Composting Science for Industry

2007
Third Edition

An overview of the scientific principles of composting processes
This package has undergone national peer review by a range of technical and industry experts (see acknowledgments) and has been endorsed by COMPOST NSW and the NSW branch of the Waste Management Association of Australia.
Preface to the *Composting Science for Industry* Information Sheets

The *Composting Science for Industry* package of Information Sheets has been produced to support the continuing development of the Recycled Organics (RO) industry in New South Wales though a greater focus on operation and management for quality.

Understanding the fundamentals of composting enables operators to manipulate the process to maximise the rate of decomposition of the organic material and meet other environmental or quality specifications.

Please note that these Information Sheets will provide you with a background in:

- variety of composting systems available;
- temperature and how this can be managed in composting systems;
- the importance of oxygen in composting systems;
- how water affects the composting process;
- optimising the physical properties of the composting mix;
- nutrients required for rapid composting;
- role of pH;
- the compost recipe, processing time and curing.

We hope that the Information Sheets will assist operators of composting facilities better understand the principles behind their processes, permitting better process management and formulation of quality products that meet the needs of their customers.
1. Information Sheets in “Composting Science for Industry”
This package contains a collection of nine Information Sheets:

- Information Sheet No. 5-1: Composting science for industry
- Information Sheet No. 5-2: Composting systems
- Information Sheet No. 5-3: Temperature
- Information Sheet No. 5-4: Oxygen
- Information Sheet No. 5-5: Water
- Information Sheet No. 5-6: Porosity, structure, texture and particle size
- Information Sheet No. 5-7: Carbon to nitrogen ratio (C:N) and other nutrients
- Information Sheet No. 5-8: pH
- Information Sheet No. 5-9: The compost recipe, processing time and curing

2. Other Packages
A series of eight packages are available on important aspects of recycled organics industry development. These are listed below.

- Package 1: Establishing a licensed composting facility;
- Package 2: Guide to developing a process control system for a composting facility;
- Package 3: Producing quality compost
- Package 4: Guide to selecting, developing and marketing value-added recycled organics products;
- Package 5: Composting science for industry;
- Package 6: Buyers guide for recycled organics products;
- Package 7: How to use recycled organics products;
- Package 8: Occupational health and safety and commercial composting.

All of these packages are obtainable from http://www.recycledorganics.com

3. Who should read the Information Sheets?
The series of nine Information Sheets have been developed for all stakeholders in the RO sector who wish to gain a better understanding of the basics of composting science, and how these basics can be applied to commercial-scale composting processes for the purpose of maximising the rate of decomposition of the organic material, and to meet other environmental or quality specifications.

More specifically, the Information Sheets have been developed for:

- existing manufacturers and suppliers of products containing RO;
- prospective RO processors;
• local council waste management officers;
• Resource NSW officers;
• NSW EPA officers;
• Planning NSW officers;
• industry consultants;
• waste educators, and
• marketing agencies.

4. Terminology
Terms used throughout this package of Information Sheets have been officially adopted by the NSW Waste Boards (now Resource NSW) in July 2000 in the form of the *RO Dictionary and Thesaurus: Standard terminology for the recycled organics industry*, produced by the Recycled Organics Unit. This document is freely downloadable from [http://www.rolibrary.com](http://www.rolibrary.com)

5. How to cite this publication
This publication consists of a series of Information Sheets that are compiled into a set. When citing information from this publication, the set of Information Sheets must be cited (not individual Information Sheets), as shown below:


6. Acknowledgements
The authors would like to extend a special thank you to all members of the peer review committee who have invested their valuable time in reading and providing feedback on this package of Information Sheets. The following reviewers are graciously thanked for their contributions:

• Dr Trevor Gibson, Program Leader, Organic Waste Recycling Unit, NSW Agriculture.
• Dr Kevin Wilkinson, Program Leader, Institute for Horticultural Development, Agriculture Victoria.
• Mr Darren Bragg, Manager (Organics), Resource NSW.
• The committee of COMMPOST NSW.

The Recycled Organics Unit would also like to acknowledge a portion of the information in this package was originally developed by the Institute for Horticultural Development, for EcoRecycle Victoria.
Introduction to composting science

Aerobic composting is essentially a biological process governed by the activity of naturally occurring microorganisms (Figure 1).

Understanding the fundamentals of composting enables operators to manipulate the process to maximise the rate of decomposition of the organic material and meet other environmental or quality specifications.

The means to control composting conditions differ from site to site depending on the type of technology employed, the types of materials being processed, environmental considerations, the desired end-product and the preference and experience of the site operator.

Like all living things, including ourselves, the aerobic microorganisms responsible for composting need adequate living conditions to grow and multiply.

These conditions relate to the availability of:

- oxygen (air contains 21% oxygen);
- water;
- food – carbon, nitrogen and other nutrients; and
- suitable environmental conditions (including mainly warmth or heat).

Heat is produced in composting as a by-product of microbial activity and is also important in eliminating pathogens and weeds.

Feedstocks processed in composting systems

A range of organic materials can be processed in composting systems.

Commercial composting operations use source separated organic materials as raw material, or feedstock.

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Figure 1. Process diagram for composting systems. All composting processes are based on the same principles. O₂, oxygen; CO₂, carbon dioxide. Modified from Rynk et al., (1992).
The five major categories of compostable organic materials are shown in Table 1.

The financial viability of composting operations is closely related to the conversion of quality, source separated organics into quality composted products that meet market requirements.

A good understanding of the composting process is essential to produce high-value quality products.

**Composting science for industry**

The *Composting Science for Industry* series of information sheets provides an excellent introduction to composting science.

Titles are shown below:

- Information Sheet No. 5-2. Composting Science for Industry: Composting systems.
- Information Sheet No. 5-3. Composting Science for Industry: Temperature.
- Information Sheet No. 5-4. Composting Science for Industry: Oxygen.
- Information Sheet No. 5-5. Composting Science for Industry: Water.
- Information Sheet No. 5-6. Composting Science for Industry: Porosity, structure, texture and particle size.
- Information Sheet No. 5-7. Composting Science for Industry: Carbon to nitrogen ratio (C:N) and other nutrients.
- Information Sheet No. 5-8. Composting Science for Industry: pH.
- Information Sheet No. 5-9. Composting Science for Industry: The compost recipe, processing time and curing.

### Table 1. The five major categories of source separated compostable organics most commonly processed in composting operations (Recycled Organics Unit, 2002).

<table>
<thead>
<tr>
<th>Compostable Organic Material Class</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garden organics</td>
<td>Any garden derived organic (plant) materials generated by domestic, construction &amp; demolition and commercial &amp; industrial sources. Garden organics is defined by its component materials including: putrescible garden organics (grass clippings); non-woody garden organics; woody garden organics; trees and limbs, and stumps and rootballs.</td>
</tr>
<tr>
<td>Food organics</td>
<td>Food organics includes organics generated by any one of the following activities: the manufacturing, preparation or consumption of food (including beverages); the processing of meat, poultry or fish, and the manufacturing of edible grocery products. Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste.</td>
</tr>
<tr>
<td>Wood and timber</td>
<td>Any untreated, uncontaminated wood waste material produced by domestic, construction &amp; demolition and commercial &amp; industrial sources, including: off-cuts; crates; pallets and packaging; saw dust and timber shavings.</td>
</tr>
<tr>
<td>Agricultural organics (including forestry residuals)</td>
<td>Any residual organic materials produced as by-products of agricultural and forestry operations, including: weeds (woody and non-woody); animals (processing residuals, stock mortalities, pests), and crop residuals (woody and non-woody), and manures.</td>
</tr>
<tr>
<td>Biosolids</td>
<td>Organic solids or semi-solids produced by municipal sewage treatment processes. Solids become biosolids when they come out of an anaerobic digester or other treatment process and can be beneficially used. Until such solids are suitable for beneficial use they are defined as waste-water solids. The solids content in biosolids should be equal to or greater than 0.5% weight by volume (w/v). Biosolids are commonly co-composted with garden organics and/or residual wood and timber to produce a range of recycled organics products.</td>
</tr>
</tbody>
</table>
Composting Green Organics

Important references


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Definitions*

Aerobic
In the presence of, or requiring oxygen.

Pathogens
Microorganisms capable of producing disease or infection in plants or animals. Pathogens can be killed by heat produced during thermophilic composting.

Source Separation
Separation of recyclable materials from other waste at the point and time the waste is generated (ie. at its source). This includes separation of recyclable material into its component categories (e.g. paper, glass, aluminium), and may include further separation within each category (e.g. paper into computer paper, office whites and newsprint).

Feedstock
Organic materials used for composting or related biological treatment systems. Different feedstocks (or raw materials) have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).

* Recycled Organics Unit (2002).

Produced by:
Recycled Organics Unit
PO Box 6267
The University of New South Wales
Sydney Australia 1466

Online contact details:

ROU Angus Campbell
Internet www.recycledorganics.com

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Overview of composting systems

At least eight different forms of composting systems are available for processing a wide range of organic materials.

Turned windrow systems have been the predominant form of composting in Australia, particularly for garden organics.

Higher technology composting systems are now being implemented for processing materials that have traditionally been difficult to process in outdoor turned windrow systems, such as food organics.

In-vessel composting systems are becoming more common, although infrastructure costs are usually higher.

This Information Sheet on composting systems gives readers some basic information about the distinguishing characteristics of the main types of systems that are commercially available.

General comparisons between the composting systems

Composting systems are often described in terms of a complete process from the reception of raw material through to the handling of the end-product.

However, when only the composting process itself is considered, most systems are nearly always variations of a common theme.

All systems aim to control and/or optimise compost production by manipulating temperature, oxygen and moisture during composting.

Another important control over compost quality is achieved by the selection, pre-treatment and mixing of the raw materials prior to composting.

Some composting systems can more effectively deal with specific types of organic materials.

For example, highly odorous material (e.g. food organics and some industrially-produced organics) are more easily processed in systems with forced aeration and odour control equipment.

This technology allows for better control and minimises negative environmental impacts such as odour.

The most common form of composting is the turned windrow system.

This system is adequate for many organic materials, but requires a high degree of process control in order to maintain optimum composting conditions. Temperature and aeration control is managed by physically turning the mass by either a front-end loader or specialised windrow turner.
Capital outlays for windrow type systems are relatively small (unless a concrete pad is installed), but operating costs can be high because they are usually labour intensive.

Improved process control is achieved by utilising forced aeration systems. Forced aeration improves control of both temperature and oxygen during composting.

Systems using forced aeration do not necessarily produce a compost of higher quality than windrow systems, but shorter processing times are usually possible.

Environmental control of odours and leachate can usually be built in with systems utilising forced aeration.

Forced aeration systems are usually more expensive to install, but operating costs can be lower compared to turned windrow systems.

The major difference between composting systems sometimes only concerns the first stage of composting — preliminary decomposition or pasteurisation.

The aim of this stage of composting is usually to:

- maximise the rate of decomposition of the readily available organic fraction;
- eliminate pathogens and weeds from the starting materials- 'pasteurisation'; and
- control leachate and odours.

This period of intensive control is usually employed only for a short period (from 3 to 14 days in most cases).

Further decomposition, or curing, usually then takes place in windrows.

The curing phase requires significantly less management than the active composting phase. Minimal odour generation occurs during the curing phase.

Definitions*

Windrow (with or without aeration)
System of composting involving the aeration of horizontally extended piles formed by a front-end loader or windrow turner. Extended piles are generally 1.5 to 3 m in height, and length is limited by the size of the composting pad. Aeration can be achieved by mechanical turning and/or the delivery of air from the base of the windrow (see aerated static pile).

Garden Organics
Any garden derived organic (plant) materials generated by domestic, C&D and C&I sources. Garden Organics is defined by its component materials including: putrescible garden organics (grass clippings); non-woody garden organics; woody garden organics; trees and limbs, and stumps and rootballs. Garden organics is one of the primary components of the compostable organics stream.

Food Organics
Food Organics includes organics generated by any one of the following activities: the manufacturing, preparation or consumption of food (including beverages); the processing of meat, poultry or fish, and the manufacturing of edible grocery products. Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste. Food organics is one of the primary components of the compostable organics stream.

In-vessel
System of composting involving the use of an enclosed chamber or vessel in which (in most cases) the composting process is controlled by regulating the rate of mechanical aeration. Aeration assists in heat removal, temperature control and oxygenation of the mass. Aeration is provided to the chamber by a blower fan which can work in a positive (blowing) and/or negative (sucking) mode. Rate of aeration can be controlled with temperature, oxygen or carbon dioxide feedback signals.

Forced Aeration
Means of supplying air to a composting pile or vessel which relies on blowers to move air through the composting materials.

Process Control
Stringent and documented monitoring of all critical control points in a composting operation so as to minimise defects and make products which can be guaranteed to customers.

Pasteurisation
The process whereby organic materials are treated to kill plant and animal pathogens and weed propagules.

* Recycled Organics Unit, (2002).
Features of common composting systems

<table>
<thead>
<tr>
<th>Turned windrow</th>
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<tbody>
<tr>
<td>Most common system for organics of low odour generating potential</td>
</tr>
<tr>
<td>Low capital costs unless concrete pads are installed</td>
</tr>
<tr>
<td>High operating costs</td>
</tr>
<tr>
<td>Very flexible system - a range of organic materials can be composted and adjustments can be made within a composting cycle</td>
</tr>
<tr>
<td>Aeration by turning with front-end loader or specialised machine</td>
</tr>
<tr>
<td>Slow rate of decomposition due to varying conditions in pile</td>
</tr>
<tr>
<td>Stable compost in 3-6 months</td>
</tr>
<tr>
<td>Windrows can be outdoors or formed under a roof (no sides)</td>
</tr>
<tr>
<td>Great care needed for effective odour and leachate control</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Passively aerated windrow</th>
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<tbody>
<tr>
<td>Cheapest system; no turning</td>
</tr>
<tr>
<td>Windrows must be covered with finished compost to reduce odours</td>
</tr>
<tr>
<td>May be more space efficient than turned windrows</td>
</tr>
<tr>
<td>Reduced flexibility - careful preparation of starting materials essential</td>
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<tr>
<td>Little control of temperature and aeration during composting</td>
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<tr>
<td>Compost in 3-6 months</td>
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<table>
<thead>
<tr>
<th>Aerated static pile</th>
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<tbody>
<tr>
<td>Medium capital costs</td>
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<tr>
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<tr>
<td>Forced aeration</td>
</tr>
<tr>
<td>Reduced flexibility - careful preparation of feedstock is essential</td>
</tr>
<tr>
<td>Space efficient</td>
</tr>
<tr>
<td>Piles are usually covered (e.g. with compost) to reduce odours</td>
</tr>
<tr>
<td>Some control of temperature and aeration resulting in faster composting (6-12 weeks); further curing usually required</td>
</tr>
</tbody>
</table>
Aerated covered windrow

- Medium capital costs
- Medium operating costs
- Cover for windrows reusable
- Forced aeration; computer control of composting possible
- Reduced flexibility - careful preparation of feedstock essential
- Space efficient
- Improved control of temperature and aeration resulting in faster composting (3-6 weeks); further curing usually required

Rotating drum

- High capital cost
- Medium operating costs
- Less preparation of starting materials required due to constant mixing and size reduction
- Rapid initial decomposition in drum (up to seven days)
- Further decomposition required in windrows or aerated static piles
- Provides mixing and aeration by means of drum rotation and forced aeration

Agitated bed or channel

- High capital cost
- Medium operating costs
- Flexible system – both forced aeration and mechanical mixing used
- Space efficient
- Beds are covered in a fully enclosed building or roof
- Good capacity for odour and leachate control
- Rapid composting: 2-4 weeks; further curing usually required
In-vessel (horizontal configuration)

- High capital cost
- Automated system
- Uniform temperature and oxygen profile throughout contents of vessel
- Composting vessels can be housed in a building or outdoors
- Excellent control of odours and leachate
- Can be located with minimal buffer distances
- Very fast composting (7-14 days)
- Further curing in windrows or in-vessel usually required

In-vessel (vertical configuration)

- High capital cost
- Automated system and low operating cost
- Uniform temperature and oxygen profile throughout contents of vessel
- Composting vessels can be housed in a building or outdoors
- Excellent control of odours and leachate
- Can be located with minimal buffer distances
- Very fast composting (7-14 days)
- Further curing in windrows or in-vessel usually required

Important references


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Temperatures during composting

The temperature reached during composting depends on the size of the pile or system, its moisture content, aeration and the availability of food for the microbes — principally carbon and nitrogen.

Heat in composting systems is produced by microorganisms when they consume food (organic materials).

Heat builds up in compost when the insulating properties of the mass results in the rate of heat gain being greater than the rate of heat loss. Small volumes of organic materials (<1-2 m³) may not heat up because the heat generated by the microbial population is lost quickly to the atmosphere.

The outer layer of compost in a non-enclosed system insulates the interior of the pile, allowing temperatures to build up in the centre.

Temperature has a self-limiting effect on microbial activity and thus the rate of degradation of organic materials.

The highest rates of decomposition of organic materials usually occur at thermophilic temperatures between 50 and 55 ºC.

Thermophilic conditions begin at temperatures above 45ºC (Figure 1).

The different phases of composting are represented in Figure 1. As shown in Figure 1, temperature can also indicate when a compost product is stable or mature.

Keep in mind however that temperatures also rise and fall during composting as a result of other factors, such as limited moisture or air.

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**Figure 1.** Temperature development and stages in aerobic composting.
Temperature and composting organisms

Temperature affects the rate of decomposition of organic materials by directly influencing the make-up of the microbial population. Bacteria, fungi and actinomycetes all play a major role in the decomposition of organic materials during aerobic composting.

In addition, some types of invertebrates such as nematodes, mites, earthworms, snails and slugs consume organic residues, but they are only active at cooler temperatures.

As such, a dynamic food web is at work in a compost pile in which there is a succession of organisms that dominate depending primarily on temperature and the types of food available for consumption.

The initial period of composting, which is characterised by a rapid increase in microbial activity and the first signs of a rise in temperature, is mainly due to the activity of mesophilic bacteria consuming freely available compounds (Figure 1).

As the temperature rises towards 45°C, mesophilic organisms begin to die off (because it is too hot for them) and thermophilic (heat loving) organisms then begin to dominate.

If the temperature reaches to 65-70°C, the thermophilic organisms start to die off, and only some spore forming bacteria can survive. At this point, the rate of decomposition slows.

The highest rate of decomposition occurs mostly during the thermophilic stage of composting (>45°C), due mainly to the activity of thermophilic bacteria.

The curing phase and composting organisms

Once the temperatures begin to drop, aeration is usually done (by turning or forced delivery of air) to keep temperatures in the thermophilic range to maximise the level of decomposition and to ensure pasteurisation (killing of weed seeds and pathogens).

During the curing phase, after temperatures begin to fall, fungi and actinomycetes re-invade the compost and decompose the more resistant materials such as cellulose and lignin. These microbes are naturally present in soil.

Re-invasion of compost with beneficial microbes, such as bacteria, fungi and actinomycetes during curing usually occurs when the compost (whether in a windrow or in-vessel system) is placed in areas where contact or exposure to soil is possible.

These microbes can often be seen just below the surface of a compost heap as a white or grey layer.

The curing phase is very important in reducing the presence of phytotoxic compounds usually present in immature compost (see Information Sheet No. 5-9).

Temperature profiles

Temperatures attained in composting systems are rarely uniform throughout the entire mass.

Temperatures on the outside of a windrow can be 20 to 45°C cooler than the insulated centre.

Such temperature differences may be as small as 2-5°C in an insulated in-vessel composting system.

Temperature differences between the surface and centre of a composting system, such as an aerated static pile,
Pathogens can be killed by heat produced during thermophilic composting.

Pasteurisation
The process whereby organic materials are treated to kill plant and animal pathogens and weed propagules.

Pathogen
Microorganisms capable of producing disease or infection in plants or animals. Pathogens can be killed by heat produced during thermophilic composting.

Lignin
A substance that, together with cellulose, forms the woody cell walls of plants and the cementing material between them. Lignin is resistant to decomposition.

Windrow (with or without aeration)
System of composting involving the aeration of horizontally extended piles formed by a front-end loader or windrow turner. Extended piles are generally 1.5 to 3 m in height, and length is limited by the size of the composting pad. Aeration can be achieved by mechanical turning and/or the delivery of air from the base of the windrow (see aerated static pile).

Phytotoxic
Toxic to plants. Partially decomposed organic materials or immature composts are often phytotoxic, but this usually decreases with time. Such products may be phytotoxic due to a number of factors, including: low nutrient content; high oxygen consumption; presence of fatty acid or alcohol metabolites formed by microorganisms under anaerobic conditions; or due to excessive concentrations of salts, heavy metals and other organic compounds.

In-vessel
System of composting involving the use of an enclosed chamber or vessel in which (in most cases) the composting process is controlled by regulating the rate of mechanical aeration. Aeration assists in heat removal, temperature control and oxygenation of the mass. Aeration is provided to the chamber by a blower fan which can work in a positive (blowing) and/or negative (sucking) mode. Rate of aeration can be controlled with temperature, oxygen or carbon dioxide feedback signals.

* Recycled Organics Unit, (2002).
Pasteurising conditions usually occur throughout the entire mass in an in-vessel system because the insulating walls of the vessel minimise heat loss.

This is a process known as pasteurisation.

Pasteurising temperatures cannot occur in materials on the outer surfaces of an un-insulted windrow because heat is lost to the atmosphere (Figure 4).

To ensure that the entire mass is subjected to pasteurising temperatures, the exterior must be turned and deposited into the centre of the pile where pasteurising temperatures occur.

Microbial pathogens (and weed seeds) can be killed in composting systems as most can only grow under low temperature conditions (<37°C).

A wide range of beneficial microorganisms, however, are not killed under these conditions.

**Important references**


- Recycled Organics Unit (2002). Recycled Organics Industry Dictionary & Thesaurus: standard terminology for the recycled organics industry. Recycled Organics Unit, internet publication: [http://www.rolibrary.com](http://www.rolibrary.com)

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PO Box 6267
The University of New South Wales
Sydney Australia 1466

**Online contact details:**

ROU Angus Campbell
Internet [www.recycledorganics.com](http://www.recycledorganics.com)

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Information Sheet No. 5-4
Composting Science for Industry
Oxygen

Importance of oxygen

The microorganisms responsible for *aerobic* composting, by definition, cannot grow in the absence of oxygen.

Many microorganisms are capable of growth at low oxygen concentrations, while some are killed in the presence of oxygen (termed *anaerobic* microorganisms).

The oxygen concentration in air is about 21%, but aerobic microorganisms cannot function effectively at concentrations below about 5% in compost.

Oxygen concentrations of about 10-14% in a compost mass are ideal and results in optimum composting conditions (provided other parameters are correct).

In *windrow* systems, aeration is assisted by physical turning with either a front-end loader or a specialised windrow turner.

The main reasons for turning windrows are to move the outside portions of a windrow into the middle, and to loosen and fluff the material so that air can move more

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**Figure 1.** Scanning electron micrograph of thermophilic *Bacillus* sp. bacteria commonly found in composting systems (left). Note their characteristic ‘rod’ shape. A phase-contrast light microscope picture of *Bacillus* sp. bacteria in chain form (right). These bacteria are in a spore generating phase. Heat resistant spores are produced when temperatures exceed that tolerable by the cells (e.g. temperatures above 65°C).
freely into the windrow.

The agitation of composting particles that occurs during turning stimulates higher rates of decomposition by exposing new surfaces to microbial attack.

Windrow turners are usually more effective at breaking up clumps and aerating the mass than front-end loaders.

Windrow turners are also more effective at mixing the materials as they pass over a windrow.

Note that oxygen supply to a composting system does not have to involve turning.

Mechanical blowing or sucking air into and/or through materials by an aeration fan can remove excess heat and also increase the concentration of oxygen in the material.

**Mechanism of aeration**
Oxygen gets into the pile or system by convection and diffusion. Natural convection is the movement of outside air into a compost pile or system as a result of the “chimney effect” — warm air rises through the pile or system and cool air enters the lower sections, as long as the mix is “loose enough” to permit air flow (Figure 2).

Diffusion then transports oxygen into the smaller pores of compost and into the water layer surrounding compost particles.

In windrows or piles, convection is assisted by physical turning.

Turning only adds a small amount of oxygen directly, but it loosens and fluffs the material (reducing its density) so that air can move more freely into the windrow by convection.

In **forced aeration** systems, convection also occurs mechanically with blowers — delivering air by suction or blowing or a combination of the two.

**Forced Aeration**
Means of supplying air to a composting pile or vessel which relies on blowers to move air through the composting materials.

**Aerated Static Pile**
Forced aeration method of composting in which a free standing pile is aerated by a blower moving air through perforated pipes located beneath the pile.

**Windrow (with or without aeration)**
System of composting involving the aeration of horizontally extended piles formed by a front-end loader or windrow turner. Extended piles are generally 1.5 to 3

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*Definitions*

**Aerobic**
In the presence of, or requiring, oxygen.

**Anaerobic**
In the absence of oxygen, or not requiring oxygen. Composting systems subject to anaerobic conditions often produce odorous compounds and other metabolites that are partly responsible for the temporary phytotoxic properties of compost. Anaerobic conditions are important for anaerobic digestion systems.

**Turning**
A composting operation which mixes and agitates material in a windrow pile or vessel. Its main aeration effect is to increase the porosity of the windrow to enhance passive aeration. It can be accomplished with front-end loaders or specially designed turning machines.

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`Turning ensures that decomposition proceeds at a rapid rate, but also ensures that all clumps are broken up in a composting mass and are exposed to conditions necessary to eliminate pathogens and weeds.’

‘Turning can provide sufficient aeration for six to seven days, provided that careful attention is paid to optimising the particle size in the compost recipe and mixing of materials in windrows.’

Figure 2. Convective flow of air in a compost windrow.

Continued on page 4
to the cooler outer layers, which assists in decomposition.

Another advantage of forced aeration systems is that the exhaust air can be recirculated and treated to remove odorous compounds.

Convection can be increased by constructing piles or windrows over channels or inserting pipes that extend from outside through to the core of the heap (passively aerated windrow).

**Oxygen profiles**

Turning or the forced delivery of air into a composting mass is necessary to ensure that the entire mass is kept in an aerobic state.

As with temperature, the concentration of oxygen is not uniform throughout the composting mass.

The centre of a turned windrow often has the lowest concentration of oxygen, whilst the exterior surface often has the highest concentration of oxygen.

This occurs because oxygen entering the outer surface of the pile is consumed by microorganisms before it has a chance to reach the centre (Figure 3).

The centre of the pile, therefore, becomes anaerobic, resulting in odour production. When these piles are turned, odours are often released into the air, potentially affecting the amenity of neighbours.

To minimise the release of odour during turning, turning should be performed when the concentration of oxygen decreases to about 12-14% (Standards Australia AS 4454, 2002). This is usually measured at the centre of the pile where oxygen limitations are most pronounced.

![Figure 3. A typical oxygen profile of a turned windrow of size reduced garden organics and biosolids three days after turning during the thermophilic stage of composting.](image)

Changes in the concentration of oxygen after physical turning of a windrow can be seen in Figure 4.

**Odours produced during composting**

Odour formation is strongly associated with the development of anaerobic conditions in composting systems.

These odours are produced through the anaerobic decomposition of organic matter.

Composting odours are mostly produced as vapours, though particulate (i.e. aerosol) odours can be produced.

Table 1 lists some specific compounds reported to cause odour problems during composting. Note that it is often difficult to identify individual components of an odour by olfaction (i.e. through smelling with your nose).

The main odour produced by composting operations is ammonia.

Odours can easily be treated in composting systems that permit the collection of process air. Examples
include in-vessel systems with forced aeration, or an aerated static pile with a suction-type aeration system. Process air produced by these systems can be directed to a biofilter — a vessel containing mature compost — to remove the odorous compounds from the air. Bacteria present in the biofilter decompose the odourous compounds and use them as a food source, thereby removing the smell from the air.

### Table 1. Some compounds implicated in composting odours, and their characteristics. Modified from Miller and Macauley, (1988).

<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
<th>Characteristic odour</th>
<th>Threshold (nL/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanal</td>
<td>CH₃CHO</td>
<td>Pungent</td>
<td>2</td>
</tr>
<tr>
<td>Butanoic acid</td>
<td>CH₃CH₂CH₂COOH</td>
<td>Rancid</td>
<td>0.28</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>Pungent</td>
<td>37</td>
</tr>
<tr>
<td>Trimethyl amine</td>
<td>(CH₃)₃N</td>
<td>Pungent</td>
<td>4</td>
</tr>
<tr>
<td>3-methylindole (skatole)</td>
<td>C₆H₅C(CH₃)CHNH</td>
<td>Faecal</td>
<td>7.5x10⁻⁵</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>H₂S</td>
<td>Rotten egg</td>
<td>1.1</td>
</tr>
<tr>
<td>Carbon oxysulfide</td>
<td>COS</td>
<td>Pungent</td>
<td>-</td>
</tr>
<tr>
<td>Dimethyl sulfide</td>
<td>CH₃SCH₃</td>
<td>Foul</td>
<td>20</td>
</tr>
<tr>
<td>Dimethyl disulfide</td>
<td>CH₃SSCH₃</td>
<td>Foul</td>
<td>-</td>
</tr>
<tr>
<td>Diethyl sulfide</td>
<td>CH₃CH₂SCH₂CH₃</td>
<td>Foul</td>
<td>0.25</td>
</tr>
<tr>
<td>Methanethiol</td>
<td>CH₃SH</td>
<td>Decaying cabbage</td>
<td>1.1</td>
</tr>
<tr>
<td>Ethanethiol</td>
<td>CH₃CH₂SH</td>
<td>Decaying cabbage</td>
<td>0.016</td>
</tr>
<tr>
<td>1-Propanethiol</td>
<td>CH₃CH₂CH₂SH</td>
<td>Unpleasant</td>
<td>0.075</td>
</tr>
<tr>
<td>1-Butanethiol</td>
<td>CH₃CH₂CH₂CH₂SH</td>
<td>Skunk like</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Important references

- Recycled Organics Unit (2002). Recycled Organics Industry Dictionary & Thesaurus: standard terminology for the recycled organics industry. Recycled Organics Unit, internet publication: [http://www.rolibrary.com](http://www.rolibrary.com)

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Produced by:

Recycled Organics Unit
PO Box 6267
The University of New South Wales
Sydney Australia 1466

Online contact details:

ROU  Angus Campbell
Internet  [www.recycledorganics.com](http://www.recycledorganics.com)

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Importance of water

Moisture, or water, is essential to all living organisms.

The optimum moisture content for composting is generally between 50 and 60%. Below about 30%, microbial activity virtually stops. Moisture contents above 50% are critical for effective pathogen and weed control during the thermophilic stage of composting.

Organic particles are attacked by microorganisms present in a water film surrounding these particles (Figure 1). If water becomes limiting, the water films reduce in size and microorganisms die of water stress. No water, no decomposition!

Moisture is lost during composting by evaporation. This has the benefit of cooling the compost and can prevent overheating and associated reductions in microbial activity.

With windrows, water can be added during turning with a mechanical windrow turner connected to the water supply. Where this is not possible, or where front-end loaders are used for turning, water can be added manually by hose, sprinklers or soaker hoses.

Care must be taken to minimise pooling during watering by providing adequate drainage and water (run-off) collection systems. Pooling 'Care must be taken to ensure that the compost does not dry out too quickly, because decomposition will cease, resulting in a partly finished compost. This material will rapidly decompose and produce heat when re-wetted. Re-heating in bags can produce odour, and bags can split during handling.'

Figure 1. Decomposition model for solid particles in a composting system. Decomposition is performed by microorganisms present within the liquid film and on the surface of particles. At high moisture contents, the air-filled zone between the particles become filled with water, restricting oxygen movement, leading to the development of anaerobic conditions (Rynk et al., 1992).
water is a problem because it can attract disease-spreading breeding mosquitoes and other insects.

Where possible, collected water (containing valuable nutrients) should be re-used to maintain good levels of moisture in the compost, in the process of avoiding discharge into the water table.

Significant moisture loss can occur in aerated static piles and in in-vessel systems too, particularly when air is forced into the material with a blower.

The feedstock around the ventilation pipe can dry out and cease being decomposed if the moisture content falls below 30%.

To minimise excessive drying around ventilation pipes, a combination and blowing (positive) and sucking (negative) aeration modes have been used successfully.

The sucking aeration mode encourages moisture movement toward the ventilation pipe, thereby encouraging decomposition to occur.

Excess moisture causes anaerobic conditions and odours

As moisture content increases, the thickness of the layer of water surrounding each compost particle increases (Figure 1). Secondly, water fills the smallest pores (the space between particles) first, creating water filled zones between particles.

The decomposition of organic matter occurs at the interface between this water layer and the surface of the particle. Oxygen diffusion into the film of water around particles is sufficient to meet the needs of aerobic microorganisms when moisture content of compost is maintained between 35 and 60%.

Definitions*

<table>
<thead>
<tr>
<th>Moisture Content</th>
<th>Aerated static pile</th>
</tr>
</thead>
<tbody>
<tr>
<td>The fraction or percentage of a substrate comprised of water. Moisture content equals the weight of the water portion divided by the total weight (water plus dry matter portion).</td>
<td>Forced aeration method of composting in which a free standing pile is aerated by a blower moving air through perforated pipes located beneath the pile.</td>
</tr>
</tbody>
</table>

Windrow (with or without aeration)

System of composting involving the aeration of horizontally extended piles formed by a front-end loader or windrow turner. Extended piles are generally 1.5 to 3 m in height, and length is limited by the size of the composting pad. Aeration can be achieved by mechanical turning and/or the delivery of air from the base of the windrow (see aerated static pile).

In-vessel

System of composting involving the use of an enclosed chamber or vessel in which (in most cases) the composting process is controlled by regulating the rate of mechanical aeration. Aeration assists in heat removal, temperature control and oxygenation of the mass. Aeration is provided to the chamber by a blower fan which can work in a positive (blowing) and/or negative (sucking) mode. Rate of aeration can be controlled with temperature, oxygen or carbon dioxide feedback signals.

Notes:

*A Recycled Organics Unit, (2002).
Important references


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Recycled Organics Unit
PO Box 6267
The University of New South Wales
Sydney Australia 1466

Online contact details:
ROU Angus Campbell
Internet www.recycledorganics.com

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Information Sheet No. 5-6
Composting Science for Industry
Porosity, structure, texture and particle size

Particle size characteristics and aeration

Porosity, structure and texture relate to the physical properties of the materials such as particle size, shape and consistency.

They affect the composting process by their influence on aeration (Rynk et al., 1992).

The physical properties of a composting mix can be adjusted by selecting suitable raw materials and by grinding or mixing.

Materials added to adjust these properties are referred to as bulking agents (Rynk et al., 1992).

Bulking agents reduce the density of a compost mix, enabling improved air flow.

Some compost mixes that do not contain sufficient bulking agents tend to be too dense, reducing air flow and often quickly become anaerobic. These mixes produce odour and decompose slowly.

It is therefore very important that compost mixes are prepared consistently. If the recipe is incorrect, more time is required for decomposition and it is very difficult to produce a consistent product.

Getting the compost mix correct and using the recipe consistently saves time and money.

Porosity

Porosity is a measure of the air space within the composting mass and determines the resistance to airflow.

Porosity is determined by particle size, the size gradation of the materials, and the continuity of the air spaces.

Structure

Structure refers to the rigidity of particles — that is, their ability to resist settling and compaction.

Good structure prevents the loss of porosity in the moist environment of a compost pile.

Texture

Figure 1. Particle size and its effect of porosity and air flow resistance. Mixes comprising very small particles (left) undergo rapid decomposition and are susceptible to the development of anaerobic conditions. Mixes comprising a range of small and large particles are less susceptible to the development of anaerobic conditions (right).
Texture refers to the available surface area for microbial attack.

Most decomposition during composting occurs on the surfaces of particles. As particle size reduces, the amount of surface area for decomposition increases.

For example, an apple chopped up into many pieces will decompose much more rapidly than a whole apple in a composting system because there are more surfaces for microbial attack.

When the majority of particles in a mix are small (<3 mm), anaerobic conditions can develop because of the resistance to air flow (Figure 1). This occurs because the mix is too dense, thereby reducing porosity.

When the majority of particle sizes in a composting mix are large (>50 mm), decomposition proceeds slowly because of the low surface area for microbial attack.

Thus, a compromise is needed between small particle sizes to encourage rapid decomposition and large particles to maintain porosity (Figure 1).

For most raw materials, an acceptable porosity and structure can be achieved if the moisture content is less than 65% (Rynk et al., 1992).

**Important references**


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**Definitions**

**Bulking Agent**

An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms “bulking agent” and “amendment” are often used interchangeably.

**Anaerobic**

In the absence of oxygen, or not requiring oxygen. Composting systems subject to anaerobic conditions often produce odorous compounds and other metabolites that are partly responsible for the temporary phytotoxic properties of compost. Anaerobic conditions are important for anaerobic digestion systems.

**Moisture Content**

The fraction or percentage of a substrate comprised of water. Moisture content equals the weight of the water portion divided by the total weight (water plus dry matter portion).

* Recycled Organics Unit, (2002).
What is the carbon to nitrogen ratio?

Carbon (C) in organic matter is the energy source and the basic building block for microbial cells.

Nitrogen (N) is also very important and along with C, is the element most commonly limiting.

Microorganisms require about 25-30 parts of carbon by mass for each part of nitrogen used for the production of protein.

A carbon to nitrogen ratio of 30 parts carbon to 1 part nitrogen (by mass) is written as a ratio, 30:1. Therefore, a C:N ratio of 500:1 (e.g. sawdust) represents a high C:N ratio, and 5:1 (e.g. meat) represents a low C:N ratio.

Preparing feedstock to an optimum C:N ratio results in the fastest rate of decomposition — assuming other factors are not limiting (e.g. oxygen, moisture, nutrients etc.).

In general, a high C:N ratio slows the rate of decomposition so that the composting process takes longer.

How organic materials break down

Compost feedstock is a complex mix of organic materials ranging from simple sugars and starches to more complex and resistant molecules such as cellulose and lignin.

In general terms, composting microbes first consume compounds that are more 'susceptible' to degradation in preference to compounds that are more resistant (Table 1).

The breakdown of organic matter is

Plate 1. Examples of common feedstocks in compost recipes with different C:N ratios. Low C:N pre-consumer food organics (left) and high C:N wood chips (right). When these materials are blended approximately at a 1:1 ratio (w/w), a good composting mix with a C:N ratio of ~35:1 is achieved.
therefore a step-wise reduction of complex substances to simpler compounds.

During the intensive phase of composting, the more easily degradable compounds are broken down first (Table 1).

Feedstocks that contain a high proportion of compounds that are difficult to break down, such as lignin, require longer periods of composting — decomposition of lignin occurs more rapidly during the curing phase, at mesophilic temperatures.

However, the decomposition of organic matter is a dynamic process because different composting microorganisms have the capacity to utilise compounds of varying complexity and resistance to degradation.

For many organic materials, a period of maturation is also essential to eliminate compounds that are toxic to plant growth (phytotoxic).

**C:N ratios of common feedstock materials**

The chemical and physical characteristics of various feedstock materials can be seen in Table 2.

| Table 1. Susceptibility of organic compounds found in compost feedstock to decomposition. |
|----------------------------------|------------------|
| Organic compound | Susceptibility |
| Sugars | Very susceptible |
| Starches, glycogen, pectin | |
| Fatty acids, lipids, phospholipids | |
| Amino acids | |
| Protein | Usually susceptible |
| Hemicellulose | |
| Cellulose | |
| Lignocellulose | |
| Lignin | Resistant |

| Table 2. Physical and chemical characteristics of various feedstocks. |
|------------------|------------------|
| Feedstock | Moisture | Structure | C:N | %N |
| Garden organics | | | | |
| Mixed tree and shrub prunings | dry to moist | good | 70-90 | 0.5-1 |
| Eucalyptus bark | dry | good | 250 | 0.2 |
| Eucalyptus sawdust | dry | average | 500 | 0.1 |
| Pinus radiata bark | dry | good | 500 | 0.1 |
| Pinus radiata sawdust | dry | average | 550 | 0.09 |
| Grass clippings | moist to wet | poor | 9-25 | 2-6 |
| Food organics | | | | |
| Mixed food organics | moist to wet | average | 14-16 | 1.9-2.9 |
| Vegetable produce | wet | poor | 19 | 2.7 |
| Fruit | wet | poor | 20-49 | 0.9-2.6 |
| Fish | moist to wet | poor | 2.6-5 | 6.5-14.2 |
| Biosolids | | | | |
| Biosolids | moist to wet | poor | 5-16 | 2-6.9 |
| Agricultural organics | | | | |
| Wool scour waste: | | | | |
| (1) raw decanter sludge | moist | poor | 13.8 | 0.81 |
| (2) raw flocculated sludge | moist | poor | 19 | 1.61 |
| Tannery waste (hair) | dry to moist | average | 3.1-4.3 | 11.7-14.8 |
| Mixed abattoir wastes | moist to wet | poor | 2-4 | 7-10 |
| Chicken manure (layers) | dry to moist | poor | 3-10 | 4-10 |
| Chicken manure (broiler) | dry to moist | poor | 12-15 | 1.6-3.9 |
| Seaweed (kelp) | dry to moist | average | 25 | 1.5 |
| Sawdust | dry | poor | 200-750 | 0.06-0.8 |
| Wheaten straw | dry | good | 100-150 | 0.3-0.5 |
| Paper products | | | | |
| Newsprint | dry | poor | 398-852 | 0.06-0.14 |
| Paper | dry | poor | 127-178 | 0.2-0.25 |

Sources: Rynk et al., (1992); Handreck and Black (1994); State Chemistry Laboratory unpublished data, Werribee, Victoria.
Concept of available carbon

Not all materials contain carbon that is readily degraded through microbial attack.

For example, much of the carbon present in woody garden organics is unavailable to microbial attack — such as that present in the form of lignin.

Addition of wood chips as a bulking agent to food organics or manure, for example, does little to supply carbon to the mix, though its main function is to increase porosity and air flow through the mix.

Organic materials, such as grass clippings, undergo rapid decomposition because they are high in nutrients (such as nitrogen) and high in available carbon, present mostly in the form of starch and hemicellulose.

Inclusion of only available carbon (instead of total organic carbon) in the C:N ratio for compost recipe calculations is rarely done due to the difficulty in accurately estimating available carbon.

The concept of available carbon is important in understanding why some organic materials break down a lot faster in composting systems than others.

Other nutrients

Apart from carbon and nitrogen, compost microorganisms require an adequate supply of other nutrients such as phosphorus, sulfur, potassium and trace elements (e.g. iron, manganese, boron etc.).

These nutrients are usually present in ample concentrations in compost feedstock, though phosphorus (P) can sometimes be limiting. A C:P ratio of between 75 and 150:1 is required.

Feedstock with low P levels can include gum leaves, woody plant residues and grass clippings. Good sources of P include superphosphate fertiliser, poultry manure, bone meal and rock phosphate.
Important references


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Role of pH in composting

The composting process is relatively insensitive to pH, within the range commonly found in mixtures of organic materials, largely because of the broad spectrum of microorganisms involved (Rynk et al., 1992).

Although opinions vary, the optimum range for composting is somewhere in the range of 5.5 to 9.

It is important to note that composting is likely to be less effective at 5.5 or 9 than it is at a pH near neutral (pH 7).

pH does become important with raw materials that have a high percentage of nitrogen (e.g. manure and biosolids).

A high pH, above 8.5, encourages the conversion of nitrogen compounds into ammonia gas, resulting in nitrogen loss from the compost (Figure 1).

Loss of nitrogen in the form of ammonia to the atmosphere not only causes nuisance odours, but also reduces the nutrient value of the compost.

Adjusting the pH downward below 8.0 reduces ammonia loss. This can be achieved by getting the right balances of materials in the compost recipe, or by adding an acidifying agent, such as superphosphate or elemental sulfur.

An outer layer of compost, used with aerated static piles and passively aerated windrows, helps to reduce ammonia loss. The (moist) particles in the layer retain ammonia as it

Figure 1. Typical changes in pH during the composting process (Gray and Biddlestone, 1971). Note that above pH 8.5, ammonia formation occurs. This results in nuisance odour production and a reduction in the nutritional value of the compost.
passes out of the pile.

The ammonia is converted to less mobile forms of nitrogen in the cooler and more stable environment of the outer layer (Rynk et al., 1992).

The biofiltration of nitrogen occurs best when the moisture content of the outer layer of mature compost is maintained at around 60%.

**Definitions***

**pH**
A measure of the concentration of hydrogen ions in a solution. pH is expressed as a negative exponent. Material that has a pH of 8 has ten times fewer hydrogen ions than a material with a pH of 7. The lower the pH, the more hydrogen ions are present, and the more acidic the material is. The higher the pH, the fewer hydrogen ions present, and the more basic it is. A pH of 7 is considered neutral.

**Manure**
The fecal and urinary excretion of livestock and poultry. Sometimes referred to as livestock waste. This material may also contain bedding, spilled feed, water or soil.

**Biosolids**
Organic solids or semi-solids produced by municipal sewage treatment processes. Solids become biosolids when they come out of an anaerobic digester or other treatment process and can be beneficially used. Until such solids are suitable for beneficial use they are defined as wastewater solids. The solids content in biosolids should be equal to or greater than 0.5% weight by volume (w/v). Biosolids are commonly co-composted with garden organics and/or residual wood and timber to produce range of recycled organics products.

**Ammonia (NH₃)**
A gaseous compound comprised of nitrogen and hydrogen. Ammonia, which has a (sharp) pungent odour, is commonly formed from organic nitrogen compounds during composting.

**Aerated Static Pile**
Forced aeration method of composting in which a free standing pile is aerated by a blower moving air through perforated pipes located beneath the pile.

**Passively Aerated Windrow**
A composting method in which windrows are constructed over a series of perforated plastic pipes, which serve as air ducts for passive aeration. Windrows are not turned.

* Recycled Organics Unit, (2002).

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The compost recipe

Ideal compost recipes allow for rapid microbial breakdown of the organic fraction, whilst minimising impacts on the environment through the generation of odour, leachate and attraction of pests and vermin.

Minimising the time that feedstocks are retained on site means that the processing capacity of the site can be increased.

Well managed commercial composting operations that have good compost recipes can process significantly more material — into quality products — than those that are poorly managed and have poor compost recipes.

The formulation of good compost recipes, therefore, is essential so that a composting operation can maximise revenue generated from the sale of products in the market place.

Key factors that influence the composting recipe are (as discussed in previous Information Sheets):

- C:N ratio
- moisture content;
- particle size and porosity
- pH; and
- other nutrients such as phosphorus.

Processing time

The length of time it takes to convert raw materials into mature compost depends upon many factors, including:

- feedstocks used;
- temperature;
- moisture; and
- frequency of aeration.

To achieve the shortest possible composting period, sufficient moisture, an adequate C:N ratio and good aeration is required.

Recommended conditions for rapid composting are shown in Table 1.

### Table 1. Recommended conditions for rapid composting (modified from Rynk et al., 1992).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Reasonable range</th>
<th>Preferred range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon to nitrogen ratio (C:N)</td>
<td>20:1 – 40:1</td>
<td>25:1 – 35:1</td>
</tr>
<tr>
<td>Moisture content</td>
<td>40 – 65%</td>
<td>50 – 60%</td>
</tr>
<tr>
<td>Oxygen concentrations</td>
<td>Greater than 5%</td>
<td>Greater than 12%</td>
</tr>
<tr>
<td>Particle size (diameter in mm)</td>
<td>3 – 13</td>
<td>Varies</td>
</tr>
<tr>
<td>pH</td>
<td>5.5 – 9.0</td>
<td>6.5 – 8.0</td>
</tr>
<tr>
<td>Temperature (℃)</td>
<td>45 – 65</td>
<td>55 – 60</td>
</tr>
</tbody>
</table>

* These recommendations are for rapid composting. Conditions outside these ranges can also yield successful results.

* Depends on specific materials, pile size and/or weather conditions.
Conditions which slow the process include a lack of moisture, a high C:N ratio, low temperatures, insufficient aeration, large particles and a high percentage of resistant materials (Rynk et al., 1992).

For instance, if the compost is to be applied to cropland well before the growing season, it can be cured and finished in the field.

The duration of the composting process is somewhat governed by the type of composting used, and the level of process control the operator can exercise over the process.

A guide to typical composting times for selected combinations of methods and materials is given in Table 2.

### Curing

Curing is a critical and often neglected stage of composting during which the compost matures (Plate 1).

Curing occurs at low, mesophilic temperatures (<45°C) for periods of up to 6 months, depending on the material composted. In this process, the rate of oxygen consumption, heat generation, and moisture evaporation are much lower than in the active composting phase (Rynk et al., 1992).

Curing is normally performed in piles, preferably under cover and on an impermeable surface. Protection of the compost from rain is necessary for the material to slowly dry out, thereby allowing for easier handling.

During the curing phase, mesophilic microorganisms re-invade the

### Definitions*

**Carbon to Nitrogen (C:N) Ratio**

The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.

**Process Control**

Stringent and documented monitoring of all critical control points in a composting operation so as to minimise defects and make products which can be guaranteed to customers.

**Curing**

Final stage of composting in which stabilisation of the compost continues but the rate of decomposition has slowed to a point where turning or forced aeration is no longer necessary. Curing generally occurs at lower, mesophilic temperatures. See stability.

**Mesophilic**

A temperature range of 20-45°C. Mesophilic microorganisms grow well at these temperatures and are also important for decomposition during the cool-down or maturation stage of composting. Most pathogenic microorganisms grow in this temperature range, and are thus destroyed under high temperature (thermophilic) conditions during composting.

**Aerobic**

In the presence of, or requiring oxygen.

**Phytotoxic**

Toxic to plants. Partially decomposed organic materials or immature composts are often phytotoxic, but this usually decreases with time. Such products may be phytotoxic due to a number of factors, including: low nutrient content; high oxygen consumption; presence of fatty acid or alcohol metabolites formed by microorganisms under anaerobic conditions; or due to excessive concentrations of salts, heavy metals and other organic compounds.

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**Table 2. Typical composting times for selected combinations of materials and methods (modified from Rynk et al., 1992).**

<table>
<thead>
<tr>
<th>Method</th>
<th>Materials</th>
<th>Active composting time</th>
<th>Range</th>
<th>Typical</th>
<th>Curing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(weeks)</td>
<td>(weeks)</td>
<td>(weeks)</td>
</tr>
<tr>
<td>Windrow – infrequent turning a</td>
<td>Garden organics + Manure + amendments</td>
<td>26 – 52</td>
<td>36</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Windrow – frequent turning b</td>
<td>Garden organics + manure</td>
<td>4 – 16</td>
<td>8</td>
<td>4 – 8</td>
<td></td>
</tr>
<tr>
<td>Passively aerated windrow</td>
<td>Manure + bedding or Food organics + garden organics</td>
<td>10 – 12</td>
<td>–</td>
<td>4 – 8</td>
<td></td>
</tr>
<tr>
<td>Aerated static pile</td>
<td>Biosolids + woodchips</td>
<td>3 – 5</td>
<td>4</td>
<td>4 – 8</td>
<td></td>
</tr>
<tr>
<td>Rectangular agitated bay</td>
<td>Biosolids + garden organics + manure + sawdust</td>
<td>2 – 4</td>
<td>3</td>
<td>4 – 8</td>
<td></td>
</tr>
<tr>
<td>Rotating drums</td>
<td>Biosolids / food organics + garden organics</td>
<td>0.5 – 2</td>
<td>–</td>
<td>8 c</td>
<td></td>
</tr>
<tr>
<td>In-vessel (vertical configuration)</td>
<td>Biosolids / food organics + garden organics</td>
<td>1 – 2</td>
<td>–</td>
<td>8 c</td>
<td></td>
</tr>
</tbody>
</table>

a For example, with a front-end loader;
b For example, with a specialised windrow turner;
c Often involves a second composting phase (for example, windrows or aerated static piles).

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Continued on page 3
Compost, often enhancing its plant disease suppressive properties.

Curing also furthers the aerobic decomposition of resistant compounds, large particles and clumps of material that remain active after composting (Rynk et al., 1992).

Importantly, phytotoxic organic acids formed during the composting process are broken down during curing as well.

Because curing continues the aerobic decomposition process, adequate aeration in necessary. If piles are to be naturally aerated (i.e. no active means of aeration), pile size needs to be relatively small (height ~1 m) and moisture must be within an acceptable range.

When available space is limiting, thus necessitating the use of large curing piles, or if the moisture content of the compost is high, anaerobic conditions can form, leading to a slowing of decomposition and the production of odour.

Larger piles of moist material can be cured in an aerated static pile with forced aeration. Forced aeration assists in moisture removal and maintenance of aerobic conditions.

Plate 1. Photograph of a curing pile of compost prepared from food and garden organics. The material shown had been composted in an in-vessel (vertical configuration) system for approximately three weeks. The material is heaped in a small curing pile for another six weeks before being used as a composted mulch.

Important references


Acknowledgement

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