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Composting Animal Mortalities

Table of Contents

List of Figures

List of Tables

1 Introduction

Disposing of animal mortalities is a natural part of animal agriculture; however, it is not limited to on-farm applications. Meat processors and distributors, the fishing industry, public works and environmental managers also routinely need to dispose of carcasses or other animal by-products. As traditional methods of disposal – burial, incineration and rendering – have lost favor or increased in cost, farmers, butchers and public works departments are finding it increasingly difficult to find biosecure, inexpensive and environmentally safe disposal. Composting is providing another option, at least in North America.

Carcasses from routine livestock and poultry mortalities, animals killed in catastrophic events (e.g. disease outbreaks, storms), road kill, beached sea mammals and meat and fish from processing operations (e.g. butchers) may all be composted. The common factor among these applications is that they involve concentrated amounts of animal tissue, with high proportions of protein and moisture. Typically, organs, flesh, hides, feathers and bones may be included. Handling and composting these materials demands care and special practices to accommodate their challenging properties and to control disease, odors, flies, scavengers and leachate. In these applications, the composting system tends to be dedicated to treating or managing the carcasses; the production of compost is usually incidental.

Composting animal mortalities is rapidly spreading in the United States and Canada. Regulations concerning carcass disposal in the U.S. vary. Because of the instability in the U.S. rendering industry many states are now addressing this in regulations[1]. In the European Union, regulation prohibits composting of unprocessed mortalities. According to the Department for Environment, Food and Rural Affairs in the UK, deads can be composted if they are pressure-rendered and butcher/slaughter house waste can be composted without any pre-treatment (https://www.gov.uk/dealing-with-animal-by-products). The argument is that the safety of mortality composting is unproven for prion diseases and some other animal diseases. The concern is that handling the carcasses and distributing the compost might contribute to the spread of diseases like Bovine Spongioform Encephalopathy (BSE or "mad cow disease"). Even where mortality composting is accepted, BSE and other prion diseases remain a concern because of the prion's resistance to destruction by heat (see sidebar).

Prion Diseases

Bovine Spongiform Encephalopathy (BSE or mad cow disease), Chronic Wasting Disease (CWD) in deer and elk and Scrapie in sheep and goats are all diseases called Transmissible Spongiform Encephalopathies (TSEs) caused by prions. A prion is a protein chain that has become mis-folded and can infect and replace normal protein chains in the brain of an animal. Transmission among same and different species is not completely understood with prion diseases. Disabling this protein chain is difficult: it takes exposure to heat of 1800-2000°F or alkaline digestion. Neither of these conditions occurs in the compost process. There is some evidence that certain enzymes and competition from organisms might have an effect. Research is ongoing to further explore prion destruction.

In cases where animals are suspected of, or confirmed with prion diseases, work with state and federal veterinarians. Composting might be completed in a contained area to reduce volume and moisture. Then the resulting residuals, chips and bones could be burned in a high temperature incinerator to destroy the prion. Burning whole animals at high temperatures is energy intensive and it is difficult to achieve high temperatures throughout large carcasses.

The scarcity and cost of rendering is probably the biggest factor in the growing reliance on composting. While renderers once paid farmers for animals, in many locations, the farms are now being charged for the service, or the service is unavailable. Many rendering operations have been curtailed by disease concerns that have caused fluctuation in prices for hides, tallow, meat, bone meal and the other useful commodities derived from animal carcasses. Some butchers process animal species (e.g. goats, sheep, ostrich, deer and wild hog) that are not acceptable in the rendering stream so they are limited in their disposal.

Composting provides an alternative to traditional carcass disposal as it can be less expensive, is self-sufficient

1 Forty-three states have regulations in place listing composting as an acceptable method. California allows composting of non-mammals only. AK, CT, NV, NH, NJ, WV and WI do not list composting as a method. AK, WV and WI list every other method but composting. CT and NV list only burial and burning. NH lists burial only and NJ does not list any methods except rendering for hogs that die of cholera.

Figure 6-1. Whale bone remains following composting

site by farm staff using their own machinery. It requires no outside personnel or vehicles that may be carrying pathogens from other farms. Dead animals can be isolated and incorporated in the compost pile promptly, rather than sitting on the ground waiting for pick up from rendering or landfill service providers or for the accumulation of enough material to fire up an incinerator.

and is biosecure. The temperatures achieved through the composting process may eliminate or greatly reduce pathogens, hindering the spread of disease. Research continues to demonstrate effective destruction of nearly all livestock diseases of concern. Properly composted material is environmentally safe and a useful soil amendment.

Composting also provides farms the advantage of biosecurity. Biosecurity refers to possible introduction of potentially infectious organisms (pathogens) from outside sources, such as wild animals, and people and vehicles that have traveled from other farms and facilities. Normally, composting is accomplished on-site by farm staff using their own machinery. It requires no outside personnel or vehicles that may be carrying pathogens from other farms. Dead animals can be isolated and incorporated in the compost pile promptly, rather than sitting on the ground waiting for pick up from rendering or landfill service providers or for the accumulation of enough material to fire up an incinerator.

When considering the disposal of animal carcasses and by-products, one should remember that composting is not necessarily the most desirable method. All things equal, preference should be given to processes that recover non-diseased animal by-products for food or feed for animals and render them into commercial products. As an example, the raw and basted dog bone business is thriving in the U.S. and may offer outlets of local markets to farmers and butchers.

This guide provides an overview of composting animals and animal tissue in order to familiarize the reader with the associated applications, requirements, methods and management practices. For readers who wish to pursue this composting option, numerous publications, video programs and web sites are available that provide many details, such as state regulations, step-by-step procedures

A Whale of a Tale!

In 1999, a Northern Right Whale in the North Atlantic became severely entangled in fishing equipment. About six months later the whale was found dead off the coast of New Jersey. The US Coast Guard hauled the 30,000-pound whale to shore. Since there are only approximately 300 Northern Right Whales left, a call went out to museums to see if there was interest to preserve this whale in some way. The Paleontological Research Institute (PRI) in Ithaca, NY requested the whale carcass, primarily to recover the skeleton.

In New Jersey, some of the flesh and blubber was cut off the carcass and it was hauled on a flat-bed truck to Ithaca. Behind PRI, next to the Cayuga Medical Center, the whale was laid in a large bed of horse manure and completely covered and left to compost in a large pile. The pile was left for six months (October-April) and gently uncovered so the bones could be tagged and turned by hand. The bones, bits of flesh and skin were again covered and left until October (Figure 6-1). With many volunteers, the bones were cleaned and weighed and ready to be assembled. It is interesting to note that in one year the bones actually showed signs of pitting and degradation, suggesting that, for preservation purposes, the bones could have been removed from the pile sooner. The whale skeleton that was composted on their site is on display at the PRI in Ithaca for various applications and instructions for building composting windrows and structures. For further guidance, see suggested reading and references at the end.

2 Mortality Composting -- Not Your Typical Compost

2.1 Overview

To state it bluntly, mortality composting deals with animal flesh – whole dead animal carcasses and/or animal parts such as afterbirth, offal, organs, blood, fish wastes, bones, feathers, hides and raw meat from butchers[2]. Composting this flesh waste differs from other categories of composting. While most of the fundamental principles are the same, specific practices evolved for composting mortalities for two reasons: First, the production of salable compost is usually not a primary goal. Second, there is a higher concern for disease, hygiene, odors, flies, vermin and scavengers.

Farm mortalities and similar materials are composted by a variety of methods. Nearly all methods share distinct procedures that isolate the carcasses from the environment until they decompose. Composting carcasses in vessels provides some of that isolation, but material needs to be fairly uniform. Grinding carcasses makes the process more like conventional composting and also makes forced aeration practical but adds an extra step and requires additional health and safety precautions. Composting whole carcasses in passively aerated piles/bins is the most common approach and receives the most emphasis here.

The first stage of animal mortality composting in passively aerated piles can be described as above ground disposal or entombment within an organic biofilter. With a few exceptions, carcasses are not mixed with other feedstocks but rather they are layered and/or surrounded by other feedstocks (Figure 6-2). Those other feedstocks include dry, carbon-rich and moisture-absorbing amendments (e.g. straw, sawdust, wood chips, recycled compost) and may also include other ingredients like poultry litter and manure. Composting is more efficient and effective if air can flow through the amendments to keep the pile aerobic. Simply put, an optimum habitat needs to be created for microorganisms to thrive and digest flesh. A mix of chunky and fine carbon-rich material can be used. In dry climatic conditions, water may be added to the amendments during pile construction. For weeks to months, the carcasses decompose undisturbed within an envelope of carbonaceous amendments. In this stage, the flesh substantially decomposes while the temperatures increase to and remain at thermophilic levels gretly reducing pathogens.

In the first stage of composting, the carcasses are dense, wet and have a low C:N ratio, while the surrounding amendments are relatively dry, porous and typically have a high C:N ratio. At different times in the process, there are aerobic and anaerobic zones in the pile, producing liquids and gases that migrate into, and are absorbed within, the envelope of amendments. The liquids and gases continue to decompose along with the amendments. The surrounding media serves as a biofilter, adsorbing volatile organic compounds and trapping leachate and odors (Figure 6-3). The pile can be left intact for curing for 6-9 months or it can be turned or combined with other

Mass Casualty / Emergency Response

Death of large numbers of animals can occur for many reasons including fire, lightning, barn collapse, power interruptions, disease outbreaks, floods, fish kills and marine mammal beaching. Composting can provide a timely solution for any amount of animals if space and bulking materials are available. Finding enough appropriate carbon sources can be tough in emergency situations, so those planning should have a list of possible sources (see Compost Bulking Materials fact sheet #5). If there is a disease issue where typical thermophilic temperatures may not provide sufficient disease or pathogen control, additional measures can be taken. Organization is the most important factor in responding to such an emergency. Plans should be developed with multiple disposal tools so that response time will be quick and effective. For example, the Department of Agriculture in Maine has developed a plan for the event where truckloads of carbon are needed. Active sludge composting is common in many areas and the product is available. They plan to lay the carcasses on a bed of active sludge compost and cover it, allowing the heat of the sludge compost to jump-start the mortality composting process.

carcass piles. The medium (bones and still available carbon) can be reused for another carcass.

If turned, the remains of the carcasses, plus the liquids and gasses released, are blended with the surrounding feedstocks and composting continues more uniformly, more like conventional composting. Temperatures usually return to thermophilic levels for several weeks longer. Additional turnings may shorten the second stage, depending on the management preferences and conditions. While one pile composts through the second stage, another pile can be composted through the first stage.

In practice, it is best not to rush the compost process. Composting a 1000-pound cow under good conditions generally takes 3-4 months for the flesh to disappear; for small carcasses like birds and fish the flesh decomposes in 2-3 weeks. However, this time relates to just the first stage (thermophilic phase), as the compost itself does not reach adequate maturity for another 4-12 months in the curing phase. The composting time for both phases depends on the size of the carcass.

Even after the process is finished and the compost is mature, bones persist, (unless the animals are immature or soft-boned). Clean bones can be recycled through the process. They add structure to pile and become brittle with age. Feathers from poultry and wool from sheep take longer to decompose than meat. Large chips, feathers and bones can be recycled as part of the media for future piles or bins.

2.2 Differences due to Scale and Animal Size

Procedures for composting animal mortalities vary with the size of the carcass and the scale of the task; that is, the number of carcasses handled at each loading. The most common situation is composting of routine mortalities – the fraction of the flock or herd that periodically die of natural causes. Depending on the type of farm, and its size, each loading can range from a single cattle carcass to several dozen fish or birds.

The dimensions of individual piles and bins vary with the animal species, size of the operation and equipment used. Heights typically range from 4 to 6 ft. (1.2 to 1.8 m), although heights of 8 ft. (2.4 m) are sometimes used. Some bins (e.g. mini-bins) for poultry and fish are only 3 ft. (0.9 m) high. Freestanding piles and windrows tend to be 10 to 16 ft. (3.0 m to 4.8 m) wide at the base. The width of bins depends on the means of loading and unloading. They range from 3 ft. (0.9 m) for mini-bins to up to 12 ft. 2.7 m) for large operations.


Figure 6-2. Enveloping a carcass with wood chips

Mortality composting methods evolved from the basic passively aerated pile or bin approach developed for composting poultry mortalities. With that approach, a number of carcasses are placed in a layer on a base of dry amendment and capped with more amendment. Layers are built upward in succession until the pile or bin reaches its desired maximum height (Figure 6-4). Layering predominates with small

Figure 6-3. Compost pile opened after 4 months. Most of the soft tissue is gone, leaving some hide, hair and bones. The wood chips are dry on the outside having adsorbed and contained leachate and odors.

carcasses (e.g. birds and fish) and moderate carcasses (e.g. pigs, small deer and calves). However, a pile or bin cannot accommodate numerous layers of whole large carcasses, such as mature sows, cattle and horses. Larger animals are typically composted in a pile, windrow or bin with only one or two layers. As more animals are added, additional piles are started or the pile is expanded in length creating a windrow.

As the size of the carcass increases, a greater volume of amendment is required per unit carcass. In addition, while small carcasses can be loaded by hand, a tractor or a loader is required to handle large animal carcasses. If carcasses are ground prior to composting, there is virtually no distinction between the procedures for large and small carcasses as grinding permits more conventional composting practices to be followed. However, grinding animal flesh and bone is hard on equipment and the people that are grinding.

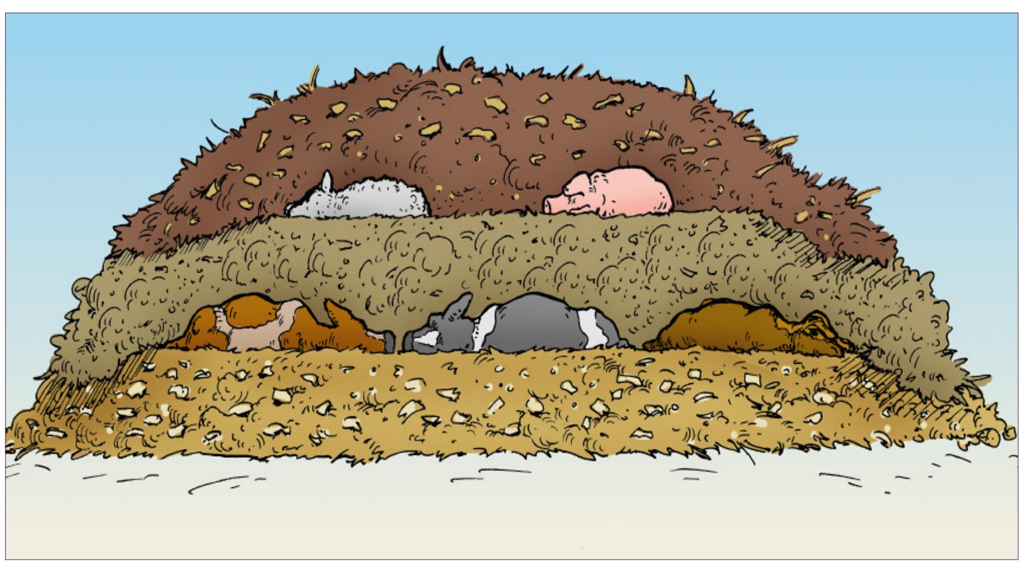

Figure 6-4. Layering animal mortalities

Weights and mortality rates for various animal species are listed in Table 6-1.

3 Feedstock Characteristics and Requirements

3.1 Carcass Characteristics

The primary feedstocks in mortality composting are the animal carcasses or animal tissues separated from a carcass such as meat, offal and organs. Carcasses include bones, feathers, hide and fur. The different components decompose at different rates and to a varying extent. Bones are the most resistant and usually pass through the composting process intact, though they become brittle. Feathers, hides, wool, animal hooves and poultry legs take longer to decompose than the soft tissue.

While the various components of carcasses present varying characteristics, *in general,* animal carcasses can be considered sources of nitrogen and moisture. Most animal tissues, including feathers and fur, are a concentrated source of protein with a relatively high nitrogen content. Cells of animal tissue hold a great deal of water, which is released as the cells break down. Depending on the animal and source, carcasses can also include appreciable amounts of fats, which are a rich source of carbon. While carbon and nitrogen ratios are important, if the animal carcass is managed whole the ratio will not be in balance to start with. As the animal decomposes the carcass and the carbon source slowly mix together with the ending C:N ratio of most typical finished composts.

An important characteristic is the high potential for nuisance issues, something that can, and must be, kept in checked. Left exposed, carcasses attract scavenging animals and insect pests including rodents, birds, dogs and flies. In addition, the wet and protein-rich composition makes animal tissue prone to putrid odors. The proteins break down to produce ammonia and odorous amines, especially at low C:N ratios and under anaerobic conditions. The odors produced by amines are exemplified by the names of two particular amine compounds: putrescine and cadaverine. Both of these foul-smelling compounds occur in decaying animal tissue. Animal fats and oils contribute to the formation of volatile fatty acids, which are also odorous. Distinctive features of animal mortality composting, such as thick covers of amendment and restricted turning have been developed to control pests and odors.

3.2 Preprocessing Carcasses

Although any animal can be composted whole with minimal processing, preprocessing may speed up the process. Large swine carcasses are often splayed under each leg and from the neck down to open up the stomach cavity. It is a good practice to pierce the stomachs, especially the rumen, of cattle and other ruminants to prevent bloating and, possible explosion, from accumulating gases. Total size reduction like grinding or chipping will expedite the process but requires specialized equipment, as well as additional worker health and safety requirements. It can be messy and unsettling. Size reduction will also solve problems with bones in the end-product and make the process and product less recognizable. Grinding allows for management of an evenly sized waste stream and would be managed more like butcher waste.

3.3 Amendments – Carbon Sources/ Bulking Agents

Mortality composting relies on other feedstocks, selected to make composting of the carcasses practical. Feedstocks

Table 6.1 - On-farm mortality rates and average weights

Species	Mortality rate (%)	Average weight (lbs)[e]
Horse[a] – Foals	4.9	100
Adult	1.8	1200-1500
Sheep[b] – Lambs	11.2	8
Adult	5.0	80-170
Dairy Cows[c] – Still births	6.5	
Pre-wean	7.8	90
Heifers	1.8	600
Cows	5.7	1400
Beef Cows[d] – Pre-wean	3.6	600
Feedlot	1.5	850
Poultry[e] – Laying hen	14	4.0
Broiler breeding hen	11	7.0
Broiler breeder pullet	5	4.3
Commercial egg pullet	5	2.8
Broiler	5	4.5
Roaster	8	8.0
Turkey hen	6	16.0
Turkey tom	9	25.0
Swine[e] – Still births	0.1-1	2-3
Farrow to wean	10-15	10
Nursery	2-5	30
Grow/Finish	2-8	160
Breeding herd	2-6	350

[a]USDA APHIS, 2007: Trends in Equine Mortality, 1998, 2005
[b]USDA APHIS, 2011: Sheep 2011
[c]USDA APHIS, 2007: Dairy
[d]USDA APHIS, 2008: Beef
[e]Rozeboom, et al., 2007

are commonly referred to as *amendments* because they are added to complement a primary feedstock, in this case, animal carcasses. They may also be referred to as *bulking agents* and *carbon sources*. The carcasses are commonly composted with a single amendment that serves the purpose well, or well enough. In other cases, a combination of different amendments is used to improve the characteristics of the media, or because a single amendment is not available in sufficient quantity. Most often, the medium includes fresh amendments and/or some of the compost recycled from previous batches.

The amendments within the composting medium serve several functions (Figure 6-5). They absorb moisture, and trap and degrade volatile gases and odors from decomposing carcasses. Most importantly, the amendments provide carbon, structure, porosity for air exchange and a barrier with the surrounding environment. Thus, good amendments have the following characteristics:

- Relatively dry (<50% moisture)
- Particles with some rigidity plus a large surface area
- High C:N ratio (>40:1) with available forms of carbon
- Non attractive to pests
- Decompose well enough to produce usable compost
- Low bulk density (porous)

Wood chips, wood shavings, sawdust, chopped straw, recycled compost and poultry litter are the amendments most often used for mortality composting. Table 6-2 indicates their general characteristics. Other materials that have been used as amendments include horse stall bedding (with manure), feed refusal, old corn silage, old hay, dry manure, peanut hulls, corn cobs, corn stalks, shredded paper products, shredded yard trimmings, bark, peat moss, active compost and mature compost. Shredding improves, and may be necessary for, feedstock with large particles (e.g. straw, hay, corn stalks, cardboard and leaves). A one to two inch (2.5 to 5.1 cm) particle size with different size fines mixed in, works best. Passive aeration will not be efficient with small particle sizes. For example, sawdust that is very fine without larger pieces mixed in, will absorb moisture, but then fill with water and no longer provide aeration. The particle size of the base material should promote aeration of piles and bins and also be thick enough to absorb the moisture generated above.

When considering amendments, it should be remembered that, “All amendments are not created equal.” For instance, particle size makes a difference: wood chips are larger and provide more porosity than shavings; and shavings provide more porosity than sawdust. In terms of degradability and the availability of carbon, sawdust would be best of the three choices and wood chips, the worst. However, wood chips are preferable because they give the pile the structure it needs to facilitate aeration. The condition of the amendment matters, perhaps more than the type of material. The moisture content, particle size, porosity, bulk density, C:N ratio and age can vary for almost any type of amendment. Wet sawdust does not absorb moisture as well as dry wood chips. Mature compost, aged manure and very old silage may not provide enough carbon or energy to sustain heating while

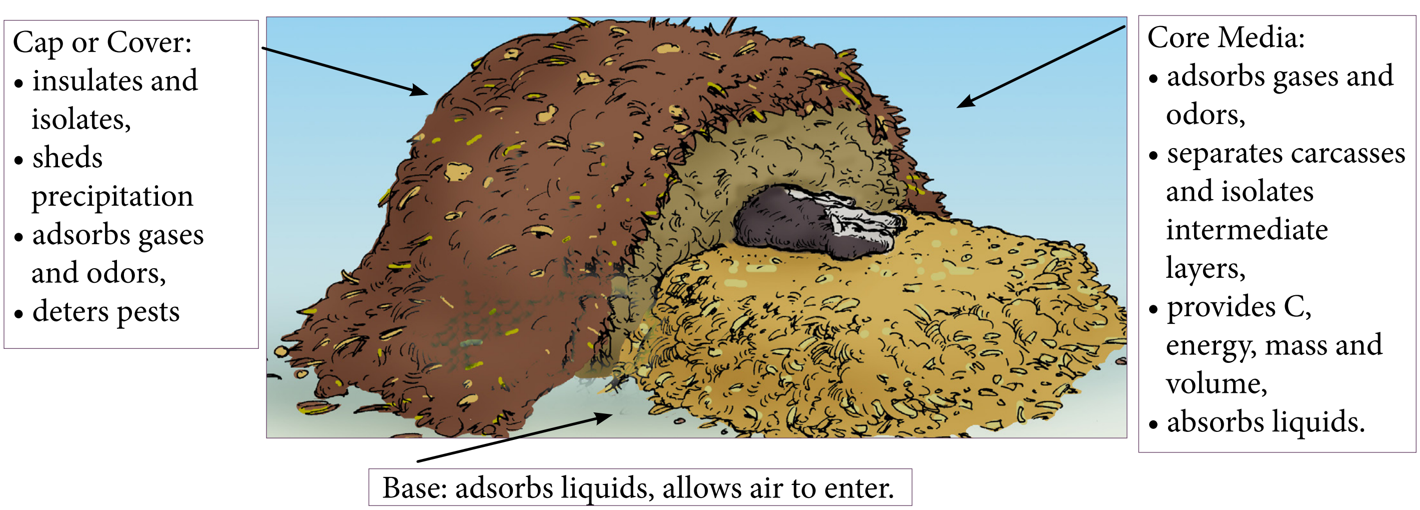

Figure 6-5. The functions of amendments in mortality composting

Table 6-2. Attributes of common on-farm composting materials (adapted from Rynk, 1992)

Material	C:N ratio	Moisture (%)	Characteristics
Animal Carcass	5:1	60	Very dense. High moisture content.
Cattle Manure	13–20:1	67–87	Nitrogen rich. High moisture content. Uniform, small particle size.
Poultry Litter/ Manure	3–16:1	22–75	Nitrogen rich Moderately moist (depending on bedding)
Horse Manure With Bedding	25–30:1	55–75	High moisture content. Uniform, small particle size.
Wheat Straw	100–150:1	10–14	Best when chopped and mixed with denser materials. Needs moisture. Highly degradable source of carbon.
Corn Silage	38–43:1	65–68	Good particle size. Poor structure when wet. Strong odor.
Hay	15–32:1	8–10	Best when chopped and mixed with denser materials. Needs moisture. Highly degradable source of carbon.
Sawdust/Wood Shavings	100–750:1	19–65	Maintains structure when wet (with mixed particle size) but difficult to keep moist in dry climates. Low odor.
Wood Chips	100–1000:1	--	Adds structure. Excellent base under primary compost materials. Larger chips absorb less water and odor and are slow to degrade but can be reused.
Finished Compost	20–40:1	--	Low available nutrients. Good as absorbent base or biofilter cover.

immature compost, fresh manure and “fresh” silage would.

In most cases, the amendment of choice depends on the availability and cost of these materials. Because a large volume of amendment is required, composters tend to use what is economically and locally available. However, the material must still be suitable for the purpose. Regardless of the materials selected, a ready supply of amendment should always be kept on-site. It is also advisable to maintain a list of locations where additional amendment can be obtained for emergency situations.

The required volume of fresh amendment can be reduced by up to 50% by recycling the compost produced for additional batches of mortalities as long as particle size is adequate for aeration. Recycled compost generally absorbs moisture well, provides good to fair porosity, does not attract pests, provides some carbon and energy (if it is not too degraded it can be used up to 3 times) and also inoculates the next pile with microorganisms (helpful but not necessary). It works particularly well for the base as the chips and partially decomposed bones add structure. If used as cover, this mixture may draw attention to the piles as bones will be visible. The cap, base and internal media can be, and typically are, the same feedstock.

4 Siting and Sizing the Mortality Composting Operation

4.1 Siting considerations

Siting is among the most important aspects of composting, particularly when it involves carcasses. Flesh is not a typical compost feedstock and people are not familiar with it. Therefore, it is important to be especially conscientious and considerate of neighbors. The potential for nuisance and environmental problems exists if something goes wrong. Although odors, flies and scavengers can be avoided through management practices, occasional incidents should be anticipated and planned for. In addition, decomposing carcasses release abundant moisture. Nutrient-rich leachate can leak from the pile or bin if the amount of amendment is insufficient. Surface and groundwater must be protected.

Siting of mortality composting operations is guided by the same requirements as conventional composting plus the added concern of biosecurity. The location must be large enough to accommodate the piles, bins and/or composting vessels as well as storage of amendments. It should be away from dwellings and property lines, be

A note about veterinary pharmaceuticals

In 2003, the Food and Drug Administration added an environmental warning to animal euthanasia products stating that "euthanized animals must be properly disposed by deep burial, incineration or other method in compliance with state and local laws to prevent consumption of carcass material by scavenging wildlife. Properly built and managed compost piles are an "other method". If the animal(s) being composted has been euthanized with a drug such as sodium pentobarbital, care should be taken to dispose of the remains as quickly as possible. They will contain potentially harmful residues. Wildlife and domestic animals may be attracted by the carcass and become intoxicated or die if allowed to feed on it. Properly built compost piles will deter pets and wildlife from feeding on carcasses when the concentration of drug residue is at the highest level. Sodium pentobarbital has been shown to degrade during the composting process so that by the time composting is finished (within six months) very low concentrations of the drug remain (Schwarz, et al., 2013).

environmentally safe and convenient. The site should be well drained and out of the drainage paths of uphill areas (or such drainage needs to be diverted). It should be at least 200 feet (60 m) from water courses, sinkholes, seasonal seeps or other landscape features that indicate the area is hydrologically sensitive (check your state laws for setback requirements).

To improve biosecurity, it is preferable to limit the transport of animal carcasses within the smallest area possible, in order to contain any pathogens that they might carry. At the same time, human and vehicle traffic in animal production areas must be minimized, especially traffic that may travel to other farms. Thus, a good site location is near the animal rearing areas but at the periphery so that the animals are buffered from vehicles delivering amendments and removing compost. Sites that are within the animal housing areas (e.g. mini-bins, in house composting) provide excellent biosecurity if vehicles from outside of the farm are not a factor.

4.2 Sizing Guidelines

The amount of space needed for a mortality composting operation depends on the animal species, size of farm, mortality rate, duration of composting, composting method, number and size of individual piles or bins, the type of amendment and other factors such as equipment used, additional feedstocks and processing activities. The total volume of an individual pile or bin is determined by the weight of mortalities generated over the cycle time, that is, how many days of mortality are included. Rozeboom et al., 2009 suggest that the most important factor in determining composting volume is the *target animal tissue density*. This density has been determined through experimentation where animal tissue composting has been successfully accomplished using densities varying from one-half to 15 lbs. of animal tissue (mortality) per cubic foot of bulking material (carbon). However, when animal tissue density is greater than 10 lb/ft^3, intensive management of aeration and moisture is necessary.

When composting in-vessel, additional space must be included for the walls of the bin and room to access it and maneuver equipment. Because a minimum of two primary units (curing or mesophilic phase) are necessary (one for loading while the previous unit is composting), approximately twice the area is necessary. For piles or windrows, additional space may also be needed for equipment access around and between the piles.

Most guidelines recommend that second stage piles or bins should be allotted the same volume as the primary units. This recommendation is a conservative one as some shrinkage in the volume does occur during the first stage of decomposition. The volume loss depends on the proportion and nature of the amendments and the duration of the first stage of composting: shorter processing time and less degradable amendments result in less shrinkage. It is generally safe and prudent to assume an equal volume is necessary for the second stage of composting. However, it is worth recognizing that some reduction in volume is likely between the two stages (from 20 to 50 percent).

There are three calculators available for determining how much space is needed to compost animal mortalities and animal tissue. Keener et al., 2000, at the Ohio State Agricultural Research and Development Center, Ohio State University developed procedures and equations for sizing of structures and windrows for composting animal mortalities based on animal decomposition times. The

Co-composter model, developed by Cornell University's Department of Biological and Environmental Engineering and Cornell Waste Management Institute in 2001, provides mass and volume balances, area estimations for storage, active composting and curing, and a cost analysis of alternate composting systems based on inputs entered in a series of excel spreadsheets. Spartan Animal Tissue Composting (ATC) System Planner, developed by Rozeboom, Person and Kriegel at Michigan State University in 2009 is an Excel application that assists in designing a composting system using a static approach, calculating the amount of space needed for composting only.

To use any of these the user needs to know 4 things: 1) weight and/or volume of tissue (mortalities) generated, 2) weight and/or volume of carbon needed for the tissue above, 3) type of composting system to be used, and 4) length of time needed for decomposition of soft tissues (primary composting or thermophilic phase). Depending on the program used, other variables may need to be known.

Figures 6-6 a-d shows the results of using these programs for the fictitious Bessy's Dairy with 200 milking cows, 200 calves and 100 heifers. Spartan ATC System Planner (Figure 6-6a) requires the user to pick the type of producer (Bovine), the type of composting system (Windrows) and the target animal tissue density (5 lb/ft^3). It then has the user enter production information to calculate the daily mortality rate in lb/day. The user then enters information on time to form a windrow, windrow dimensions, duration of active composting and equipment working space. The results for this dairy give the size of the pad to be 2,886 ft^2. For the Co-Composter model (Figure 6-6b), the user must enter the annual volume (ft^3/yr) of mortalities in step 8 of the program. Assuming that the density of flesh waste is 87.4 lb/ft^3, the annual mortality

System Planner Worksheet

Name: Sample Bovine Plan
Phone: 800-COW-MOO
Fax:

Address: Bessy's Dairy
On the Farm
Anywhere, USA

Select first type of producer: Bovine
Select second type of producer: None
Select third type of producer: None

Select type of composting system: Windrows

Target animal tissue density: 5 lb/ft^3

Bovine Animal Production Information

Item	Cows	Calves	Heifers	Feeder Cattle
Capacity:	200	200	100	0
Days in this production phase:	365	365	168	
Percent mortality:	6%	8%	2%	
Average weight of animals during phase (lb):	1400	90	600	
Number of animals per year:	200	200	217	0
Calculated daily mortality (lb/day):	46	4	7	0

Total farm mortality: 57 lb/day

Composting System Plan Using Windrows

Design Parameters

Desired time to form a windrow and batch:	3.0	months
Windrow length:	25	ft
Windrow width:	12	ft
Height of compost material:	6	ft
Duration of active composting in windrow/batch:	6	months
Equipment working space or apron width:	6	ft

Total farm mortality = 5215 lb per 3 months
Volume needed to fill windrow in desired time = 1043 cubic ft
Effective volume of windrow = 1206 cubic ft

Compost Facility Summary

Number of windrows needed	4	
Apron area needed to form and turn windrows	1686	ft^2
Total efffective volume of system	4824	ft^3
Size of pad including working space	2886	ft^2

Recommendations

Windrows are 16% larger than needed to meet anticpated mortaility rate
Animal tissue density is ok.

Figure 6-6a. Results for Bessy's Dairy using Spartan ATC System Planner

8) Enter annual volumes (ft^3), maximum days of storage and value of additional materials to be composted.

Material	% Moisture	C/N Ratio	Bulk Density	Annual Volume (ft³/yr)	Max. Days of Storage at the Composting Pad	Typical Max. Days of Storage	Value of Materials: Tipping Fee ($/ft³)[a]	Value of Materials: Cost ($/ft³)[b]
Food Waste	▲	▼	▼	0	0	2	$0.00	$0.00
Paper (shredded)	▼	▲	▼	0	0	60	$0.00	$0.00
Cardboard	▼	▲	▼	0	0	60	$0.00	$0.00
Yard Waste*	–	▲	▼	0	0	180	$0.00	$0.00
Grass Clippings	▲	▼	▼	0	0	7	$0.00	$0.00
Leaves	–	▲	▼	0	0	180	$0.00	$0.00
Shrub Trimmings	▼	▲	▼	0	0	180	$0.00	$0.00
Tree Trimmings	▲	▼	▲	0	0	180	$0.00	$0.00
Paper Pulp	▲	▲	▲	0	0	2	$0.00	$0.00
Food Process Waste	"If added, fill in chart below"			0	0	2	$0.00	$0.00
Other	"If added, fill in chart below"			226	0	2	$0.00	$0.00

	Density (lb/ft³)	Moisture Content (%)	N (% dry wt)	C/N
Food Process Waste	0	0	0	0
Other	87.4	65	3	6

1 yd³ = 27 ft³

{See Section F of the Background sheet, if further information on storage is needed} * Yard Waste is the ave. of grass clippings, leaves, and trimmings.

a: Tipping Fee is money paid to the composter by the provider of materials b: Cost is money paid to the provider of materials by the composter

Active Composting

Compost period (days	180
Composting area (ft²):	**1,554**
Number of rows / piles	1
Row/pile height (ft):	6.0
Row/pile width (ft):	12.0
Row/pile length (ft):	25

9) *Enter annual volumes (ft³), maximum days of storage, & value of the bulking agents.*

Bulking agents are added to increase the porosity of the compost mixture, permitting better air flow.

Bulking Agent	% Moisture	C/N Ratio	Bulk Density	Annual Volume (ft³/yr)	Max. Days of Storage at the Composting Pad	Typical Max. Days of Storage	Value of Materials: Tipping Fee ($/ft³)[a]	Value of Materials: Cost ($/ft³)[b]
Wood Chips	▼	▲	▼	3,942	0	180	$0.00	$0.00
Straw	▼	▲	▼	0	0	180	$0.00	$0.00
Corn Stalks	▼	▲	▼	0	0	180	$0.00	$0.00
Compost - dry				0	0	180	$0.00	$0.00
Other	"If added, fill in chart below"			0	0	180	$0.00	$0.00

	Density (lb/ft³)	Moisture Content (%)	N (% dry wt)	C/N
Other		0	0	0

1 yd³ = 27 ft³

Curing

Curing period (days):	90
Curing area (ft²):	**1,375**
Number of rows:	0
Row height (ft):	6.0
Row width (ft):	12.0
Row length (ft):	25

Total land requirement*

Total Area (ft²) =	**2,929**	*(excludes roads, equipment storage)
Total Area (ac) =	**0.07**	

Figure 6-6b. Results for Bessy's Dairy using Co-Composter

of 54 lbs/day over 365 days equals 226 ft^3/yr. The user also enters the annual volume of carbon material, in this case wood chips, calculated using the same target animal tissue density used by Spartan. The results from this program calculate the total land requirement to be 2,929 ft^2. Figure 6-6c shows the steps for determining the sizing of windrows for composting mortalities developed by Keener, et al., 2000, and Figure 6-6d shows the results for Bessy's Dairy, 2,904 ft^2. All three of these calculated approximately the same land area requirement.

Equations for Sizing of Windrows for Composting Mortalities

(adapted from Keener, et al., 2000)

Procedure:

1. Determine ADL (average daily loss) using farm records or livestock mortality rates
2. Determine composting times (primary, secondary and storage cycles). An equation was developed for primary (hot) composting time based on the number of days needed to successfully compost different weight animals. Secondary and storage cycle times are based on the primary cycle time.
3. Determine the volumes needed based on ADL and composting times. Two equations were developed, one for small animals and one for large animals and was based on the volume needed for successful composting.
4. Determine the dimensions of the windrows based on volumes. A table was developed giving section areas and base widths based on windrow height and assuming a 3 foot top width and 1:1 side slopes.

Windrow Height (ft)	Section Area (ft)	Base Width (ft)
5	30	11
6	42	13
7	56	15

5. Determine the pad length: Windrow length + equipment access distance
6. Calculate the pad area: Equipment access distance + primary windrow base + equipment access distance + secondary windrow base + equipment access distance.
7. Determine pad area: Pad length x pad width.
8. Determine carbon requirement for the year: Carbon = lbs loss/year x 0.0069

Figure 6-6c. Steps used to determine windrow size

An Example: Bessy's Dairy – 200 milking cows, 200 calves, 100 heifers

1. ADL: Livestock mortality rates (from the Spartan Planner example) indicate an ADL of 54 lbs/day
2. Composting Times: W1 is the weight of the largest animal (in kg)
   Primary cycle time, T1 = 7.42 X W10.5 = 7.42 x 6360.5 kg (1400 lb cow) = 187 days
   Secondary cycle time, T2 = 1/3 x T1 = 1/3 x 187 = 62 days
   Storage cycle, T3 >= 30 days
3. Composter Volume: W1 is the weight of the largest animal (in lb). 0.20065 represents the volume needed per pound of mortality for successful composting – similar to Rozeboom's animal tissue density.
   Primary Volume, V1 = 0.20065 X W1 x Integer (ADL x T1/W1) = 0.20065 x 1400 x Integer (54 x 187/1400) = 0.20065 x 1400 x 8 = 2247 ft3
   Secondary Volume, V2 = 0.20065 X W1 x Integer (ADL x T2/W1) = 0.20065 x 1400 x Integer (54 x 62/1400) = 0.20065 x 1400 x 3 = 843 ft3
   Storage Volume, V3 = 0.20065 X W1 x Integer (ADL x T3/W1) = 0.20065 x 1400 x Integer (54 x 30/1400) = 0.20065 x 1400 x 2 = 562 ft3
4. Windrow Dimensions: Using a windrow height of 6 ft which means a base width of 13
   Primary windrow length = V1/Section area = 2247/42 = 54 ft
   Secondary windrow length = V2/Section area = 843/42 = 20 ft
   Storage windrow length = V3/Section area = 562/42 = 14 ft
5. Pad Length: Longest windrow length + (equipment access x 2) = 54 + 12 = 66ft
6. Pad width: Equipment access + primary windrow base width + equipment access + secondary windrow base width + equipment access = 6 + 13 + 6 + 13 + 6 = 44ft
7. Pad area: Pad length x pad width = 66 x 44 = 2904 ft2
8. Carbon Requirement: Pounds loss/year x 0.0069 = ADL x 365 x 0.0069 = 54 x 365 x 0.0069 = 135 yd3

Figure 6-6d. Results for Bessy's Dairy using equations developed by Keener, et al., 2000

5 Mortality Composting Methods and Procedures

The methods used to compost animal mortalities have expanded with the growing number of applications. They include static pile or passively aerated windrow composting, turned windrows, in-vessel, forced aeration, rotating drum or the combination of several methods. Passively aerated static piles and bins remain the predominant approach. Factors such as the location, proximity to population, primary wind direction and characteristics of the nitrogen source, the volume generated from the business and space available need to be considered when choosing the site and method.

5.1 Passively Aerated Static Piles/ Windrows and Bins

Passively aerated static piles and bins are the most common methods used in composting mortalities. Carcasses are layered or enveloped within amendments and left to decompose undisturbed for weeks or months. Air flow through the pile occurs by passive convection (Figure 6-7). The pile/windrow can be left in place to finish the process or turned after the soft tissue disappears and composting continues for several months longer. Although this is considered "static" (i.e. no agitation or turning), it can be helpful to turn the material at least once after the soft tissue has decomposed, or when odors will not likely be liberated. Turning homogenizes the materials and provides the transition to the second stage. The second stage can include additional turnings to accelerate the process. The procedures are essentially the same whether freestanding piles, long windrows or bins are used. However, slight variations in practices exist for different types of bins (see section 5.4)

Site cleanliness is the most important aspect of composting: it deters scavengers, helps control odors, and promotes good neighbor relations.

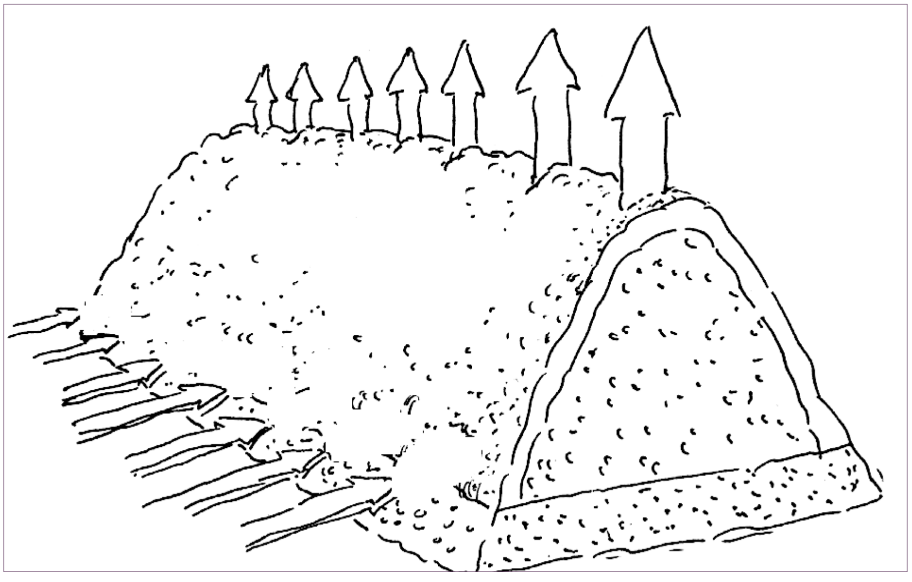

Figure 6-7. In well-built piles with chunky carbon bases, air circulates naturally through the pile

The *general* steps are as follows: Lay down a *base layer* of amendment, approximately 18 to 24 inches (30 to 60 cm) thick, to create a base for the pile or bin (Figure 6-8). The primary function of the base layer is to absorb moisture released from the decomposing carcass to prevent leaching. The second function is to provide pore space for air-flow. The thickness of the layer depends on the absorbency of the amendment and the size of the carcasses (larger carcasses tend to contain a higher proportion of water). Amendments with large particles, like wood chips, should be used for the base layer. If liquids leak from the base of piles, the thickness of the base layer should be increased when building future piles or a more absorbent material should be used.

1. *Place the carcasses on the base layer*: Small carcasses (birds, fish) can be spread over the layer evenly without being spaced apart. Animals of moderate size (pigs, sheep, deer, etc.) should be spaced evenly over the base, separating carcasses by a few inches (Figure 6-9). For very large animals, like mature cattle and horses, only one carcass may fit the width of the pile or bin. In most cases, carcasses should not be stacked on top of one another nor placed near the outer edges of the piles or bins. A minimum buffer of 18 to 24 inches (45 to 61 cm) from the outer edges of piles and bin walls should be maintained.

2. *Cover the carcasses with amendment*: How much cover and what material to use depends on whether additional layers will be added and how soon. Place 12 inches (30 cm) of cover over smaller animals and add another layer. If this is a continuous process with animal additions daily or

weekly in layers, it is best to stair step the animals into the pile. Build the first end and extend a carbon bed out so that it is ready for additional animals. In the case of large animals, there is no middle layer, so this will be the final cover layer or biofilter and should be 24 inches (61 cm). When animals are added to the pile, dates should be recorded, especially the last one. If it is a windrow, dated flags can be placed in the pile to keep track; one end of a 100 foot (30 m) windrow will be finished before the other. Always make sure animals are well covered to avoid related problems (odor, vermin, etc.).

Figure 6-8. Static windrow composting with bed prepared for additional animals or butcher waste

3. *Add water as necessary*: Although the carcasses supply considerable water, it may not be sufficient to support decomposition of the amendments. In addition, water released from the carcasses concentrates in small regions within the amendments. Therefore, the amendments should also be moderately moist (40 to 60%) at the time they are placed. The amendment should feel and look damp, not wet; this is especially important in arid climates.

4. *Cap the pile or bin:* The final layer of carcasses should be covered with a thicker layer of amendment. For small to moderate animals, 12 to18 inches (30 to 45 cm) is typical. For large animals, 18 to 24 inches (45 to 60 cm) is necessary. The appearance of scavengers and flies means that the thickness should be increased. The same amendment used to cover intermediate layers can also be used for the final cap.

Figure 6-9. Deer carcasses placed on the base layer

5. *Moisture management:* Piles/windrows can be shaped to shed moisture or include it depending on climate. Piles with peaked tops will shed moisture in high precipitation areas. Creating a flat top will allow moisture that falls on the pile to soak in. Creating a trough will allow moisture to collect and soak in. When piles are working efficiently it is hard to add moisture, as much of it is released into the atmosphere.

6. *Stage 1 composting:* After the pile or bin is capped, it is left to

Figure 6-10. NYS Department of Transportation applying road kill compost along highway

compost undisturbed for roughly 2 weeks to 6 months, depending on the largest carcass size and management objectives. The pile/bin should be monitored for temperature, odors, and signs of scavengers, flies and leachate. Any problems that are detected should be corrected (Monitoring Compost Piles or Windrows). In the meantime, new piles or bins may be started to treat additional mortalities.

7. *Turn and commence Stage 2:* Many piles are not turned; however, the process can be expedited through turning after most of the flesh has been decomposed. The end of the first stage of composting may be indicated by falling temperatures. Turning is typically accomplished with a bucket loader or windrow turner. As in conventional composting, turning mixes the material, distributes moisture and nutrients, and recharges the process. After turning, some parts of the carcass may not be fully decomposed. Any recognizable pieces of meat, organs, hide, feet and bones that remain exposed after turning should be covered with clean amendment. The material can be turned again or not depending on the management preferences.

8. *Use of the end product and bones:* Use of the material as the base for the next pile is recommended and can be done 4-6 months after the last carcass is added and the pile has gotten hot (110^{o}F). The remaining bones add structure to the base material for improved aeration. After a year of composting, the end product can also be used on roadside construction and maintenance projects (Figure 6-10) or farm fields. Testing to prove the safety of carcass compost materials would be a very expensive undertaking, and would require the testing of essentially every pile. It is, therefore, appropriate to limit the use of these products to areas where there is low human or pet traffic. Applying this compost to “table-top” crops directly consumed by people or distributing the compost material for public use is not recommended. In addition, all compost materials may contain environmental microbes and decomposition products, such as mold spores, which may pose an inhalation, ingestion or contact risk to some individuals.

5.2 Turned Windrow Composting

Turned windrows can be used to compost small whole animals under 25 pounds (11 kg) and sized reduced large animals or butcher waste. This method is acceptable if the facility has no close neighbors and the prevailing wind direction is away from populated areas. As odors will be generated each time the pile is turned (especially in the early stages), a biofilter may need to be placed on the pile after turning early in the process. Odor and neighbor knowledge of this type of facility is the most common reason for operational shutdowns.

In general, well-managed, turned piles will expedite processing and completion. It is important to ensure there is good airflow within the pile: the coarser the carbon source, the better the airflow hence less turning is required. A combination of the passively aerated windrow system (PAWS) and turning can be the most effective combination in controlling both odors and pathogens.

5.3 Forced Aeration

Forced aeration can be used alone or as a component in different composting systems, and can vary in sophistication. In this method, air is mechanically forced through the composting pile through perforated tubing, gravel channels or cement floors designed with holes.

Forced aeration systems can be helpful during Stage 1 composting of animal mortalities, for example, to prevent the release of unacceptable levels of odors, or to reduce composting times.

It is important to make sure the system is designed for easy cleaning. Holes and channels can get clogged and perforated pipes may harbor leachate that creates a perfect breeding area for flies. The most common management problem is that operators force too much air through the pipes, excessively drying the feedstock and shutting down the process. As with all systems, there is a learning curve to make the feedstock and equipment work efficiently.

5.4 In-Vessel Composting

In-vessel composting is an option that can control most aspects of the process depending on the sophistication of the system. In-vessel means contained in some way, and can range from hay bale or wood containment to inside a building and include film plastic, cement or metal tunnels. These systems can handle feedstock in batches or as a continuous feed depending on design.

In-vessel systems vary in the level of sophistication and process control. There are units that have very short retention times, but need to be used in concert with a turned or aerated system. Tunnels and silos can be used for mortality under 25 pounds (11 kg), size reduced mortality or butcher waste. Some units have mixers on the front end and some are loaded with a prepared mixture. Before choosing a system, it is important to ensure the technology matches the need of your feedstock, and that there is adequate space to finish the compost after it has gone through the hot composting phase.

5.5 Bins

The main difference between bins and freestanding piles is that bins offer the convenience of physical containment. They provide a measure of protection from pests, the weather and use space more efficiently. On the negative side, most bins are fixed in size and location and the structural material for bins adds to the cost of the operation.

There are many options regarding the configuration and construction of bins including:

- Temporary, portable or fixed
- Open, roofed or inside a building
- Four, three or two sided (open on each end)
- Square, wide and shallow, or narrow and deep
- Constructed of wood, poured concrete, concrete blocks, moveable barriers (e.g. Jersey barriers) or large bales (hay or straw, round or rectangular)

Bins that are fixed tend to have concrete floors. Temporary bins usually are placed on soils. At least two and normally three or more bins are situated side-by-side. When turning occurs, the material is moved into an adjacent bin.

Several common styles of mortality composting bins are available. The choice depends on factors that include the type of operation, animal species, regularity and

Figure 6-11. Example of a wooden bin used for poultry

In Australia, a modular, aerated, transportable container (modified trash dumpster) has been used to compost poultry mortality. The container is gradually layered with poultry carcasses and carbon source, and then it is removed and taken to a centralized composting facility to be finished in compost windrows. At the same time, a new container is delivered to the farm. It seems to work but two containers might be more useful: one for filling, and the other left for several weeks after being filled to optimize the process.

frequency of mortalities, weather and available capital, including the availability of cost share funds. Covered wooden bins have been popular in the poultry industry (Figure 6-11).

The dimensions of individual piles and bins vary with the animal species, size of the operation and equipment used. Some bins for poultry and fish are only 3 ft (0.9 m) high. Otherwise, maximum recommended heights typically range from 4 to 8 ft (1.2 to 1.8 m). Aeration becomes more difficult as the height increases. The width of the bin depends on the means of loading and unloading. In general, they range from 3 ft (0.90 m) for hand-loaded mini-bins to up to 16 ft (4.8 m) for large operations with temporary bins. The bin should be wide enough to fit the bucket loader that will be used.

A multi-bin system can be effective in many situations. It is an option for any size of operation with meat or seafood residuals, poultry and small livestock.

5.7 Rotating Drums

Rotating drums serve to accelerate the first stage of composting carcasses: tumbling of feedstock exposes the material to air, distributes heat and homogenizes the mix thereby creating conditions that promote rapid decomposition. Retention time for carcasses and amendments is typically 3-21 days. The drum itself also isolates the carcasses and odors from the surrounding area.

Poultry mortalities and other small carcasses (<30 lbs. [<13.6 kg]) are loaded into the drums intact and mixed with amendment. Carcasses over 30 lbs. must be ground up then mixed with amendment. Small pigs, about 100 pounds each are loaded into drums for composting as well.

Models used for composting carcasses are typically about 10 ft. (3 m) in diameter and 50 ft. (15 m) in length (Figure 6-13). Units used for composting carcasses have not been aerated with fans, although fans are used in many other applications. The drums are loaded with a screw conveyor through a port at one end. The compost mix is discharged through unloading doors or shoots at the opposite end. The partially composted and well-blended mix emerges and requires further composting, which can take place in passively aerated piles, bins, windrows or mechanically aerated piles.

5.6 Mini-Composters

Mini-composters are small portable bins made of pallets, lumber, and/or plastic or wire mesh (Figure 6-12). They must be large enough to generate and retain heat, with minimum dimensions of 4 ft x 4 ft x 3 ft high (1.2 m x 1.2 m x 0.9 m high). This size bin can hold a total of 600 lbs. (272 kg) of carcasses.

Mini-composters represent a special application of passively aerated bins. They were developed for poultry but can be used for any small animals up to 30 lbs. (13.6 kg) including piglets, rabbits and fish. The beauty of mini-composters is that they can be located within the animal rearing areas and can be sized according to need.

Figure 6-12. Wire bin mini-composter

Figure 6-13. Rotating drum for carcass composting

6 Monitoring Compost Piles or Windrows

A record of temperature, odor, vectors (any unwanted animals), leachate (liquid that comes out of the pile), spills and other unexpected events should be kept as a record of the process. This will allow the composter to see if sufficiently high temperatures were reached and adjust the process if there are any problems. Also, odor can be an issue and compost piles are an easy target for complaints. Maintaining records can help identify a problem and uphold or disprove a complaint.

Monitoring of the pile is done primarily by checking temperatures. Internal compost temperatures affect the rate of decomposition as well as the reduction of pathogenic bacteria, fungi and weed seeds. The most efficient temperature range for composting is generally between 104°F and 140°F (40°C and 60°C), however, with butcher waste piles, it is not uncommon to reach temperatures as high as 170°F (77°C). As these piles are high in moisture, spontaneous combustion does not seem to be a problem. On the other hand, if temperatures get too high this can indiscriminately kill beneficial as well as pathogenic organisms, causing temperatures to drop.

Compost temperatures depend on how much of the heat produced by the microorganisms is lost through aeration or surface cooling. During periods of extremely cold weather, piles may need to be larger than usual to minimize surface cooling. As decomposition slows, temperatures will gradually drop and remain within a few degrees of ambient air temperature. Thermometers with 3-6 foot probes and data loggers are available, although care needs to be taken when inserting them into the pile, as they can bend or break when hitting rock, bone or dense material.

Monitoring oxygen will also indicate how well the process is progressing. With static piles it is important to keep oxygen levels high by using bulky carbon sources. Ideally, oxygen levels should be kept between 5-14%.

7 Pathogen Control

Different methods of composting will result in different levels of pathogen reduction. Turned piles will continue to turn material into the center of the pile so that all material is exposed to thermophilic temperatures. Different regulators have different time-temperature requirements to meet certain needs. For example, the USEPA lists processes to further reduce pathogens (PFRP) which requires temperature between 131°F and 170°F. To comply with the standard, composting operations that utilize an in-vessel or static aerated pile system must maintain a temperature within that range for a minimum of three days. Composting operations that utilize a windrow composting system must maintain a temperature within that range for a minimum of 15 days, during which time the materials must be turned five times. This protocol is set up to ensure that pathogen levels are low at the time of compost application.

Pathogen kill in PAWS may take longer than in-vessel or turned piles. It generally takes between 9-12 months or a combination of PAWS for 2-4 months and then turning several times to ensure pathogen reduction.

7.1 Special Considerations

As some pathogens are easily transmitted through the air, it is best to compost diseased mortality in situ. With diseases like Avian Influenza (AI) and Foot-and-Mouth Disease that are caused by highly infectious viruses, extra precautions must be considered such as composting in barns, plastic tubes or containers, as the disease is caused by highly infectious viruses. In the case of prion diseases such as BSE, scrapie or CWD, temperature alone is not sufficient in the process to disable the prion. However, composting would reduce the volume by almost 50% and the end-product could be burned in a high temperature waste-to-energy facility to complete the prion destruction; it is more efficient to burn bones and wood chips than whole animals.

8 References Cited and Suggested Readings

References Cited:

Keener, H.M., Elwell, D.L. and Monnin M.J. 2000. Procedures and Equations for Sizing of Structures and Windrows for Composting Animal Mortalities. Applied Engineering in Agriculture 16(6): 681-692.

Haith, H., Crone, T., Sherman, A., Lincoln, J., Reed, J., Saidi, S. and Trembley, J. 2003. Co-Composter. Cornell University. http://compost.css.cornell.edu/CoCompost.html.

Rozeboom, D.W., H.L. Person and R.D. Kriegel. Spartan Animal tissue Composting System Planner, version 1.02. 2009. Available at: https://www.msu.edu/~rozeboom/catrn.html.

Rynk, Robert (Ed). On-farm Composting Handobook. Natural Resource, Agriculture and Engineering Service, Ithaca, NY. 1992. NRAES-54.

Schwarz, M., Bonhotal, J., Bischoff, K. and Ebel, J.G. Jr. 2013. Fate of Barbiturates and Non-steroidal Anti-inflammatory Drugs During Carcass Composting. *Trends in Animal and Veterinary Sciences Journal* 4(1):1-12.

USDA APHIS Beef 2008 Part IV: http://www.aphis.usda.gov/animal_health/nahms/beefcowcalf/downloads/beef0708/Beef0708_dr_PartIV.pdf

USDA APHIS Dairy 2007 Part I: http://www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dairy07/Dairy07_dr_PartI.pdf

USDA APHIS: Highlights of Equine 2005 Part 1: Baseline Reference of Equine Health and Management, 2005. http://www.aphis.usda.gov/animal_health/nahms/equine/downloads/equine05/Equine05_is_PartI_Highlights.pdf

USDA NRCS Livestock mortality rates and design weights: ftp://ftp-fc.sc.egov.usda.gov/OH/pub/fotg/mortality_rate_new.PDF

USDA APHIS, National Animal Health Monitoring System: http://www.aphis.usda.gov/animal_health/nahms/

USDA APHIS Sheep 2011 Part II: Reference of Marketing and Death Loss on U.S. Sheep operations. http://www.aphis.usda.gov/animal_health/nahms/sheep/downloads/sheep11/Sheep11_dr_PartII.pdf

USDA APHIS: Trends in Equine Mortality, 1998-2005. http://www.aphis.usda.gov/animal_health/nahms/equine/downloads/equine05/Equine05_is_Mortality.pdf

Suggested Reading

Adams, D., Flegal, C., and Noll, S. Composting Poultry Carcasses. NCR-530, Purdue University, West Lafayette, IN. Available at https://www.extension.purdue.edu/extmedia/NCR/NCR-530.html.

Bonhotal, J., Telega, S.L., and Petzen, J.S. 2002. Natural Rendering: Composting Livestock Mortality and Butcher Waste, Cornell Waste Management Institute, 12-page fact sheet, DVD and 3 posters. Available at http://cwmi.css.cornell.edu/mortality.htm.

Bonhotal, J., Harrison, E.Z., and Schwarz, M. 2007. Composting Road Kill, Cornell Waste Management Institute, 12-page fact sheet, DVD, poster, peer-reviewed articles and literature review. Available at http://cwmi.css.cornell.edu/mortality.htm

Bonhotal, J., Schwarz, M., and Brown, N. 2008. Natural Rendering: Composting Poultry Mortality. The Emergency Response to Disease Control, Cornell Waste Management Institute, 12-page fact sheet, DVD, poster and literature review. Available at http://cwmi.css.cornell.edu/mortality.htm

Collins, E.R., Jr. 2009. Composting Dead Poultry. Virginia Cooperative Extension Publication 424-037. Available at http://pubs.ext.vt.edu/442/442-037/442-037_pdf.pdf.

Cornell University, Department of Biological and Environmental Engineering and Cornell Waste Management Institute, Ithaca, NY. 2001. Co-Composter version 2a. Available at: http://compost.css.cornell.edu/CoCompost.html.

Kansas State University, Purdue University and Texas A&M Univeristy, 2004. Carcass Composting: A Comprehensive Review. Report prepared by the National Agricultural biosecurity Center Consortium

Carcass Disposal Working Group for the USDA Animal and Plant Health Inspection Service. Available at http://fss.k-state.edu/FeaturedContent/CarcassDisposal/CarcassDisposal.htm.

Keener, H., Elwell, D., and Mescher, T. 1997. Composting Swine Mortality Principles and Operation. Available at http://ohioline.osu.edu/aex-fact/0711.html.

Larson, J., 2006. Disposal of Dead Production Animals Bibliography. Available at http://www.nal.usda.gov/awic/pubs/carcass.htm#2006.

Ritz, C.W., and Worley, J.W. 2012. Poultry Mortality Composting Management Guide. Available at http://extension.uga.edu/publications/files/pdf/B%201266_3.PDF.

Rozeboom, Dale W., Suzanne Reamer and Jerrod Sanders. Michigan Animal tissue Compost Operational Standard. 2007. Available at: https://www.msu.edu/~rozeboom/catrn.html.

University of Maine Cooperative Extension: Safe Disposal of Backyard Poultry Flocks. Available at http://extension.umaine.edu/publications/12e/