Composting
FACTSHEET

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THE COMPOSTING PROCESS

Composting is the biological decomposition of organic matter under controlled conditions brought about by the growth of microorganisms and invertebrates. While decomposition occurs naturally, it can be accelerated and improved by human intervention. Composting stabilizes organic matter, yielding an end product that contains humus, and has a uniform crumbly texture. An understanding of the composting process is important for producing a high-quality product and preventing operating problems. Figure 1 illustrates the basic composting process. The microorganisms and invertebrates that decompose manure and other farm wastes require oxygen and water, and produce compost, carbon dioxide, heat and water. The organic wastes provide nutrients (nitrogen and carbon) necessary for microorganisms to carry out decomposition efficiently.

The heat produced increases the temperature in the compost pile from near-ambient air temperature to as high as 70°C (160°F). The temperature rise results in increased water evaporation. As the process nears completion (after one month to one year), the compost pile once again approaches ambient air temperature.

Composting leads to a volume reduction. Much of this reduction results from the loss of carbon dioxide, water and other minor gases to the atmosphere.

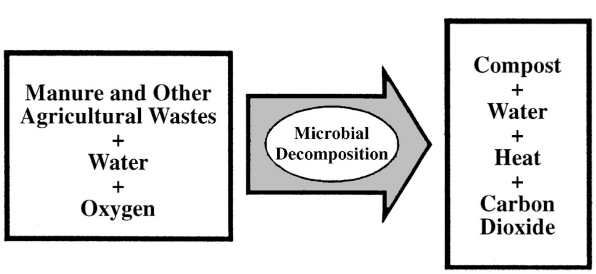

Figure 1 The Basic Composting Process

Further reduction occurs as loose bulky materials are rendered into crumbly, fine-textured composts without any of the recognizable structure of the starting materials. Finished compost is comprised of microorganisms and invertebrates, their skeletons and decomposition products, and organic matter that is not readily degradable by these organisms. Finished compost takes on many of the characteristics of humus, the organic fraction of soil.

The rate at which the final product (compost) is generated and the magnitude of temperature rise during the composting process depend upon factors discussed on the following pages. Once composting is complete, the pile will have been reduced in volume by 20 percent to 60 percent, the moisture content to less than 40 percent, and the weight reduced by up to 50 percent. The finished compost pH is near neutral, and the carbon to nitrogen ratio should be below 20:1. Undesirable odours that typically emanate from the starting material are generally replaced by an earthy smell.

DECOMPOSERS

Naturally occurring microorganisms and invertebrates are the primary decomposers that accomplish composting. These microorganisms include bacteria, mould or fungi, actinomycetes and protozoa. Tiny invertebrate animals such as mites, millipedes, insects, sowbugs, earthworms and snails are the primary agents of physical decay. They break up waste debris and transport microorganisms from one site to another.

The ease with which organic materials are composted depends on the type of decomposers, the type of organic material being composted and the composting method used. For example, many decomposition organisms can utilize the carbon in sugar found in straw, while fewer decomposers can use the carbon in cellulose or lignin fibres found in paper or wood. As carbon compounds decompose, part of the carbon is converted to microbial and invertebrate cell structure, while most is converted to carbon dioxide, which is lost to the atmosphere.

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Different decomposers prefer different organic materials and temperatures; therefore, the more diverse the microbial populations, the better. If the environment becomes unsuitable for a decomposer, that organism will become dormant, die or move to a more hospitable area of the pile. Changing conditions during the composting process lead to an ever-changing ecosystem of decomposition organisms. Decomposer activity diminishes when the microorganisms cannot readily consume the remaining organic material.

Microorganisms in Composting

Microorganisms such as bacteria, fungi and actinomycetes account for most of the decomposition, as well as the rise in temperature that occurs in the compost process. Some microbes require oxygen to function, others do not. Those requiring oxygen are preferred in composting. Also, different microorganisms thrive in different temperature ranges. The goal in constructing and managing compost is to create an environment suitable for the desired microorganisms.

Aerobic Versus Anaerobic Microorganisms

Aerobic organisms thrive at oxygen levels greater than five percent (fresh air is approximately 21 percent oxygen). They are the preferred microorganisms, since they provide the most rapid and effective composting. Anaerobic organisms thrive when the compost pile is oxygen deficient. Decomposition by anaerobic micro-organisms is referred to as fermentation. Anaerobic conditions are undesirable in a compost pile. Some of the products of anaerobic decomposition are hydrogen sulfide, cadaverine and putrescine, which cause offensive odours. In addition, anaerobic processes can generate acids and alcohols that are harmful to plants.

Aerobic Microorganisms and Temperature

Among all microorganisms, aerobic bacteria are the most important initiators of decomposition and temperature increase within the compost pile. Psychrophilic bacteria work in the lowest temperature range and have an optimum temperature lower than 5°C (40°F). Mesophilic bacteria do best at temperatures between 10°and 45°C (50° and 110°F). Thermophilic bacteria are heat-loving and thrive above 50°C (120°F). Each category includes many strains of bacteria.

The initial temperature of the compost pile usually is related to the ambient air temperature. If the initial pile temperature is less than 21°C (70°F), psychrophilic bacteria begin decomposition. Their activity generates a small amount of heat and causes an increase in pile temperature that changes the environment for dominance by mesophilic bacteria. In turn, the more rapid decomposition by mesophilic bacteria can further increase the pile temperature to create an environment where the thermophile can thrive. Later, as the thermophilic bacteria in the pile decline in number and temperature decreases, mesophilic bacteria again become dominant.

While high temperatures have the advantage of killing pathogenic organisms and weed seeds, moderate temperatures encourage the growth of mesophilic bacteria, the most effective decomposers. If the material being composted is not diseased and does not contain seeds, there is no need to be concerned about achieving high temperatures. Many decomposers are killed or become inactive if temperatures rise above 60°C (140°F). The rise and fall of temperature during the process will depend on the material being composted, the composting method used and the water available for evaporative cooling.

Food Web of the Compost Pile

The food web of the compost pile is illustrated in Figure 2. The waste in the compost pile provides food for the first level of decomposers. Cellulose decomposition by microorganisms begins soon after the compost pile is established. Fungal mycelia quickly penetrate all parts of the heap, and early fruiting bodies of mesophilic fungi grow on the surface. Later, if the temperature rises enough, thermophilic actinomycete colonies can give the surface a grey appearance.

The availability of readily digestible food results in maximum microorganism growth and a temperature increase. During the heating period, soil invertebrates either die, become dormant, or migrate to cooler parts of the pile. These organisms return when the temperature declines. First-level consumers are attracted and become food for second-level consumers. Third-level consumers, such as centipedes, rove beetles, ground beetles, and ants prey on second-level consumers. Mites, millipedes, sow bugs, snails and slugs ingest plant tissue. Soft tissues of decaying plants and animals support the growth of worms. Earthworms ingest, digest and reshape organic matter. These activities of invertebrates tend to mix material, break larger particles into smaller ones and transform organic material into more digestible forms for micro-organisms.

FACTORS AFFECTING THE COMPOSTING PROCESS

All natural organic material eventually decomposes. Under natural conditions, the decomposition process can extend over a period of months or even years, depending on climatic conditions. However, the natural process can be accelerated by controlling the process factors. Each of these factors has the potential to significantly affect the composting process.

Some of the more important factors in the composting operation are listed as follows:

- Carbon:Nitrogen Ratio (C:N)
- Surface Area and Particle Size
- Aeration
- Porosity
- Moisture Content
- Temperature
- pH of Materials
- Nutrients
- Toxic Substances

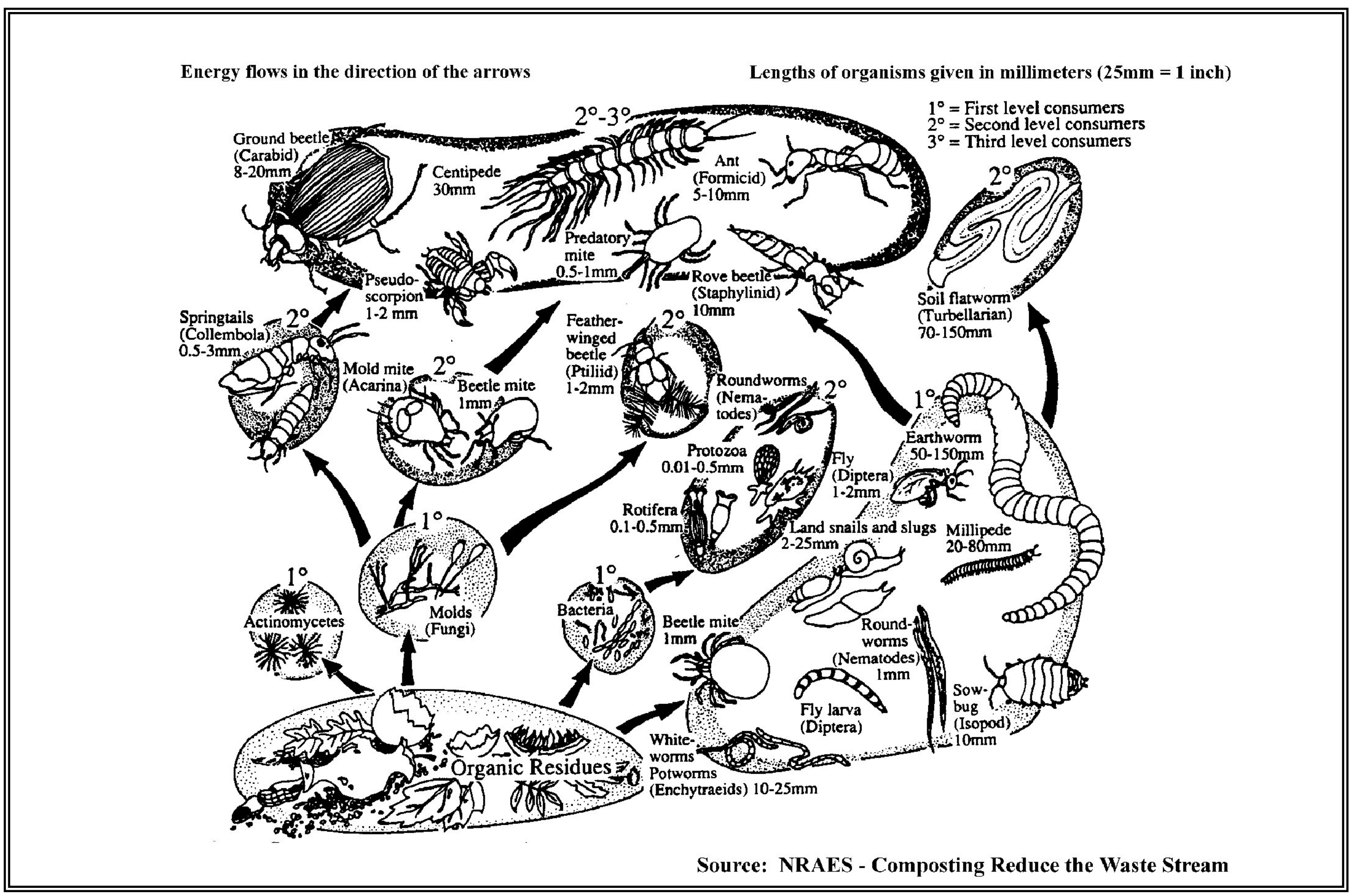

Figure 2 The Organisms in the Food Web of the Compost Pile

Carbon-to-Nitrogen Ratio

Carbon (C) and nitrogen (N) compounds are the components most likely to seriously limit the composting process if present in either excessive or insufficient amounts, or when the carbon-to-nitrogen (C:N) ratio is incorrect. Microorganisms in compost digest (oxidize) carbon as an energy source, and ingest nitrogen for protein synthesis. The proportion of these two elements should approximate 30 parts carbon to 1 part nitrogen by weight. C:N ratios within the range of 25:1 to 40:1 result in an efficient process. Softwood shavings, sawdust and straw are good sources of carbon. Other inexpensive sources of carbon include municipal waste and shredded newsprint or cardboard. Most manures are a good source of nitrogen. Table 1 lists carbon-to-nitrogen ratios for materials commonly included in farm compost piles.

Given a steady diet at a 30:1 ratio, microorganisms can decompose organic material quickly. When the C:N ratio is too high, there is too little nitrogen and decomposition slows. When the C:N ratio is too low, there is too much nitrogen and it will likely be lost to the atmosphere in the form of ammonia gas. This can lead to odour problems.

Most materials available for composting do not fit this ideal 30:1 ratio, so different materials must be blended to meet the ratio. In general, coarse, dried-out material contains very little nitrogen. For example, woody materials are very high in carbon. However, green wastes, such as foliage and manure, contain relatively high proportions of nitrogen. Proper blending of carbon and nitrogen helps ensure that composting temperatures will be high enough for the process to work efficiently.

Although proper blending is necessary, it can be difficult to blend materials to achieve this ratio exactly. Without knowing the moisture content of the materials being used, neither the dry weight nor the final C:N ratio of the combined material can be estimated. The typical C:N ratio, moisture content and bulk density for products commonly used for on-farm composting are given in Characteristics of On-Farm Composting Materials, Factsheet No. 382.500-3.

Blending of materials to achieve a workable C:N ratio is part of the art of composting. If a high-nitrogen material such as manure is being composted, it should be blended with a high-carbon material such as sawdust or paper. With experience, composters will develop procedures that result in workable mixtures for the materials being composted. Blending Materials for the Composting Process, Factsheet No. 382.500-4, is provided as a guide.

TABLE 1
CARBON TO NITROGEN RATIOS FOR SELECTED MATERIALS

Materials with High Nitrogen Values	**C:N**
Poultry manure with litter	13-18:1
Vegetable waste	12-20:1
Pig manure solids	15-25:1
Dairy manure	20:1
Material with High Carbon Values	
Wood chips and sawdust	100-500:1
Paper	150-200:1
Straw	40-100:1
Foliage (green)	30-80:1
Material with Neutral C:N Ratios	
Peat moss	18-36:1
Horse manure with litter	30-60:1

Surface Area and Particle Size

Microbial activity occurs at the interface of particle surfaces and air. The surface area of material to be composted can be increased by breaking it into smaller pieces, or by other means. Increased surface area allows the microorganisms to digest more material, multiply faster and generate more heat. Generally, the smaller the size and the more fragile the particle, the greater the biological activity and rate of composting. Chopped crop residues, softwood shavings and sawdust, for example, require no further size reduction. Materials can be chopped, shredded, split or bruised to increase their surface areas. A wide range of shredders and chippers are available, from large models used by tree services to small gas engine types.

Aeration

Aeration replaces oxygen-deficient air in the centre of the compost pile with fresh air. Rapid aerobic decomposition can only occur in the presence of sufficient oxygen. Aeration occurs naturally when air warmed by the compost rises through the pile, drawing in fresh air from the surroundings. Wind also stimulates aeration. Initial mixing of materials usually introduces enough air to start composting. Oxygen requirements are greatest during the initial weeks of most vigorous activity. Air movement through the compost pile is affected by porosity and moisture content. Regular mixing of the pile, referred to as turning, enhances aeration in a compost pile.

Porosity

Porosity refers to the spaces between particles in the compost pile, and is calculated by taking the volume of spaces or pores, and dividing by the total volume of the pile. If the material is not saturated with water, these spaces are partially filled with air that can supply oxygen to decomposers and provide a path for air circulation. As the material becomes water saturated, the space available for air decreases.

Compacting the compost pile reduces its porosity. Excessive shredding can also impede air circulation by creating smaller particles and pores. Turning fluffs up the material and increases its porosity. Adding coarse materials, such as straw or woodchips, can increase the pile porosity, although some coarse materials will be slow to decompose. As the compost process proceeds, the porosity decreases, restricting aeration.

Moisture Content

Moisture plays an essential role in the metabolism of microorganisms and indirectly in the supply of oxygen. Microorganisms can utilize only those organic molecules that are dissolved in water. A moisture content of 40 to 60 percent provides adequate moisture without limiting aeration. If moisture content falls below 40 percent, bacterial activity will slow down, and will cease entirely below 15 percent. When the moisture content exceeds 60 percent, nutrients are leached, air volume is reduced, odours are produced (due to anaerobic conditions), and decomposition is slowed. If the pile becomes too wet, it should be turned and restacked. This allows air to circulate back into it and loosens the materials for better draining and air drying. Adding dry material, such as straw, sawdust or finished compost can also remedy an excess moisture problem.

If the pile is too dry, water can be added. A more effective practice is to turn the pile and rewet materials in the process. Certain materials will shed water or absorb it only on their surface. Sawdust, hay, straw and vegetables must gradually be moistened until they glisten, then the squeeze test should be used to evaluate the moisture content. Optimum moisture content of raw materials should be in the range of 50 to 60 percent (wet basis), depending on particle size, available nutrients and physical characteristics.

Temperature

Heat generated by microorganisms, as they decompose organic material, increases compost pile temperatures. There is a direct relation between temperature and rate of oxygen consumption. The higher the temperature, the greater the oxygen uptake and the faster the rate of decomposition. Temperature increases, resulting from microbial activity, may be noticeable within a few hours of forming a pile. Pile temperatures between 32° and 60°C (90° and 140°F) indicate rapid composting. Temperatures greater than 60°C (140°F) reduce the activity of many of the most active organisms. Therefore, the optimum temperature range is between 32° and 60°C. Large volumes of organic matter provide both critical mass and insulating properties that allow interior temperatures to rise to 55° to 60°C (130° to 140°F) within a few days of compost start-up. Temperatures of composting materials characteristically follow a pattern of rapid increase to 55° to 60°C (130° to 140°F) and remain near this thermophilic level for several weeks. Temperatures gradually drop to 38°C (100°F) and finally drop to ambient air temperature. This characteristic pattern of temperature change over time reflects the types of decomposition and stabilization as composting proceeds, and is shown in Figure 3. Stabilized, finished compost products should have a very low rate of decomposition and will, therefore, not generate much heat. A temperature probe or soil thermometer should be used to keep track of pile temperatures.

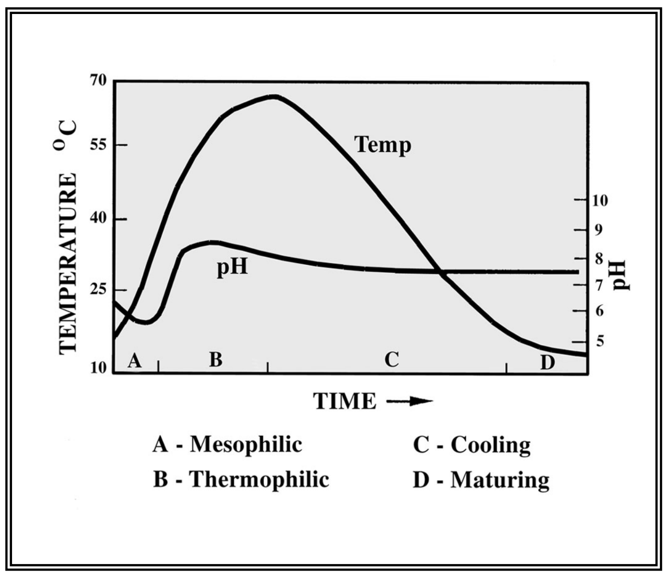

Figure 3 Compost Temperature and pH Variation with Time

pH of Materials

Composting may proceed effectively over a range of pHs without seriously limiting the process. The optimum pH for microorganisms involved in composting lies between 6.5 and 7.5. The pH of most animal manures is approximately 6.8 to 7.4. Composting itself leads to major changes in materials and their pH, as decomposition occurs. For example, release of organic acids may, temporarily or locally, lower the pH (increase acidity), and production of ammonia from nitrogenous compounds may raise the pH (increase alkalinity) during early stages of composting. Whatever the pH measured in the starting materials, composting will always yield an end product with a stable pH usually near neutral. Figure 3 shows how pH typically changes over the composting process. Little heating will occur with a pH below 6.0 since bacteria work sluggishly until the pH rises to a more desirable level.

Nutrients

Adequate levels of phosphorus and potassium are also important in the composting process and are normally present in farm organic material such as manure, or poultry or pork mortalities.

Toxic Substances

Some organic materials may contain substances that are toxic to aerobic thermophilic bacteria. Heavy metals such as manganese, copper, zinc, nickel, chromium and lead may fall into this category. Heavy metals may be immobilized chemically prior to composting. In some manures, heavy metals are present in appreciable concentrations.

SUMMARY

The compost process depends on many factors as discussed, especially carbon-to-nitrogen ratios, surface area, aeration, moisture content, and temperature. The art of composting is balancing these factors to achieve the final product quality in the desired time frame. Composting will survive most forms of neglect, however, non-optimal conditions, caused by neglect, will simply slow down the process.

This is one of a series of Factsheets on Composting. A list of references used in producing this series is included in the Composting Factsheet "Suggested Reading and References."

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