COMPOST FUNDAMENTALS

Will Rogers, who lived through the great dust bowl once said: “They’re making more people every day—but they ain’t making any more dirt.”

Once soil is disturbed, we may not be able to restore it to its native state, but we can help build a new balance of beneficial soil organisms to support the desired vegetative life.

While it takes thousands of years for the earth’s forces to build good soil, we can help do this in 5 – 10 years by adding compost—which adds microorganisms, arthropods, worms, and humus to the soil. The word “compost” comes from Latin where it meant “to put together.” This is what we do when we compost—we put together the correct amounts of compostable materials to make a great soil amendment.

For centuries, farmers have made and used compost to improve soil. Composting is part of the earth’s biological cycle of growth and decay. Energy from the sun, carbon dioxide from the air, and nutrients from water and soil make plants grow. When they die and decompose through a complex process involving microorganisms such as fungi, bacteria, insects, mites and worms, nutrients go back into the soil, and carbon dioxide back into the air. The humus remaining from this decay process provides soil with organic matter that can hold water and nutrients in the soil, making it easier to till.

Think of composting as the act of growing microorganisms. While a vegetable farmer is attuned to fertility, cultivation, water and seasonal needs of a crop, a composter should consider their types of compostable materials, sometimes called feedstocks, how to prepare them, and their moisture needs to ensure quality compost. Actually, it is easier for composters to control compost pile conditions than it is for a farmer to control the weather.

This manual explains the many interdependent factors fundamental in planning composting projects or analyzing composting operations:

Biology and chemistry of compost

Compost needs (materials & methods to ensure quality compost)

Composter's needs (considerations before choosing a compost method)

- destruction of pathogenic organisms
- pesticides and herbicides
- fly control
- reclamation of nitrogen and other nutrients
- time required

Compost benefits and uses

- economic aspects
- testing and judging condition of compost;
- quality of composts
- benefits of compost
- use of compost

Conclusion

Whether you have a large operation, or a small backyard pile, whether you compost "hot" and fast, or "slow" and cold, making compost always involves the same biological principles. Composting methods may be different, depending on various conditions or economic considerations. When choosing what method to use, keep in mind all the factors to decide whether to pursue a traditional, well established compost plan or create another innovative method that can meet the same expectations

Aerobic Decomposition

Organic material decomposing with oxygen is an "aerobic" process. When living organisms that use oxygen feed upon organic matter, they develop cell protoplasm from the nitrogen, phosphorus, some of the carbon, and other required nutrients. Carbon serves as a source of energy for organisms and is burned up and respired as carbon dioxide (CO_2). Since carbon serves both as a source of energy and as an element in the cell protoplasm, much more carbon than nitrogen is needed. Generally, organisms respire about two-thirds of the carbon they consume as CO_2, while the other third is combined with nitrogen in the living cells.

Biological activity diminishes if the compost mix contains too much carbon in relation to nitrogen. Several cycles of organisms are required to burn excess carbon. This is a complex chemical process. When organisms die, their stored nitrogen and carbon become available to other organisms. These new organisms form new cells which again need nitrogen to burn excess carbon and produce CO_2. Thus, the amount of carbon is reduced and the limited amount of nitrogen is recycled. Finally, when the ratio of available carbon to available nitrogen is low enough, nitrogen is released as ammonia. Under favorable conditions, some ammonia may oxidize to nitrates. Phosphorus, potash, and various micronutrients are also essential for biological growth. These are normally present in more than adequate amounts in compostable materials.

In nature, the aerobic process is most common in areas such as the forest floor, where droppings from trees and animals are converted into relatively stable organic matter. This decomposition doesn't smell when adequate oxygen is present. We can try to imitate these natural systems when we plan and maintain our landscapes. As we learn more about the biology and chemistry of composting, we can actually hasten the decomposition process.

When carbon is oxidized to CO_2, a great deal of energy is released as heat. For example, if a gram of glucose molecules is dissimilated under aerobic conditions, 484 to 674 kilogram calories (kcal) of heat may be released. If organic material is in a large enough pile or arranged to provide some insulation, temperatures during decomposition may rise to over 170° F. At temperatures above 160° F, however, the bacterial activity decreases.

There are many different kinds of bacteria at work in the compost pile. Each type needs specific conditions and the right kind of organic material. Some bacteria can even decompose organic material at temperatures below freezing. These are called psychrophilic bacteria, and although they work best at around 55°, they continue to work down to 0° F. As they work, they give off small amounts of heat. If conditions are right, this heat will be enough to set the stage for the next group of bacteria, the “mesophylic,” or middle range temperature bacteria.

Mesophylic bacteria thrive from 70° to 90° F, but just survive at temperatures above and below (40° to 70° F, and 90° to 110° F) In many backyard piles, these mid range bacteria do most of the work. However, if conditions are right, they produce enough heat to activate the “thermophilic,” or heat loving bacteria. Thermophilic bacteria work fast. Their optimum temperature range is from 104° to 160° F.

High temperatures destroy pathogenic bacteria and protozoa (microscopic one celled animals), and weed seeds, which are detrimental to health and agriculture when the final compost is used on the land.

Aerobic oxidation does not stink. If odors are present, either the process is not entirely aerobic or there are materials present, arising from other sources than the oxidation, which have an odor. Aerobic decomposition or composting can be accomplished in pits, bins, stacks, or piles, if adequate oxygen is provided. To maintain aerobic conditions, it is necessary to add oxygen by turning the pile occasionally or by some other method.

Anaerobic Fermentation

Composting without oxygen results in fermentation. This causes organic compounds to break down by the action of living anaerobic organisms. As in the aerobic process, these organisms use nitrogen, phosphorus, and other nutrients in developing cell protoplasm. However, unlike aerobic decomposition, this reduces organic nitrogen to organic acids and ammonia. Carbon from organic compounds, is released mainly as methane gas (CH_4). A small portion of carbon may be respired as CO_2.

This anaerobic process takes place in nature. Examples include decomposing organic mud at the bottom of marshes and buried organic materials with no access to oxygen. Marsh gas is largely methane. Intensive reduction of organic matter by putrefaction is usually accompanied by unpleasant odors of hydrogen sulfide and of reduced organic compounds that contain sulfur, such as mercaptans (any sulfur-containing organic compound).

Since anaerobic destruction of organic matter is a reduction process, the final product, humus, is subject to some aerobic oxidation. This oxidation is minor, takes place rapidly, and is of no consequence in the utilization of the material.

There is enough heat energy liberated in the process to raise the temperature of the putrefying material. In the anaerobic dissolution of the glucose molecule, only about 26 kcal of potential energy per gram of glucose molecules is released compared to 484 to 674 kcal for aerobic decomposition. The energy of the carbon is in the released methane (CH_4). The conversion of CH_4 to CO_2 produces large amounts of heat. This energy from anaerobic decomposition of organic matter can be used in engines for power and burned for heat.

Pathogens could cause problems in anaerobic composting because there is not enough heat to destroy them. However, aerobic composting does create high enough temperatures. Although heat does not play a part in the destruction of pathogenic organisms in anaerobic composting, they do disappear in the organic mass because of the unfavorable environment and biological antagonisms. They disappear slowly. The composted material must be held for periods of six months to a year to ensure relatively complete destruction of Ascaris eggs, for example. Ascaris are nematode worms that can infest the intestines. They are the most resistant of the fecal-borne disease parasites in wastes.

Anaerobic composting may be accomplished in large, well packed stacks or other composting systems. These should contain 40% to 75% moisture, into which little oxygen can penetrate, or 80% to 99% moisture so that the organic material is a suspension in the liquid. When materials are composted anaerobically, the odor nuisance may be quite severe. However, if the material is kept submerged in water, gases dissolve in the water and are usually released slowly into the atmosphere. If the water is replaced from time to time when removing some of the material, odor does not become a serious nuisance.

Both aerobic and anaerobic composting require bacteria. Some bacteria work better in one or the other environment. Compost piles under aerobic conditions may attain a temperature of 140° to 160° F in one to five days depending upon the material and the condition of the composting operation. This temperature can also be maintained for several days before further aeration is needed. The heat necessary to produce and maintain this temperature must come from aerobic decomposition, which requires oxygen. After a period of time, the material will become anaerobic unless it is aerated. There is probably a period between the times when the oxygen is depleted and anaerobic conditions become evident, during which the process is aerobic.

"Aerobic composting" requires a considerable amount of oxygen and produces none of the characteristic features of anaerobic putrefaction. Aerobic composting can be defined as a process in which, under suitable environmental conditions, aerobic organisms utilize considerable amounts of oxygen in decomposing organic matter to fairly stable humus.

"Anaerobic composting" describes the process of putrefactive breakdown of organic matter by reduction in the absence of oxygen where end products such as CH_4 and hydrogen sulfide (H_2S) are released.

Organisms Involved

Compostable materials normally contain a large number of many different types of bacteria, fungi, molds, and other living organisms. More species of bacteria are involved in aerobic decomposition than in anaerobic putrefaction. Many of the same organisms are no doubt as active in anaerobic composting such as sludge digestion. However, since environmental conditions of aerobic compost stacks, particularly moisture and nutritional materials, differs greatly from that of sludge digestion tanks, the biological population would also be expected to differ.

Although many types of organisms are required to decompose different materials, the necessary variety is usually present and organisms thrive when environmental conditions are satisfactory. During decomposition, marked changes take place in the nature and abundance of the biological population. Some of the many species will multiply rapidly at first but will dwindle as the environment changes and other organisms are able to thrive. Temperature and changes in the available food supply probably exert the greatest influence in determining the species of organisms comprising the population at any one time.

Aerobic composting is a dynamic process in which the work is done by combined activities of a wide succession of mixed bacterial, actinomycetes, fungal, and other biological populations. Since each is suited to a particular environment of relatively limited duration and each is most active in decomposition of some particular type of organic matter, the activities of one group complement those of another. The mixed populations parallel the complex environments afforded by the heterogeneous nature of the compostable material. Except for short periods during turning, the temperature increases steadily in proportion to the amount of biological activity until equilibrium (state of balance) with heat losses is reached, or the material becomes well stabilized.

In aerobic composting, bacteria, actinomycetes, and fungi are the most active. Mesophilic (low temperature) bacteria are characteristically predominant in the start of the process, soon giving way to thermophilic (high temperature) bacteria, which inhabit all parts of the stack where the temperature is satisfactory; this is eventually, most of the stack. Thermophilic fungi usually appear after 5 to 10 days and actinomycetes become conspicuous in the final stages when short duration, rapid composting is practiced.

Except in the final stages of the composting period, when the temperature drops, actinomycetes and fungi are confined to a sharply defined outer zone of the stack, 2 to 6 inches in thickness, beginning just under the outer surface. Some molds also grow in this outer zone. Unless very frequent turning is practiced, so that there is adequate time or conditions for growth, the population of fungi and actinomycetes is often great enough to impart a distinctly grayish white appearance to this outer zone. The sharply defined inner and outer limits of the shell (in which actinomycetes and fungi grow during the high temperature active-composting period) are due to the inability of these organisms to grow at the higher temperatures of the interior of the stack. The thermophilic actinomycetes and fungi have been found to grow in the temperature range between 120° and 150° Fahrenheit. Frequent turning -such as is sometimes necessary for fly control- inhibits their growth, since the cooler outer shell is turned into the interior before they can develop in large numbers.

Various investigations show that many different types of thermophilic bacteria apparently play a major part in decomposing protein and other readily broken down organic matter. They appear to be solely responsible for the intense activity characteristic of the first few days, when temperatures reach 150° to 160° Fahrenheit. Major changes in the nature of the compost stack are taking place then: the stack is drastically shrinking and the appearance of the material is undergoing rapid change. They continue to predominate throughout the process in the interior of the piles, where temperatures are inhibitory to actinomycetes and fungi.

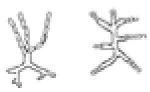
Fungi and actinomycetes play an important role in the decomposition of cellulose, lignin, and other more resistant materials, despite being confined primarily to the outer layers and becoming active only during the latter part of the composting period. These tough materials are attacked after more readily decomposed materials have been used. There are many bacteria that attack cellulose. However, in the parts of compost stacks populated chiefly by bacteria, paper hardly breaks down, whereas in the layers or areas inhabited by actinomycetes and fungi it becomes almost unrecognizable.

Considerable cellulose and lignin decomposition by actinomycetes and fungi can occur near the end of the composting period or "curing" when the temperatures have begun to drop and the environment in a larger part of the pile is satisfactory for their growth. Hence, in the interest of their activity, turning should not be more frequent during curing than is necessary for providing aerobic conditions and controlling flies. Among the actinomycetes, streptomyces and micromonospora common in compost, micromonospora are the most prevalent. Compost fungi include *Termonmyces sp*., *Penicillium dupontii*, and *Aspergilus fumigatus*.

Since organisms necessary for composting are usually present and will carry on the process when the environment is suitable, an extensive knowledge of the characteristics of the various organisms is not necessary for operating a compost operation. A more detailed knowledge of the organisms, however, may lead to further improvement and economics in the process.

Organisms to Look For

A compost pile is a zoo of critters! All of the organisms, microbial and non microbial, have a dramatic effect on the soil food web. Although it is common to divide creatures into “good” and “bad” bugs, in the compost pile, every organism has a specific role to play. The larger organisms visit the pile when it has cooled down and feast on the former inhabitants. Here are just a few samples of what creatures you will find if you look closely in your pile:



Actinomycetes: Primarily decomposers common in early stages of compost. They produce the grayish cobwebby growths throughout compost and give it an earthy smell, similar to a rotting log. They prefer woody material, and survive in a wide range of temperatures.

Fungi: They are also primary decomposers. Fungi send out thin mycelia fiber like roots, far from their spore forming reproductive structures. Mushrooms are most common. They’re not as efficient as bacteria, since they can’t live in the cold.

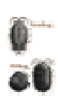
Nematodes or roundworms: They are the most abundant invertebrates in soil. Less than one millimeter in length, they prey on bacteria, protozoa, fungal spores and each other. Most nematodes in the soil are beneficial.

Fermentation mites or mold mites: These transparent bodied creatures feed primarily on yeast in fermenting masses or organic debris. They can develop into seething masses over a fermenting surface such as a winery, but are not pests in compost.

Springtail: Along with nematodes & mites, they share numerical dominance among soil invertebrates. They feed on fungi, nematodes and small bits of organic detritus. They help control fungi.

Wolf spiders: They build no webs, but run freely hunting prey. They prey on all sizes of arthropods, invertebrate animals with jointed legs and segmented bodies

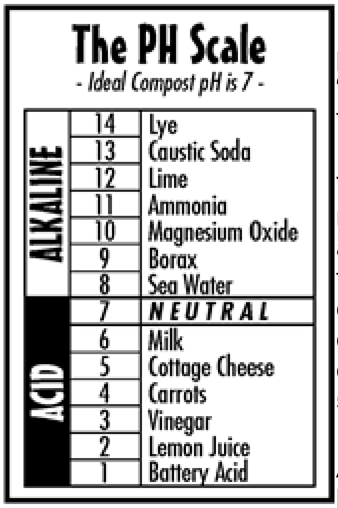
Centipede: They prey on almost any type of soil invertebrate near their size or larger.



Sow bugs: They feed on rotting woody material and leaf tissues.

Ground beetles: Most feed on other organisms but some feed on seeds and other vegetable matter.

Acid/Alkalinity Issues



pH is the measure of the acidity or alkalinity of soil, with 7 considered “neutral” and numbers below acidic and above alkaline. Composting feedstocks have a pH, which will fluctuate during the composting process.

The initial pH of garbage, yard clippings, manure, and other compostable material is likely between 5.0 and 7.0 unless it contains ash or other highly alkaline materials. If the material has begun putrefying before being received for composting, the pH will be near the lower value, since anaerobic organisms produce acids. When the initial pH is between 6.0 and 7.0, the pH of the composting material may drop a little during the first two or three days of aerobic composting, also due to the formation of acids. If the pH is 5.0 or 5.5, there will be little change during this period.

After two to four days the pH usually begins to rise and will level off at between 8.0 and 9.0 towards the end of the process. The control of the pH in composting is seldom a problem requiring attention if the material is kept aerobic, but large amounts of organic acids are often produced during anaerobic decomposition on a batch basis. Ash, carbonates, lime or other alkaline substance will act as a buffer and keep the pH from becoming too low. Adding alkaline material is rarely necessary in aerobic decomposition. In fact, it may do more harm than good because the loss of nitrogen by the release of ammonia as a gas will be greater at a higher pH. Since the optimum pH for most organisms is around 6.5 to 7.5, it would probably be beneficial if the pH could be maintained in that range. However, since composting is necessarily a batch-process operation, minor changes in the pH are normal.

Apparently, initial pH values of 5.0 to 6.0 do not seriously retard initial biological activity since active decomposition and high temperatures develop rapidly after material is placed in the stack. Temperatures do appear to increase a little more rapidly when the pH is in the range around 7.0 and above. The usual feedstocks available for composting present no problem of pH control.

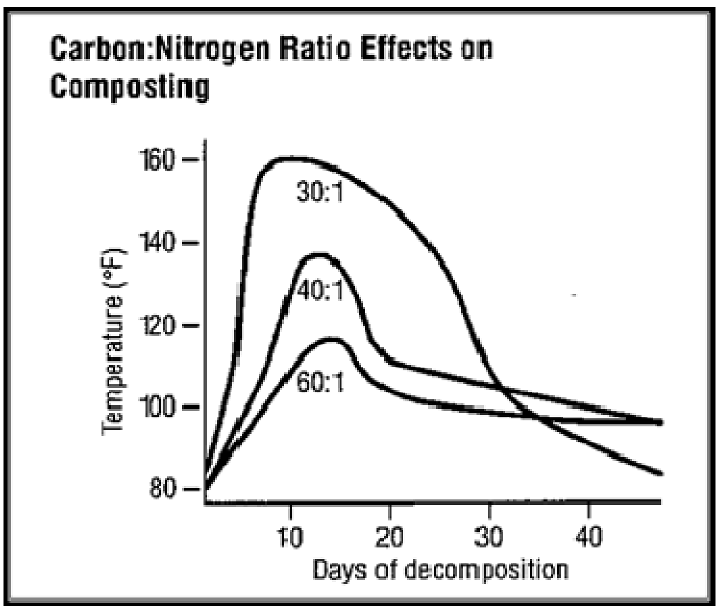
(Materials & methods to ensure quality compost)

There are some essential factors involved in determining what type of pile to build and how to manage the feedstocks. Organisms cannot decompose organic material as efficiently without certain requirements, such as air, water and appropriate particle size. Following are the most important considerations.

carbon-nitrogen relationships

The course of decomposition of organic matter is affected by the presence of carbon and nitrogen. The **C:N** ratio represents the relative proportion of the two elements. A material, for example, having 25 times as much carbon as nitrogen is said to have a **C:N** ratio of 25:1, or more simple, a **C:N** ratio of 25. Actually, the ratio of available carbon to available nitrogen is the important relationship because there may be some carbon present so resistant to biological attack that its presence is not significant.

Organisms that decompose organic matter use carbon as a source of energy and nitrogen for building cell structure. They need more carbon than nitrogen. If there is too much carbon, decomposition slows when the nitrogen is used up and some organisms die. Other organisms form new cell material using their stored nitrogen. In the process more carbon is burned. Thus the amount of carbon is reduced while nitrogen is recycled. Decomposition takes longer, however, when the initial **C:N** ratio is much above 30.



In the soil, using organic matter with excess carbon can create problems. To complete the nitrogen cycle and continue decomposition, the microbial cells will draw any available soil nitrogen in the proper proportion to make use of available carbon. This is known as "robbing" the soil of nitrogen, and delays availability of nitrogen as a fertilizer for growing plants until some later season when it is no longer being used in the life-cycles of soil bacteria.

When the energy source, carbon, is less than that required for converting available nitrogen into protein, organisms make full use of the available carbon and get rid of the excess nitrogen as ammonia. This release of ammonia to the atmosphere produces a loss of nitrogen from the compost pile and should be kept to a minimum.

A **C:N** ratio of 20, where C and N are the available quantities, is the upper limit at which there is no danger of robbing the soil of nitrogen. If a considerable amount of carbon is in the form of lignin or other resistant materials, the actual **C:N** ratio could be larger than 20. The **C:N** ratio is a critical factor in composting to prevent both nitrogen robbing from the soil and conserving maximum nitrogen in the compost..

Since organisms use about 30 parts carbon for each part of nitrogen, an initial **C:N** (available quantity) ratio of 30 promotes rapid composting and would provide some nitrogen in an immediately available form in the finished compost. Researchers report optimum values from 20 to 31. A majority of investigators believe that for **C:N** ratios above 30 there will be little loss of nitrogen. University of California studies on materials with a initial **C:N** ratio varying from 20 to 78 and nitrogen contents varying from 0.52% to 1.74% indicate that initial **C:N** ratio of 30 to 35 was optimum. These reported optimum **C:N** ratios may include some carbon which was not available. Composting time increases with the **C:N** ratio above 30 to 40. If unavailable carbon is small, the **C:N** ratio can be reduced by bacteria to as low a value as 10. Fourteen to 20 are common values depending upon the original material from which the humus was formed. These studies showed that composting a material with a higher **C:N** ratio would not be harmful to the soil, however, because the remaining carbon is so slowly available that nitrogen robbery would not be significant.

CARBON NITROGEN (C:N) RATIOS IN FEEDSTOCKS

Plant residues are made up largely of the following:

1. sugar, starch, simple proteins	(decompose rapidly)
2. crude protein	(decompose slowly
3. hemicellulose	(decompose slowly
4. cellulose	(decompose slowly
5. lignin, fat, wax, etc.	(decompose slowly

Rate of decay and release of nutrients to the soil vary greatly. Likewise, demands of living soil microorganisms vary as they "break down" plant residue. Sawdust (made primarily of lignin and cellulose) uses vast amounts of energy to maintain the lives of microorganisms digesting it. A major product of plant decay is nitrogen (N) while the undigested portion is primarily carbon (C).

The optimum ratio in soil organic matter is about 10 carbons to 1 nitrogen, or a **C:N** ratio of 10:1.

Following are some sample **C:N** ratios of organic matter:

Sandy loam (fine)	7:1
Humus	10:1
Food scraps	15:1
Alfalfa hay	18:1
Grass clippings	19:1
Rotted manure	20:1
Sandy loam (coarse)	25:1
Vegetable trimmings	25:1
Oak leaves	26:1
Leaves, varies from	35:1 to 85:1
Peat moss	58:1
Corn stalks	60:1
Straw	80:1
Pine needles	60:1 to 110:1
Farm manure	90:1
Alder sawdust	134:1
Sawdust weathered 3 years	142:1

Newspaper	170:1
Douglas fir bark	491:1
Sawdust weathered 2 months	625:1

(Materials & methods to ensure quality compost)

blending or proportioning

Most composters judge what composition of the material will provide good compost by appearance. An experienced operator can generally do proportioning from visual estimates of the quantity and character of the feedstock. In large-scale municipal composting operations, however, there may be times when operators rely on laboratory analyses to determine how the various materials should be blended or proportioned for composting.

The **C:N** ratio and moisture content are the two factors to be considered in blending. There is no need for blending when the **C:N** ratio is between 25 and 50, although 30 to 40 is a better range. If materials containing much paper, straw, sawdust, or other substances rich in carbon are to be composted, the **C:N** ratio materials should be proportioned to provide a near optimum **C:N** ratio. Similarly, materials too dry for good composting and materials too wet to compost without odors should be blended in proper proportions. Where initial shredding is practiced, proportioning can usually be done at the shredder; otherwise, the materials are mixed and placed in piles together.

Some compost operators add soil to organic materials hoping to increase the number of microorganisms and thus expediting composting. But organisms necessary for decomposition are indigenous to the organic materials, and those added in the soil will have no significant effect. Sometimes, dry soil is added to reduce moisture content and to absorb ammonia in low **C:N** ratio materials. This is fine if sufficient dry organic materials are not available, but the efficiency of nitrogen reclamation by the addition of soil is not great. Adding cellulose organic matter to provide a **C:N** ratio above 30 is much more efficient.

Soil may be added to compost if the materials have a high acidity content, to neutralize acid conditions. It may be added to improve the appearance of the finished compost, to give it a more granular texture, and to increase the ease of handling by giving the compost more body. But adding soil to the compost pile might make the mass heavier to work with. This added weight promotes less air penetration, and prevents it from reaching optimum temperatures.

(Materials & methods to ensure quality compost)

placement and structures

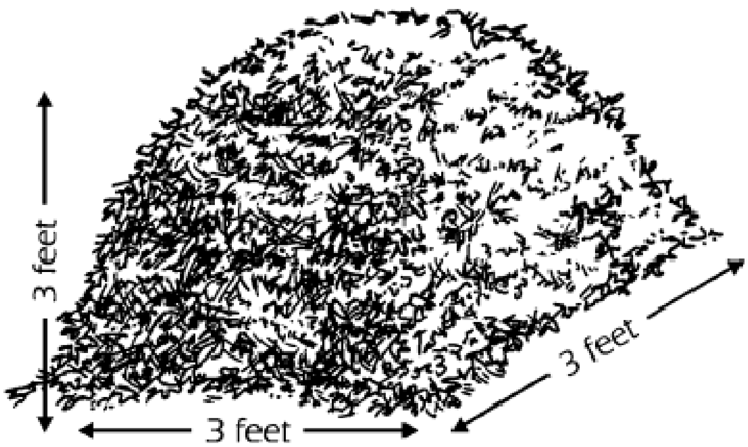
There are many ways, such as bins, barrels, pits and windrows to compost organic matter. Open piles, windrows, or bins are the most widely used methods for aerobic decomposition and maturing of organic refuse. Exact use and arrangement of these systems depends on local requirements of materials, labor, cost of systems, climatic conditions such as temperature, rainfall, and wind.

To aerobically maintain the composting process by frequent turning for aeration, windrows, piles and bins above the surface of the ground are more efficient than pits. On the other hand, if the decomposition is to be entirely anaerobic or aerobic only during a short initial period, pits 3 to 4 feet deep and varying in length and width in accordance with the daily quantity of raw material should be used.

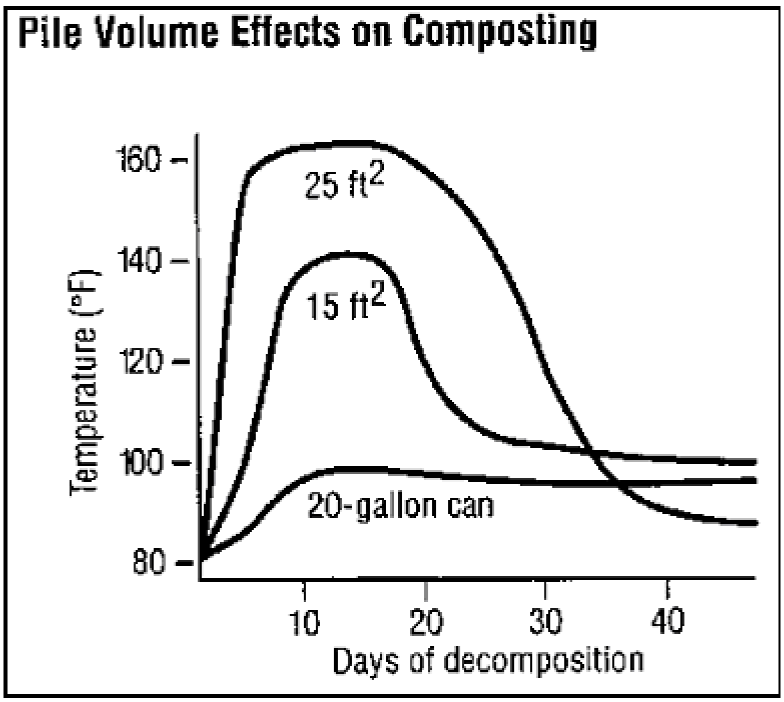
Structures:
WINDROWS, PILES AND BINS

Material in aerobic composting piles should be loosely stacked to allow space for air in the interstices. Windrows or piles may be of any length, but the height of the pile is critical. If piled too high, material will be compressed by its own weight, thus reducing pore space, which results in increased turning labor (costs) or longer composting time as anaerobic conditions develop. In some instances, the maximum practical height may be governed by the equipment used for stacking the feedstocks, or by the tendency of the pile to become excessively hot. Large piles in warm weather may reach temperatures excessively high for bacterial life. Some have even caught fire.

Piles that are too low lose heat rapidly. They do not get hot enough for destruction of pathogenic organisms and decomposition by thermophiles
Also, if the piles are too small, loss of moisture may be excessive, especially near the edges, and decomposition slows.



Five to six feet is about the maximum height for any pile, and 3 feet is the minimum for most shredded fresh organic matter. The height can be greater in cold weather than in warm weather.



Thoroughly mixing compost materials in bins, windrows or piles provides quickest and most complete decomposition. The pile may normally be started directly on the ground. To ensure aeration to the bottom of the pile and improve drainage, dig a trench across the base of the area and cover with stiff wire mesh (hardware cloth) before adding material.

Home gardeners may not have enough materials daily for windrows. In this case circular or rectangular piles 4 – 6 feet in diameter and 3 to 5 feet high works, with a rounded top for shedding rainwater.

PITS

For shallow pits, either the walls and bottom of the pit are lined with brick or masonry or the natural earth is tamped and packed. The material is stacked to a height of 1 foot or more above the ground, making a total of 3 to 4 feet. The material can be turned in the pit as often as necessary to provide the high temperatures and aerobic conditions as required. When pits are used, a smaller stack surface is exposed to the air, and the walls and bottom of the pit provide some insulation against heat and moisture loss.

Any type of pit should be lined and is usually provided with a chimney and trenches, or a porous bottom, for aeration and drainage of liquid seepage from the pile. The same shape trenches without aeration and drainage channels and without masonry lining may be used. But unless pits are lined, the walls are apt to crumble and the shape of the pit becomes irregular. When hand labor is used, turning the material in a pit may be about the same as in a stack on the ground surface.

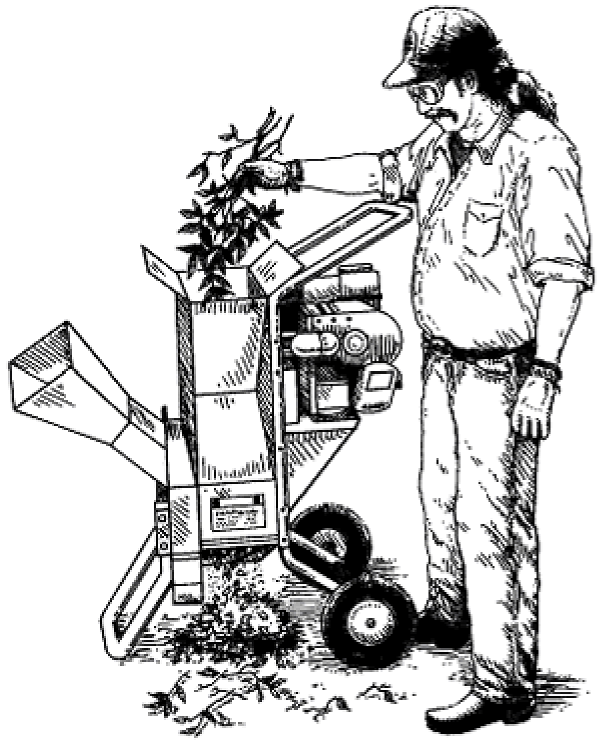
One effective method involves composting in pits approximately 3 feet deep by a system of providing aerobic conditions and high temperatures for the first few days and then anaerobic conditions for 4 to 6 months. Material is mixed in the pit. There is sufficient oxygen in the initial stack for a high temperature to be produced by aerobic organisms during the first few days. High temperatures are usually retained for two weeks or so, owing to the insulating properties of the stack, even though anaerobic conditions may exist after the first few days. Leave the material to compost in the pit with no turning for about three months.

SHEET or TRENCH COMPOST

To sheet compost, work a thin layer of material such as leaves into the garden in the fall. By spring, the material should be broken down. This would not be appropriate for materials such as wood chips that would take a longer time to decompose, and might tie up soil nitrogen in the spring, making it unavailable to other plants.

For trench compost, dig a trench 8 – 15 inches deep, bury the feedstocks, then cover back up with soil. It takes about a year to decompose.

particle size



Shredding or grinding raw materials is beneficial, particularly when composting fibrous materials such as leaves, woody plants or corn stalks. Shredding exposes a greater surface area, which makes it more susceptible to bacterial invasion. Large pieces of wood or leaves packed together do not decompose quickly in a compost pile. Insufficient oxygen in the center of a wood chunk or a wad of leaves does not permit more rapid aerobic decomposition.

Shredding material makes it more uniform in size, aerates it, and makes it easier to handle and keep moist. Smaller particles enable the compost to heat more evenly, and to withstand excessive drying at the surface. The compost pile is then is insulated against heat loss, and also better resists moisture penetration from rain. Fly control is also better when material is pulverized or shredded. Uniform compost made from shredded material can be more easily applied to the land.

The best sized particles for composting are less than 2 inches in the largest dimension, but larger particles can be composted satisfactorily. The particle size of material being composted is determined by the finished product requirements and by economics. If the material is to be used on lawns or flower gardens, compost should be screened through a one-inch screen so it looks better and is easier to apply and work into the soil.

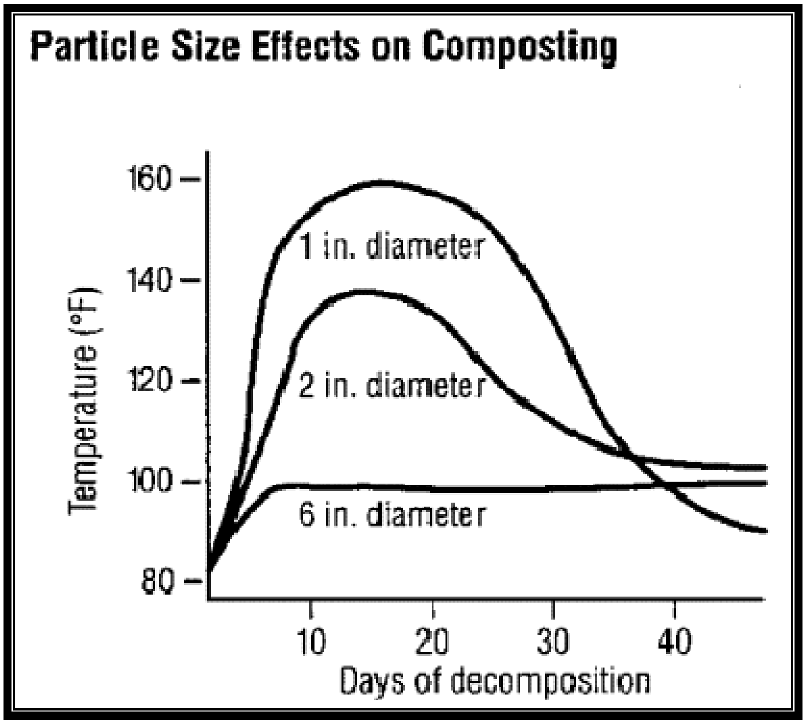
Sometimes it may not be worth added cost and labor to shred the material. Particles too large can be forked or screened out or broken up when necessary. Some people are not particular about uniformity of compost structure when preparing compost. For example, uniformity is not as important for agricultural fields as for the home gardener.

Initial shredding of all material is not absolutely necessary. Often, the best practice is to shred only large pieces of organic materials. Using some larger irregular pieces creates greater air spaces and hence more entrapped oxygen.

Large, tough feedstocks may require grinding to speed decompostition. Vegetative and herbaceous matter should not be ground up because it becomes soggy. The high moisture content of these materials makes them more difficult to manage in aerobic composting. The type of raw materials for composting determines when to shred.

Regrinding can be done either after the compost is mature, or near the end of the maturing process. Regrinding near the end of the period of active decomposition can serve as the last turning for aeration, and the pile can be left to stabilize.

Whether to grind or shred depends upon the nature of the raw material, the desired features of the final product--such as the appearance, size, and quality--and the economic requirements of the operation. Shredding and grinding the materials will shorten the decomposition time.



(Materials & methods to ensure quality compost)

moisture

Just like people, compost organisms need water to live. Some microorganisms use the film of water to move—slipping and sliding to another section of the pile. Biological activity stops when the pile dries out.

If adequately aerated, composting material with moisture content between 30% and 100% will be aerobic. In practical aerobic composting, however, high moisture content must be avoided because water displaces air from the interstices between the particles causing anaerobic conditions. However, too low moisture content deprives organisms of water needed for their metabolism, and inhibits their activity.

Maximum moisture content for satisfactory aerobic composting varies with materials used. If straw and strong fibrous materials are used, the maximum moisture content can be much larger without destroying structural qualities or causing material to become soggy, compact and unable to contain enough air in the interstices. But if it contains lots of paper or grass clippings, which have little structural strength when wet, or if granular, like ash and soil, less water is better.

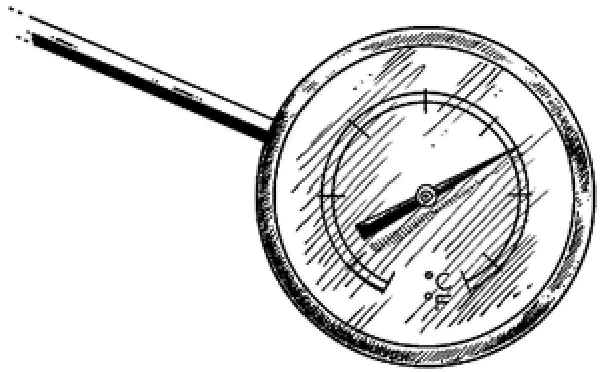
Ideally, home compost piles whould contain 40 - 60% moisture. It should feel as moist as a wrung out sponge. Dry carbon layers can be watered as the pile is built, then with each turning, add more water as necessary.

In University of California studies, fibrous materials containing an abundance of straw were composted aerobically with moisture contents of 85% to 90%, but other composts containing much paper became anaerobic in one day when the moisture content was about 70%.

If anaerobic composting is practiced, the maximum moisture content is not as important, since oxygen maintenance is not a factor. The upper limit of moisture, which may be from 80% to over 90%, is the amount of which excessive drainage from the compost will be produced. If the composting procedure has initial aerobic conditions to produce high temperatures lasting a few days for the destruction of pathogenic organisms, followed by anaerobic composting, the maximum initial moisture content may be as high as 65% to 85%, depending on the character of the composting materials.

(Materials & methods to ensure quality compost)

temperature



In aerobic composting proper temperature is important. Heat is released in the process. Since composting material has relatively good insulation properties, a composting mass large enough (3' x 3') will retain the heat of the exthermo-biological reaction and high temperatures will develop.

High temperatures are essential for destruction of pathogenic organisms and undesirable weed seeds. Also, decomposition is more rapid in the thermophilic temperature range. The optimum temperature range is 135° -160° Fahrenheit. Since few thermophilic organisms actively carry on decomposition above 160° F, it is undesirable to have temperatures above this for extended periods.

Eggs of parasites, cysts and flies have survived in compost stacks for days when the temperature in the interior of the stack is around 135° F. Since a higher temperature can be readily maintained during a large part of the active composting period, all the material should be subjected to a temperature of at least 150° F for safety.

Sometimes compost operators avoid prolonged high temperatures because the nitrogen loss is greater at high temperatures because ammonia vaporizes, which takes place when the **C:N** ratio is low. But there are other ways of minimizing nitrogen loss than operating at a lower temperature. The advantages of destroying pathogenic organisms and weed seeds, controlling flies, and providing better decomposition outweigh any small nitrogen loss due to high temperatures.

A drop in temperature in the compost pile before material is stabilized can mean that the pile is becoming anaerobic and should be aerated. High temperatures do not persist when the pile becomes anaerobic. The temperature curve for different parts of the pile varies somewhat with the size of the pile, the ambient (surrounding) temperature, the moisture content, the degree of aeration, and the character of the composting material. To maintain high temperatures during decomposition, compost must be aerobic. The size of the compost pile or windrow may be increased to provide higher temperatures in cold weather or decreased to keep the temperatures from becoming too high in warm weather. Experience shows that turning to release the heat of compost piles, which have become so hot (170°-180° F.) that bacterial activity is inhibited, is not very effective. When the material is actively decomposing, the temperature, which falls slightly during turning, will return to the previous level in two or three hours. Also, it is impossible to bring about any significant drop in temperature by watering the material without water logging the mass.

Variations in moisture content between 30% and 75% have little effect on the maximum temperature in the interior of the pile. The initial temperature rises a little more rapidly when the moisture content is 30% to 50% than when it is 70%. Studies show an important and significant correlation between the moisture content and the temperature distribution within the pile. When moisture content is high, temperatures near the surface will be higher, and the high temperature zone will extend nearer to the surface than when the moisture content is low. For example, in experiments at University of California during mild weather when the air temperature fluctuated between 50° and 80° Fahrenheit, the zone of maximum temperature in a pile with a moisture content of 61% extended to within about one inch of the surface while the maximum temperature zone in a pile containing 40% moisture began 6 inches below the surface.

Deeper piles caused higher temperatures and better temperature distribution, and subject more material to a high temperature at any one time. Hence, the actual mass of the material evolving heat is important in providing adequately high temperatures.

Shredding or pulverizing feedstock also provides better temperature distribution and less heat loss.

Materials with a high **C:N** ratio or containing large amounts of ash or mineral matter usually attains high temperatures more slowly in the compost pile.

Aeration to maintain aerobic conditions in the compost pile is essential for high temperatures. When the compost pile becomes anaerobic, temperature drops rapidly. Even small areas which have become anaerobic will often exhibit a lower temperature than surrounding aerobic material.

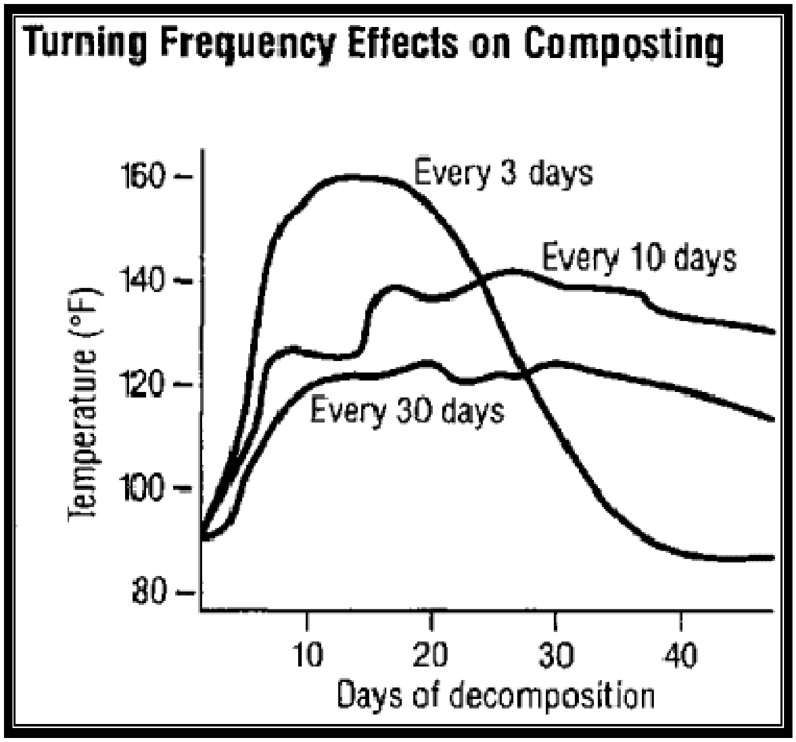
(Materials & methods to ensure quality compost)

aeration

Aerobic organisms need to breathe air to survive. Aeration is necessary in high temperature aerobic composting for rapid odor-free decomposition. Aeration is also useful in reducing high initial moisture content in composting materials. Several different aeration techniques can be used. Turning material is the most common method of aeration when composting is done in stacks. Hand turning of the compost piles or in units is most commonly used for small garden operations. Mechanical turning or static piles with a forced air system are most economical in large municipal or commercial operations.

The most important consideration in turning compost, apart from aeration, is to ensure that material on the outside of the pile of units is turned into the center where it will be subject to high temperatures. In hand turning with forks, this can be easily accomplished. For piles or windrows on top of the ground, material from the outer layers can be placed on the inside of the new pile. For static piles with a forced air system, finished compost or a physical “cover” can be placed on the composting material, ensuring it reaches high temperatures uniformly. Volume reduces during the compost process. Piles or windrows can eventually be combined when turned, particularly if long composting periods are used.

Frequencies of turning or total number of turns are governed primarily by moisture content and type of material. Moisture is the most important. High moisture content reduces the pore space available for air as well as reducing the structural strength of the material. This permits greater compaction and less interstitial or void space for air in the pile. Materials with a high **C:N** ratio may not have to be aerated as often as material which decomposes more actively and rapidly.



Studies at the University of California indicated that turning at fairly frequent intervals during the first 10 to 15 days of composting achieved approximately the same degree of stabilization as making the same number of turns over a longer period. Greater aeration during the initial stages of decomposition intensifies the activity of the microorganisms, shortens the period of active decomposition, and, consequently, reduces time and land area needed for composting.

Air availability is a function not only of turning frequency but also moisture content and structure of the material. Air requirement for the biological activity depends on the availability of nutrients in the feedstocks (e.g., a very high **C:N** ratio material would not support as large a biological population). Thus, it is impossible to specify a minimum frequency of turning or number of turns for a variety of different conditions. Studies on composting of mixed refuse, (lawn and tree trimmings, and considerable quantities of paper and combustible rubbish) at the University of California indicated that the following schedule of turning is adequate to permit rapid decomposition.

If the initial moisture content is below 70%, the first turn should be made about the 3rd day. Thereafter, turn approximately as follows until the 10th or 12th day:

- Moisture 60%-70%: turn at 2 day intervals; approximate number of turns, 4 to 5
- Moisture 40%-60%: turn at 3-day intervals; approximate number of turns, 3 to 4
- Moisture below 40%: add water.

If material initially contains much more than 70% moisture, it should be turned every day until the moisture content is reduced to less than 70%. The above schedule should then be followed.

This turning schedule will permit rapid decomposition at thermophilic temperatures. Fewer turns would not produce as rapid composting but might be sufficient to prevent serious anaerobic conditions and odor.

When compost is stored before using, moving it into a stack can sometimes serve as the last turn. It should be noted that, while the above schedule was desirable for mixed refuse, less frequent turning might have been satisfactory under other conditions.

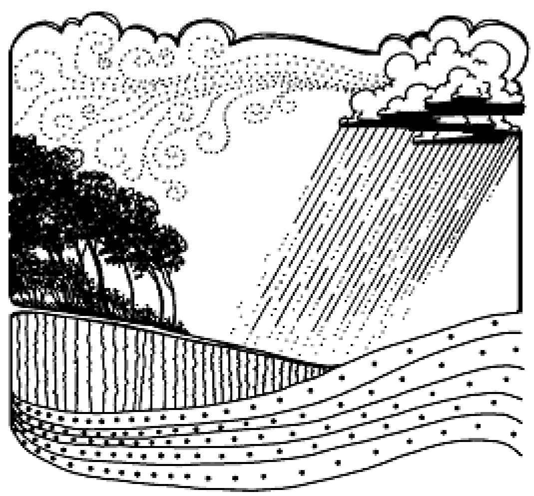
Experienced operators can estimate turning and water needs. If foul odors of anaerobic and putrefactive conditions exist when the pile is disturbed either by turning or by digging into it for inspection purposes, turn the pile daily until odors disappear. No matter how anaerobic a pile may become, it will recover under a schedule of daily turning that reduces moisture and provides aeration. Sometimes daily turning is necessary to controlling fly breeding. A temperature drop during the first 7 or 10 days of composting is a good indication that turning for aeration is necessary.

Daily turning inhibits development of fungi and actinomycetes. In piles turned daily these organisms only develop sporadically, whereas in piles allowed to remain undisturbed for 2 or 3 days, they form a thick continuous layer, which reaches a maximum thickness in about 4 days. Some prefer to manage a hot or thermophilic pile for several weeks, then stop turning the pile letting mesophilic organisms take over, which encourages fungi and actinomycetes development. Fungi and actinomycetes are the best decomposers of woody matter, such as sawdust or branches. Actinomycetes gives compost the earthy smell—like that of the forest floor.

In summary, avoiding anaerobic conditions, maintaining high temperatures, and controlling flies are the important criteria for degree of aeration.

(Materials & methods to ensure quality compost)

climatic conditions



Climatic conditions, particularly temperature, wind, and rainfall influences the composting process. The lowest temperature at which composting might be satisfactorily done, is not known. A slightly larger compost pile in winter weather will reduce the heat loss per unit volume.

Organic compost material has excellent insulating properties. A steep temperature gradient exits at the outer surface of compost stacks. The difference in temperature may be several degrees Fahrenheit per inch of material. Composting can can occur at severe freezing temperatures, providing snow conditions do not interfere with turning and the snow becomes mixed with the compost. Turning would not have to be done quite as often as in warm weather, because there would be a longer temperature recovery period after each turn when the colder exterior of the pile was turned into the interior.

Strong winds markedly lower temperatures on the windward side of a compost pile. Two factors play an important role: (a) the coarseness of the material, which affects the porosity and dessication of the pile, and (b) the moisture content. Unshredded or coarsely shredded material has a greater porosity and permits greater penetration of wind into the pile. Consequently, more evaporation takes place. When the material becomes too dry, bacterial activity is inhibited. Shredding or grinding to produce a maximum particle size of about 2 inches provides a more homogeneous mass that is not as easily penetrated by winds. Thoroughly wetting the exterior of the pile, particularly on the windward side, will reduce wind penetration and permit the interior high-temperature zone to extend nearer to the surface of the pile.

In an area of strong prevailing winds, a windbreak could be built to protect compost piles. This should seldom be necessary, however, since increasing the size of and wetting the pile will control temperatures, and all material will be exposed to high temperatures by turning. Wind cooling and drying of compost piles is of little significance when piles or bins are used, since the material is protected on all sides except the top, which wetting will protect.

To avoid problems with rain, piles can be finished with a rounded top so that the rainwater can run off, and adequately drained to ensure they are not in standing water. Heavy rains accompanied by high winds will penetrate a pile of coarsely shredded material as much as 12 to 15 inches on the windward side, but the effect on large piles can be overcome by subsequent turning.

Turning should not be done in the rain, because the material may become waterlogged. If the material cannot be turned on regular schedule owing to rain, it is better to let it become deficient in air for a short time than soaked. Rainy weather can present more of a problem when composting is done in pits or bins. The top of the pit should be rounded to turn the water, which will, however, seep along the edges to the bottom. The bottom should therefore be adequately drained to remove the water and to allow a minimum of penetration into the compost. In rainy areas, pits should be lined with concrete, brick, or masonry, and provided with tile drains. Or roofs could be built over the bins or pits to protect them from rain.

During rainy weather, shredding or grinding, and the segregation of the materials should be done under cover. Facilities for storing the incoming materials for a short time should be provided, so that stacking or piling does not have to be done during rain.

Composting can be done satisfactorily in relatively cold climates or in areas of considerable rainfall with a minimum of roofed buildings. Heavy snowfall will greatly hinder continuous composting operations and removal of snow from the composting piles or bins will usually be required. Material will not become anaerobic or create an odor nuisance during really cold weather. Hence, if an ample composting area is available, the material can be allowed to stand for long periods without turning until the weather is favorable.

(considerations before choosing a compost method)

When deciding how to compost, there are many considerations. How much time and effort do you want to spend? Do you want your compost within months, or do you have space for a slow pile that you can leave for a year? What types of materials will you be composing? Will they possibly have pathogens and weeds, or will you only compost “safe” materials? Do you want to spend lots of money for a fancy bin, or will a heap, or bin made out of free pallets suffice?

destruction of pathogenic organisms

Destruction of pathogenic organisms is a most important aspect-and a problem- of compost. Experiments have shown that aerobic composting at high temperatures is effective in destroying pathogenic organisms. The absence of health hazards is characteristic of well-managed composting operations. This is significant evidence of the effectiveness of thermophilic composting.

An analysis of the typical temperature and of thermal death points of a number of pathogenic microorganisms, parasites, and parasite ova, indicates the unlikelihood of survival of some of the common disease-bearing organisms. The highest thermal death points are appreciably lower than the maximum temperatures found inside the composting pile or bin. The magnitude and duration of the high temperatures, as well as the antibiosis which is characteristic of a mixed population of microorganisms, provide a sound basis for believing that no pathogens, parasites, or parasite ova survive the aerobic composting process.

The high temperature zone usually extends only to within 4 to 8 inches of the surface. Therefore, turning is necessary, quite apart from its function in aerating the mass, for ensuring pathogen and parasite destruction, particularly if a composting period under six months is used. The compost temperature curves and thermal-death-point values may indicate that one turning will be sufficient eliminate the pathogens and parasites if all of the surface material is completely turned to the inside, thus exposing any organisms present to lethal internal temperatures. But, although this may be true in many cases, as a safety factor, and to guard against failure to turn all of the material to the inside, at least two turns are required, and at least three for maximum assurance of complete destruction. Three turns would also be the normal practice for aeration purposes when rapid composting is done in stacks or piles on the ground surface.

In some composting operations the material is turned only once or not at all. A thermophilic temperature is developed after the initial aerobic stacking. This is considered to be sufficient to destroy pathogens and parasites. Unless composting was under a thermal cover, or in vessel, it is doubtful this practice is sufficiently safe when contaminated material is composted, since some pathogen and parasites may escape destruction in the cooler side and top layers.

Anaerobic composting in the mesophilic temperature range does not affect good destruction of parasites in an anaerobic environment. The biological antagonisms will eventually eliminate them, but this will generally take at least 6 months.

Unless six months or more can be allowed to elapse before the compost is used, anaerobic composting should be preceded by aerobic conditions and thermophilic temperatures for at least a week with at least one turning, in order to ensure the desired destruction of pathogens.

General cleanliness and systematic attention to the details of operation around the compost site, is necessary and particularly important when contaminated material is used.

(considerations before choosing a compost method)

pesticides and herbicides

Is it safe to use compost from yard wastes that have come in contact with pesticides, or other toxic chemicals? The major route of breakdown of pesticides is through microbial degradation, which is the process of decomposition. Any pesticide a homeowner can buy without a license will be broken down in the compost pile before the end of the process. The one exception to this is clopyralid, which is contained in certain Dow products. Confront is the product that homeowners might use. This is a long lasting herbicide, and vegetation that has been treated with this should NOT be composted, since the resulting compost can cause serious injury to sensitive crops.

Some typical home yard chemicals, and their reaction to composting:

Slug bait: Most commercial slug baits contain metaldehyde which, when exposed to water, quickly breaks down to a harmless alcohol. (Fresh metaldehyde is toxic to slugs, snails, birds, cats, dogs, raccoons, rabbits, and humans).

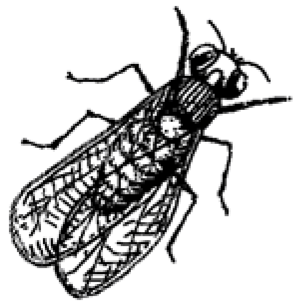
Herbicides: Some herbicides become harmless in a very short time in the soil and compost piles (such as Diquat, Paraquat). Others (such as 2,4-D and propanil) break down in compost piles, but only after thorough composting. Still others (such as arsenic, borate, picloram, simazine, sodium chlorate) are extremely long-lived and will probably survive most composting processes. Do not use organic matter in your compost pile if it was treated with long-lived herbicides, such as CONFRONT.

Insecticides: All contemporary insecticides will break down during the decomposition process. Old chlorinated hydrocarbon insecticides such as DDT (which has been banned for a long time) may survive.

Fungicides: Vegetation that has been just sprayed with a fungicide may suppress the development of decomposing fungi if it is added to the compost pile. A few weeks will degrade the fungicide enough so that it will not effect the decomposition process. Currently, one turf fungicide, PMA, contains mercury and may only be used by commercial pesticide operators. This should not be used.

Do not use **pressure treated wood** to construct compost bins. It is now well demonstrated that chemical components of the pesticide do leach from treated lumber. The compost may retain a good share of those chemicals, and some would be carried with water into the soil or drains below. This could affect the compost's quality, as well as safety and performance.

(considerations before choosing a compost method)



fly control

One of the most important problems in composting is controlling flies. Garbage, animal manure, tomato and several other food-processing wastes, are excellent media for breeding and development of large fly populations. If adequate control measures are not practiced, particularly when composting manure, the compost systems will be infested with extremely large numbers of flies, and create a health hazard.
Fly breeding can be controlled in composting operations during the fly season, with little more effort than is normally necessary for good sanitary composting. Added manure and fresh food scraps in the composting systems should be kept covered.

Fly larvae in composting material may originate from eggs laid in the material at the place of collection or from eggs laid during the handling of the material at the compost site. If the latter were the main source, fly control would be no problem. However, much of the material is infested with eggs and larvae in various stages of development, sometimes even at the pupal stage, before arriving at the compost site. Therefore, material must be prepared immediately for composting and placed in compost systems where high temperatures and environmental conditions are unsatisfactory for continued emergence of flies.

The predominant species of flies encountered in composting will vary with the area and with the type of material. The variety of materials available for composting offers satisfactory breeding conditions for many different species, but generally speaking, the compost operator does not have to worry about the particular species, since the most satisfactory control measures in composting apply equally well to different species.

The life cycle of the ordinary housefly, "*musca domestica*," is usually from about 7 to 14 days when conditions are favorable. The time of the different stages varies with temperature and other conditions, but on average it may be considered as follows: egg, 1 to 2 days; larva 3 to 5 days; pupa, 3 to 5 days; emergence of young fly, 7 to 10 days; and egg laying by new fly, 10 to 14 days. Fly control measures must interrupt this cycle and prevent the adult flies from emerging.

Some procedures, particularly grinding, turning, and systematic cleanliness, which are useful in providing compost of good quality and in destroying parasites and pathogens, are also effective for controlling flies. Initial shredding or grinding to produce material more readily attacked by bacteria also destroys a large number of the larvae and pupae in the raw material. Also, the texture of material shredded to a maximum size of 2 inches is not as suitable for fly breeding.

Studies at the University of California on mixed garbage and refuse demonstrated that after raw material containing considerable numbers of eggs and larvae had been ground and placed on the pile, no fly breeding took place using normal composting procedures of turning every 2 to 3 days. Apparently, the destruction of the larvae by grinding, mixing, and the structural changes caused by grinding, results in garbage that is no longer attractive to flies. Heat quickly generated in compost piles effectively stops flies breeding in refuse containing a considerable proportion of garbage. However, this is not the case, for compost materials containing large amounts of animal manure, food scraps and other fresh and decaying fruits.

When materials attractive to flies and containing large numbers of larvae and pupae are composted, some of the larvae will move to other cooler layers and continue their life cycle. The most effective method of destroying these larvae is frequent turning. Turning compost stacks at daily interval, when the raw material contains many larvae and pupae and when fly breeding conditions are favorable, and at a maximum interval of 3 or 4 days when fly breeding conditions are not especially favorable, provides good fly control

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(considerations before choosing a compost method)

reclamation of nitrogen and other nutrients

Compost can provide essential nutrients to soil. Of the major nutrients-nitrogen, phosphorus, and potash- the nitrogen conservation is the most important in most areas of the world because so often the shortage of nitrogen limits the amount of food that is produced. Nitrogen is also more difficult to conserve than phosphorus and potash, as are the micronutrients, which, owing to the chemical condition in which they are present, are lost only to leaching. Leaching may lose nitrogen, but the major loss comes from escape of ammonia or other volatile nitrogenous gases from compost material to the atmosphere.

There has been much research and writing on conserving nitrogen and other nutrients, particularly with respect to microbiology of the soil. Results of investigations and studies on nitrogen utilization in the basic biological processes provide fundamental information on the control of nitrogen loss in composting.

Nitrogen loss as ammonia in aerobic composting is affected by the **C:N** ratio, pH, moisture content, aeration, temperature, and the form of nitrogen compounds at the start of the composting materials.

Since organisms use about 30 parts of carbon for each part of nitrogen, a **C:N** ratio in the raw compostable material of around 30:1 is best for good composting is satisfactory for tying up or binding nitrogen in biological cell material, preventing its escape.

To avoid nitrogen loss, optimum ratios of C:N range from 26 to as high as 38 depending on conditions. A ratio of available carbon to available nitrogen of about 30 or more permits minimum loss of nitrogen, but the ratio of carbon to nitrogen measured chemically is often not the ratio of available carbon to available nitrogen. Since many feedstocks contain considerable amounts of cellulose and lignins resistant to biological decomposition, and since most of the nitrogen is usually in a readily available form, an actual **C:N** ratio of 30 may be necessary to provide maximum conservation of nitrogen. Also, studies indicated that nitrogen conservation decreased rapidly as the **C:N** ratio increased from 40 to 50. This rapid decrease is not entirely consistent with the fundamental aspects of bacterial decomposition. Above a **C:N** ratio of 50, nitrogen conservation remained uniform at about 70% of the optimum. Basically there should be little drop in nitrogen conservation below the maximum when the initial **C:N** ratio is above the ratio utilized by the organisms. When carbon is higher than the ideal **C:N** ratio, organisms will require all the nitrogen for decomposition of the carbonaceous materials. University of California studies found Nitrogen losses of around 50% when the **C:N** ratio was in the range 20 to 25. From about 30 upward, nitrogen losses were very small.

NITROGEN CONSERVATION IN RELATION TO C:N RATIO

Experimental test	Initial C:N ratio	Final percentage of nitrogen	Nitrogen conservation %
1	20	1.44	61.2
2	20.5	1.04	51.9
3	22	1.63	85.2
4	30	1.21	99.5
5	35	1.32	99.9

This table shows a few examples of nitrogen conservation for different **C:N** ratios. In manure composts, nitrogen was conserved only when the **C:N** ratio was adequate and when immediate decomposition set in. This resulted in transformation of soluble forms of nitrogen into insoluble forms. Whenever decomposition was delayed, owing to too low or too high a temperature, losses of volatile forms of nitrogen occurred. From 85% to 90%, and possibly 95%, of the nitrogen in the raw materials can be conserved if the **C:N** ratio is high and other avenues for nitrogen loss are controlled.

There are three phases in the relation of nitrogen supply and conservation to available carbon in biological decomposition:

a. When more nitrogen is available than necessary for organisms to use carbon, large quantities of ammonia and volatile forms of nitrogen are given off and lost;
b. When the requisite amount of nitrogen to carbon for bacterial utilization is present, decomposition proceeds without appreciable loss of nitrogen;
c. When nitrogen is low in relation to carbon, some of the organisms will die and their nitrogen will be recycled. Small additional amounts of nitrogen may be picked up by nitrogen fixation when conditions are satisfactory.

In all three phases there is a tendency to reach the same final amount of nitrogen, that which the bacteria can hold when the compost is in a stabilized condition. In the first phase nitrogen is lost; in the second, it is stabilized and conserved; and in the third, it is recycled, conserved, and sometimes accumulated. This illustrates that composting operations can be operated to conserve most nitrogen.

Ammonia escapes as ammonia hydroxide as the pH rises above 7.0. In the later stages of composting the pH may rise to between 8.0 and 9.0. At this time there should not be an excessive amount of nitrogen present as ammonia. Materials that contain large amounts of ash will have a high pH and may be expected to lose more nitrogen.

Some compost operators add lime to improve composting. This should be done only under rare circumstances, such as when raw material has a high acidity due to acid wastes or contains materials that give rise to highly acid conditions during composting. When the pH remains above 4.0 to 4.5, lime should not be added. The pH will be increased by biological action and nitrogen conserved.

The moisture content of compost affects nitrogen conservation less than the **C:N** ratio and the pH. Ammonia escape is greater when the moisture content is low. The water serves as a solvent and diluent for the ammonia, thereby reducing vapor pressure and volatilization. A moisture content range of 40% to 60%, satisfactory for other aspects of composting, will assist in conserving nitrogen.

Aeration and turning adversely affect nitrogen conservation. If ammonia is present, it will escape more easily when material is disturbed and exposed to the atmosphere. However, if the initial **C:N** ratio is high enough, nitrogen losses during turning will be small. Since some ammonia may be present during the dynamic transitional phases of active decomposition, turn only as often as necessary to maintain aerobic conditions and control flies.

High temperatures increase volatilization and escape of ammonia. Since high temperatures are fundamental in aerobic composting and destruction of pathogen, not much can be done about controlling temperatures other than to avoid temperatures above 160° Fahrenheit, which retard bacterial activity and permit ammonia accumulation. Since the greatest ammonia loss occurs during early stages of active decomposition, only little conservation of nitrogen will be gained by reducing temperatures after the two turns or after the first 6 to 8 days of active decomposition.

The nitrogen initially present in the material may affect nitrogen conservation. If large amounts of ammonia are present in raw materials, some of this ammonia may be volatilized and lost before the organisms have had sufficient time to utilize and stabilize it, even though the **C:N** ratio is satisfactory for nitrogen conservation. This can be an important factor since much of the nitrogen loss occurs during the first few days of composting.

Some materials, such as cellulose and porous fibrous matter, have the capacity to absorb or hold moisture and volatile substances, thereby reducing the tendency to escape. Materials of this type play a part in reducing nitrogen loss from compost, which contain accumulated ammonia. Materials containing considerable quantities of horse or cow manure exhibit less nitrogen loss at low **C:N** ratio than other materials, and can be considered nitrogen carriers. This could have been due to the form of nitrogen, to the absorptive of nitrogen holding capacity, or to some other characteristic of the manures.

Also, addition of soil to compost with high ammonia content absorbed some of the nitrogen.

Loss of nitrogen by leaching may occur in rainy weather or if the composting material has too high initial moisture content and excess liquid drains away. Loss by leaching depends on the amount of soluble nitrogen in the compost and on the amount of rainfall. Arranging compost piles so that water can’t enter may minimize leaching.

The greatest nitrogen conservation may be accomplished by anaerobic digestion in water when liquids as well as the solids are conserved. In such cases, while nitrogen fixation would not be expected, there should be almost no nitrogen loss, since ammonia in low concentration in the liquid would not escape.

Conservation of phosphorus and potash in composting is not difficult since about the only loss occurs through leaching during rainy weather.

(considerations before choosing a compost method)

time required

Organic matter can compost to safe, stable material in as little as three weeks, or as long as six months or more. The actual composting time is not particularly important, provided that is it sufficient for destruction of pathogens and parasites, and for nitrogen conservation. Composters need to determine how quickly they want finished compost.

The time required for satisfactory stabilization depends primarily upon:

a. initial **C:N** ratio
b. particle size
c. maintenance of aerobic decomposition and
d. moisture content.

The **C:N** ratio determines time required for stabilization, provided moisture content is in the optimum range, compost is kept aerobic, and particles of material are of such size as to be readily attacked by the organisms present - all factors that can be controlled in the composting operation. Low **C:N** ratio feedstocks decompose in the shortest time because the amount of carbon to be oxidized to reach a stabilized condition is small. Also, a larger part of the carbon is usually in a more readily available form, while in higher **C:N** ratio materials, more of the carbon is usually in the form of cellulose and lignin which are resistant to attack. The changing biological population in the environment attacks cellulose and lignin last. When the available **C:N** ratio is above 30, additional time is required for recycling nitrogen.

If material is not kept aerobic so that high temperatures can be maintained during the active decomposition period, or if the particle size is so large that the bacteria cannot readily attack the material, or that the interior of the particle becomes anaerobic, longer composting periods are required.

Under aerobic conditions at high temperatures and when the initial **C:N** ratio is in the optimum range or below, the material takes on the appearance and odor of humus after 2 to 5 days of active decomposition. However, active decomposition is not complete at this stage, and the **C:N** ratio may not have been lowered to the level desired for fertilizer.

Compost is sometimes called “black gold,” and has long been considered a gardener’s best friend. It improves the textures of any type of soil; sandy, clay loose or hard. Soils can both hold more water and drain more efficiently when compost is added. Compost, and the beneficial soil life it includes such as bacteria, fungi, redworms and dung beetles replenish the soil to make it a healthy, productive environment for plants to grow and thrive.

economic aspects

Farmers and experienced gardeners realize that yields and the maintenance of soil fertility depend upon reclamation of organic materials. Soil scientists and soil ecologists study the interaction of soil microorganisms and their effects on the soil food web and soil management. Plants depend on organic matter in soil for their nutrient supply and protection against disease. In fact, soil microbiologist Mary Ann Bruns explains the extreme importance of these organisms: “If all humans were eliminated from the planet, it would still be a livable place—there would be plenty of oxygen and water. But if the microscopic organisms were eliminated, we would die because they’re totally responsible for purifying our water and for maintaining the correct mixture of gases in the air for us to breathe. And if we didn’t have microorganisms, we would be buried in our waste because we rely on them to decompose it.”

Composting organic matter to make them safe for use on agricultural lands and gardens is economically sound, and a way to cut down on the volume of waste materials at the landfills or incinerators. Keeping the organic matter out of the solid waste stream holds down the cost for the community in disposal cost.

Compost contains valuable nutrients that could replace and/or supplement use of commercial fertilizers by homeowners. Use of chemical fertilizers can be cut down to a minimum. Excessive usage of commercial fertilizers by homeowners can contaminate surface and groundwater with nitrates. Excess nitrates in ground and surface water can lead to human health hazards.

Municipalities that collect or stockpile organic matter, and are responsible for sanitary disposal, are often not directly concerned with their utilization in agriculture/horticulture. Municipalities are primarily interested in the sanitary disposal of the materials. In Whatcom County, the “clean green” yard waste that homeowners’ deposit at the site is contracted to go to a facility where it is safely composted. Other places send such organic wastes to landfills.

Salvaging urban organics for agricultural use offers an opportunity for closer cooperation between urban and rural elements in improving the total economy of an area. It has been demonstrated many times in various areas of the world that developments in one segment of a community can benefit another and be profitable for both. For example, in Snohomish County, there is a dairy farm that accepts yard trimmings and horse manure and composts, selling quality composts back to the community.

Economic reclamation of municipal organic wastes depend upon low cost production which permits distribution of large quantities of composted organic materials at a sufficiently low price to make its use attractive to agriculture and horticulture operations.

Many commercial compost plant operators have found a profitable market among truck gardeners, nurseries and landscaping operation. There is a need for good humus in our fast growing community. Many new homes and commercially buildings have topsoil brought in, which is usually stripped, from good agricultural land. The humus from composting organic wastes could be used as a substitute for or blended with topsoil now used by landscape contractors and homeowners

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testing and judging condition of compost

Composters want to ensure the compost they make is adequate for their purposes.
There are many tests and checks by which various aspects of the composting process and the condition of compost may be judged. From the point of view of the overall operation and the final product there are three groups of tests:

a. test of the sanitary quality of the operation and of the finish product, i.e., pathogen and parasite destruction and absence of flies and odors;
b. test of fertilizer or agricultural or horticultural value, i.e., the amount of nitrogen, phosphorus, potash, and other nutrients, nutrient conservation, the **C:N** ratio, and compost value ;
c. assessment of the biological activity of the compost, how many and what types of soil dwelling animals and microorganisms it contains; and
d. economic test, i.e., whether the total cost of producing the compost is less than its value as fertilizer plus the cost of disposal by other means, such as incineration or land fill.

Health organizations and laboratories can make tests for organisms of public health significance when necessary. Chemical tests for nitrogen in its different forms, phosphorus, potash and the organic character of the material can be made by standard techniques and are useful in analyzing the finished product and to determine the effect of different composting procedures. For routine day-to-day operations, temperature, appearance of material, odors, and the presence of flies are important tests. Cleanliness and the absence of flies at the site, as well as the absence of large numbers of larvae in the piles, are criteria of sanitary quality of the compost operation. Temperature is the best single indicator of the progress of aerobic composting and also the basis for determining whether pathogen, parasites, and weed seeds are being destroyed.

Laboratory analyses for nitrogen, phosphorus, and potash are more precise and require more elaborate equipment, but are relatively simple chemical determinations to make. If compost is modified by adding ammonium sulfate, phosphates, or other nutrients for special fertilizer purposes, percentages of these nutrients on a dry basis must be determined, so that users can compare them with other fertilizers. Determining the **C:N** ratio, which is so important in regard to nitrogen conservation and for estimating the quality of the finished compost, is more of a problem, because the quantitative analyses of carbon is difficult, time consuming, and expensive.

There are laboratories that specialize in “counting” living organisms in compost (fungi, bacteria, protozoa…). While it is difficult to get precise measurements, trends can be discovered, such as determining whether there is fungal or bacterial dominance in the finished compost.

The gardener, small farmer and other small compost operator usually will not be concerned with detailed tests other than those to confirm that the material is safe from a health standpoint. This will be judged from its temperature, and its satisfactory appearance as a soil additive.

The temperature of compost can be checked by:

a. digging in the pile and feeling the temperature of the material;
b. feeling the temperature of a rod after insertion into the material; or
c. using a thermometer.

Digging into the pile will give an approximate idea of the temperature. The material should feel very hot to the hand and be too high to permit holding the hand in the pile for very long. Steam should emerge from the pile when opened. A metal or wooden rod inserted 2 feet into the pile for a period of 5-10 minutes for metal and 10-15 minutes for wood should be quite hot to the touch, in fact, too hot to hold. These temperature-testing techniques are satisfactory for the smaller compost operations. Long stem metal thermometers are available for temperature testing.

Compost may be considered finished when it can be stored in large piles indefinitely without becoming anaerobic or generating appreciable heat. It can be safely spread because of its low **C:N** ratio or the poor availability of its carbon. The material, however, is still slowly active and will "ripen" somewhat in the large stacks. At this time it should be grayish-black or brownish-black in color, depending on what color of materials were used. However, color alone is not a good criterion of finished compost because the appearance of rich soil humus develops in a good compost long before the temperature decline signals the decrease in microbial activity.

Characteristic changes in odor during the period of composting help define stable compost. The material should be odorless, or have a slightly earthy odor or the musty odor of molds and fungi, similar to the forest floor. Also, look for compost critters, redworms, centipedes, sowbugs, fungi—these can identify compost as healthy and living. They are indicators of an abundance of organisms, some of which can keep disease and pests in check.

These approximate physical tests are adequate for most small compost operations

quality of composts

The nutrient value of composts varies widely, depending upon the nature of feedstock composted. If initial material contains grass clippings, weeds, or manure, it will be richer in nitrogen and other nutrients than if it contains mainly straw, litter, dirt or corn stalks.

The following analysis shows the ranges of values, on a dry basis, in which the chemical characteristics of most finished composts generally lie. These ranges vary because different initial materials will yield final composts of widely varying chemical characteristics.

Substance	Percentage by weight
Organic matter..............................	25.0-50.0
Carbon..............................	8.0-50.0
Nitrogen (as N)..............................	0.4- 3.5
Phosphorus (as P_2O_5)......................	0.3- 3.5
Potassium (as K_2O)..........................	0.5- 1.8
Calcium (as CaO)..............................	1.5- 7.0

Composts also contain a great variety of micronutrients. Since organic materials for composting contain products of agriculture or horticulture, it is logical to expect these nutrients to be present in the compost. Experiments indicate that compost manures have beneficial effects greater than those to be expected from nitrogen, phosphorus, potash, and humus content alone.

Quality compost also contains many organisms necessary for soil health. Depending on feedstock, weather and type of process used, each batch will have different organisms. This composted organic matter, when applied to the soils provides a necessary source of energy and food for the soil organisms, as well as essential nutrients for plant growth.
Think of the soil not only as a physical and chemical substrate, but as a living entity. When making quality compost you can manage the soil organisms as a high value “mini-livestock.”

Compost Benefits

Using compost as mulch, in the soil or as potting media is beneficial in many ways.

Compost contains a full spectrum of essential plant nutrients. You can test the nutrient levels in your compost and soil to find out what other supplements it may need for specific plants.

- Compost contains macro and micronutrients often absent in synthetic fertilizers.
- Compost releases nutrients slowly—over months or years, unlike synthetic fertilizers
- Compost enriched soil retains fertilizers better. Less fertilizer runs off to pollute waterways.
- Compost buffers the soil, neutralizing both acid & alkaline soils, bringing pH levels to the optimum range for nutrient availability to plants.

Compost helps bind clusters of soil particles, called aggregates, which provide good soil structure. Such soil is full of tiny air channels & pores that hold air, moisture and nutrients.

- Compost helps sandy soil retain water and nutrients.
- Compost loosens tightly bound particles in clay or silt soil so roots can spread, water drain & air penetrate.
- Compost alters soil structure, making it less likely to erode, and prevents soil spattering on

plants—spreading disease.
- Compost can hold nutrients tight enough to prevent them from washing out, but loosely enough so plants can take them up as needed.
- Compost makes any soil easier to work.

Compost brings and feeds diverse life in the soil. These bacteria, fungi, insects, worms and more support healthy plant growth.

- Compost bacteria break down organics into plant available nutrients. Some bacteria convert nitrogen from the air into a plant available nutrient.
- Compost enriched soil have lots of beneficial insects, worms and other organisms that burrow through soil keeping it well aerated.
- Compost may suppress diseases and harmful pests that could overrun poor, lifeless soil.

Healthy soil is an important factor in protecting our waters. Compost increases soil's ability to retain water & decreases runoff. Runoff pollutes water by carrying soil, fertilizers and pesticides to nearby streams.

- Compost encourages healthy root systems, which decrease runoff
- Compost can reduce or eliminate use of synthetic fertilizers
- Compost can reduce chemical pesticides since it contains beneficial microorganisms that may protect plants from diseases and pests.
- Only a 5% increase in organic material quadruples soils water holding capacity.

When that first batch of finished compost is ready to spread, congratulate yourself for your efforts because you are ecological minded, and know that organic materials should be recycled into the soil instead of being put in a garbage can. By recycling the organic materials, valuable nutrients and organic matter are recycled. You have helped alleviate the solid waste problem!

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use of compost

Compost is ready for use when the temperature in the pile drops to the temperature of the surrounding air. Other signs are:

- It smells earthy—not sour, putrid or like ammonia
- It no longer heats up after turned or watered
- It looks like dark soil

- It’s crumbly, and doesn’t have identifiable food items, leaves or grass.

The pH is usually around 7.5, and it will have a **C:N** ratio ranging from 10:1 to 20:1.

Planting in compost before it is finished could damage plants. Undecayed carbon materials as wood chips or leaves uses nitrogen from the soil to continue decomposing, robbing it from the plants you grow. Undecayed nitrogen materials can harbor pests and diseases. Immature compost can introduce weed seeds and root-damaging organic acids.

Compost can be used in many ways in the garden. Coarse, semi-decayed woody material is suitable as mulch to put on top of the soil around the plants. It can be used as mulch around trees and shrubs, to keep the moisture in, to prevent weeds from growing around trees and shrubs. The decayed material is good for digging into the soil together with commercial fertilizers at preparation time.

It can be used for installing new lawns. A fine-screened layer can be used for a top dressing on established lawns. It can be used in the planting areas of landscapes. It should be used extensively in vegetable gardens to improve the organic matter content in the soil. It can be used for houseplants, for starting seeds in planting beds or flats, or made into a compost tea for watering plants.

Compost is also useful for erosion control. Erosion often is the end result of low soil fertility. Compost and the humus it contains can actually bind to the soil, building a good structure than encourages optimum fertility and erosion resistance. Studies have shown that a layer of compost works much better along newly planted hillsides beside highways than straw that was traditionally used.

An exciting new use for compost is bioremediation. Many things can contaminate surface waters, soils and reservoirs. Using compost can often restore these. The microorganisms in compost can sequester or break down contaminants in water or soil. Contaminates are digested, metabolized and transformed into humus and inert byproducts such as carbon dioxide, water and salts. Compost bioremediation is effective in degrading or altering chlorinated and nonclorinated hydrocarbons, wood preserving chemicals, solvents, heavy metals, pesticides, petroleum products and explosives

Why Compost | Biology & Chemistry | Compost Needs
Composter's Needs | Benefits & Uses | Conclusion

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