E-479
06-08

TEXAS A&M AGRILIFE EXTENSION

Composting Manure and Sludge

John M. Sweeten and Brent W. Auvermann*

Composting is a controlled, microbial process that converts biodegradable, organic materials into a stable, humus-like product. The microorganisms that do most of the work are *thermophilic* microbes (bacteria, actinomycetes and fungi), which thrive in relatively high temperatures (greater than 131 degrees F).

Composting is generally done under *aerobic* conditions, in which atmospheric oxygen is present at 5 percent or more by volume. (At sea level, oxygen is normally present in air at about 20 percent by volume.) Aerobic decomposition converts biodegradable organic matter in manure or sludge to oxidized end products, primarily carbon dioxide (CO_2) and water. The thermophilic temperature range, from 131 degrees F to 160 degrees F (55 degrees C to 71 degrees C), inactivates most pathogens and weed seeds. Although there may be offensive odors during the initial stages of composting, the final product generally has an inoffensive odor characterized as musty or sweet.

■ Anaerobic (very low oxygen) conditions occur in a compost pile when excess moisture, fine particle size, or compaction reduce the flow of oxygen into the pile.

By contrast, *anaerobic* decomposition occurs when the oxygen concentration in a compost pile drops below about 5 percent. Anaerobic organisms typically do not tolerate such high temperatures; as a result, the temperature of an anaerobic pile will usually be 130 degrees F or less. The end products, or *metabolites*, of anaerobes include organic fatty acids, aldehydes, alcohols, hydrogen sulfide, and many other compounds responsible for obnoxious odors.

This publication addresses only *aerobic, thermophilic composting*.

Advantages and Disadvantages

Composting is an important treatment process for many organic wastes and residues, including animal manure, municipal and industrial sludge, and solid or semisolid crop residues.

Major Advantages of Composting

- It produces a biochemically stable product that has low odor and good physical properties, and it attracts few flies.
- It significantly reduces the volume of material that must be stored, transported, disposed of, or used.
- It is a forgiving, robust and simple process that can be done on-site without a tremendous investment in heavy infrastructure.

The improved physical properties of compost include low moisture content (usually below 35 percent by mass), more uniform particle size, friable texture, reduced volume and reduced weight. These properties

* Resident Director and Professor, Texas AgriLife Research and Extension Center, Amarillo; Associate Professor and Extension Agricultural Engineer, Amarillo

lower the hauling costs per unit of active ingredient and make it easier to spread the material uniformly. Aerobic, thermophilic composting also inactivates or kills most pathogens and weed seeds.

■ **High-temperature composting is effective against many weed seeds and pathogens, but some are resistant. For example, many spore-forming bacteria (e.g., *Bacillus anthracis*, or anthrax) or hardened seeds (e.g., *Convolvulus* spp., or bindweed) may survive in even the most active compost piles.**

Phosphorus, potassium and other mineral elements are retained in composted material. While ammonia nitrogen may be *volatilized*, or lost to the atmosphere as a gas, total nitrogen usually remains stable as a proportion of total dry matter. Because of those advantages, there is greater market potential for compost than for unstabilized organic wastes.

Major Disadvantages of Composting

- Equipment and labor costs may be prohibitive.
- Market demand for compost may be temporal and difficult to sustain.
- Obnoxious odors may be produced during the initial stages of composting.
- Some states require a permit for the construction of composting facilities.

Factors Affecting Composting Rates

The primary factors that affect biological activity and composting rates are moisture content, physical structure and consistency, aeration, nutrient balance, pH, and temperature.

Moisture Content

The microbes responsible for aerobic, thermophilic composting require moisture. The moisture content should be 40 to 60 percent (by mass) initially. If the moisture content is below about 35 percent, the decomposition rate will be much slower. Water should be added to dry manure to initiate composting.

If the moisture content of compost material is too high, water in the pore spaces displaces air and restricts gas movement, creating anaerobic conditions around the particles. Excess moisture often lowers the temperature in the pile and increases the amount of time required for compost to stabilize and mature. In mechanical systems, a moisture content of more than 65 percent can cause the composting material to agglomerate ("ball up") and restrict airflow.

Before composting, wet organic materials should be mixed with a dry material, or *bulking agent*, to reduce the initial moisture content. Suitable bulking agents include cotton burrs, sawdust, peanut hulls, corncobs, wood chips, rice hulls and brush trimmings. These materials also provide carbon, which helps microorganisms break down organic matter.

Finished compost usually has a final moisture content of 20 to 30 percent. Some of this product can be recycled as a bulking agent, but it should not be used as more than 50 percent of the bulking agent for the next pile.

Structure and Consistency

To promote aeration, composting materials should have enough pore space, or porosity, to allow air to flow freely through the matrix. Bulking agents are usually necessary to increase the porosity of fine-textured materials (such as sewage sludge or poultry manure) and absorb excess moisture. The amount of bulking agent may range from less than 1:1 (volume/volume) to more than 5:1, depending on particle size and initial moisture content.

Aeration

A compost pile must be aerated to support aerobic microbial activity. Aeration also removes released moisture and excess heat that would otherwise reduce microbial activity. Generally, more air is required for moisture and temperature control than for microbial activity. Air within or exhausted from the composting materials should contain 5 to 15 percent oxygen.

There are two methods of aeration. With the first, the compost pile is turned mechanically using front-end loaders or specially designed compost turners. The pile should be turned several times per week initially, and less often later in the process. The compost should then be stockpiled for *curing*, during which final degradation occurs. During the curing process fungi and actinomycetes may appear; they primarily digest hemicellulose.

■ **Compost organisms consume a variety of carbohydrates, fats and proteins, some of which are more easily digested than others. Lignin is among the least digestible of the carbohydrates. Cellulose and hemicellulose are among the more digestible.**

The second aeration method is a forced-air system that either blows or draws air through the compost. The aeration rate should be sufficient to create measurable free oxygen in the exhaust air. The aeration rate can be reduced as composting progresses. Once composting is complete, the material should be aged in a stockpile for about 2 months to complete its stabilization.

Carbon, Nitrogen and Other Nutrients

Microorganisms that decompose organic residues require nitrogen and other nutrients for metabolism and reproduction. The amount of nitrogen required per unit of organic matter varies with the type of microorganisms involved, but it is generally accepted that the carbon/nitrogen (C/N) ratio of the wastes will influence the decomposition rate. Carbon is used to build microbial cells and to supply energy for microorganisms. Much of the carbon is converted to carbon dioxide, which is then lost to the atmosphere. Thus, decomposition of organic material leads to a large decrease in carbon, but usually a smaller decrease in nitrogen.

■ **Mechanical turning mixes compost materials more thoroughly, making it less likely that anaerobic (very low oxygen) zones will develop within a pile. It also ensures that all of the material in a pile, including the material on the surface, is subjected at some point to the elevated temperatures near the core of the pile. As a result, mechanically turned compost may be a more uniform, consistent product than compost aerated by a forced-air system.**

If the nitrogen content is low and the C/N ratio is high (above 30), microorganisms must recycle the nitrogen through many generations of bacteria as the carbonaceous matter is decomposed. During composting, most nitrogen is immobilized and stored in the bodies of the microorganisms, although some nitrogen is lost as ammonia or nitrogen gas. As a result, the C/N ratio normally decreases during the composting process.

An optimum C/N ratio, below which nitrogen ceases to be a rate-limiting factor, depends partially on the potential rate of decomposition of the carbon source. For example, a readily available carbon source such as sugar creates an immediate nitrogen demand and requires a low C/N ratio. On the other hand, cellulose and lignin are more slowly degradable and have a low nitrogen demand, requiring a higher C/N ratio.

The ideal initial C/N ratio for composting most manure and sludges is between 20:1 and 30:1. Because the C/N ratio for livestock manures is usually about 10:1, it is often desirable to add carbon-rich material (e.g., crop residues or sawdust) to raise the C/N ratio. These materials may also reduce the moisture content and increase the porosity of the compost.

Adequate phosphorus (P) and potassium (K) must also be present to compost organic wastes. Phosphorus is a constituent of microbial protoplasm, and potassium is necessary for regulating osmotic pressure relationships within bacterial cells. Ideally, the phosphorus content should be about 20 percent that of nitrogen.

Consequently, a C:N:P:K ratio of approximately 25:1:0.2:0.08 is desirable for composting common types of organic wastes.

pH and Toxic Substances

The pH should be 6.5 to 7.2 initially for best composting results. In the beginning stages of composting wet manure or sludge, the pH may drop below 6.0 as organic acids form. These acids are potent odorants, and they retard the activity of aerobic, thermophilic bacteria. Little heating will occur with a pH below 6.0 because bacteria do not digest as efficiently until near-neutral conditions are reestablished. During the initial stage of composting, it may be desirable to add a buffering agent or lime. Final pH values of finished compost will range from 7.5 to 8.5 or greater.

Some organic materials (e.g., industrial sludges) may contain substances that are toxic to aerobic, thermophilic bacteria. Heavy metals such as manganese, copper, zinc, nickel, chromium and lead may be toxic to certain microorganisms. Heavy metals can be immobilized chemically before composting. Heavy metals are not present in appreciable concentrations in manure, but they may be worth considering in some municipal or industrial sludges.

Temperature

Temperature is the main determinant of the rate of composting, and it serves as a guide to the relative degree of stabilization of the composting materials. Organic materials usually start out at ambient temperatures and a few hours or days may pass before the temperature begins to increase. During the digestion phase, the microorganisms multiply and actively metabolize the available food, releasing heat.

Aerobic, thermophilic composting is said to begin when the temperature reaches 113 degrees F. After that, the temperature usually rises rapidly as heat is released by the breakdown of complex molecules or organic matter to simpler compounds. The peak temperature may exceed 150 degrees F. If the temperature rises as high as 185 degrees F it may indicate that a dangerous conversion from biological to chemical oxidation is taking place, which could result in a spontaneous compost fire. As pile temperatures approach 160 degrees F, the pile should be cooled by mechanically turning it or increasing the aeration rate.

During composting, susceptible pathogens are almost completely destroyed by high temperatures and competition with thermophilic organisms. The U.S. Environmental Protection Agency (EPA) regards composting temperatures of 104 degrees F for 5 days as a "process to significantly reduce pathogens" in sewage sludge. To be classified as a "process to further reduce pathogens," which is considered equivalent to pasteurization, a temperature of 131 degrees F must be attained for 3 days within vessels, bins or aerated static piles or for 15 days within windrows being turned at least five times. Most weed seeds are inactivated at 150 degrees F to 160 degrees F.

■ Optimum temperatures for the core of a compost pile are 131 degrees F to 150 degrees F.

Composting Systems

The two basic steps for successful composting are materials preparation and biological stabilization. The preparation stage consists primarily of adjusting moisture content, structure and/or chemical content as necessary. High-moisture manure or sludge can be dried to below 60 percent moisture content by blending it with finished compost or bulking agents (wood chips, cotton gin trash, cornstalks, straw, etc.). The moisture content of dry manure or sludge may be raised to 40 to 60 percent by adding water. Sorting, removing or grinding very large particles (e.g., slabs of dry feedlot manure) or foreign materials may also be necessary. The organic waste may be "seeded" with microorganisms from commercial sources. As an alternative, finished compost can be added to help start decomposition.

Composting can be carried out in windrows, aerated static piles, or aerated bins or vessels. Each method involves various types and levels of mechanization that affect processing time, cost, and the amount of space, labor and management required.

A tow-behind compost turner runs through a steaming windrow of dairy manure in California's Central Valley.

Windrow Operations

The most commonly used method of composting is the *windrow* process, which involves stacking organic wastes into long windrows that are turned periodically. A basic windrow composting operation is relatively simple and requires little attention other than monitoring temperature and moisture.

Windrows should be 3 to 5 feet tall and have a base width of about 10 to 15 feet. Air should move through the porous composting material from the bottom up through the top, like a chimney, as internal heating occurs.

Mechanical Aeration

Windrows can be mechanically aerated, often with the same equipment used for manure collection and loading (wheel loaders, etc.). There are also composting machines designed to move a rotating, spiked drum or auger through the compost while traveling the length of the windrow. One type of composter straddles the windrow and turns the compost in place using a rotating spiked drum. Another type uses a cross-auger to lift, mix and redeposit the compost to form a new windrow parallel to the original.

> ■ **Uncured, immature compost should not be used for fertilizer. It may compete with horticultural plants for nitrogen, stunting their growth. It also may still contain compounds that are toxic to plants—such as acetic acid—that would have been broken down into nontoxic products during the curing phase.**

Windrows should be turned often at first and then less frequently. A reasonable turning schedule might be as follows:

- 1st week – three turnings
- 2nd week – one to three turnings
- 3rd week – two turnings
- 4th and 5th weeks – one turning
- beyond 5th week – none (curing phase)

If the moisture content falls below 35 percent during the first 5 weeks, it may be necessary to add water during the turning operation to ensure that the composting process restarts efficiently after turning.

> ■ **To measure compost temperature accurately, carefully insert long-stemmed thermometers into piles and windrows at several different locations and from different directions to ensure that hot and cold spots do not distort the overall picture. Take the average of five to ten measurements for static piles or small bins, or five to ten measurements per 15 feet of windrow length.**

Such a lengthy schedule assumes that the end goal is the commercial market and that the material is to be used as a garden fertilizer or soil amendment. A less aggressive schedule of turning can be used if the goal is to (a) apply the compost to agricultural land or (b) use it as a biofuel.

The temperature of the compost pile should be used to determine the need for turning. The best tool is a long-stemmed thermometer, 3 to 4 feet long.

Minimum composting time is 1 month in the turned windrow, followed by at least 2 months in a curing pile. Afterwards, the compost should be ready to be bagged and marketed.

Forced-Air Aeration
Windrows also can be aerated by forced-air systems. The manure or sludge is placed in a windrow or pile over an array of perforated pipes. Air is blown through the pipes and upward into the compost through the perforations. An alternate procedure is to apply suction to the aeration pipes and draw air into the compost windrow or pile. Forced aeration eliminates frequent turning but requires an electric compressor/blower and pipe network to distribute the air. At least 5 to 10 standard cubic feet per minute (scfm) of air per cubic yard of compost is required initially. This aeration rate can be gradually reduced to 1 scfm per cubic yard during the 3rd or 4th week. In general, no aeration is needed after 4 weeks of composting because the microbes' oxygen demand has decreased significantly.

The most important diagnostic tool for composting manure and sludge is a long-stemmed (4 ft) thermometer. A compost pile that is properly assembled should warm to the 140 degree F range within three or four days.

The so-called Beltsville Aerated Pile Method (named for the USDA–Agricultural Research Service composting research facility at Beltsville, Md.) is one type of forced-air windrow composting. Developed specifically for wet sewage sludge, the method involves mixing wood chips or a similar bulking agent with the sludge and then building an elongated pile of sludge/wood chip mixture that is placed on a pad of wood chips or unscreened, finished compost. The pad contains a loop of perforated pipe for forced aeration. The pile is covered with a blanket of unscreened, finished compost, which insulates the pile and serves as an odor barrier. Air is drawn into the pile by a blower-induced vacuum, and exhaust air is discharged through a small pile of finished, screened compost that serves as a partial odor filter. The blower is cycled on and off in 15-minute intervals. The recommended average aeration rate with the blower operating is 8 to 10 scfm per dry ton, which is adequate to remove excess moisture and to maintain greater than 5 percent oxygen in the pore spaces.

When designing a forced-air system, take into account the air pressures, depth of pile, airflow velocities, friction losses in air distribution pipes, and blower power requirements.

Within 3 days after composting begins, pile temperatures should have increased to between 140 degrees F and 160 degrees F. In a well insulated pile, the temperatures will remain high for most of the 3-week composting period. Afterward, the composted material is removed and transferred to an unaerated pile for a 1-month curing phase that consists of low-rate composting and drying, with no further mixing. The bulking agent is then separated by screening and is reused by blending it with incoming sludge.

Aerated-Bin Composting
Aerated-bin composting systems are either continuous-flow (mechanically stirred) operations or batch-operated (unstirred) systems. Continuous-flow systems are more highly mechanized than batch systems. After materials are prepared (grinding, mixing and moisture adjustment), the mixture is gradually fed into the aerated composting bin via wheel loaders, gravity-fed hoppers or belts. Environmental conditions in the aerated bin are controlled so that microorganisms maintain a steady rate of

decomposition. Aeration within the reactor is done by draft compressors, blowers or a combination of the two. The compost is usually mechanically mixed or turned daily to ensure that oxygen reaches all microorganisms. Forced aeration usually exceeds 5 to 10 scfm per cubic yard during the first 2 weeks, is 1 to 2 scfm per cubic yard the 3rd week, and is 1 scfm per cubic yard or less the 4th week. Temperature and oxygen probes are used to determine proper turning frequencies and aeration schedules, which may differ for each composting mixture.

A continuous-flow, aerated bin often produces well-stabilized end products from manure and sludge within 1 month. Then the material should be cured in a stockpile for several weeks.

Aerated-bin composting can also be carried out in batch mode. Aeration is provided by perforated pipe, with air under either positive or negative pressure or some alternating combination of the two. Every few days the composting material is transferred into an adjacent bin using wheel loaders, flighted lifter-mixers, or conveyors.

Summary

Livestock and poultry manure and sewage sludge can be composted to produce improved materials for land application or horticultural planting mixtures. Composting stabilizes the organic matter and makes it easier to handle. It also preserves most of the nutrients and reduces noxious odors.

The objective in composting should be to provide a proper nutrient balance and environment for the reproduction of aerobic, thermophilic bacteria. Factors such as temperature, moisture content, structure, carbon-nitrogen ratio, pH and aeration are critical to successful composting. When the material is kept at 131 degrees F to 150 degrees F for extended periods of time, fly larvae and most pathogens and weed seeds will be killed.

Composting can be carried out in windrows or bins aerated either by mechanical turning or forced air. Aerated bins with mechanical equipment for turning and/or aeration are generally more efficient but cost more than windrow composting. Before investing heavily in equipment, producers should ensure that they have sustainable supplies of manure (or sludge) and bulking agents as well as a stable market for finished compost.

Texas A&M AgriLife Extension Service

AgriLifeExtension.tamu.edu

More Extension publications can be found at *AgriLifeBookstore.org*

Produced by Texas A&M AgriLife Communications