The Science and Engineering of Composting
Composting Experiments

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Composting Experiments

Ideas for Student Research Projects

Compost Ingredients

1. Garden supply stores and catalogs often sell compost "starters," which supposedly speed up the composting process. Develop a recipe for a compost starter and design a research project to test its effect on the compost temperature profile.
2. How well do human nutrition concepts apply to compost microorganisms? For example, will the microbes get a "sugar high," demonstrated by a quick, high temperature peak when fed sugary foods, compared with a longer but lower peak for more complex carbohydrates?
3. Measure the pH of several different compost mixes. How does the pH of initial ingredients affect the pH of finished compost?
4. Some instructions call for adding lime to increase the pH when compost ingredients are mixed. Other instructions caution to avoid this because it causes a loss of nitrogen. How does adding various amounts of lime to the initial ingredients affect the pH of finished compost?

Microorganisms

1. Composting recipes sometimes call for inoculating the pile by mixing in a few handfuls of finished compost. Is there any observable difference in appearance of microbes between systems that have and have not been inoculated?
2. Does the pH of the initial compost ingredients affect the populations of microorganisms during composting?

Compost Physics

1. What type of insulation works best for soda bottle bioreactors? Does it help to have a reflective layer? Do different insulative materials or different thicknesses affect the temperature profile?
2. When constructing compost bins or piles, some people incorporate perforated pipe, wire mesh, or other systems to increase passive air flow. What is the effect of different methods of aeration on the temperature profile of any one compost system?
3. How do various means and schedules for turning a pile affect the temperature profile and the time needed for production of finished compost?
4. What is the effect of forced aeration (with an aquarium pump or similar apparatus) on the temperature profile in a soda bottle or a two-can bioreactor?
5. Try mixing the same ingredients in a large outdoor pile, a two-can bioreactor, and a soda bottle bioreactor. Which system reaches the hottest temperatures? Which remains hot the longest? How does this affect the compost produced?
6. What is the effect of layering versus mixing organic ingredients on the compost pile temperature profile?

Worm Composting

1. Do organic wastes in compost break down more readily in the presence of worms than through composting that depends solely on microbial decomposition?
2. In some experiments, plants have not shown increased growth when planted in fresh worm castings. Does aging or "curing" worm castings increase their ability to enhance

plant growth? Are there chemical differences between fresh and older worm castings? Should worm compost be mixed with soil before being used to grow plants?
3. How do different food sources affect reproductive and growth rates of red worms (*Eisenia fetida*)?
4. Red worms grow best in wastes with pH between 5.0 and 8.0. How sensitive are their cocoons to pH? Will they hatch after being exposed to extreme pH? How sensitive are they to extreme drought or temperatures?

Effects of Compost on Plant Growth

1. Some leaves, such as those of black walnut or eucalyptus trees, contain chemicals that inhibit growth of other plants. Are these compounds broken down by composting?
2. Finished compost is near neutral pH. Can you design an experiment to answer one or more of the following questions: Is compost detrimental to use on acid-loving plants such as blueberries or azaleas? Does compost buffer the soil pH, making it harder to provide acidic conditions? How does it compare to peat moss in this regard?
3. Water in which compost has been soaked (often called compost tea) is said to be beneficial to plants. Can you design experiments to test whether different types, concentrations, and amounts of compost tea enhance plant growth?
4. In China, farmers dig parallel trenches and fill them with organic wastes mixed with cocoons of Eisenia fetida. Soybeans planted in rows between the trenches are highly productive. Can you design and test a planting system using vermicompost?

These are a few ideas about possibilities for student research projects on composting. For more ideas, plus detailed information about techniques for carrying out composting experiments, refer to our book, Composting in the Classroom: Scientific Inquiry for High School Students, by N.M. Trautmann and M.E. Krasny. ISBN 0-7872-4433-3. Available from Kendall/Hunt Publishing Company (OUT OF PRINT)

Monitoring the Composting Process

As composting proceeds, several changes occur in its physical, chemical, and biological characteristics. Monitoring some of these variables will help you to assess the status of your compost and to compare the progress of systems with different initial conditions or ingredients.

Monitoring Compost Moisture

Composting proceeds best at a moisture content of 40-60% by weight. At lower moisture levels, microbial activity is limited. At higher levels, the process is likely to become anaerobic and foul-smelling.

When you are choosing and mixing your compost ingredients, you may wish to measure the moisture content (page 15). After the composting is underway, you probably don't need to repeat this measurement because you can observe whether appropriate moisture levels are being maintained.

If your compost starts to smell bad, chances are it's too wet. Excess water fills the pore spaces, impeding the diffusion of oxygen through the compost materials and leading to anaerobic conditions. Mixing in additional bulking agent such as dry wood chips, cardboard pieces, or newspaper strips is likely to alleviate the problem. If you are composting in a bioreactor with drainage holes, you may notice leachate draining out. This liquid is often rich in nutrients and

can be diluted for use on plants. You may find it useful to record the amount of leachate produced by each system, for comparison with initial moisture content, temperature curves, or other variables.

If you are blowing air through your compost system, you will need to be careful not to dry it out. If the temperature drops sooner than expected and the compost looks dry, moisture may have become the limiting factor. In this case try mixing in some water and see if the temperature rises again.

Monitoring Compost Temperature

Temperature is one of the key indicators in composting. Is the system heating up? How hot does it get? How long does it remain hot? How does mixing affect the temperature profile?

Heat is generated as a byproduct of microbial breakdown of organic material, and you can use the temperature of your compost to gauge how well the system is working and how far along the decomposition has progressed. For example, if your compost heats up to 40 or 50C, you can deduce that the ingredients contained adequate nitrogen and moisture for rapid microbial growth.

To take your temperature readings, make sure to use a probe that reaches deep into the compost. Leave the probe in place long enough for the reading to stabilize, then move it to a new location. Take readings in several locations, including at various depths from the top and sides. Compost may have hotter and colder pockets depending on the moisture content and chemical composition of ingredients. Can you find temperature gradients with depth? Where do you find your hottest readings? For systems in which air enters from the bottom, the hottest locations tend to be two-thirds or more of the way up. Is this true for your system?

By graphing compost temperature over time, you can tell how far along the decomposition has progressed. A well-constructed compost system will heat up to 40 or 50C within two to three days. As readily decomposable organic matter becomes depleted, the temperature begins to drop and the process slows considerably.

The temperature at any point depends primarily on how much heat is being produced by microorganisms and how much is lost through aeration and surface cooling. How long the system remains hot therefore depends on the chemical composition of the ingredients as well as the size and shape of the system. Moisture content also affects temperature change; since water has a higher specific heat than most other materials, drier compost mixtures tend to heat up and cool off more quickly than wetter mixtures, providing adequate moisture levels for microbial growth are maintained.

For more information on the science of compost temperatures, go to the Physics of Composting (page 11).

Monitoring Compost pH

Why is compost pH worth measuring? Primarily because you can use it to follow the process of decomposition. Compost microorganisms operate best under neutral to acidic conditions, with pH's in the range of 5.5 to 8. During the initial stages of decomposition, organic acids are formed. The acidic conditions are favorable for growth of fungi and breakdown of lignin and cellulose. As composting proceeds, the organic acids become neutralized, and mature compost generally has a pH between 6 and 8.

If anaerobic conditions develop during composting, organic acids may accumulate rather than break down. Aerating or mixing the system should reduce this acidity. Adding lime

(calcium carbonate) generally is not recommended because it causes ammonium nitrogen to be lost to the atmosphere as ammonia gas. Not only does this cause odors, it also depletes nitrogen that is better kept in the compost for future use by plants.

At any point during composting, you can measure the pH of the mixture. In doing this, keep in mind that your compost is unlikely to be homogeneous. You may have found that the temperature varied from location to location within your compost, and the pH is likely to vary as well. You therefore should plan to take samples from a variety of spots. You can mix these together and do a combined pH test, or test each of the samples individually. In either case, make sure to make several replicate tests and to report all of your answers. (Since pH is measured on a logarithmic scale, it doesn't make sense mathematically to take a simple average of your replicates.)

pH can be measured using any of the following methods. Whichever method you choose, make sure to measure the pH as soon as possible after sampling so that continuing chemical changes will not affect your results:

- **Soil Test Kit:** Test kits for analysis of soil pH can be used without modification for compost samples. Simply follow the manufacturer's instructions.
- **pH Paper:** If your compost is moist but not muddy, you can insert a pH indicator strip into the compost, let it sit for a few minutes to soak up water, then read the pH using color comparison.
- **Compost Extractions:** Using a calibrated meter or pH paper, you can measure pH in a compost extract made by mixing compost with distilled water. It is important to be consistent in the ratio of compost to water and to account for the initial moisture content of the compost, but there is no universally accepted protocol specifying these procedures.

One approach is to read the pH in oven-dried samples that have been reconstituted with distilled water.

1. Spread compost in a thin layer in a pan, and dry for 24 hours in a 105-110°C oven.
2. Weigh or measure 5 g samples of oved-dried compost into small containers.
3. Add 25 ml distilled water to each sample.
4. Mix thoroughly for 5 seconds then let stand for 10 minutes.
5. Read the pH with a calibrated meter or with pH paper and record as compost pH in water, or pHw.

An alternative is to measure pH in samples that have not been dried. In this case, the amount of water that you add will need to vary to compensate for the varying moisture content of the compost. You will still need to dry some of the compost to measure moisture content, but you can take the pH readings on samples that haven't been altered by drying.

1. Calculate the % moisture of your compost: a) Weigh a small container. b) Weigh 10 g of compost into the container. c) Dry the sample for 24 hours in a 105-110°C oven, or for 5 minutes in a microwave oven. If you use a microwave oven, place a beaker containing 100 ml of water in the oven during the drying to protect the oven's magnetron. d) Reweigh the sample, subtract the weight of the container, and determine the moisture content using the following equation:$M = ((W_w-W_d)/W_w) \times 100$ in which: M = moisture content (%) of compost sample W_w = wet weight of the sample, and W_d = weight of the sample after drying.

2. Use the % moisture to figure out how much water to add. For example, if your compost sample is 40% moisture, you will compensate by adding only 60% of the water you would need if the sample were air dried (0.60 x 5 ml = 3 ml water needed).
3. Weigh or measure 5 g samples of compost into small containers.
4. Add the calculated amount of distilled water to each sample.
5. Mix thoroughly for 5 seconds.
6. Let stand for 10 minutes.
7. Read the pH with pH paper or a calibrated meter and record as compost pH in water, or pHw.

Monitoring Compost Odors

A well-constructed compost system should not produce offensive odors, although it will not be odor-free. You can use your nose to detect potential problems as your composting progresses. For example, if you notice an ammonia odor, your mix probably is too rich in nitrogen (the C/N ratio is too low), and you should mix in a carbon source such as leaves or wood shavings. If you smell a musty odor, it may be because the mix is too moist, which you can correct by adding more of your bulking agent. Left uncorrected, compost that is too wet may go anaerobic, producing a foul sulfurous odor that is hard to ignore. If this occurs in indoor bioreactors, you may wish to take them outside or vent them to the outside, then aerate or mix thoroughly and add additional absorbent material such as wood chips or sawdust. In an outdoor compost pile, turning the pile may be sufficient to correct the anaerobic condition, although initially this may make the odor even more pronounced.