

Basic Principles for Composting of Biodegradable Household Wastes^{*}

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1 Fundamentals

In the process of composting, microorganisms break down *organic matter* and produce *carbon dioxide, water, heat, and humus*, the relatively stable organic end product.

1.1 Build-up of organic matter through photosynthesis

The build-up of organic matter through the process of photosynthesis can be generalized by the following reaction:

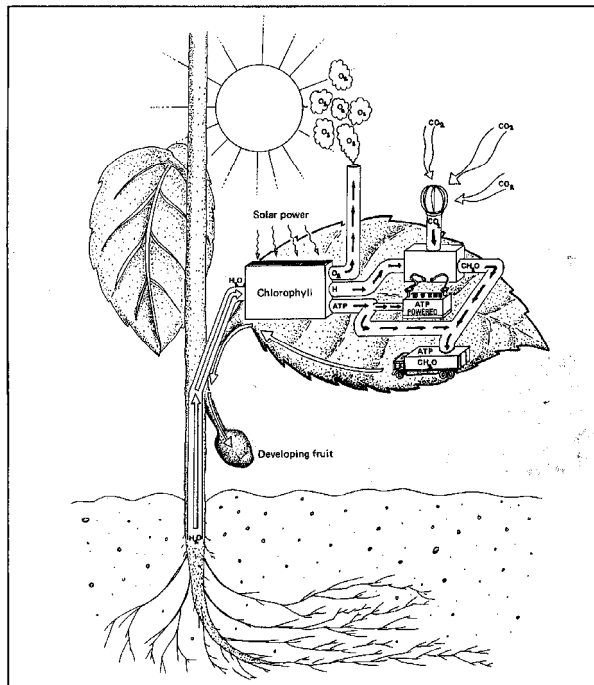
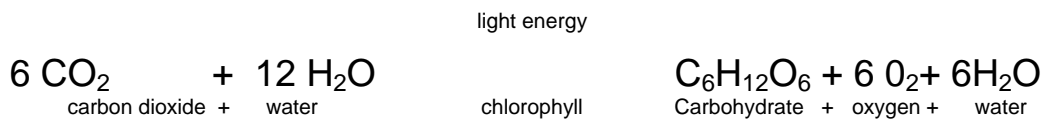


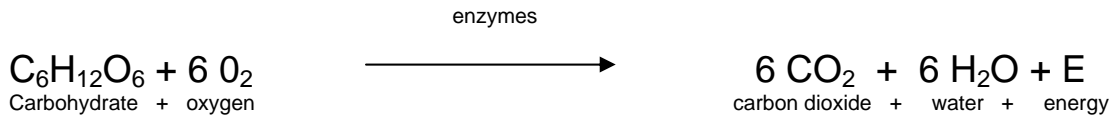
Figure 1: Schematic representation of photosynthesis

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1.2 Respiration

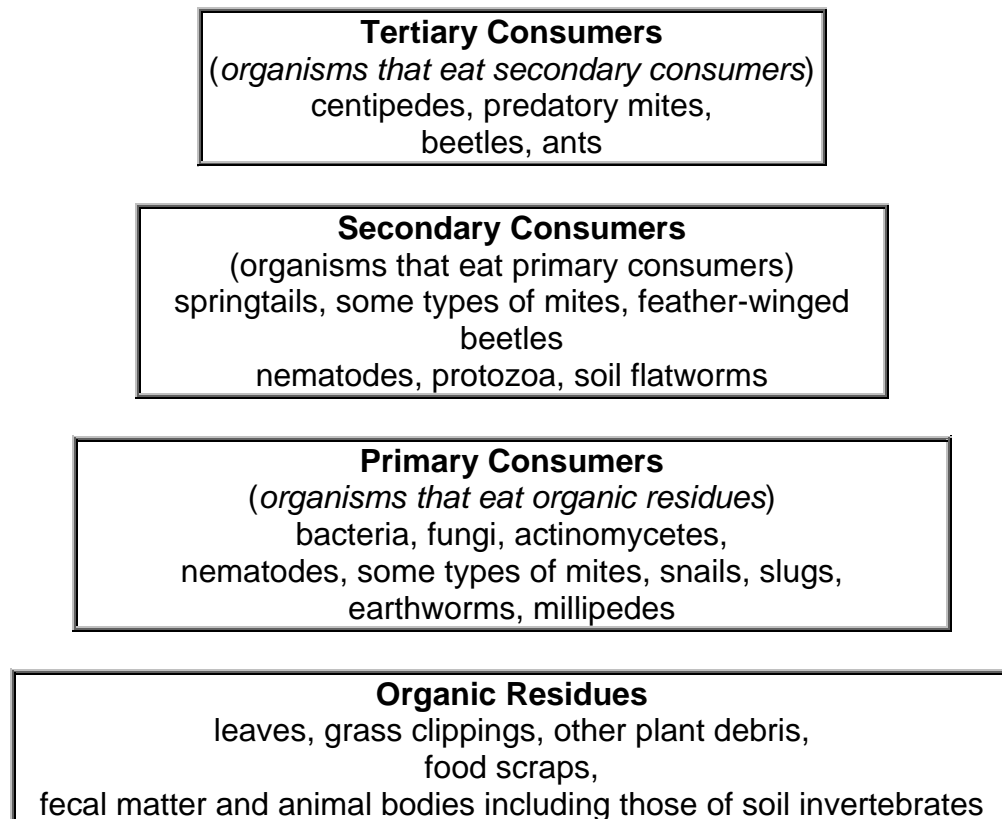
In respiration, organic matter is broken down and energy is released to power necessary processes within the cells of the microorganism involved in the decomposition:



Respiration requires

- 1) Organic matter
- 2) Oxygen
- 3) Enzymes

1.3 Decomposition of organic matter in a compost heap



2 Suitable materials for household composting














































	YES	NO	
Organic kitchen waste			Recyclable materials
Vegetable remains			Plastics
Salad leftovers			Metals
Fruit remains (also citrus)			Plastic foam
Potato peelings			Polystyrene
Eggshells			Compound materials
Bread crusts			Used glass
Coffee ground			Cardboard boxes
Teabags			Paper in bulk
Cut flowers			Drink cartons
Potted plants (without pot)			Plastic foil
Paper napkins			Harmful substances
Kitchen roll			Batteries
Tissues			Paints
Packing paper (For wrapping kitchen waste, but not plastic foil)			Oils
			Medicines
Organic garden waste			Glue
Grass cuttings			Alkaline solutions / acids
Leaves			Solvents
Twigs			Pesticides and herbicides
Bark			Residual waste
Tree, hedge and bush prunings (Branch diameter 12 cm max.)			Cooked and prepared food
Roots			Meat leftovers
Herbs / seeding weeds			Fish leftovers
Flowers			Bones
Moss			Nappies / hygiene articles
Windfalls			Cigarette ends
Diseased parts of plants			Glossy paper
Other parts of plants			Pet litter (in small amounts)

Figure 1: Suitable and non-suitable materials for household composting

3 Compost Chemistry

3.1 C/N Ratio

Carbon and Nitrogen are the two most important elements required for microbial decomposition:

Carbon:	energy source and the basic building block of microbial cells (more than 50 %).
Nitrogen:	crucial component of the proteins, nucleic acids, amino acids, enzymes and co-enzymes necessary for microbial cell growth and function
Ideal C/N ratio for composting:	30 parts carbon for each part nitrogen by weight (C:N ratio = 30:1)
C:N < 30:1	nitrogen will be supplied in excess and will be lost as ammonia gas, causing undesirable odors
C:N > 30:1	not sufficient nitrogen for optimal growth of the microbial populations -> compost will remain relatively cool and degradation will proceed at a slow rate.

Table 1: C/N ratio of some raw compost materials

Nitrogen-rich waste	C/N ratio	Carbon-rich waste	C/N ratio
Liquid manure	2-3	Leaves	40-60
Chicken dung	10	Fruit	35
Grass cuttings	12	Legume straw	40-50
Kitchen waste	13-23	Corn cobs/Rice straw	80-100
Cow/pig/horse dung	20-25	Sawdust	100-500
Feathers, hair	30	Paper/cardboard	200-500

During the decomposition process the C/N ratio diminishes to approximately 12 in the matured compost.

3.2 Oxygen

Another essential ingredient for successful composting is oxygen. As microorganisms oxidize carbon for energy, oxygen is used up and carbon dioxide is produced. Without sufficient oxygen, the process will become anaerobic and produce undesirable odors, including the rotten-egg smell of hydrogen sulfide gas.

3.3 Nutrient Balance

Adequate phosphorus, potassium, and trace minerals (calcium, iron, boron, copper, etc.) are essential to microbial metabolism. Normally these nutrients are not limiting because they are present in ample concentration in the compost source materials.

Table 2: Additives to improve decomposition conditions and compost

Additive	Composition and application
Standard compost	Compost rich in soil organisms for inoculation
Algae meal	Principally a source of trace elements
Bone mea & Rock phosphate	Increases content of P and Ca
Wood chippings, twigs	Bulking materials to improve drainage and aeration
Sand	In small doses useful for its silicic acid content which is important for healthy plant growth

3.4 pH value

A pH value between 5.5 and 8.5 is optimal for compost microorganisms. As bacteria and fungi digest organic matter, they release organic acids.

4 Compost Physics

4.1 Temperature Curve

Under optimal conditions, composting proceeds through three temperature phase:

- 1) the mesophilic, or moderate-temperature phase, which lasts for a couple of days,
- 2) the thermophilic, or high-temperature phase, which can last from a few days to several months,
- 3) a several-month cooling and maturation phase.

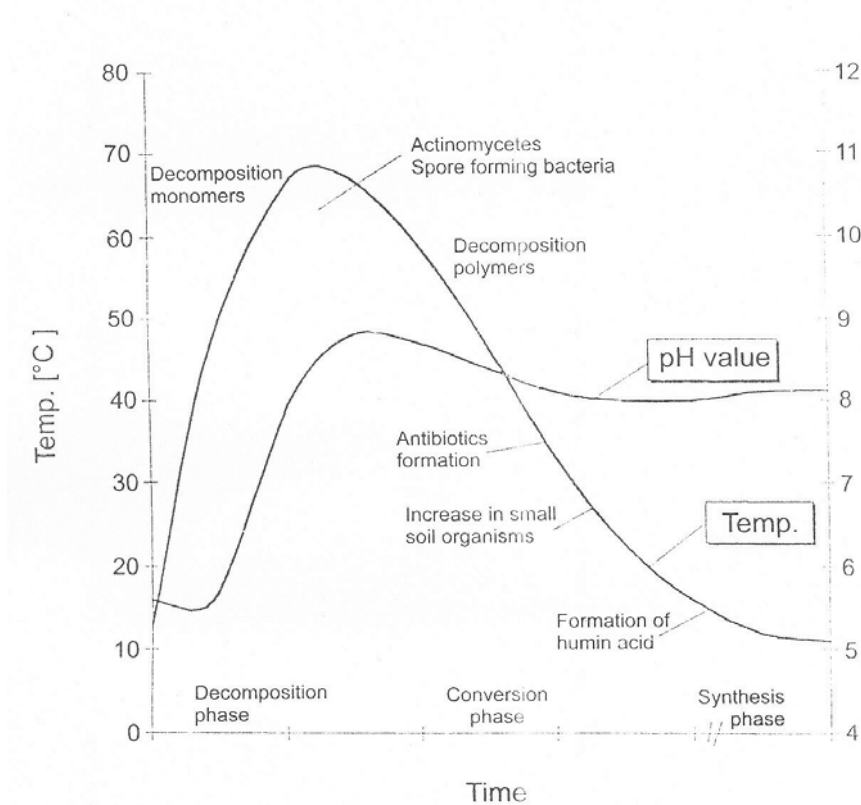


Figure 2: Temperature and pH curves of composting process

4.2 Particle Size

Microbial activity generally occurs on the surface of the organic particles. Therefore, decreasing particle size, through its effect of increasing surface area, will encourage microbial activity and increase the rate of decomposition.

On the other hand, when particles are too small and compact, air circulation through the pile is inhibited. This decreases O₂ available to microorganisms within the pile and ultimately decreases the rate of microbial activity.

4.3 Aeration

Oxygen is essential for the metabolism and respiration of aerobic microorganisms, and for oxidizing the various organic molecules present in the waste material.

As biological activity progresses, the O₂ concentration falls and CO₂ concentration increases. If the average O₂ concentration in the pile falls below about 5%, regions of anaerobic conditions develop. If the anaerobic activity increases above a certain threshold, *undesirable odors* may result.

Maintaining aerobic conditions can be accomplished by various methods:

- drilling air holes
- inclusion of aeration pipes
- mixing or turning

4.4 Moisture

A moisture content of 50-60% is generally considered optimum for composting.

- too little moisture (<30%) inhibits bacterial activity
- too much moisture (>65%) results in slow decomposition, odor production in anaerobic pockets, and nutrient leaching.

Squeeze a handful of well-mixed compost or raw compost material. If your hand becomes moist but without any drops of moisture forming, the moisture content is optimal. If water trickles out when compost is squeezed, it is too wet. If the compost crumbles, it is too dry.

4.5 Size and Shape of Compost System

A compost pile must be of sufficient size to prevent rapid dissipation of heat and moisture, yet small enough to allow good air circulation.

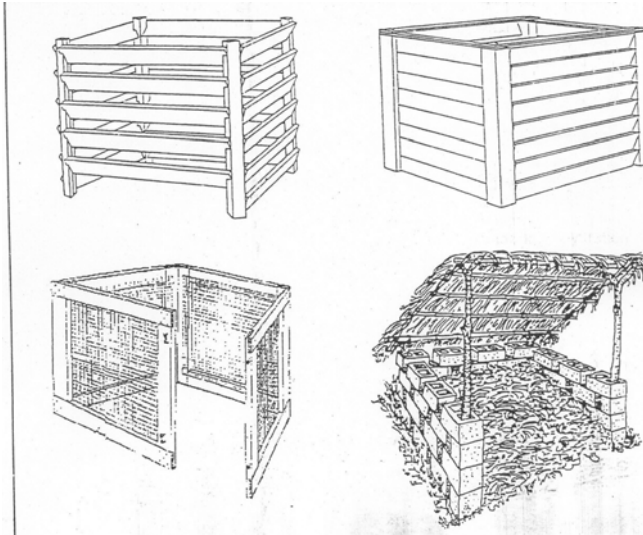
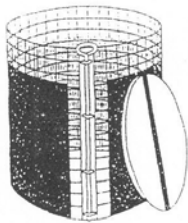


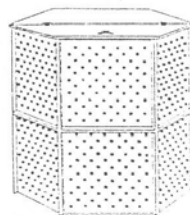
Figure 3: Compost racks



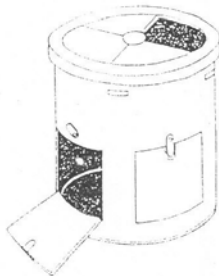
Compost silo made of steel wire, can be opened at side and is easy to transport. Jute or perforated plastic sides.



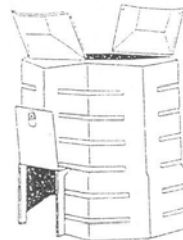
Compost silo made of wooden slats, can be opened at side.



Compost container made of perforated plastic sheets, removable individually to extract compost.



Compost container divided into several chambers according to composting phases, insulated and ventilated.



Compost container insulated, open at base with ventilation slits and flap in lower part for removing compost.

Figure 4: Small composters

5 Setting up a compost pile

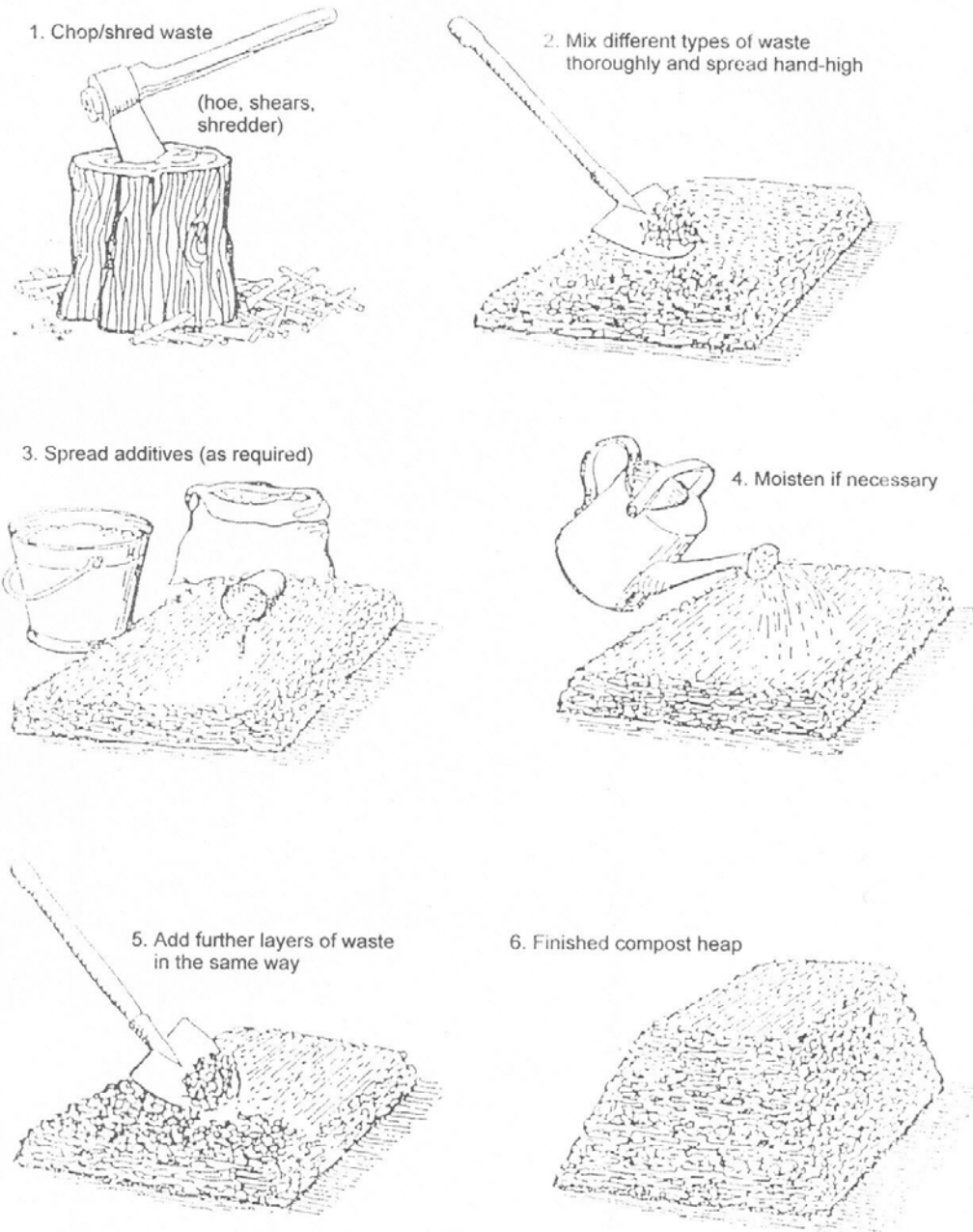


Figure 4: Setting up a compost pile

5.1 Compost sites

When selecting a suitable site for backyard composting, the following criteria should be taken into consideration:

- A shady place protected from wind is ideal. Direct sunlight causes oxidation of organic material. Precipitation can cause waterlogging and leaching of nutrients.
- Soil is a good base but is not always necessary.
- The compost site should be easily accessible and not too far away from the area where the organic waste is produced. However, it should be far enough to prevent nuisance to residents caused by possible emission or vermin.
- The space required is 1 to 2 m² per heap plus enough space to work.
- Water must be available within a reasonable distance.

5.2 Basic equipment for backyard composting

The following implements and materials are suitable in backyard composting:

- Composting containers with lid over cover
- If necessary materials to make protective walls against termites and vermin
- Bamboo or wooden poles or similar material as aeration shafts
- Pitchforks, shovels and other tools to mix the waste and turn the material.
- Knives, bolos and other tools to chop large components.

6 Diagnosis of Errors in Composting

Table 3: Errors in Composting

Problem	Reasons	Counter-Measure
<ul style="list-style-type: none"> • Material too dry • Decomposition stopped 	<ul style="list-style-type: none"> • Moisture content drops under the level required for micro-organisms due to too high in a rise temperature • Source material too dry 	<ul style="list-style-type: none"> • Turn and irrigate • Add moist fresh compost material • Cover windrow in order to avoid evaporation • Minimize surface open to wind by altering the shape and direction of windrows
<ul style="list-style-type: none"> • Material too wet, • rotten smell • green, blackish color 	<ul style="list-style-type: none"> • Heavy rainfall • Material mixture low in bulking materials and nitrogen but rich in water • Lack of oxygen 	<ul style="list-style-type: none"> • Turning, possibly on dry base of wood chips or twigs • Add dry material • Add soil, standard compost, rock dust or lime
<ul style="list-style-type: none"> • Slow decomposition 	<ul style="list-style-type: none"> • Too high percentage of lignite materials with too great a C/N ratio • Too dry 	<ul style="list-style-type: none"> • Turn • Add nitrogen-rich materials (dung, kitchen waste) • Irrigate
<ul style="list-style-type: none"> • Smell of mould 	<ul style="list-style-type: none"> • Waterlogging • Lack of oxygen • Lack of bulking materials • Too high percentage of nitrogen-rich, fresh waste • Compacted material 	<ul style="list-style-type: none"> • Turn • Add bulking material
<ul style="list-style-type: none"> • Compost contains weed seeds 	<ul style="list-style-type: none"> • Too low a temperature during decomposition 	<ul style="list-style-type: none"> • Regulate air and water content • Place weeds in center of windrow where the highest temperature exist • Increase size of windrow
<ul style="list-style-type: none"> • Compost attracts vermin 	<ul style="list-style-type: none"> • Food and animal remains are near surface and not covered 	<ul style="list-style-type: none"> • Place kitchen waste in center of windrow and cover

7 Maturity of compost

Mature compost smells pleasantly of fresh soil and has a crumbly structure. Kitchen waste has decomposed, although large pieces of chopped waste, stones from fruits, bones and eggshells will still be present in part.

In order to test the maturation degree, a bowl is filled with screened compost, vegetable seeds (those that are available at low costs such as mung, etc.) are sown on it and kept moist. The bowl is put in a light, warm, place. Since vegetable seeds react very sensitively to growth limiting materials in fresh compost, the degree of maturation can be determined by the growth rate of the vegetable.

- Mature compost: the seeds will germinate 2-3 days after and the young seedling will show healthy growth in the days after
- Fresh, immature compost: only few seeds will germinate, the seedlings will grow slowly with short and stunted roots.

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