The Biology of Composting

Mark King, Sustainability Division
mark.a.king@maine.gov
Systems Covered...

• First We’ll Discuss Composting
• Then...Digestion—Later on...
What is Composting?

• A biological process that *transforms* raw organic materials into a nutrient rich, biologically-stable soil additive suitable for plant and crop use.
Stages of Organic Matter Transformation

- Decomposition
- Humification
- Immobilization
- Mineralization
Factors Directly Impacting Microbial Activity

- Temperature
- C:N ratio
- Oxygen content (porosity)
- Moisture content
- pH
- Particle size
Microbial Classification

Based on two factors:

Oxygen consumption

- **Aerobes** (use \(O_2\), largest population)
  - Facultative-use \(O_2\), but can swap
  - Obligate-use \(O_2\) only!
- **Anaerobes** (mostly killed or inhibited by \(O_2\), but can be facultative)
Anaerobic vs Aerobic Composting

Anaerobic:
- Low oxygen
- Inefficient
- High odors

Aerobic:
- High oxygen
- Efficient
- Low odors
Microbial Classification (cont.)

Temperature range

• Mesophiles (function at 50-110 °F)
  – Initiate compost process
  – Replaced by thermophiles as temperature increases
  – Re-colonize compost during curing phase

• Thermophiles (function at 110-160 °F)
  – Do most of active composting
Phases of Aerobic Composting

- **Active Phase**
  - Mesophilic
  - Thermophilic

- **Curing Phase**

Temperature (F)

Weeks of Composting

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<th>Weeks of Composting</th>
<th>2</th>
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<td>Temperature (F)</td>
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Aerobic Composting and Temperature

- Active composting occurs in the temperature range of 50°F to 160°F.

- Pile temperature may increase above 140°F but this is too hot for most bacteria and decomposition will slow until temperature decreases again.

Remember, compost pile heat is the direct result of microbial metabolism!
So...What is a C:N Ratio? (Brown : Green Ratio)

• Supply of total carbon compared to total nitrogen in compost feedstock
• If C:N is too high the compost process will slow
• If C:N is too low, more likely to lose nitrogen as ammonia gas or in leachate
• Ideal initial C:N mixture range is 20 – 30:1
Oxygen Content

• Need oxygen for most efficient process
• 21% oxygen in air
• 5%-10% is optimal for compost process
  – <5% process slows remarkably
• As pile heats more oxygen will be consumed by microbes
Compost Moisture

- Too dry
- Optimal conditions for microbes
- Too wet

Compost Moisture (%):

- 0%
- 50-65%
- 100%
FIGURE 2.10. The relationship of free air space to water and particles in a composting media.
pH (log scale)

- Fungi (5.5-8.0)
- Compost
- Bacteria (6.0 – 7.5)

- Apples (3.0)
- Milk (6.5)
- Ammonia (12.0)
Particle Size

Microbial activity is related to availability of food source.
Does Texture Really Matter?
Moisture Distribution vs. Air Flow Through Compost Pile
Mixing

Or...
Compost Systems
Maryland Bin System

• Inexpensive to build and operate
• Fast turn around
• Designed for small scale applications
• Layering and turning can be labor intensive
• Produces crude compost suitable for crop use
EXISTING LITTER STORAGE BUILDING

CONCRETE

LITTER STORAGE TO CONFORM TO MANURE EQUIPMENT

CAP WITH DOUBLE LAYER OF LITTER

LEAVE DRY

DEAD POULTRY

STRAW

LITTER/CAGE

DEAD POULTRY

STRAW

LITTER/CAGE

STRAW

DOUBLE LAYER OF LITTER/CAGE AS BASE

CONCRETE FLOOR
Static Pile

- Compost ingredients simply stacked into a pile and left to decompose
- Least labor intensive, piles turned 4X/yr
- Least expensive method with minimal equipment (front-end loader)
- Piles require long time to finish composting
- Piles must be thoroughly mixed to ensure aerobic composting
- Potential for odor generation
- Usually used for leaves and manure
Aerated Static Pile

• Initial mixture critical, must be homogeneous with good porosity

• Odor Control
  – Outer filter layer
  – Positive vs. negative aeration
  – Enclose w/biofilter

• Higher capital cost than passive system due to blowers, monitoring, and man power

• Most common biosolid application in Maine
Turned Windrow

• Compost is formed into long, narrow piles (windrows) and then subsequently turned at regular intervals
• Typical cross-section is 3-6 feet high by 10-12 feet wide
• Turning provides aeration, rebuilds porosity, and breaks down ingredients
• Requires temperature monitoring and specialized equipment
Front-End Loader vs. Turner

- Front-end loader works well for small scale operations (<500 cubic yd/yr)
  - >500 cubic yd/yr loader tends to be time intensive, whereas turner can accomplish task in half the time

- Turner physically agitates ingredients, loader tends to form balls of compost

- Turner represents additional cost, as it requires a tractor to run. Most facilities have front-end loader
In-Vessel

- Most expensive option for composting - both capital and operational
- Allows all facets of operation to be enclosed
- Odors are captured and treated in biofilter
- Allows you to optimize the process through continuous monitoring feedback and process control
- Fastest compost time
- Required routine maintenance
X-Act Composting Systems
All Together Now...

Optimal range

- C:N ratio—20 to 30:1
- % moisture—50-65%
- Oxygen—5-10%
- pH—5.5-8.2 (acceptable)
- Particle size—1/4 to 3 inches (largest dimension)
- Temperature—thermophilic (110 -160 ° F)
A brief word on Digestion...

- Methane burned for cooking or heating
  - Carbon dioxide released to the atmosphere
- Manure
  - Anaerobic decomposition releases methane
  - Biogas Generator
  - Carbon dioxide absorbed by plants through photosynthesis
**Advantage of anaerobic processes**

1. Less energy requirement as no aeration is needed

   *0.5-0.75 kWh energy is needed for every 1 kg of COD removal by aerobic processes*

2. Energy generation in the form of methane gas

   *1.16 kWh energy is produced for every 1 kg of COD fermented in anaerobic process*

3. Less biomass (sludge) generation

   *Anaerobic process produces only 20% of sludge compared with aerobic process*

Soluble BOD 1 kg

Aerobic process

- CO$_2$ + H$_2$O
- 0.5 kg
- New biomass
- 0.5 kg

Biodegradable COD 1 kg

Anaerobic process

- CH$_4$ gas
- > 0.9 kg
- New biomass
- < 0.1 kg
...Advantages of anaerobic processes

1. Less nutrients (N & P) required

   Lower biomass synthesis rate also implies less nutrients requirement: 20% of aerobic

2. Application of higher organic loading rate

   Organic loading rates of 5-10 times higher than that of aerobic processes are possible

3. Space saving

   Higher loading rates require smaller reactor volumes thereby saving on disposal cost
Limitations of anaerobic processes

1. Long start-up time

   Because of lower biomass synthesis rate, it requires a longer start-up time to attain a biomass concentration

2. Long recovery time

   If an anaerobic system is subjected to disturbances either due to biomass wash-out, toxic substances or shock loading, it may take longer time for the system to return to normal operating conditions

3. Specific nutrients/trace metal requirements

   Anaerobic microorganisms, especially methanogens, have specific nutrients e.g. Fe, Ni, and Co requirement for optimum growth

4. More susceptible to changes in environmental conditions

   Anaerobic microorganisms especially methanogens are prone to changes in conditions such as temperature, pH, redox potential, etc.
5. Treatment of sulfate-rich wastewater

The presence of sulfate not only reduces the methane yield due to substrate competition, but also inhibits the methanogens due to sulfide production.

6. Effluent quality of treated wastewater

The minimum substrate concentration ($S_{\text{min}}$) from which microorganisms are able to generate energy for their growth and maintenance is much higher for anaerobic treatment systems. Anaerobic processes may not be able to degrade organic matter to the level to meet the discharge limits for ultimate disposal.

7. Treatment of high protein & nitrogen containing wastewater

The anaerobic degradation of proteins produces amines which are no longer able to be degraded anaerobically. Similarly, nitrogen remains unchanged during anaerobic treatment.
Picking The Right System

• Answer the feedstock questions
• Determine your annual production and end-uses
  – Compost product
  – Energy and digestate fertilizer
• Develop a financial/business plan
  – Capital for equipment, labor, storage, etc.
• View as many real-life situations as you can