added, the thermometers were moved so they maintained contact with the pig carcasses. After the temperature in the top 0.6 m (2 ft) of the piles peaked and fell, the piles were turned by hand (Table 2). We then placed the thermometers into the middle of the piles, again equidistant from the sides and each other.

Our other pile, pile 4, which we constructed in an isolation room because we included PRV, was 2.4 m (7 ft 9 inches) long × 1.2 m (4 ft) wide × 0.9 m (3 ft) high and contained in a plywood frame. This pile was built in 2 days because we used the mortalities from other large farms.

Table 2

The quantity of afterbirth and carcasses, straw or peanut hulls, turkey cake, and water added, by pile

Pile	Afterbirth and carcasses, kg (lb)	Wheat straw, kg (lb)	Peanut hulls, kg (lb)	Turkey cake, kg (lb)	Water, L (gal)
1	453 (998.5)	45 (99.85)		684 (1507.25)	184 (48.5)
2	700 (1544)	70 (154.1)		1049 (2313)	185 (48.9)
3	782 (1724.5)		157 (345.2)	1173 (2586.15)	261 (69)
4	466 (1027)		93 (205.4)	699 (1540.5)	159 (42)
5	939 (2070.7)		140 (308.4)	1159 (2555.6)	238 (63)
6	603 (1329.3)		121 (266.3)	905 (1994.25)	201 (53)
7	678 (1495)		154 (339)	1017 (2243)	229 (60.5)
Total	4622 (10189)	115 (253.95)	664 (1464.3)	6686 (14739.75)	1457 (384.9)
Ratio	1	0.1	0.19	1.45	31.5 L/100 kg 3.78gal/100lb

Salmonella

Twelve pairs of *Salmonella* spp. group B cultures were grown in trypticase soy broth. Aliquots of 5 mL were standardized to a 10 McFarland nephelometer turbidity which corresponds to 3.0×10^9 bacteria per mL. The tubes were fixed to six stakes placed vertically in compost pile 1. On three stakes, pairs of tubes were placed at 0.15 m (6 inches), 0.60 m (2 ft), and 0.75 m (2 ft 6 inches) from the bottom of the pile. On the other three stakes, tubes were placed at only 0.15 m (6 inches) and 0.75 m (2 ft 6 inches). A control tube was kept on the shelf at ambient temperature.

When the pile was first turned, day 127, one of each pair of the *Salmonella* tubes was tested for viability. The other tube of the pair was placed in the turned pile in a position similar to where it was in the first pile, and was then retrieved when the pile was turned on day 177. *Salmonella* cultures from the tubes were directly plated on selective enrichment media and further enriched using a Selenite broth and overnight incubation at 37°C before plating. Positive cultures were titrated using 1:10 dilutions.

Erysipelas

The protocol for erysipelas was similar to that for *Salmonella*. Pairs of tubes were set at 0.15 m (6 inches) for all six stakes and at 0.60 m (2 ft) for three stakes. A single tube was placed at 0.60 m (2 ft) for the other three stakes and at 0.75 m (2 ft 6 inches) for all six stakes. Again, a control tube was kept on the shelf at ambient temperature. One of each duplicate tube was retrieved on day 245 when the pile was first turned and again on day 351 when the pile was turned a second time. Erysipelas cultures from the tubes were directly plated onto blood agar and phenylethyl alcohol agar.

Pseudorabies virus

Virus

Strain 4892 PRV was grown and titrated in Vero cells grown in MEM with 10% newborn calf serum, L-glutamine, and antibiotics. Virus was diluted to a final concentration of $10^{4.42}$ $TCID_{50}$ per 1.0 mL PRV in cold MEM without calf serum and kept on ice.

Pigs

Eight 8-week-old PRV-free pigs were inoculated intranasally with 1.0 mL of the virus solution, as detailed above, in each nostril and were held in a single isolation room. The pigs were monitored for clinical signs indicating infection and euthanized 6 days later when two of the pigs were moribund and the others were gaunt and had rough hair. These carcasses and their tonsils were included in the fourth compost pile.

Tissue composting

Tonsils were removed from four of the experimentally infected pigs and were placed into sterile scintillation vials. The scintillation vials were then packed individually into sterile widemouth glass bottles with aseptically collected muscle tissue to mimic possible thermal insulating properties of the skull. The other four pigs were securely wrapped in two plastic biohazard bags each. All four bottles and four wrapped carcasses were placed into the compost pile as described above. At 29 days when the pile was turned, two of the whole pigs in plastic biohazard bags and two of the jars containing tonsilar tissue were retrieved. At 53 days the two remaining whole pigs in plastic biohazard bags and the two remaining jars were retrieved. On both occasions, tonsilar remnants were extracted from the skulls of the pigs, placed in biohazard bags, and frozen at -70°C along with the tonsils in scintillation vials.

Inoculation of sentinel pigs

Tonsillar tissue remnants were thawed and stomached individually with 15 mL MEM with 10% newborn calf serum and antibiotics at 4°C. Tissue homogenates were centrifuged at 3000 rpm for 20 minutes at 4°C. Three mL of supernatant from each sample was injected IP into individual 6-week-old PRV-free pigs. Pigs were treated with 2 mL each of 50 mg per mL gentamicin and 200 mg per mL tetracycline (LA 200) IM. Pigs were monitored daily for clinical signs of disease. Serum samples were collected from the sentinel pigs 28 days post-inoculation for serologic evaluation.

Table 3

Results from culturing tubes of *Salmonella* spp. placed at six locations and three heights in a compost pile

	Location					
Height, Sample	1	2	3	4	5	6
15 cm, First	(+)	(+)	(+)	(-)	(-)	(-)
15 cm, Second	(+)	(-)	(+)	Broke	(-)	(-)
60 cm, First	(-)	(-)	(-)	(-)	(-)	(-)
60 cm, Second	(-)	(-)	(-)	(-)	(-)	(-)
75 cm, First	(+)	(+)	(+)	None	None	None
75 cm, Second	(-)	(-)	(+)	None	None	None

A control *Salmonella* broth kept at ambient temperature had >100,000 colonies at first and second sampling.

Location notes:

- Tubes were fixed to six vertical stakes placed in the compost pile in two rows of three so they were equidistant from the four retaining walls and each other.
- Height, Sample Two tubes were fixed to each stake at 15cm, 60cm, and 75cm from the floor. One tube was taken at both the first and second pile turnings.

(+): More than 100,000 colonies of *Salmonella* cultured.
(-):No *Salmonella* cultured at 24 hrs and 72 hrs.
Broke: The tube broke.
None: No tubes were placed at these locations.

PRV serology

Sera were tested for PRV antibody using the official standard PRV ELISA following the manufacturer's recommended procedures at the Rollins Animal Disease Diagnostic Laboratory.

Flies and odor

The number of flies was visually determined and graded on a scale of none, 1-2, 3-20, and 21+ flies. The presence of odor was determined by an animal technician sniffing the air and grading the odor on a scale of none, slight, noticeable, and awful. Because the composting for the PRV was done in an isolation room we did not determine flies or odor for that pile.

Carcass residues

The extent of carcass decomposition was determined visually when piles were turned.

Analysis of humus

In September 1994, the top 6 inches of all compost piles were sampled and sent to a commercial laboratory (A & L Eastern Agricultural Laboratories, Inc. Richmond Virginia 23237) for analysis. Organic carbon was analyzed by combustion method; solids, EPA 160.3; nitrogen (TKN), EPA 351.3; pH, EPA 150.1; and volatile solids, EPA 160.4.

Results

The weights of afterbirth and carcasses, straw or peanut hulls, turkey cake, and the amounts of water added are displayed, by pile, in Table 2.

Temperatures

The maximum and minimum temperatures recorded for each pile by day are displayed in Figure 2.

Salmonella

Nine of the 15 Salmonella cultures retrieved at day 127 were negative, indicating that the temperatures achieved were adequate to kill some, but not all, of the *Salmonella* (Table 3). On day 177, at the second turning, we retrieved the duplicate set of tubes and found 11 of 14 were negative for *Salmonella* (one tube broke).

Erysipelas

All samples were negative.

Pseudorabies virus

Pigs never showed any abnormal clinical signs after inoculation. All samples were negative to ELISA.

Flies

On the whole, we did not consider flies to be a problem (Table 4).

Odor

Most of the time the odor was either not detected or recorded as "slight." For three days in May 1992 the odor from pile 1 was "noticeable."

Carcass residues

Piles 1-4 and 7, including pigs less than 13 kg, and afterbirth

When we turned the piles for the first time we could usually find some bones, some with muscle and skin tissue adhering, but most were clean. On the second turn we would again find some long bones (humeruses and femurs) and skulls, but they had no tissues adhering to the bone. At both turnings it was obvious to us that most of the bones had decomposed although we did not quantify that impression.

Piles 5 and 6, including sows and pigs greater than 13 kg

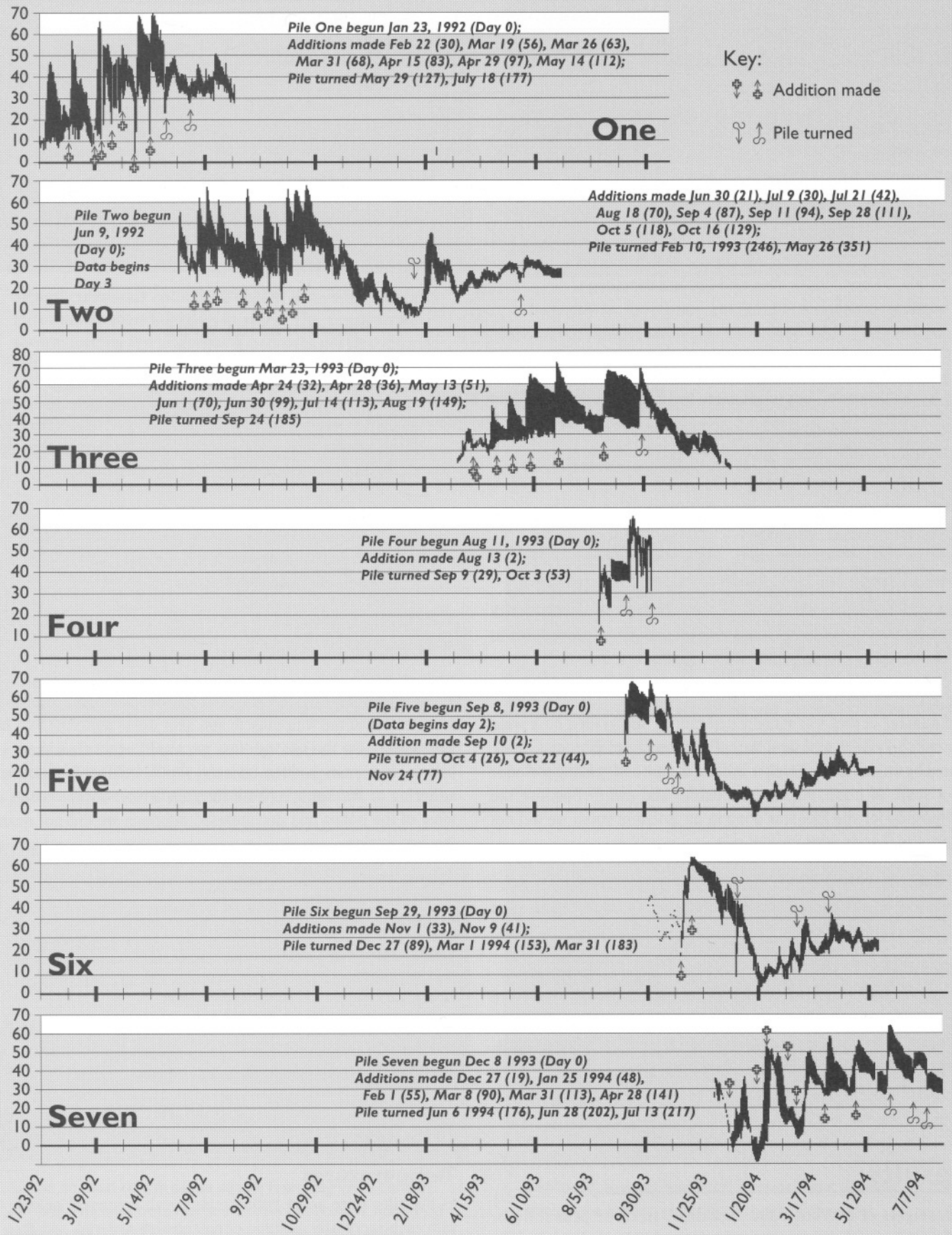
Turning pile 5 for the first time we found sections of the carcass that had only started to decompose. However, after turning it for the second time those large sections had disappeared. At the third and final turning we found all three sow skulls and some large bones including humeruses and femurs. Pile 6, which included only one sow and a few growing pigs, and took longer to build, had no large sections of the sow at the first turning, and at the second turning only the skull and some larger bones remained intact.

Discussion

Temperatures

As the piles were being built the temperatures would quickly rise with each successive addition of composting material, and then fall just as quickly. When we took more than 100 days to build the piles (1, 2, 3, and 7), with each addition the maximum temperatures

Figure 2



Maximum and minimum temperature fluctuations by compost pile

tended to increase. This is probably associated with the increasing mass of the pile and the insulation it offers, thus enabling the organisms to grow and multiply. Interestingly, in piles 1 and 2 where temperatures had reached over 60°C when we were building them, temperatures did not exceed 52°C when the piles were turned. We think this may be due to the exhaustion of available nutrients. In contrast, when pile 7 was first turned, the temperature peaked at 64°C which was higher than the previous high of 58°C. Similarly, when pile 3 was turned the temperature quickly reached a maximum of 69°C, which was high but less than the 73°C previously attained. Perhaps 73°C was too high, inhibiting the microorganisms, and thus not depleting the nutrients. Of course, other factors may explain this phenomenon, such as a low moisture content, which we did not measure.

For all piles, except pile 3 which was only turned once, the maximum temperature reached on subsequent turns was always either equivalent to, or usually less than, the maximum temperature attained on the previous turn. This phenomenon is best illustrated by pile 5, which was built in 3 days and turned 3 times in 51 days. Again, this may have been caused by the gradual exhaustion of available nutrients.

Unfortunately, we did not complete a compost pile in the winter months of December, January, and February and so did not test whether composting would work in winter in North Carolina. However, pile 7 was started in December and pile 1 in January. In the early stages of building pile 7, the temperatures did not reach 38°C but the two later additions in January and February resulted in the maximum temperatures exceeding 49°C. For pile 1, each addition in January and February resulted in a maximum temperature of 47°C and 57°C respectively. Temperatures may not have risen with the earlier additions to pile 7 because the material was too spread out and lacked the self-insulation inherent in a compact mass. Consequently, we think that composting could work in winter in North Carolina and areas with similar temperatures but recommend that early additions to the pile be kept in a compact mass and not spread out over the base of the pile.

Flies and odor

As expected, the only time we detected flies was during the warmer months of March through July. We don't know why the greatest prevalence of flies was detected with pile 3 in May 1993 through June 1993. However, it was the only pile that summer to which we were still adding carcasses and it may have been just "a bad summer for flies." It is interesting that in May 1992 we recorded, around pile 1, the worst odor but noticed no change in prevalence of flies. Also, in May 1993 we recorded the worst prevalence of flies around pile 3 but noticed no change in the odor. A score of "slight" was more an indication of the presence of a compost pile than an offensive odor. The compost piles tended to have an "earthy" or "mown grass" odor that probably came more from the top layer of wheat straw or peanut hulls that we always added last to a pile. Thus, flies and odor should not be a problem in North Carolina provided the compost piles are properly managed. These results are similar to the results obtained by Rives and others[10] who found when composting poultry mortalities that the number and species of flies associated with the composters closely parallels the background fly population of all the sites.

Carcass residues

Most of the pig body mass composted was afterbirth and neonatal mortality weighing less than 2.3 kg. As expected, and in agreement with Murphy,[6] little remained of those piglets. Again, not unexpectedly because of the density and bulk of the skull and larger bones, we always found the intact but "cleaned" skulls of composted sows and some, but not all, of the larger leg bones. Such persistence of the larger bones should not be regarded as an indication of failure of composting. The composting process results in a major reduction in the volume of carcass and the remaining large bones can be easily removed from the compost and either buried or stored for transport to a rendering plant.

Diseases

The destruction of all the *Erysipelothrix* and PRV and most of the *Salmonella* is not unexpected given the temperatures the piles reached. In vitro, *Erysipelothrix* cultures are destroyed by exposure to moist heat at 55°C for 10 minutes.[11] The survival of PRV outside the living host is dependent on pH and temperature and is inactivated at 0.6 $\log_{10}$ per day at 37°C at a pH 6-8.[12] Interestingly, porcine respiratory and reproductive syndrome virus (PRRSV) is more labile than PRV under experimental conditions and has a heat susceptibility similar to *Erysipelothrix*, surviving only 6 minutes at 56°C.[13] We chose *Salmonella* because it is one of the most temperature resistant and prevalent pig pathogens available.[9] In the laboratory, these organisms continue to grow well at 43°F, a characteristic used to reduce the growth of other bacteria in highly contaminated specimens.[14]

Our technique underestimated the bactericidal efficacy of composting because we kept the cultures at a fixed location in the pile and in culture tubes. In reality, pathogens would be exposed to bacteriocidal agents in the pile other than just heat, including toxic by-products of decomposition and microbial antagonism, as reviewed recently by Bollen.[15] Also, when the pile was turned, the pathogens would be distributed throughout the pile and would not be confined to the test locations. The tubes containing the surviving *Salmonella* organisms were located at either the top (0.15 m) or bottom (0.75 m) of the pile. After the piles were turned the thermometers were placed in the middle. Hence, it is possible that more *Salmonella* cultures would have been negative if they had the opportunity to be relocated, at turning, to the center of the pile where it was probably hotter. These conclusions are consistent with the work of Plym Forshell and Ekesbo[16] who, using a more sensitive technique, demonstrated that *S. senftenberg* and *S. typhimurium* did not survive 7 days in composted sow manure that maintained a temperature between 54–64°C.

The survival of some *Salmonella* cultures in our trial should not be regarded as an indication of the failure of composting. Composting is an on-farm procedure and the resulting humus would likely be either spread on surrounding farmland or supplied to the domestic home-garden market. Both avenues are unlikely to result in another farm's pigs consuming the humus, which is required to trans-

Table 4

The number of days, by month, when flies were prevalent

Month, year[2]	Pile 1[1] None	1-2	3-20	21+	Pile 2 None	1-2	3-20	21+	Pile 3 None	1-2	3-20	21+
March 1992	28	2	1									
April 1992	22	8										
May 1992	20	10	1									
June 1992	22	7	1			3	1					
July 1992	29	2				7	1					
April 1993	30				30				28	2		
May 1993	30	1			30	1			9	19	3	
June 1993	30				29	1			4	25	1	
July 1993	31				31				10	15	6	

[1]Empty cells indicate 0 days.
[2]For periods not recorded here, the number of days any flies were detected was 0.

mit *Salmonellosis*. Hence, survival of disease organisms in compost is not of prime concern compared to other carcass disposal methods, e.g., rendering or fermentation, the success of which depends on animals eating the end product and the possibility of directly exposing them to swine pathogens.

Carbon source

After using wheat straw as the carbon source for piles 1 and 2 we changed to peanut hulls and increased the C:N ratio added from 0.1 to 0.2. Both worked well, in that composting was successful for both substrates, but the peanut hulls seemed to work better because it appeared that more of the hulls decomposed than the wheat straw. We were surprised at how resistant wheat straw is to composting. Even at the completion of the process much of the wheat straw was still intact, which could block the mechanism of field spreaders.

Using published values for the C:N ratio of substrates, the C:N ratio for the piles with wheat straw were 12.5:1 and for peanut hulls were 13.7:1. Surprisingly, the C:N ratios for the resulting humus were about twice the starting values, suggesting that nitrogen had been lost (Table 5). It is possible that the published values for substrates were not accurate estimates for our work. If large amounts of nitrogen were lost from the compost pile we should have detected an ammonia smell, which was not the case. However, we did stockpile the turkey cake and it did have a noticeable ammonia smell. Thus, published values of the C:N ratio for our turkey cake may have overestimated the amount of nitrogen, which could account for the high C:N ratio in the resulting humus. Regardless of the C:N ratios, the composting process was successful and the humus suitable for adding to the soil. To optimize the composting process, all substrates should be analyzed before starting.

Finally, we concluded that composting is a suitable method for the disposal of swine carcasses because we were able to compost both small and large carcasses with the resulting humus being a safe and valuable soil additive. Because the compost piles reached the temperatures necessary for composting <55°C[17] and the carcasses were basically disintegrated, we conclude that wheat straw and peanut hulls are appropriate carbon sources and that turkey cake is an appropriate nitrogen source.

The temperatures reached in these trials were high enough to destroy *E. rhusiopathiae*, PRV, and most of the *Salmonella*. Our results also indicate that PRRSV would be destroyed by the temperatures reached in composting process[13] although we did not directly test this hypothesis. Consequently, we conclude that composting does not pose a risk for transmitting disease. Finally, we conclude that flies and odor from the compost pile are not objectionable and should not hinder the adoption of composting as an alternative for the disposal of swine mortalities. Additional work is needed to confirm whether composting will work in the colder months in North Carolina.

Implications

- Composting is an alternative method for the disposal of afterbirth and swine mortalities.
- Provided the pile is properly managed and maximum tem-

Table 5

Analysis of compost

Pile	Solids %	Nitrogen (TKN) %	pH	Volatile Solids %	Organic Carbon %	C:N Ratio
1	87.17	2.11	6.70	85.17	49.52	23:1
2	88.33	1.69	6.00	87.36	50.79	30:1
3	86.09	1.65	6.10	83.11	48.32	29:1
4	87.24	2.18	6.40	83.87	48.76	22:1
5	85.17	2.28	7.20	86.60	50.35	22:1
6	80.33	1.89	7.20	91.25	53.05	28:1
7	81.77	1.52	5.50	80.04	46.54	31:1

All values except solids are on a dry-weight basis. Organic carbon was analyzed by combustion method; solids, EPA 160.3; Nitrogen (TKN), EPA 351.3; pH, EPA 150.1; and volatile solids, EPA 160.4.

peratures exceed 60°C, composting will destroy most pathogens. Therefore, pile temperature should be monitored during the construction of the pile and for at least 7 days after each turn.

- It is best to obtain an analysis of the compost carbon and nitrogen substrates and adjust the ratio of added substrates accordingly.
- Properly managed mortality composting does not result in objectionable odors or in an increase in flies.
- Because composting is essentially an on-farm process it offers an alternative system for managers of high-health herds wanting to limit the movement of dead-stock trucks coming onto the site.
- Veterinarians have the opportunity to include the management of dead pig disposal in the consulting services they offer.

References:

1. USDA. National Swine Survey. Morbidity/Mortality and Health Management of Swine in the United States. Ft. Collins, CO, Animal and Plant Health Inspection Service. January 1992.

2. Hermel SR. Now what? *National Hog Farmer*. March 15, 1992;34–43.

3. Frankel G. Personal communication. 1994.

4. Carter T, et al. North Carolina Cooperative Extension Service. Poultry Science Fact Sheet #11: Composting Poultry Mortality in North Carolina. 1992

5. Morrow WEM, Ferket PR. The Disposal of Dead Pigs: A Review. *Swine Hlth and Prod*. May 1993;1(3):7–13.

6. Murphy DW. Swine composting. *University of Maryland Swine Report*. July 1992.

7. Fulhage C. *Composting dead swine* (draft). Agricultural Engineering Dept., Univ. of Missouri, Columbia, MO. November 1992.

8. Rank R. *On-Farm Composting Handbook*. Northeast Regional Agricultural Engineering Service. 1992. Cooperative Extension, NRAES-54, Ithaca, NY.

9. Gotaas HB. World Health Organization Monograph Series. No.31. Geneva. 1956.

10. Rives D, Stringham M, Carter T, Wineland M, Parsons J, Hawkins B, Bunton B. Fly populations associated with poultry mortality composting. *Proc Natl Poultry Waste Mgmt Symp*. Birmingham, Alabama. October, 1992;409–412.

11. Timoney JF, et al. Hagan and Bruner's *Microbiology and Infectious Diseases of Domestic Animals*. 8th ed. Comstock Publishing Associates; 1988:197–205.

12. Davies EB, Beran GW. Influence of environmental factors upon the survival of PRV. *Res Vet Sci*. 1981;31:32–36.

13. Bloemraad M, Dekluijver EP, Peterson A, Burkhardt GE, Wensvoort G. Porcine reproductive and respiratory syndrome — Temperature and pH stability of Lelystadt virus and its survival in tissue specimens from viremic pigs. *Vet Microbiol*. 1994;42:361–371.

14. Timoney JF, et al., Hagan and Bruner's *Microbiology and Infectious Diseases of Domestic Animals*. 8th ed. Comstock Publishing Associates; 1988:74–88.

15. Bollen GJ. Factors involved in inactivation of plant pathogens during composting of crop residues. In: Hoitink HAJ and Keener HM, eds. *Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects*. Wooster, Ohio. The Ohio State University. 1993;301–318.

16. Plym Forshell L, Ekesbo I. Survival of *Salmonellas* in composted and not composted solid animal manures. *J Vet Med B*. 1993;40:654–658.

17. McKinley VL, et al. *Biocycle*. 1985;26:47–50.