BIOLOGY OF COMPOSTING
Better Composting School

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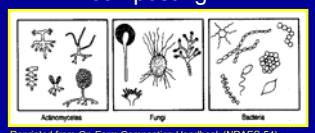
In composting, naturally-occurring biological processes are exploited to:

- treat and dispose of waste materials (residuals)
  - -reduce volume
  - -stabilize
  - -destroy pathogens
- generate a valuable product

Implications:

- To sustain a composting operation, needs of biological organisms must be met
- Have to understand what organisms are involved and how their activities are influenced by different factors

Organisms that do the decomposition work in composting:



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- Bacteria
  - -including actinomycetes
- Fungi

The needs of composting organisms are the same as those of all living things:

- Food (energy)
- Oxygen (something to respire)
- Nutrients
- Water
- A hospitable environment
  - -Temperature
  - -Neutral chemical (pH) conditions

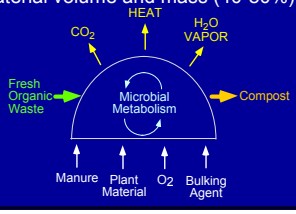
Composting basically involves establishing ideal temperature conditions for the compost microorganisms and providing them with the right combination of:

- Energy sources (carbon feedstocks)
- Nutrients (nitrogen)
- Oxygen
- Water

Carbon and nitrogen needs can be met using many different materials ⟶ = many compost recipes

The various composting methods differ in the way that oxygen is supplied/temperature is controlled.

- As the compost microbes consume O_2 and C feedstocks, they produce waste products, including:
  - -carbon dioxide (CO_2)
  - -heat → water vapor
    - → inactivates pathogens and weed seeds
- They also:
  - -convert easily digestible feedstocks to less digestible (more stable) forms
  - -reduce material volume and mass (40-80%)



Other biological organisms of interest:

Invertebrates and other higher organisms (e.g., centipedes, earthworms, mites, protozoa)

-killed by high temperatures resulting from bacterial activity

-return when temperatures drop

-feed on bacteria, fungi, and each other

-mix material, reduce material size, convert organic material to more digestible

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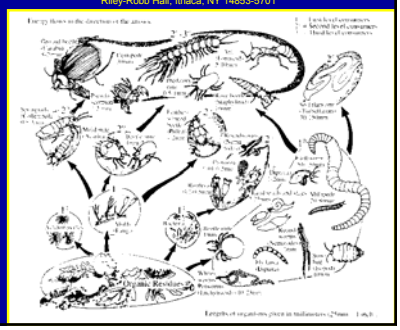


Pathogens

- harmful to humans, animals, or plants
- animal and plant pathogens found in manures, crop residues, and yard wastes
- human pathogens are found in biosolids
- pathogen levels are greatly reduced in effective composting operations by:
  - -high temperatures
  - -interactions with non-pathogenic organisms
- *Aspergillus fumigatus*
  - -abundant fungus in compost and moldy hay
  - -causes allergic reactions in 5-10% of population
  - -causes more serious problems in individuals whose immune systems are compromised

FEEDSTOCKS

Potential feedstocks-Key properties and considerations

- biosolids
  - -pH/moisture can vary extensively, permitting requirements
- yard trimmings
  - -tend to be very consistent
- municipal solid waste
  - -requires separation
- animal manures
  - -N/water levels depend on animal type/management practices
- crop residues, straw, hay, etc.
- wood waste
  - -pressure-treated wood unacceptable
- dead animals
  - -vary depending on animal type
- food processing waste
- paunch manure and other animal processing wastes
- organic industrial waste
  - -example = paper mill sludge

Forms of carbon in feedstocks:

- sugars
- oils
- fats
- starches

-First materials to be converted

-Acted on by bacteria

-Stimulate most metabolic activity = greatest amount of heat/CO_2

- cellulose
- hemicellulose

-Acted on by fungi and actinomycetes

-Generate less heat

- lignin → primary C form in compost want to add to soil

♦ Decreasing digestibility, temperature, O_2 demand

♦ Increasing abundance in finished compost

Carbon to nitrogen ratio (C:N) of feedstocks:

Biological organisms need

-C for generating energy and creating structural components and building blocks of cells

-N for production of proteins, DNA, etc.

-approximately 25 times more C than N (on the basis of weight)

- Therefore, ideally raw feedstocks are blended to provide an initial C:N ratio of around 25:1 to 35:1
- A single feedstock rarely has the correct C:N ratio
- Getting the right C:N ratio is key to good composting

If initial C:N ratios are:

- significantly lower than 25:1
  - -N is lost as NH_3 = odors and lost nutrient value
  - -maintaining aerobic conditions is difficult = odors
- significantly higher than 35:1
  - -readily digestible C will decompose slowly, if at all
  - -lower temperatures will occur = decreased inactivation of pathogens and weed seeds

C:N Ratios of Common Types of Feedstocks

Material	Range of typical C:N ratios (w/w)
Crop residues and fruit/vegetable wastes	20—120
Fish and meat processing wastes	3—25
Animal manures	13—50
Sewage sludge	5—16
Straw, hay, silage	15—150
Wood and paper	200—1200
Yard Wastes	10—80

EXAMPLE

Your primary goal is to compost manure from a free-stall dairy operation (C:N ≈ 13)

One solution: blend it with straw (C:N ≈ 80)

Finished compost should have a C:N ratio of around 20. Plants planted in compost with higher C:N ratios will be deprived of N by compost microbes.

Carbon to phosphorus ratio (C:P) of feedstocks:

- Like all living organisms, compost microbes also require phosphorus
- Most feedstocks contain enough P to meet this need e.g., manures, biosolids, yard trimmings
- Municipal solid waste (MSW), which is primarily paper (cellulose) is usually deficient in P
- When composting paper must either add a
  - -feedstock that balances N and P requirements
  - -add a fertilizer (e.g., diammonium phosphate)
- Starting material should have initial C:P ratio of approximately 250 and C:N ratio of 25 to 35

Feedstock particle size:

Microbes attack feedstock materials at their exposed surfaces

- Increased feedstock surface area = increased:
  - -rate of metabolic activity
  - -decomposition of feedstocks
- As particle size ↓ Total surface area ↑

Example:

Compare surface area of 1 lb of sawdust (~2 mm) to 1 lb of wood chips (~2")

Surface area of wood chips = 265 in^2

Surface area of sawdust = 116,500 in^2

Recommended particle size range for compost feedstocks:

1/8 to 2 inches

- Also takes into account relationship between particle size and pore size
- As particle size ↓ Size of pores between particles ↓
- Pore size is important because it affects delivery of O_2 to compost microbes

OXYGEN

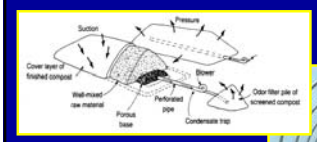
Oxygen availability–Key considerations:

- Compost microbes consume O_2 as they breakdown carbon forms
- If O_2 is deficient decomposition occurs anaerobically:
  - -slows composting process
  - -causes offensive odors
  - -can cause safety concerns (hydrogen sulfide) and formation of compounds that are toxic to plants
- Ambient air contains 21% O_2
  - -to maintain aerobic conditions in a compost pile:
    - should have at least 5% O_2 in pore spaces
    - many compost microbes can function w/2% O_2

Oxygen delivery approaches:

O_2 can be delivered to compost microorganisms:

- actively
  - -mechanical agitation (minor)
  - -forced aeration (blowers/vacuum)



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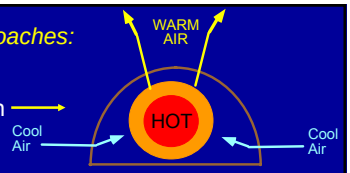
Static piles and in-vessel compost piles are often actively aerated

Oxygen delivery approaches:

- passively
  - -natural convection
  - -diffusion



Convective air flow in response to temperature gradients

Windrows are aerated primarily through passive delivery of O_2

Factors affecting passive O_2 delivery:

Feedstock particle size:

- -smaller particles pack more tightly = smaller pores and less air flow
- -particle size decreases during composting process
- -addition of bulking agents (e.g., wood chips) helps keep pore spaces open

Volume of feedstock:

- -the large the size of the pile, the more difficult it is for air to penetrate entire pile
- -limit pile size to 6 ft high and 12 ft wide

Factors affecting passive O_2 delivery:

Moisture content:

- At moisture levels ≥65%, pores are mostly filled with water, which greatly limits air flow
  - -anaerobic and sour or explosive conditions can develop
- Compost microbes need ≥15% moisture to live
  - Ideal range: 40–60% moisture
  - Bagged compost: should have ≤40% moisture

Measuring moisture levels:

Moisture squeeze test:

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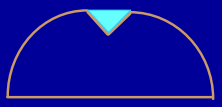
Altering moisture levels:

- If piles are too dry, they can be moistened with:
  - -a trickling hose
  - -by creating a trough along the top of the pile that is filled with water, which is beaten in



  - -some materials (e.g., leaves) shed water and are difficult to wet
- If piles are too wet:
  - -add dry materials
  - -turn frequently, releases steam/distributes air

TEMPERATURE

Temperature–Key Considerations:

Temperature control is needed because microbial decomposition releases a lot of heat

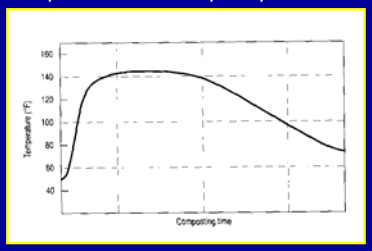
- -composting piles are self-insulating
- -high temperatures can result

High temperatures are of concern because:

- -above 160ºF many compost microorganisms die
- -high temperatures can dry piles out
- -when coupled with low moisture levels (25 to 45%) spontaneous combustion can occur

Temperature Ranges:

- The temperature of compost piles varies over time



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- Initially, temperature increases rapidly as readily digestible materials are decomposed and heat is released
- As decomposition slows, the temperature falls

Temperature Ranges:

- Different microorganisms thrive and are predominant at different temperature ranges:

50-105ºF:
- -"Mesophilic" range
- -Occurs at beginning and end of process
- -Disease suppressant properties acquired at these temperatures

>105ºF:
- -"Thermophilic" range
- -Needed to destroy pathogens, weed seeds, and fly larvae
- -Also kills mesophilic organisms

Temperature Control:

Critical thermophilic temperatures for destroying:

Human Pathogens	131°F
Weed Seeds	145°F
Tomato Seeds	150°F

Thermophilic temperatures are ideally maintained for several weeks and achieved by having adequate:

- -Pile sizes (insulation)
- -O_2
- -Digestible feedstocks
- -Moisture

Excessive temperatures are prevented by:

- -monitoring temperature, plus
- -mechanical turning or forced aeration

pH

- The pH of a material refers to how acidic or basic it is
- pH is measured on a scale of 1 (most acidic) to 14 (most basic)
- Relevant pH ranges for composting:

  Ideal = 6.5 to 8.0

  Feasible = 5.5 to 9.0

  > pH 8.5, N lost as ammonia

  < pH 5.5, fungi predominate, decomposition slows

SUMMARY

Optimal conditions for microorganisms/composting

Condition	Acceptable Range	Preferred Range
C:N ratio	20—40	25—35
Moisture content	40—65%	50—60%
O_2 levels	>5%	Much > 5%
Particle size (diameter)	varies	1/8—2 in
pH	5.5—9.0	6.5—8.0
Temperature	110—150ºF	130—140ºF