The Science of Compost

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Brown Bag Seminar Sponsored by
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Why Dig Deep?

Learning about the science behind compost can help you create better compost in your backyard.

What We'll Cover

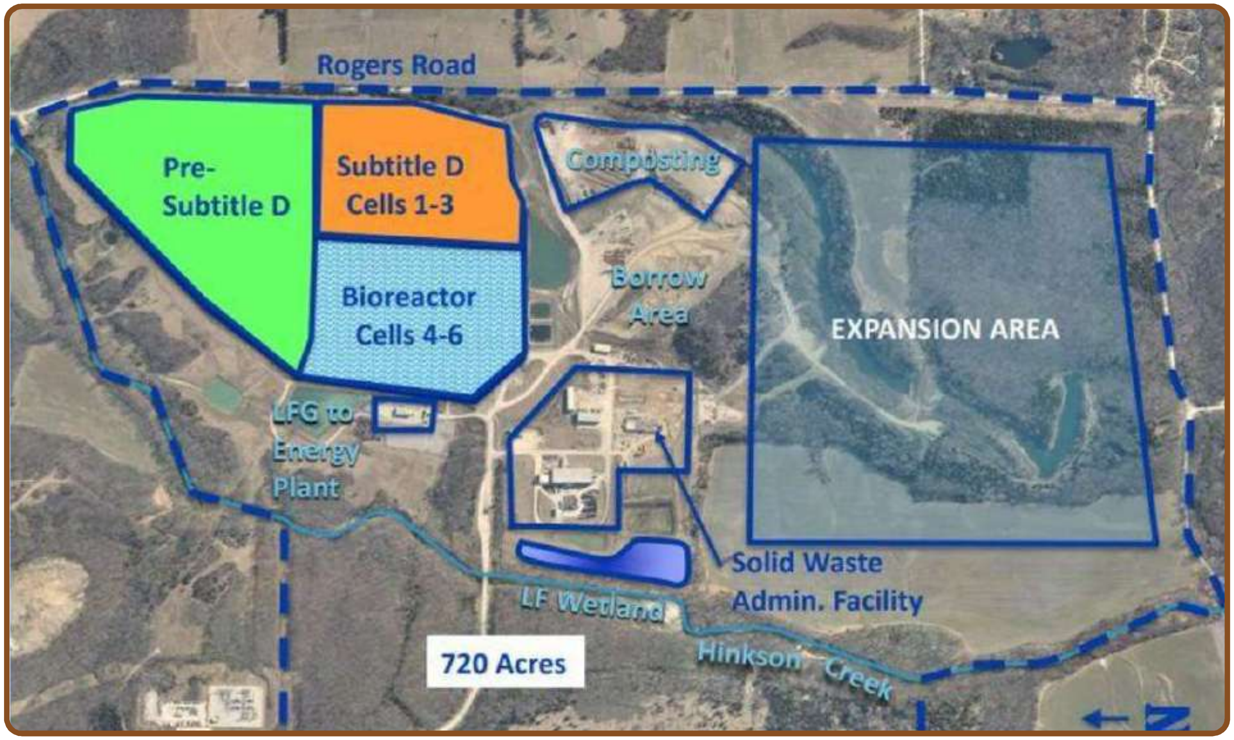
- Biochemistry and Microbiology of Hot Composting
- Anaerobic Bokashi Composting
- Vermiculture
- Comparing the Three Techniques

*Throughout the presentation we'll connect the science to home composting tips.

Why Compost?

- Reduce household waste (almost 40% of Columbia's landfill is organic waste!)
- Reduce methane (a potent greenhouse gas) emissions from landfills
- Improve soil in yard and garden
- Reduce need for fertilizer and water (saves money)
- Transform something of little value into something valuable

Composting Keeps Food Waste out of our Landfill



- When food waste decomposes in a landfill, it produces methane, which is a greenhouse gas 23x more potent than carbon dioxide.
- While Columbia's landfill bioreactor converts some of this methane to energy, it is incomplete capture and an inefficient way to produce energy.

Working Definitions

Composting:
Composting is the act of collecting and storing organic material so it can decay and be added to soil to improve its quality.

Compost:
- Contains nutrients in a form that plants can access (with help from bacteria)
- Adds organics to the soil which can help aeration (in clay) and water retention (in sand)
- Aids aggregation in the soil, which improves the structure of the soil

Organic material can be broken down in 2 ways...

Anaerobic: Without air $C_6H_{12}O_6 \longrightarrow 3\ CH_4 + 3\ CO_2$

- Landfills and incorrectly managed home compost piles
- Not an efficient way of composting (except Bokashi fermentation, which we'll cover later).
- Production of sulfur-containing molecules (strong odors) and methane, (a potent greenhouse gas)

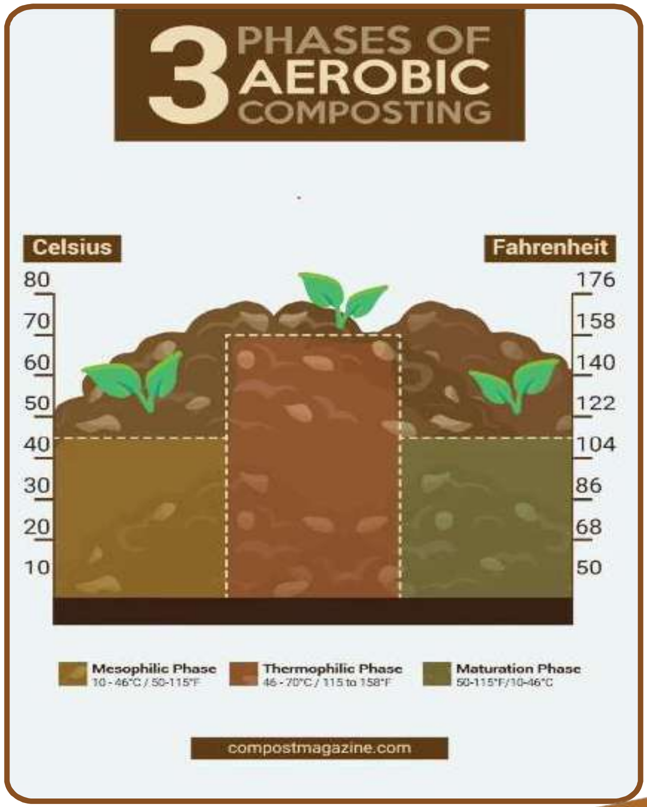
Aerobic: With air $C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$

This is how most backyard compost systems work

- Can be a faster process than anaerobic
- High temperatures = kill disease
- Produces CO_2, not methane

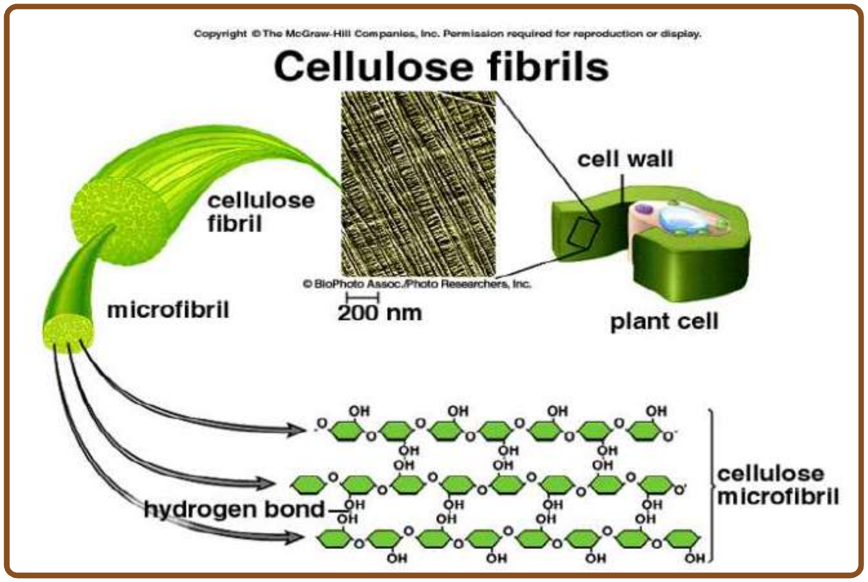
Aerobic Composting = community of soil organisms aka ecological succession

Composting creates an ecosystem of bacteria, fungi and larger organisms that work together (and sometimes consume each other!) in the process of degrading your food waste!



Greens

- Food waste, plant material
- Provide the nitrogen that feed the bacteria that will provide the nutrients to feed the fungi



Browns

- Leaves, newspaper, straw, sawdust, etc
- Cellulose, linked chains of glucose.
- Humans lack the enzymes to break down cellulose fibers
- Fungi can easily break these down

Chemistry of Compost

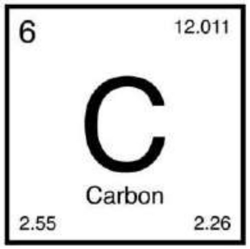
- The cells in some green materials (grass clippings) are still alive and their metabolism generates heat

- Microorganisms use molecules (enzymes) to break down plant lipids(fats) generating more heat (Needs O_2)

- A number of O_2-requiring chemical reactions (oxygenation = the process of adding oxygen, breaking the sugar ring) occur
  - Enzymes that require oxygen can break down fat/lipid molecules generating heat, water and CO_2.
  - Some bacteria, but more typically fungi can break down cellulose to individual sugar molecules which then are further broken down to release carbon dioxide.

Oxidation of sugars to $C0_2$ can release a great deal of heat.

For 1 teaspoon of glucose processed in a compost heap, the amount of energy released would be *the equivalent of* the amount of energy needed to increase the temperature 1 teaspoon of water by 14 degrees F. This energy, as heat, helps move the pile into the thermophilic phase.



Chemistry of Compost
The Carbon : Nitrogen Ratio

Both required for microbial/fungal decomposition.

- Carbon is an energy source (note the root in our word for high energy food: carbohydrate)
- Nitrogen is a crucial component of proteins, amino acids, enzymes, and DNA necessary for cell growth and function. Bacteria use nitrogen as ‘food’ to facilitate rapid growth.

Ideal ratio is 30:1 C:N

- Too much N results in more N off-gassing as ammonia
- Not enough N results in poor bacterial growth so the pile can be very slow to heat up.
- Finished compost will be closer to 10 or 15:1 as C is converted to CO2 and goes away - N might change chemical form but usually stays, in a more plant-available form.

Home Composting Tip:

Different sources of carbon are more biodegradable than others. Office paper (white and/or recycled) is more biodegradable than cardboard. However, newspapers are less biodegradable in a compost pile.

Chemistry of Compost

Carbon to nitrogen ratio of common compostable material:

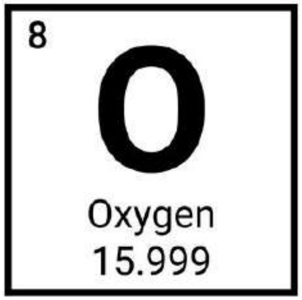
Wood chips	700:1
Cardboard (corrugated)	560:1
Sawdust	500:1
Wood bark	300:1
Newspaper	150:1
Pine needles	80:1
Straw	75:1
Cornstalks	60:1
Peat moss	60:1
Leaves	55:1
Horse manure	25:1
Coffee grounds	25:1
Compost	20:1
Food waste	20:1
Grass clippings	15:1
Cow manure	15:1
Pig manure	15:1
Alfalfa hay	12:1
Poultry manure	6:1
Blood meal	4:1

Chemistry of Compost

Microbial metabolism also requires:

- Phosphorus
- Sulfur
- Calcium
- Potassium
- Trace elements such as magnesium, iron, and copper
- WATER!

*These nutrients are not limiting because the compost ingredients provide sufficient quantities for microbial growth.



Chemistry of Compost

- Required for efficient degradation of organic matter - the organisms doing the work require oxygen!
- When oxygen supplies are insufficient, the compost becomes anaerobic. The ‘good’ chemical reactions stop and organisms become inactive. Unwanted chemical reactions occur instead, resulting in undesirable odors, including the rotten-egg smell of hydrogen sulfide
- Adding straw or sticks in the pile/layers will prevent matting of materials and allow oxygen exchange

Home Composting Tip:

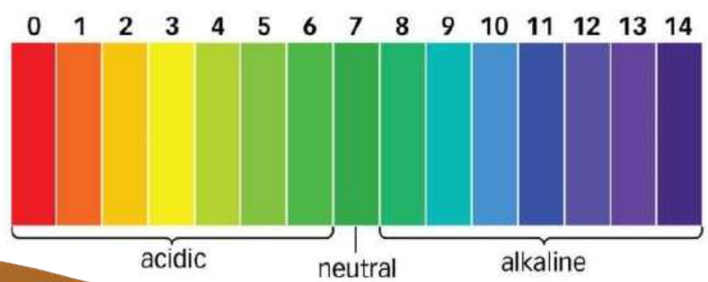
Airflow is essential for healthy compost piles!

Chemistry of Compost

Compost pH

- Household kitchen scraps = pH anywhere from pH 5 → 7 as most foods are acidic
- Aerobic microbial activity is maximized ~ pH 6.5-8.0 whereas fungal activity peaks ~ pH range of 5 - 6
- Lower pH encourages the growth of fungi

The initial chemical reactions might cause a slightly acidic pH, but subsequent reactions convert byproducts so the overall pH does not change much



Home Composting Tip:

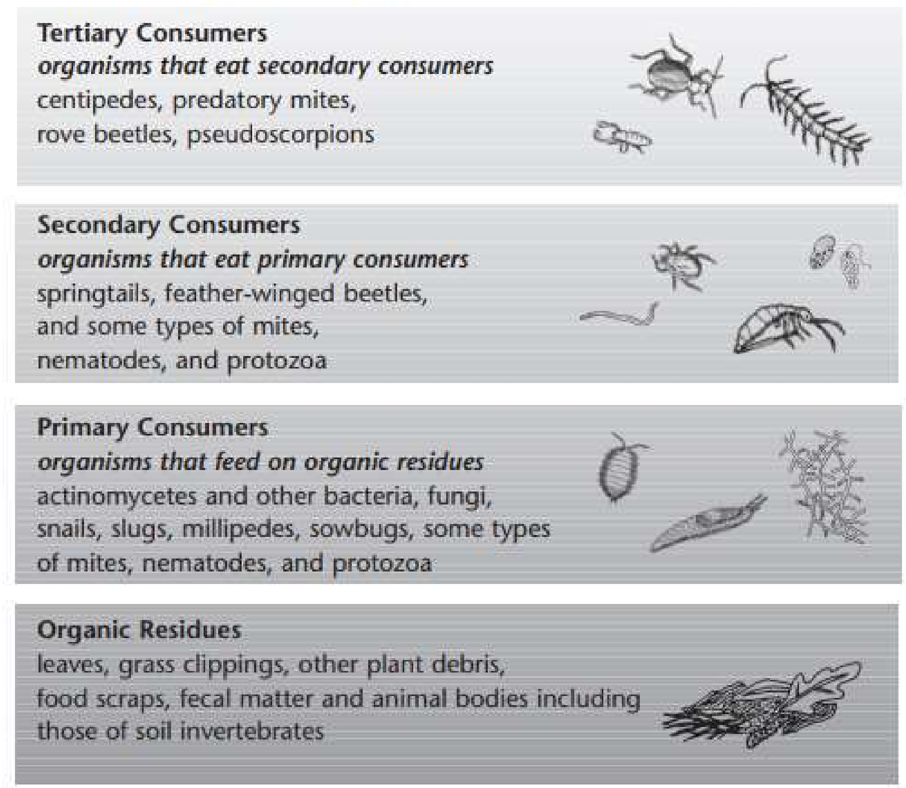
If the system becomes anaerobic, pH may drop as CO_2 plus water makes an acid. This lack of oxygen will limit microbial activity. If this happens, aeration (and sometimes adding more dry/brown material) usually is sufficient to return the compost pH to acceptable ranges and decomposition continues.

Biology of Compost

Decomposers are classified into primary, secondary and tertiary consumers.

- For example, fungi are eaten by springtails which in turn are eaten by centipedes and pseudoscorpions.
- Flies, beetles and millipedes are all eaten by soil flatworms.
- Worms are particularly important in this process. They create tunnels in the compost which allows air and oxygen to circulate and nutrients to pass through the pile.

Figure 1–6. Functional Groups of Organisms in a Compost Food Web.



Biology of Compost

- All types of composting depend on the work of bacteria and fungi.
- Up to one billion bacterium are in a pea-sized amount of soil.
- These microbes digest organic matter and convert it into chemical forms that are usable by other microbes, invertebrates, and plants.
- The microbes and fungi that are critical to decomposition already exist in the soil!

Biology of Compost

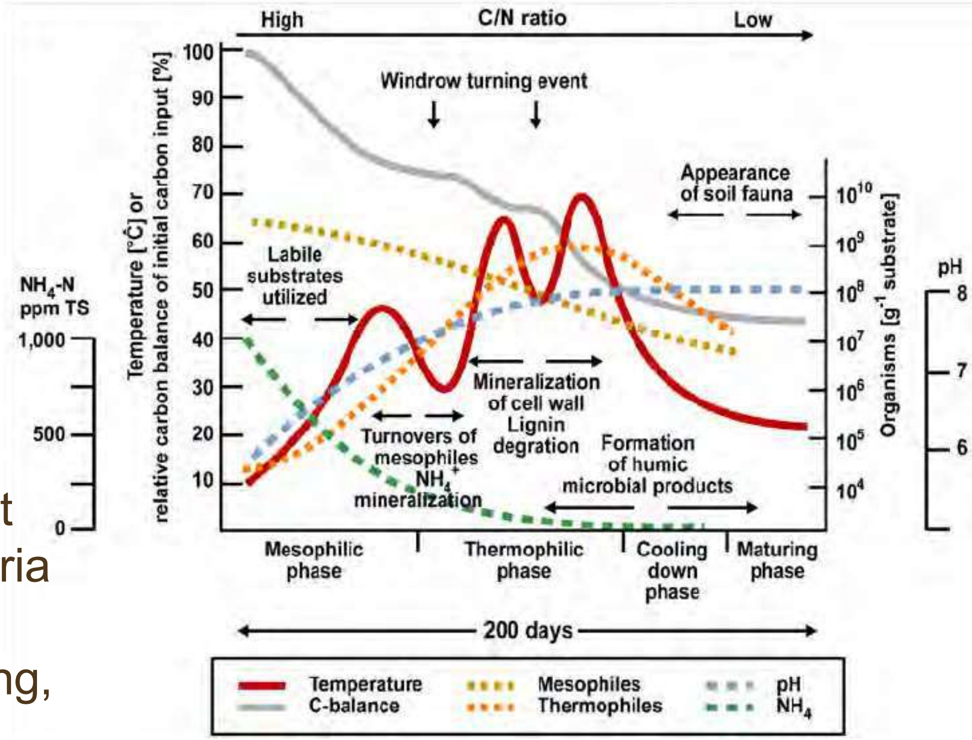
Mesophilic Bacteria

- Most active at 21°C/ 70°F to 32°C/90°F
- Give off enough heat for thermophilic bacteria to start work

Thermophilic Bacteria

- Incredibly tough bacteria, dominated by members of the genus Bacillus
- Most active at 46 – 60°C/ 115 to 140°F
- Work faster than other bacteria
- Specifically digest proteins and fats.

The thermophile stage provides the highest demand for oxygen. Most thermophilic bacteria will eventually die as oxygen is used up – unless sufficient oxygen is provided via turning, forced aeration or other methods.



Home Composting Tip:

Using a compost thermometer is a good way to see what stage your compost pile is at.

Home Composting Tip:

Turning your compost as it starts to cool off can produce another temperature peak and speed up the process. When the thermophilic phase is finished it won’t heat up again even when turned (unless new material is added and the process starts again).

Biology of Compost

Nitrifying Bacteria

- Play an important role in changing ammonium compounds to nitrates which are then accessible to plants.

Actinomycetes

- Another form of bacteria that breaks down complex, woody materials
- Prefer moderate temperatures and produce long threadlike filaments which stretch throughout the compost.
- Make up 5% of compost
- Release carbon, nitrogen and ammonia, making them available for plants.
- As a side note, actinomycetes are the origin of almost half of our antibiotics! The antibiotics they release kill off some of the other bacteria during the maturation phase of a compost pile.

Biology of Compost

Fungi

- Molds and yeasts
- Break down many complex plant polymers including cellulose.
- Attack organic residues that are too dry, acidic, or low in nitrogen for bacterial decomposition.
- Secrete digestive enzymes onto the food, and then they absorb the products of extracellular digestion.
- Fungal species are predominantly mesophilic (cooler phase)

Home Composting Tip

Reducing the size of the materials added can play a major role in speeding up the composting process. This is especially helpful with woody material. Pieces of cardboard, twigs or small branches should be shredded or broken into smaller bits, before being added to the compost pile.

Biology of Compost

Moisture vs. Oxygen

- If the thin films of water surrounding individual particles dry out the microorganisms that decompose inorganic matter will become inactive.

but

- If there's too much water in the compost pile, it is difficult for microorganisms to access oxygen

TIPS

- A moisture content of 50-60% is generally considered optimum
- Often the materials that are high in nitrogen are very wet, and those that are high in carbon are dry.
- Lowering moisture content from 66% to 61% has been shown to help increase the temperature of a compost pile from 55℃ to over 75℃.

Home Composting Tip

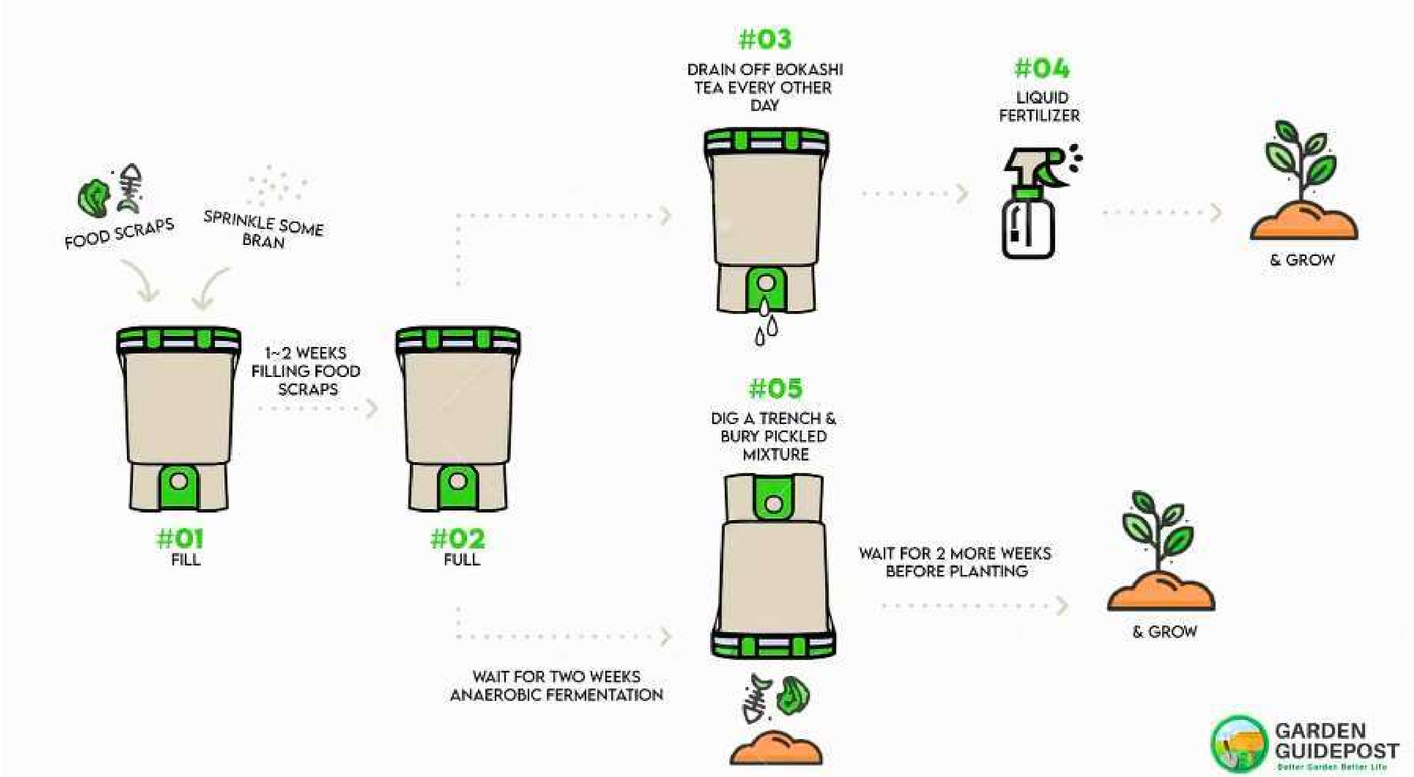
Take a handful of compost and squeeze it. It should have roughly the consistency of a squeezed-out sponge. If it’s wetter than that, add a dry material such as shredded paper or torn-up cardboard to soak up the excess moisture. If it’s too dry, you can add moisture when turning, for example.

Bokashi

- While fairly ‘new’ to the US, Bokashi was ‘invented’ in Japan in 1980s.
- Local Bokashi expert Matt Arthur (BLH Farms)
- The process uses a mix of bacteria to pre-digest waste matter anaerobically in a process that eliminates odors and decreases composting time
- Food waste materials are layered with Bokashi bran and pressed tightly into a container to sit 2-3 weeks

- The Bokashi bran contains EM1, (Effective Microorganisms1): a mix of bacteria (lactobacillus) and yeast. These have grown/fermented on a dry carbon source (bran/rice hulls/saw dust) then dried for storage.

Bokashi



Bokashi composting process

Bokashi

To finish the process, dig a hole, put Bokashi in and in 3-5 weeks = decomposed completely to soil

- Can put directly into the garden (in trench) or next to a tree (in a hole) - these allow you to put the compost at the root zone - where plants NEED it.
- NO need to worry about critters digging it up - smells like pickled veg and is not appealing to animals
- In addition to the completely decomposed compost in a few weeks, you are adding beneficial bacteria to enrich the soil.
- You can also add it to your ‘regular’ hot compost pile. It will decompose quickly, heating up evenly.

Bokashi

- The EM bacteria in the anaerobic environment prevent the production of ammonia.
- Proteins are metabolized in a way to generate amino acids which can be absorbed directly by plants.
- There is no production of CO_2, rather, cellulose is broken down to glucose and small sugar molecules which plants and other microorganisms can absorb and use directly.
- Leachate from the bucket also contains beneficial bacteria - dilute and water plants or add to garden soil.
- Adding microorganisms to the soil will help feed protozoans and worms which increase in number and create a healthier ecosystem.

Vermicomposting

- Worms convert food waste and other organic materials to a nutrient-rich compost
- Can be done indoors - pantry, utility room, under a table or desk, basement, garage
- Outdoors - prefer temps 55-77 degrees, north side of house or shed better, keep out of wind and rain
- Bedding - shredded newspaper, shredded corrugated cardboard or straw, NO glossy paper

Vermicomposting

- Space saving style of composting
- Done in a bin/s
- 1 cubic foot of space for each pound of food waste
- Red wiggler worms, not earthworms

Vermicomposting

- Red worms (aka red wigglers, Eisenia fetida / andrei) are native to Europe
- Eat at the interface between leaf litter and soil
- NOT soil-living worms. They might live in a leaf-litter layer but would not thrive there.

*Invasiveness is not likely to be an issue, but best not to release to the world when you are done. Research is on-going to try to understand the potential for these to alter a local ecosystem.

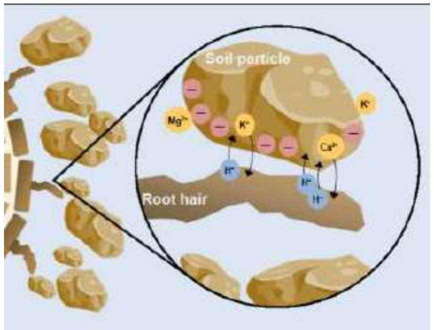
Comparison of 3 Composting Techniques

	Hot Compost pile	**Bokashi**	**Worms**
What to add (*never fats, feces, dairy)	No meat, fish bones	Anything *	No citrus, alliums, spicy peppers
How big are bits?	Smaller = better	Smaller = better	Smaller = better
Where to keep it	Outside - always	In kitchen	In kitchen
Winter?	Freeze - inactive	Works as usual	Works as usual
Turn?	YES!	No – pack solid	No, cover with newspaper
Monitor temperature?	YES!	no	no
Additives?	Brown/green balance	EM1 on dry carbon	newspaper
When done?	Looks like soil, no observable food, good smell	Looks like dried out food; needs 3-4 weeks 'in soil' to 'finish'	Looks like soil, no observable food, good smell
Is it working?	Smell, temp and texture	Smell/exudate	Visual – food gone
How to use	Screen and top dress or work in – best used outdoors*	Mix with soil to finish– if buried, is already in root zone	Screen and top dress – good for indoor plants
Worry about	4-legged critters raiding	Nothing!	Nothing (escapees?)
SCIENCE			
What is the active component	Bacteria, insects, worms, that live in the soil	EM1 – bacteria	Living red worms
oxygen	REQUIRED	NOT in bucket, Finish outside = OK	REQUIRED
pH	Starts at ~5 goes UP to ~7	Starts at 5 goes DOWN to ~3, then back to ~7 when finished in soil	Food at 5, worms convert to ~7

The Soil Connection

1: Compost Improves CEC

- Improves soil's ability to hold nutrients by increasing soil cation exchange capacity (CEC)

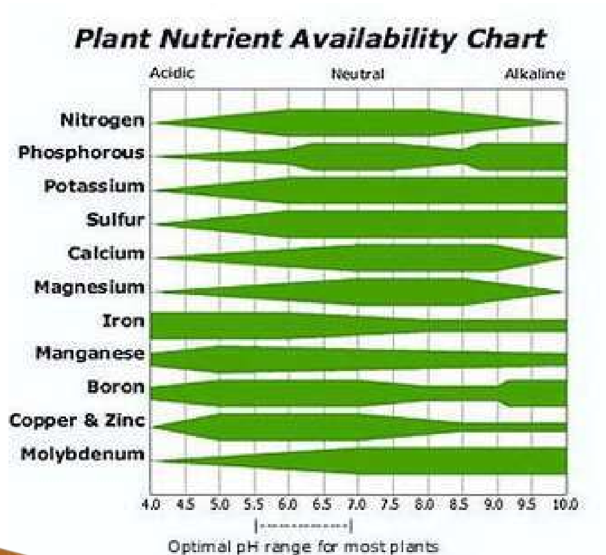


- Delivers nitrogen, phosphorus, and potassium
- Nutrients found in compost are released slowly as the compost continues to decompose, reducing nutrient movement off site.

The Soil Connection

2: Compost Balances pH

- Each specific plant species requires a specific pH range.
- Different soil nutrients are more available to plants at specific pH ranges.



The Soil Connection

3: Compost Suppresses Weeds, Pests and Disease

- Plants are more vulnerable to predation and disease when nutrients are imbalanced
- Weeds often grow in imbalanced nutrient ecosystems.
- Compost helps vegetation stand up to pests by balancing nutrients
- Plant diseases fare worse in compost due to the elevated temperatures required for development of compost.

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