Information Sheet No. 5-3
Composting Science for Industry
Temperature

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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 m^3) 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.

Few microorganisms can survive temperatures above 65ºC, causing a rapid reduction in the rate of composting.

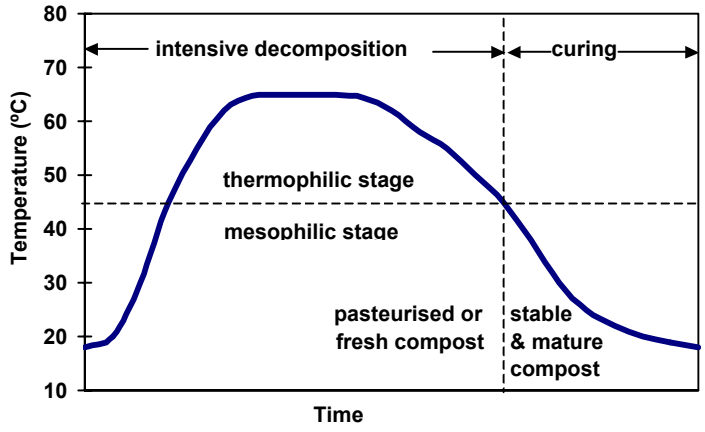
The highest rates of decomposition of organic materials usually occur at *thermophilic* temperatures between 50 and 55 ºC.

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.

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 65-70ºC, 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 (>45ºC), 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,

Definitions*

Thermophilic
Temperatures above 45°C. Used to describe a stage of composting in which high temperatures are sustained resulting in high rates of decomposition and pasteurisation of the organic material. Heat tolerant microorganisms survive well in these conditions.

Bacteria
A group of microorganisms having single-celled or non-cellular bodies. Bacteria usually appear as spheroid, rod-like, or curved entities but occasionally appear as sheets, chains, or branched filaments. Bacteria mostly break down organic materials in composting systems. It is bacteria that generate the heat associated with thermophilic composting systems. Bacteria have different temperature optima and are grouped accordingly: psychrophiles (<20°C); mesophiles (20-45°C), and thermophiles (>45°C).

Fungi
Singular - fungus. A group of simple microorganisms that lack a photosynthetic pigment. The individual cells have a nucleus surrounded by a membrane, and they may be linked together in long filaments called hyphae. The individual hyphae can grow together to form a visible body. See also bacteria.

Actinomycetes
A group of microorganisms, intermediate between bacteria and true fungi, that usually produce a characteristic branched mycelium. The organisms are responsible for the earthy smell of compost.

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)

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Figure 2. Typical temperature development at the centre and the outer surface of a turned windrow during composting. Data represents mean weekly temperatures.

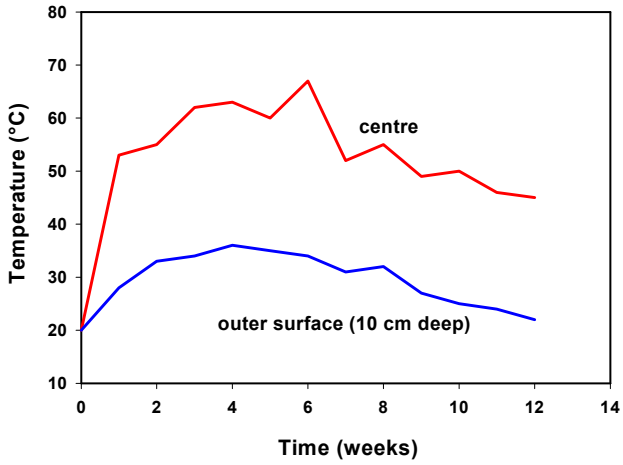
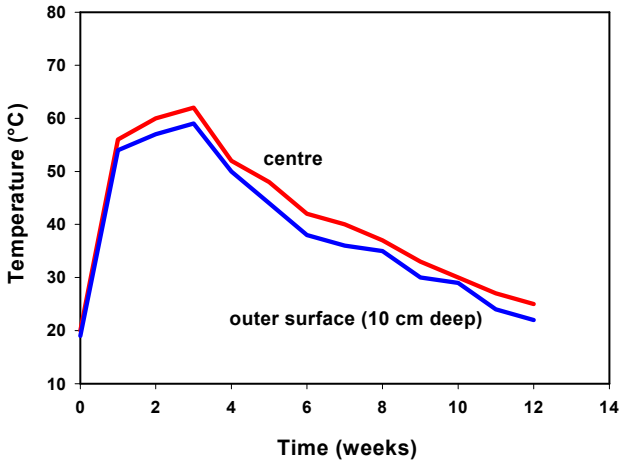


Figure 3. Typical temperature development at the centre and the outer surface of a forced aeration in-vessel composting system. Data represents mean weekly temperatures.



can be reduced by applying an insulating layer to the surface, such as straw, peat or finished compost.

Typical temperature profiles in a turned pile and a forced aeration in-vessel composting system is shown in Figures 2 and 3.

Temperature and pasteurisation

Temperatures above 55°C are necessary to destroy weeds and pathogens (animal, human and plant).

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

> 'The size of the temperature gradient between the interior and exterior depends on whether the composting system is insulated.'

This is a process known as pasteurisation.

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conditions during 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.

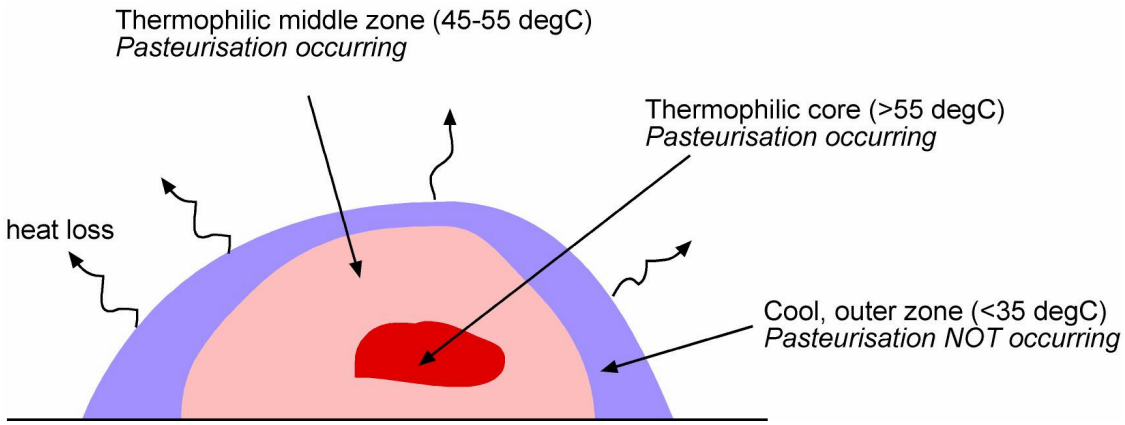
Windrow (with or without aeration)
System of composting involving the aeration of horizontally extended piles formed by a front-end loader or windrow turner. Extended piles are generally 1.5 to 3 m in height, and length is limited by the size of the composting pad. Aeration can be achieved by mechanical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

Figure 4. Typical temperature zones in an open air turned windrow (in cross-section). Note that the exterior of the windrow cannot achieve pasteurising temperatures, due to heat loss to the atmosphere. To ensure that all of the windrow is pasteurised —to eliminate weed seeds and pathogens — the outside of the windrow must be turned and deposited into the centre where high temperatures occur.



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.

> 'The whole composting mass must be subjected to pasteurising temperatures for at least 3 consecutive days to destroy weeds and pathogens' (Standards Australia AS 4454, 2002).

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

- Standards Australia (2002). Australian Standard AS 4454 for Composts, Soil Conditioners and Mulches. Standards Australia, Homebush, NSW.
- 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

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