



## THE COMPOSTING PROCESS: Fundamental Principles

### Defining the Issue

No matter what technological approach is chosen, every successful composting process is governed by the same fundamental principles. A clear understanding of these principles can help facility operators manage their sites successfully and generate a high-quality end product.

### Key Concepts

The actual breakdown of organic materials is accomplished by a wide variety of microorganisms. Managing the composting process for peak effectiveness can be seen as making sure that this vast workforce of tiny labourers is provided with everything that they need. These needs include:

- a favourable **carbon : nitrogen ratio**
- sufficient **moisture**
- adequate **oxygen**

#### C:N Ratio

All organic materials contain carbon and many contain varying amounts of nitrogen as well. In the composting process, the microbes require nitrogen in order to break down the materials that are high in carbon. The balance, or ratio, between these two elements in the mixture is important. The farther the ratio between carbon and nitrogen in an actively composting mixture is from the ideal, the more the process will be negatively affected:

- high carbon, little nitrogen [ie. C:N too high]—without adequate nitrogen, microbes lack the tools required to break down carbon sources. The process will proceed very slowly.

- high nitrogen, low carbon [ie. C:N too low]—nitrogen in excess of what the microbes need to break down the available carbon can easily be lost to the atmosphere as ammonia gas.

In order to both keep your process working well and avoid losing valuable nitrogen, your organic mixture will have to provide the microbes with the correct balance of carbon and nitrogen. Carbon to nitrogen ratios, or C:N ratios, are reported as the number of units of carbon per unit of nitrogen. The ideal ratio for a composting mixture is accepted to be 30, or thirty units of carbon for every unit of nitrogen.

Knowing the C:N ratio of each of your feedstocks will allow you to calculate the C:N ratio of the final “recipe”. Tables of average C:N ratios are available and these numbers can be very helpful for quick calculations using common feedstocks. The *On Farm Composting Handbook* offers one such table [see Useful Tools]. C:N ratios can also be obtained through laboratory analysis. Once you know the characteristics of your separate ingredients, determining the proportions needed to produce an acceptable C:N ratio in your final mixture can be done manually or using a computer program [see *C:N Calculations* in Useful Tools].

Depending on your feedstock stream, the C:N ratio of your incoming materials may change seasonally. For example, grass clippings, which are rich in nitrogen, can contribute to a lower C:N ratio during the summer months, while the extra paper waste and dry Christmas trees in January’s feedstock stream will produce a much higher C:N ratio. To maintain an optimum process, recipes must be adjusted to account for these fluctuations.

### **Moisture:**

Moisture is essential to all living organisms. Most microorganisms are very sensitive to this factor in their environment. When an actively composting mixture’s moisture content falls to between 35 and 40%, (where water makes up 35-40% of the total weight), decomposition rates slow significantly as microbes are less able to carry out

their metabolic activities; below 30% moisture they essentially stop. (This is why a dry compost cannot be considered finished simply because it is no longer reheating; if reheating behaviour is being used to establish maturity, the material must be at a moisture content favourable for microbial activity). On the other hand, too much moisture can quickly lead to anaerobic conditions as water fills in all of the tiny spaces in the mixture. This leaves no room for air, a condition that is not favourable for microorganisms that require oxygen (called aerobic microorganisms). At the same time ideal conditions are created for microorganisms that don't require oxygen (anaerobic microorganisms). The decomposition process these microorganisms use is different and can result in the production of offensive odours.

The upper limit of a moisture content providing the needed conditions for effective composting varies with different feedstock materials. This difference is based on the size and structure of the particles, since that affects their porosity, the ability to trap and retain water. For most compost mixtures, 55 to 60% is the recommended upper limit for starting moisture content. Compost recipes are usually started containing this higher amount of moisture, since the materials tend to dry out as composting proceeds: heat generated by the microbes' activity causes water to evaporate.

To calculate the starting moisture content of your recipe it is essential to know the moisture content of each of your feedstocks. This can be measured by weighing a known amount of the material before and after drying [see *Moisture Content* in Useful Tools for procedure]. It is essential when sampling to make sure that the material you are testing is representative of the whole batch—take samples from the inside of the pile, rather than the outside, where the material is subject to drying, or sample immediately after the material has been mixed. Material being collected for moisture analysis should also be protected from drying until it can be properly weighed; carrying plastic bags to transport the sample once it is removed from the pile can help ensure that the tests are accurate.

The moisture contents of your incoming feedstocks will help determine the proportions of materials that will result in an acceptable mixture. Balancing the moisture content and C:N ratio of your mixture will help ensure that your material will degrade successfully. A variety of computer programs are available to help generate possible combinations using the feedstocks that you have available [see *Recipe Formulation* in Useful Tools for a few examples].

### Oxygen

Aerobic decomposition, when aerobic microorganisms have access to enough oxygen to meet their requirements, is the preferred method of composting. When there is insufficient oxygen, conditions favour anaerobic microorganisms—this results in a less efficient process and the production of undesirable odours. In this way, moisture content and oxygen availability are linked: while microbes require moisture, material that is too wet and heavy will not have room between the particles for air to diffuse into it.

Depending on the processing method you have chosen, a variety of practices can be followed to ensure that the microbes in your composting material have enough oxygen:

- piles or windrows which will not be turned during composting can be constructed to maximize air flow through the material, using either passive or active forms of aeration;
- physically turning composting materials re-fluffs the mass, allowing air to flow into the pile more easily.

The oxygen level in a composting mass can be checked using an oxygen meter. The probe is inserted into the center of the material.

A Note on Temperature:

In tracking their process, many operators choose to monitor temperature instead of oxygen. The rise in temperature in a composting mass is the result of heat given off by the micro-organisms as they break down the material. This makes temperature a useful indicator of how the process is going: if temperature fails to rise, the mixture may not have sufficient nitrogen or moisture, while a very high temperature (above 65<sup>0</sup>C) indicates a process so active that the microbes can quickly run out of both oxygen and moisture. Temperature is simple to measure and the equipment is relatively inexpensive—though it does not give specific information on which factors may be out of balance (C:N ratio, moisture, or oxygen), it provides a quick check on how active the composting process is (see *Temperature*, Useful Tools).

#### A Note on Particle Size:

Once you have determined the proportions of feedstocks to create a recipe with acceptable C:N and moisture levels, one of the most practical ways to ensure that the microbes in your mixture continue to receive adequate oxygen and moisture throughout the decomposition process is to regulate particle size. Most materials are composed of a variety of different-sized pieces, or particles. The average size, however, is important, since an average that is too large or too fine is likely to cause difficulties:

- Particles too large: eg. tree limbs, large chunks of manure or other solid material
  - will have good air flow through the channels these particles create, but
  - will likely dry out quickly;
  - will decompose slowly since only the outside surfaces of the large pieces are exposed to microbial activity.
- Particles too small: eg. sawdust, grass clippings, sludges
  - Can have good moisture retention, but
  - Is likely to become anaerobic, as air cannot easily infiltrate the pile.

Operators and researchers have found that, in general, a particle size range of 0.5-2” (1.5-5 cm) provides the best balance of moisture retention and oxygen diffusion for

effective composting. Particle size can often be regulated during preprocessing of feedstocks before they are added to the compost mixture: most grinders and shredders are adjustable, and screens or classifiers can be used if necessary to remove large pieces of solid material.

Particle size is particularly important in static systems, where the material will not be turned during composting. In these systems the material itself needs to maintain enough porosity so that air can infiltrate the pile throughout the process.

## **Useful Tools:**

*On-Farm Composting Handbook*'s tables of average C:N values:

<http://www.cfe.cornell.edu/compost/OnFarmHandbook/apa.tab1.html>

C:N Calculations [Cornell Composting]:

[http://www.cfe.cornell.edu/compost/calc/cn\\_ratio.html](http://www.cfe.cornell.edu/compost/calc/cn_ratio.html)

Moisture Content Calculations [Cornell Composting]:

[http://www.cfe.cornell.edu/compost/calc/moisture\\_content.html](http://www.cfe.cornell.edu/compost/calc/moisture_content.html)

Recipe formulation:

<http://www.cfe.cornell.edu/compost/download.html> [recipe spreadsheets; on a PC,

log in

as “anonymous” and leave the password blank]

<http://www.cfe.cornell.edu/compost/calc/simultaneous.html> [moisture/C:N

spreadsheets]

Temperature [Cornell Composting]:

<http://www.cfe.cornell.edu/compost/monitor/monitortemp.html>

<http://www.recycle.com/compost/temperature.html>

“Best Management Practices” Factsheets [On-Farm Composting Handbook]:

<http://www.recycle.com/compost/compost.html>

Other Composting Problems (*On-Farm Composting Handbook*):

<http://www.recycle.com/compost/otherprob.html#anchorcomplaints>

## **Additional Informational Links:**

US Composting Council: <http://compostingcouncil.org/index.cfm>

Cornell Composting: [http://www.cfe.cornell.edu/compost/Composting\\_homepage.html](http://www.cfe.cornell.edu/compost/Composting_homepage.html)

US Environmental Protection Agency Composting: <http://www.epa.gov/compost/>

The Composting Association of the UK: [http://www.compost.org.uk/dsp\\_home.cfm](http://www.compost.org.uk/dsp_home.cfm)

Washington State University Compost Connection: <http://csanr.wsu.edu/compost/>

Compost Education and Resources for Western Agriculture:

<http://www2.aste.usu.edu/compost/>

Recycling and Composting Online: <http://www.recycle.cc/>

## **Feedback:**

Are you an operator who has had experiences—faced particular challenges, solved specific problems—that would be of help to other operators? To share tips or solutions your facility has developed with regards to the subjects in this fact sheet, please click on the button below. Thanks for sharing your practical ingenuity!

[%% %]