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## Composting

### Composting principles

Composting is the controlled aerobic biological decomposition of organic matter into a stable, humus-like product, called compost (Figure 51-1). It is essentially the same process as natural decomposition except that it is enhanced and accelerated by mixing organic waste with other ingredients in a manner that optimizes microbial growth.

The compost pile will pass through a wide range of temperatures over the course of the active composting period (Figure 51-2). As the temperature varies, conditions will become unsuitable for some microorganisms while at the same time become ideal for others.

Initially, as the microbial population begins to consume the most readily degradable material in the compost pile and grow in size, the heat generated by the microbial activity will be trapped by the self-insulating compost material. As the heat within the pile accumulates, the temperature of the compost pile will begin to rise. As the pile temperatures increase, the pile will become inhabited by a diverse population of microorganisms operating at peak growth and efficiency. This intense microbial activity sustains the vigorous heating that is necessary for the destruction of pathogens, fly larvae, and weed seeds. The diversity of the microbial population also allows the decomposition of a wide range of material from simple, easily degradable material to more complex, decay resistant ones such as cellulose. The temperatures will continue to rise and peak between 130 to 160°F. Once this peak is reached, microbial activity begins to decrease in response to a depletion in readily degradable material or excessively high temperatures that are detrimental to their function.

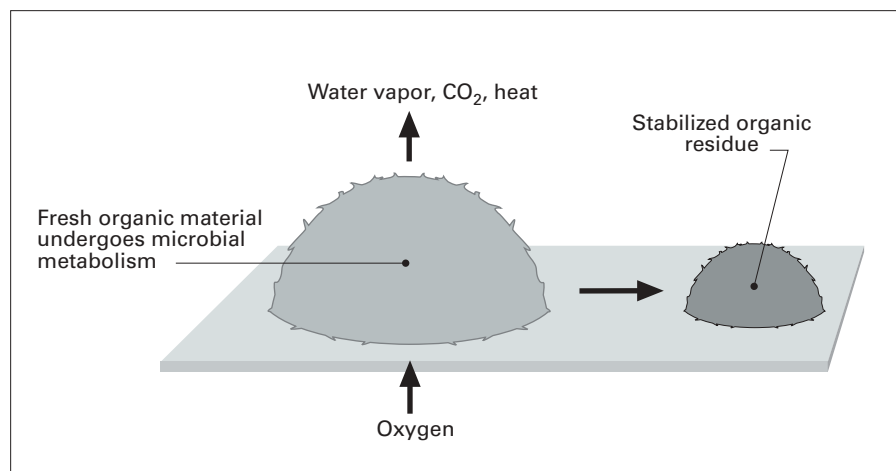


Figure 51-1. Composting process.

Efficient composting requires that the initial compost mix have

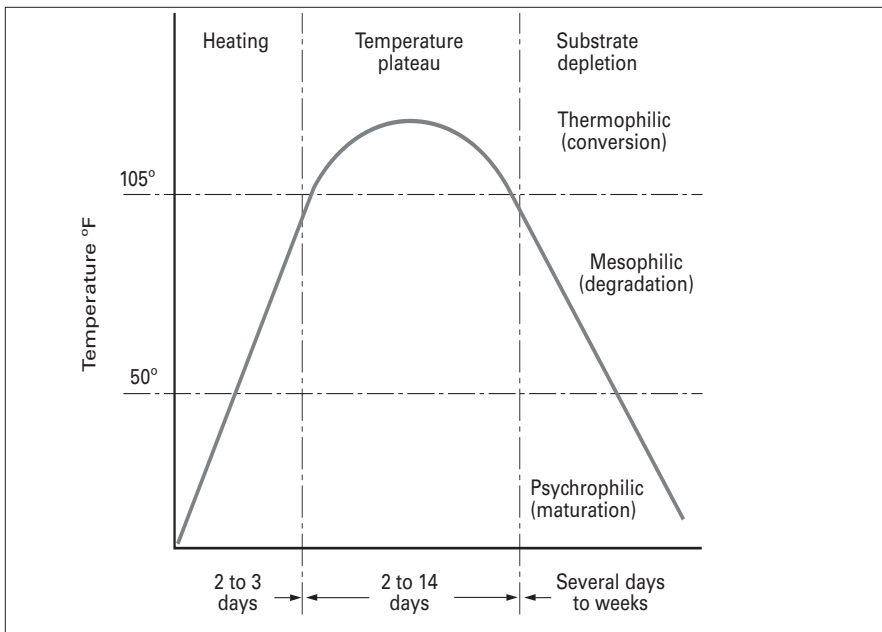
- A balanced source of energy (carbon) and nutrients (primarily nitrogen), typically with a carbon-to-nitrogen (C:N) ratio of 20:1 to 40:1.
- Sufficient moisture, typically 40% to 60%.
- Sufficient oxygen for an aerobic environment, typically 5% or greater.
- A pH in the range of 6 to 8.

These compost mix characteristics must be maintained throughout the composting process as well.

The proper proportion of the material to be composted combined with amendments and bulking agents is commonly called the compost mix or the “recipe” (Figure 51-3). A composting amendment is any item added to the

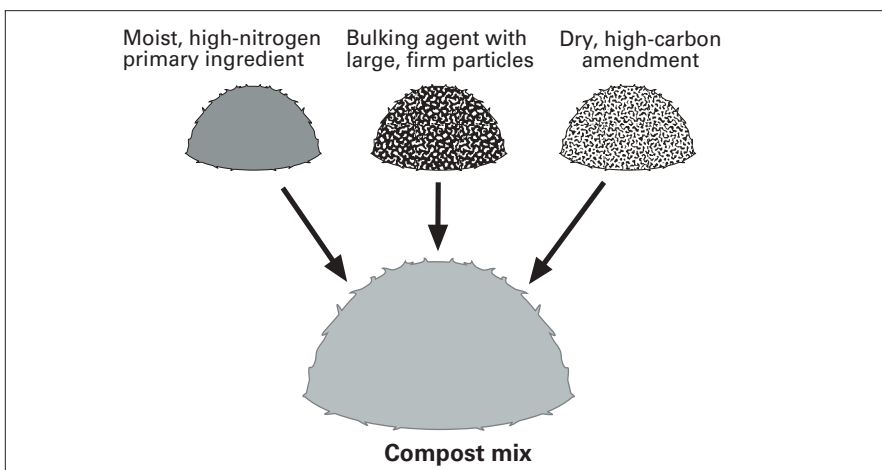
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- A balanced source of energy and nutrients...
- Sufficient moisture...
- Sufficient oxygen for an aerobic environment...
- A pH in the range of 6 to 8.



**Figure 51-2. Compost temperature ranges.**

Source: NRCS Agricultural Waste Management Field Handbook 1996, p. 10-55.



**Figure 51-3. Components of the compost mix.**

**A number of methods are used to compost organic wastes including**

- Passive composting pile
- Windrow
- Passively aerated windrow
- Aerated static pile
- In-vessel

compost mixture that alters the moisture content, C:N, or pH. Crop residue, leaves, grass, straw, hay, and peanut hulls are examples of the material suitable for use as a compost amendment. A bulking agent, such as wood chips, is used primarily to improve the ability of the compost to be self-supporting or have structure and to allow internal air movement. Some bulking agents may alter the moisture content and/or C:N ratio. This type of material would serve as both an amendment and a bulking agent.

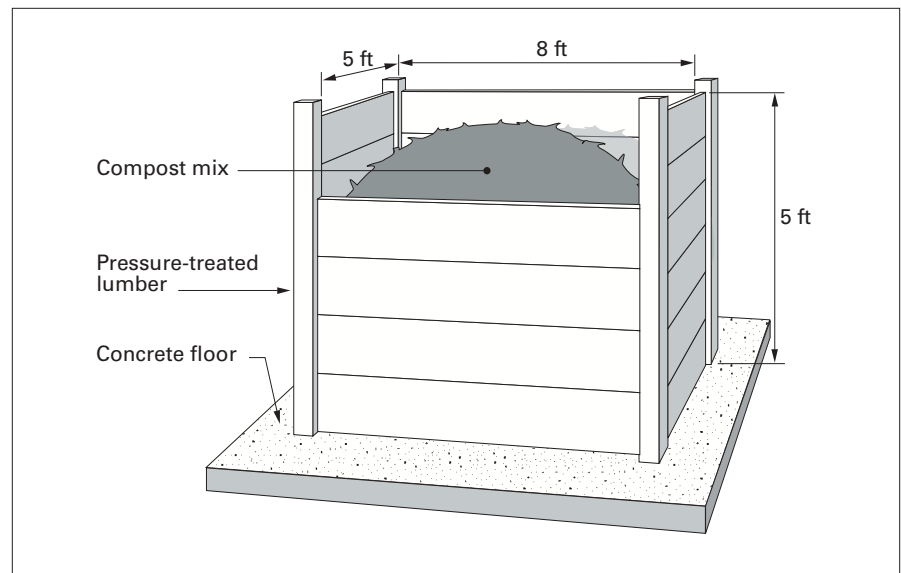
Recipe recommendations are available for composting many types of organic wastes. However, when it is necessary to determine the recipe from scratch, the characteristics of the waste, amendments, and bulking agents must be known. The characteristics that are the most important in determining the recipe are moisture content, carbon content, nitrogen content, and C:N ratio. If any two of the last three components are known, the remaining one can be calculated. The determination of the recipe is normally an iterative process of adjusting the C:N ratio and moisture content by adding amendments. If the C:N ratio is out of the acceptable range, then amendments are added to adjust it. If this results in high or low moisture content, amendments are added to adjust the moisture content. The C:N ratio is again checked, and the process may be repeated. After a couple of iterations, the mixture is normally acceptable.

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- Passive composting pile.
- Windrow.
- Passively aerated windrow.
- Aerated static pile.
- In-vessel.

**Dead animal composting**

Dead animal composting generally employs the in-vessel method using composting bins (Figure 51-4). Dead animals may also be composted using the windrow or passive composting pile methods, the preferable methods for



**Figure 51-4. Compost bin.**

Adapted from NRCS Agricultural Waste Management Field Handbook 1996, p. 10-59.

composting larger dead animals.

As already emphasized, organic wastes are generally blended into a homogenous mix having the appropriate C:N ratio, pH, oxygen, and moisture to facilitate efficient decomposition. Dead animal composting, however, requires a different approach. For dead animal composting, the carcasses and amendments are layered into the pile, and no mixing is done until after the high-rate phase of composting has occurred and the dead animals are fully decomposed. For that reason, the initial pile in which dead animals are composted is an inconsistent, nonhomogeneous mixture. Figure 51-6

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Figure 51-5. Windrow.

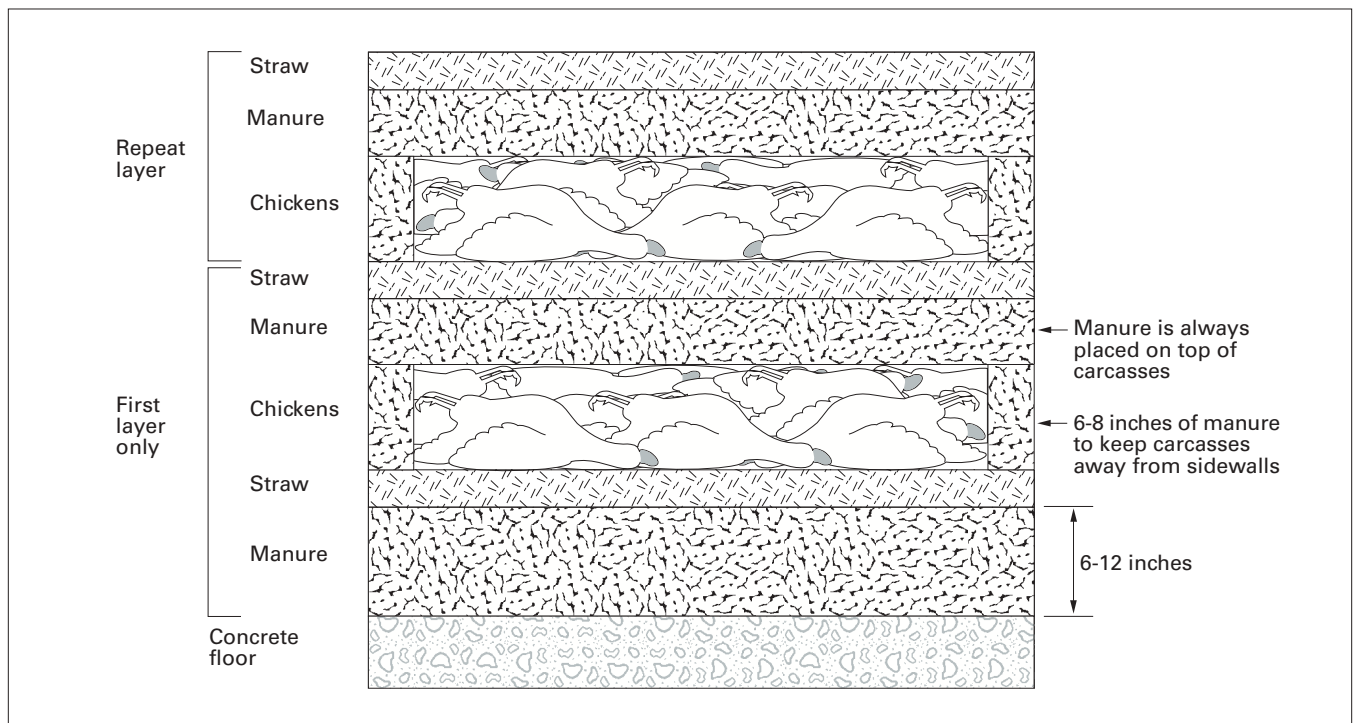


Figure 51-6. Initial layering of the mix for composting dead broiler chickens.

Adapted from NRCS Agricultural Waste Management Field Handbook 1996, p. 10-61.

**Composting mortality can be likened to above-ground burial in a biomass filter with the pathogens killed by high temperatures.**

illustrates how two amendments, straw and chicken litter, are layered with dead broiler poultry in bin composting. Regulations in some states do not allow including chicken litter in the compost mix. Where chicken litter is not allowed, dead animals can be composted with sawdust as the only amendment. However, where use of chicken litter is allowed and it is conveniently available, its use will allow the compost process to be more efficient because the C:N ratio is adjusted.

Composting mortality can be likened to aboveground burial in a biomass filter with the pathogens killed by high temperatures (Figure 51-7). At least one foot of biofilter should be provided between the dead animals and the sides of the bin or the outside surface of the windrow. For large animals, this distance should be increased to two feet. The composting process for mortality is shown schematically in Figure 51-8.

For bin composting, a permanent structure, such as bins constructed of treated lumber or concrete within a pole-frame building with concrete floors (Figure 51-9), is the most desirable. This type of facility offers easier overall operation and management especially during inclement weather and for improved aesthetics. Some states may require that composters be roofed and/or be located on impermeable surfaces, such as concrete or compacted clay. Consult the Natural Resources Conservation Service, Extension Service, MidWest Plan Service, or Northeast Regional Agricultural Engineering Service for composter plans that will meet your needs.

Temporary bins can also be constructed with bales of low-quality hay or straw (Figure 51-10). This type of construction is less expensive and provides the flexibility, such as the number of bins and their location, that a permanent structure would not. When the need arises, bale bins can also be used along with a permanent structure facility to provide additional composting capacity. Straw bale composters, for example, could be used for catastrophic mortality.

The correct sizing of the composting facility is critical for its successful operation and depends on the size of the animals and the amount of material

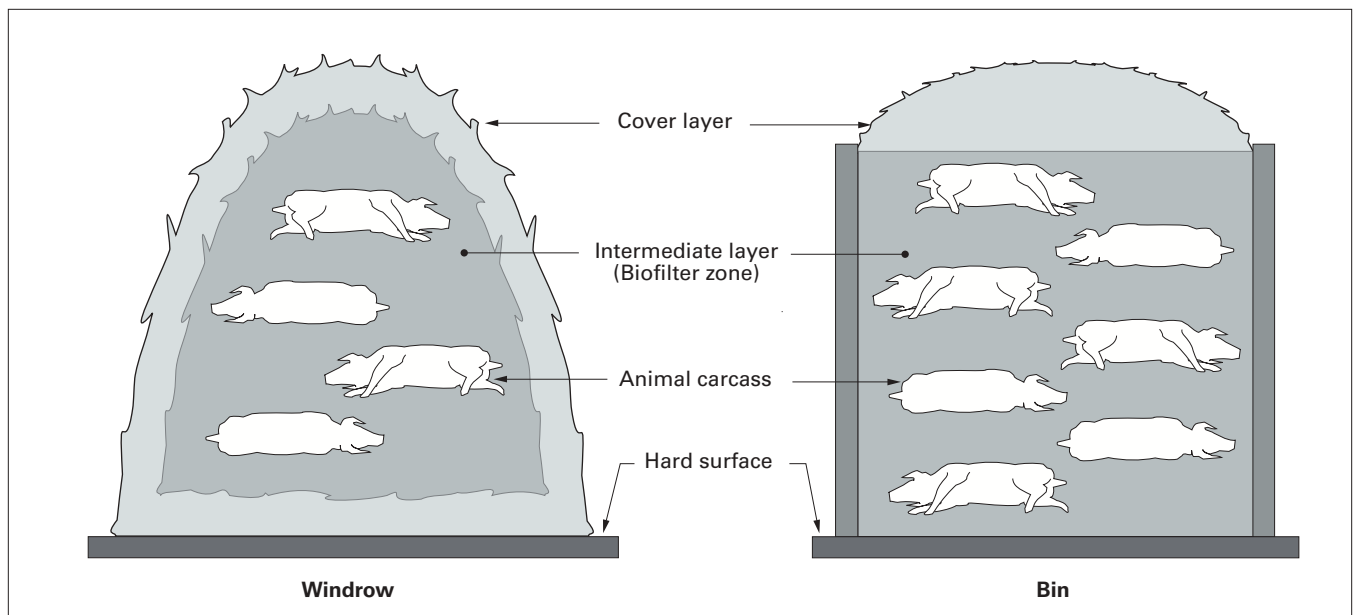


Figure 51-7. Schematic of dead animal composting using a windrow or bin.

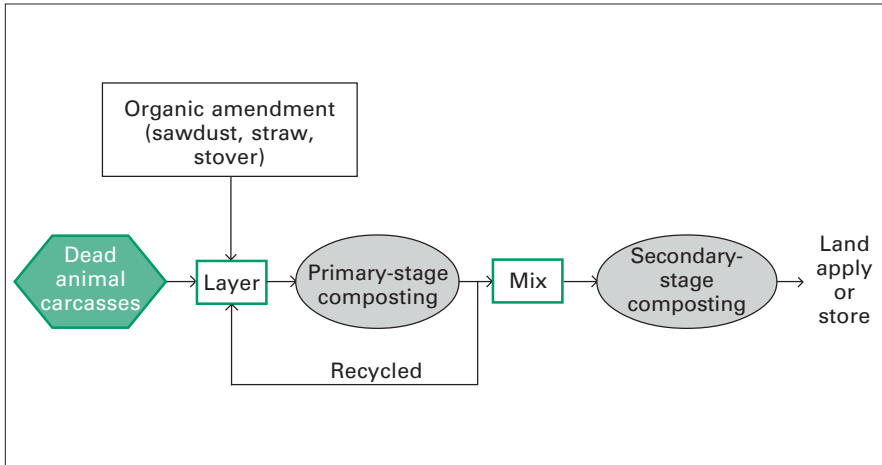


Figure 51-8. Composting process schematic.



Figure 51-9. Composting building.

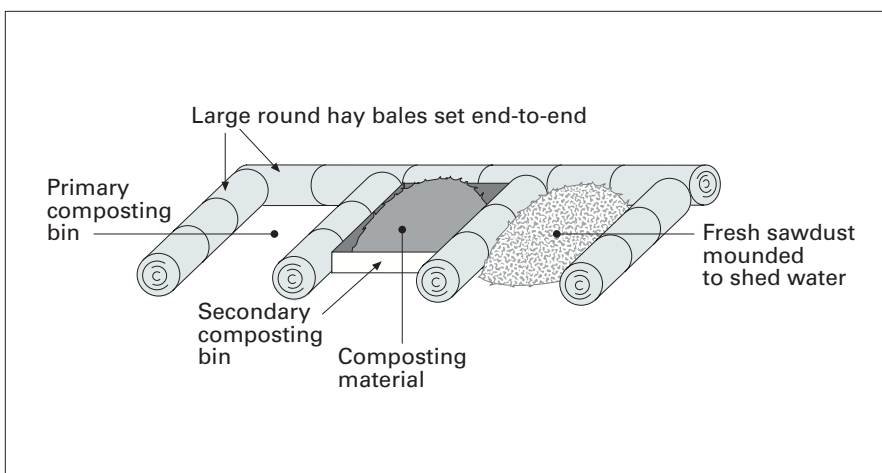


Figure 51-10. Straw bale composter.

Consult the Natural Resources Conservation Service, Extension Service, MidWest Plan Service, or Northeast Regional Agricultural Engineering Service for composter plans that will meet your needs.

**Step A—**  
Determine the weight of the animal carcasses to be composted.

**Step B—**  
Determine the composting cycle times for the “design weight” to be composted in each windrow or bin.

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to be composted on a daily basis. Proper sizing makes the management and operation of the composting process easier. For example, composting facilities that are undersized can lead to problems with odor and flies. Sizing is fairly easy, using the universal sizing procedure. The steps of this procedure are given in Table 51-4. It is applicable to the sizing of either bins or windrows and for any type of dead animal.

**Step A**—Determine the weight of the animal carcasses to be composted. Use farm records for building capacity, animal sizes, and livestock production values and loss records when possible or use the mortality table developed for the various livestock species. Table 51-5 is an example of a mortality table for poultry. Determine the average daily death loss for each growth stage on the farm. Then estimate both the pounds of mortality produced by the operations in one year using “average weight” and the average daily loss in pounds per day to be composted. For species such as cattle or sheep where the majority of mortality occurs during a short period such as during lambing and calving, the average daily loss needs to be determined on the shorter period rather than the entire year.

**Step B**—Determine the composting cycle times for the “design weight” to be composted in each windrow or bin. The time for primary composting as well as the needed composting volume increases as the animal weight increases. An operation with different growth stages should evaluate the feasibility of using segregated bins or windrows. For mature cattle or horses, the preferred approach is to place each individual mortality in a pile on a composting pad. Separate facilities are recommended for animals in the following weight ranges:

- Less than 50 lbs
- 50 to 250 lbs

**Table 51-4. Universal sizing procedure.**

Step	Description
A	Determine the average daily weight of animal carcasses to be composted.
B	Determine the composting cycle times for the “design weight” to be composted in each windrow or bin. <ol style="list-style-type: none"> <li>1. Primary cycle time (days) = 5.00 x (design animal weight, lbs)<sup>0.5</sup>, minimum time ≥10 days</li> <li>2. Secondary cycle time (days) = 1/3 Primary cycle time, minimum time ≥ 10 days</li> <li>3. Storage time (days) = Year’s maximum period of time between land application events. Must be in keeping with the timing requirements of the nutrient management plan.</li> </ol>
C	Determine the needed composter volumes. <ol style="list-style-type: none"> <li>1. Primary composter volume (ft<sup>3</sup>) = 0.2 x Average daily loss (lbs/day) x Primary cycle time (in days)</li> <li>2. Secondary composter volume (ft<sup>3</sup>) = 0.2 x Average daily loss (lbs/day) x Secondary cycle time (in days)</li> <li>3. Storage volume (ft<sup>3</sup>) = 0.2 x Average daily loss (lbs/day) x Storage time (days)</li> </ol>
D	Determine the dimensions of the compost facility including bin dimensions and number of bins or windrow size and area requirements.
E	Determine the annual sawdust requirement for the composting system. Annual sawdust needs (yd <sup>3</sup> /yr) = Annual loss (lbs/yr) x 0.0069.

<sup>1</sup>Adapted from Ohio’s Livestock and Poultry Mortality Composting Manual 1999.

- Greater than 250 lbs

The following equations may be used to determine the composting times required for bins:

1. Primary cycle time (in days) =  $5.00 \times (\text{design animal weight, lbs})^{0.5}$ , minimum time  $\geq 10$  days  
The “design animal weight” used in the equation for determining the primary cycle time is usually taken as the weight of the largest individual animal to be composted.
2. Secondary cycle time (in days) =  $1/3$  Primary cycle time, minimum time  $\geq 10$  days.
3. Storage time (in days) = Years maximum period of time between land application events. Must be in keeping with the timing requirements of the nutrient management plan. For example, if the longest period of time during the year when land application cannot be made is from October 1 to March 30, the storage time required is 6 months or about 180 days.

**Step C**—Determine the compost volumes. The following equations are used to determine the needed compost volumes (ft<sup>3</sup>).

1. Primary compost volume (ft<sup>3</sup>) =  $0.2 \times \text{Average daily loss (lbs/day)} \times \text{Primary cycle time (in days)}$
2. Secondary compost volume (ft<sup>3</sup>) =  $0.2 \times \text{Average daily loss (lbs/day)} \times \text{Secondary cycle time (in days)}$
3. Storage volume (ft<sup>3</sup>) =  $0.2 \times \text{Average daily loss (lbs/day)} \times \text{storage time (days)}$

**Step D**—Determine the dimensions of the compost facility, bin dimensions, and windrow size or number of bins. For a bin system, the minimum front dimension should be 2 feet greater than the loading bucket width. A minimum of two primary bins is required. An alternative to individual secondary bins is an area or areas large enough to accommodate the contents of the primary bins. Secondary bins/areas are generally directly behind the primary bins.

**Step E**—Determine the annual amount of sawdust required for the composting. The following equation estimates the total annual amount of fresh sawdust needed. In practice, it is recommended that up to 50% of the fresh sawdust needs be met with finished compost. The equation allows for a 1-foot sawdust base in the bin on which to begin placing the dead animals, 1-foot of sawdust between layers, 1 foot of sawdust clearance between the dead animals and the sides of the bin, and a 1-foot cover depth. Of course, if values different than these are used in the construction of the pile, either more or less sawdust will be required.

$$\text{Annual sawdust needs (yd}^3\text{/yr)} = \text{Annual loss (lbs/yr)} \times 0.0069$$

**Table 51-5. Poultry mortality rates.**

Poultry Type	Avg. Weight, lbs	Loss Rate, %	Flock Life, days	Design Weight, lbs
Broiler	4.2	4.5-5	42-49	4.5
Layers	4.5	14	440	4.5
Breeding Hens	7-8	10-12	440	8
Turkey, females	14	5-6	95	14
Turkey, males	24	9	112	24

**Step C**—  
Determine the  
composter  
volumes.

**Step D**—  
Determine the  
dimensions of the  
compost facility, bin  
dimensions, and  
windrow size or  
number of bins.

**Step E**—Determine  
the annual amount  
of sawdust required  
for the composting.



## EXAMPLE

**Given:** A broiler operation. The operation's nutrient management plan does not allow land application between September 1 and March 30 or 210 days. Flock cycles occupy the facility 365 days per year.

**Required:** Compost bin volume requirements using the universal sizing method.

**Solution:**

**Step A—Determine the weight of animal carcasses to be composted.**

From farm records, it can be determined that the average daily loss (ADL) is 30 lbs/day. A design mortality weight (W1) of 3 lbs will be assumed.

$$\begin{aligned}\text{Annual loss} &= \text{ADL} \times 365 \\ &= 30 \times 365 \\ &= 10,950 \text{ lbs/yr}\end{aligned}$$

**Step B—Determine the composting cycle times for the “design weight” to be composted in each windrow or bin.**

$$\begin{aligned}\text{Primary cycle time (days)} &= 5.00 \times (\text{design animal weight, lbs})^{0.5}, \text{ Minimum time} \geq 10 \text{ days} \\ &= 5.00 \times (3)^{0.5} \\ &= 8.7 \text{ days} < 10 \text{ days Use 10 days.}\end{aligned}$$

$$\begin{aligned}\text{Secondary cycle time (days)} &= 1/3 \text{ Primary cycle time, Minimum time} \geq 10 \text{ days} \\ &= 1/3 \times 10 \\ &= 3 \text{ days} < 10 \text{ days. Use 10 days.}\end{aligned}$$

$$\begin{aligned}\text{Storage time (days)} &= \text{Year's maximum period of time between land application events.} \\ &= 210 \text{ days (from nutrient management plan)}\end{aligned}$$

**Step C—Determine the needed composter volumes.**

$$\begin{aligned}\text{Primary composter volume (ft}^3\text{)} &= 0.2 \times \text{Average daily loss (lbs/day)} \times \text{Primary cycle time} \\ &= 0.2 \times 30 \times 10 \\ &= 60 \text{ ft}^3\end{aligned}$$

$$\begin{aligned}\text{Secondary composter volume (ft}^3\text{)} &= 0.2 \times \text{Average daily loss (lbs/day)} \times \text{Secondary cycle time} \\ &= 0.2 \times 30 \times 10 \\ &= 60 \text{ ft}^3\end{aligned}$$

$$\begin{aligned}\text{Storage volume (ft}^3\text{)} &= 0.2 \times \text{Average daily loss (lbs/day)} \times \text{Storage time (days)} \\ &= 0.2 \times 30 \times 210 \\ &= 1,260 \text{ ft}^3\end{aligned}$$

**Step D—Determine the dimensions of the compost facility, bin dimensions, and windrow size or number of bins.**

Any dimension that is acceptable to the producer and will provide the volume requirement for primary and secondary composter volumes and the storage volume is acceptable. A building to store the finished compost and fresh sawdust should be considered.

**Step E—Determine the annual sawdust required for the composting.**

$$\begin{aligned}\text{Annual sawdust needs (yd}^3\text{/yr)} &= \text{Annual loss (lbs/yr)} \times 0.0069 \\ &= 10,950 \times 0.0069 \\ &= 76 \text{ yd}^3\text{/yr}\end{aligned}$$

Assuming that 50% of the sawdust needs will be met by using finished compost, the annual sawdust need is  $76 \times 50\% = 38 \text{ yd}^3\text{/yr}$ .

The universal sizing procedure sizes the facilities. It does not prescribe the materials or recipe. The recipe used to compost mortality depends on the raw material that is available and especially on the material that is available on-farm. The recipe may also depend on what state and county regulations allow. For example, some states do not permit the use of chicken litter as an amendment in the recipe for composting dead animals. In these states, it is necessary to compost without chicken litter even though it is an effective amendment and may be readily available at low cost. Composting is a combination of art and science. Therefore, it is necessary to adjust the recipe using trial and error until the desired results are achieved.

Straw can be used instead of or to replace a portion of the volume of sawdust computed in the universal sizing equations. Sawdust generally provides superior structure to the compost pile. However, if sawdust is not available or is very expensive, it may be advantageous to use straw. The straw used must yield the same compressed volume as the sawdust to provide clearance and cover equal to that of sawdust. Straw will generally compress to over one-half its loose volume. For this reason, straw must be chopped and initially layered to twice its desired final depth.

Chicken litter can be used to replace a portion of the sawdust, if regulations permit, to improve the C:N ratio of the pile and enhance the compost process. Up to two-thirds of the required sawdust can be replaced with chicken litter. Studies have shown that dead broiler chickens can be successfully composted with only chicken litter (McCaskey 1994).

### Composter operation

The compost pile must be monitored and the appropriate adjustments made throughout the composting period to sustain a high rate of aerobic microbial activity for complete decomposition with a minimum of odors as well as maximum destruction of pathogens. A convenient and meaningful compost parameter to monitor is temperature; it is an indicator of microbial activity. By recording temperatures daily, a normal pattern of temperature development can be established. Deviation from the normal pattern of temperature increase indicates a slowing of or unexpected change in microbial activity. Temperatures should begin to rise fairly steadily as the microbial population begins to develop. If the temperatures do not begin to rise within the first several days, adjustments must be made in the compost mix. A lack of heating indicates that aerobic decomposition has not been established. This state can be caused by any number of factors such as a lack of aeration, inadequate carbon or nitrogen source, low moisture, or low pH. Poor aeration is caused by inadequate porosity that, in turn, can result from material characteristics or excessive moisture.

Specific guidelines for the operation of a compost facility include

- Use only approved plans to construct compost facilities.
- Remove mortalities daily from housing facilities.
- Shape piles and windrows so that precipitation will run off.
- Add fresh carbon amendment to outside of the pile for biofilter and to absorb leachate and odors.
- Monitor the compost pile temperature. To eliminate pathogens, an average temperature greater than 122°F must be achieved throughout the compost for at least 5 days during either the primary or secondary composting stages or as the cumulative time with temperatures

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greater than 122°F in both stages.

- Leave primary compost in the bin until the temperature reaches its maximum and then shows a steady decline for one week. Use care to avoid short circuiting the primary cycle time.
- Mix and aerate the compost by moving the compost to the secondary bin.
- Store stabilized compost until it can be applied in accordance with the timing prescribed by the nutrient management plan or prepared for sale to others.

**Compost end use**

The primary final use of finished compost is for land application. While the main value of applying compost to land is to improve the soil’s structure and water-holding capacity, compost does contain many nutrients. These nutrients are generally not present in the same quantities per unit of volume as inorganic fertilizer. For this reason, a high-rate application of compost will be needed to meet crop nutrient needs. Regardless, the application rate must be based on soil testing and compost nutrient content testing and be applied in keeping with a nutrient management plan.

The advantage of using compost as a fertilizer is that it releases nutrients slowly, usually under the same warm, moist soil conditions required for plant growth. Thus, nutrient release is matched with plant uptake, resulting in a more efficient utilization of nitrogen and a decreased potential for nitrogen leaching. While the potential for leaching still exists when conditions are suitable for nutrient release from the compost, there is no plant growth to use the nitrogen. This can occur, for example, in early fall after crops have been harvested, but there is still adequate soil moisture and temperature for nutrient release.

In summary, the composting method for managing mortality has the following advantages and disadvantages (Table 51-6).

**Table 51-6. Mortality management by composting.**

Advantages	Disadvantages
1. Conserves nutrients contained in the dead animals	1. High initial cost
2. Low odor	2. Labor intensive
3. Environmentally safe	3. Regular monitoring and maintenance is required
4. No need to store dead animals	4. Cropland required for utilization of finished compost