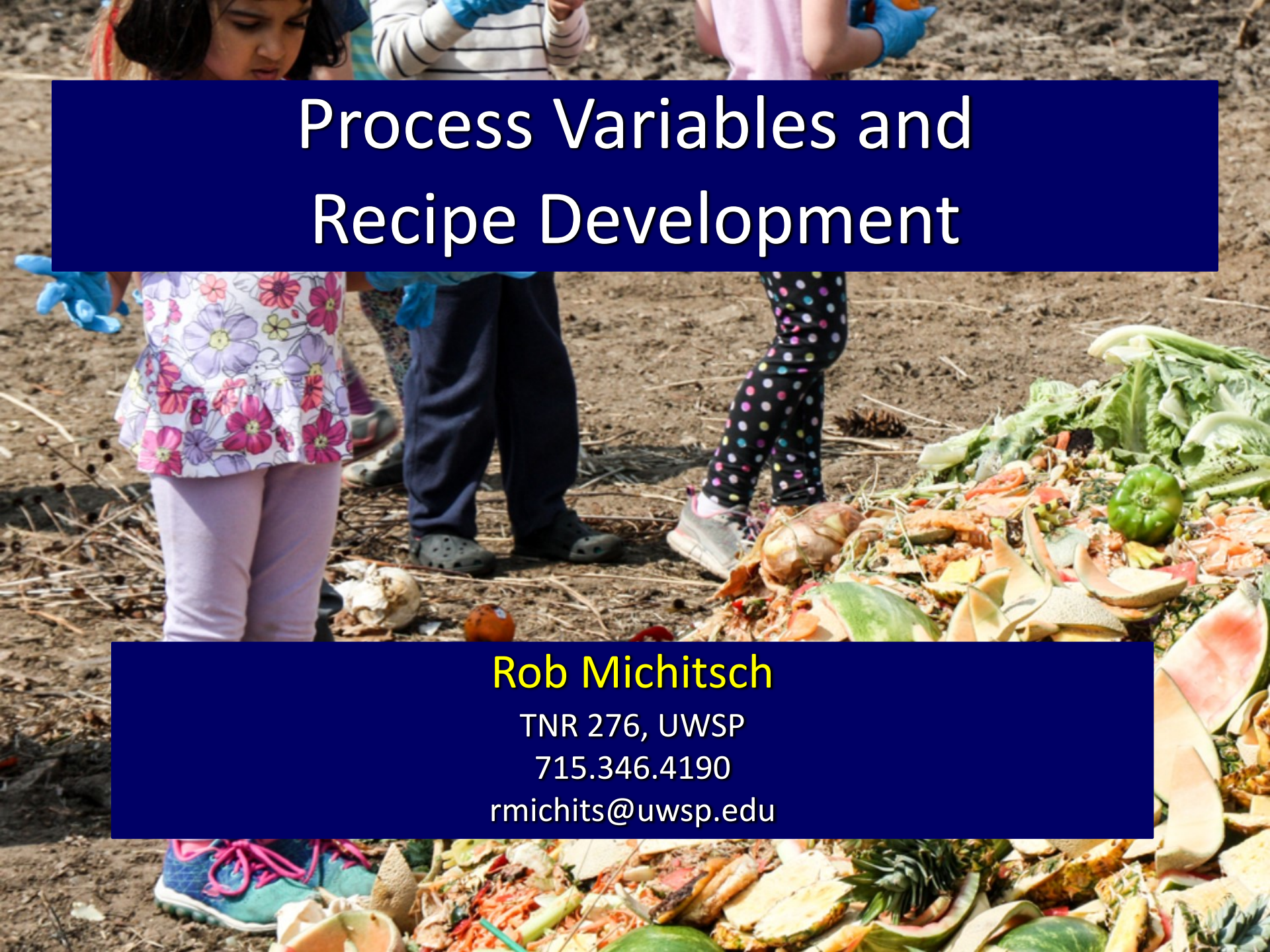

Process Variables and Recipe Development

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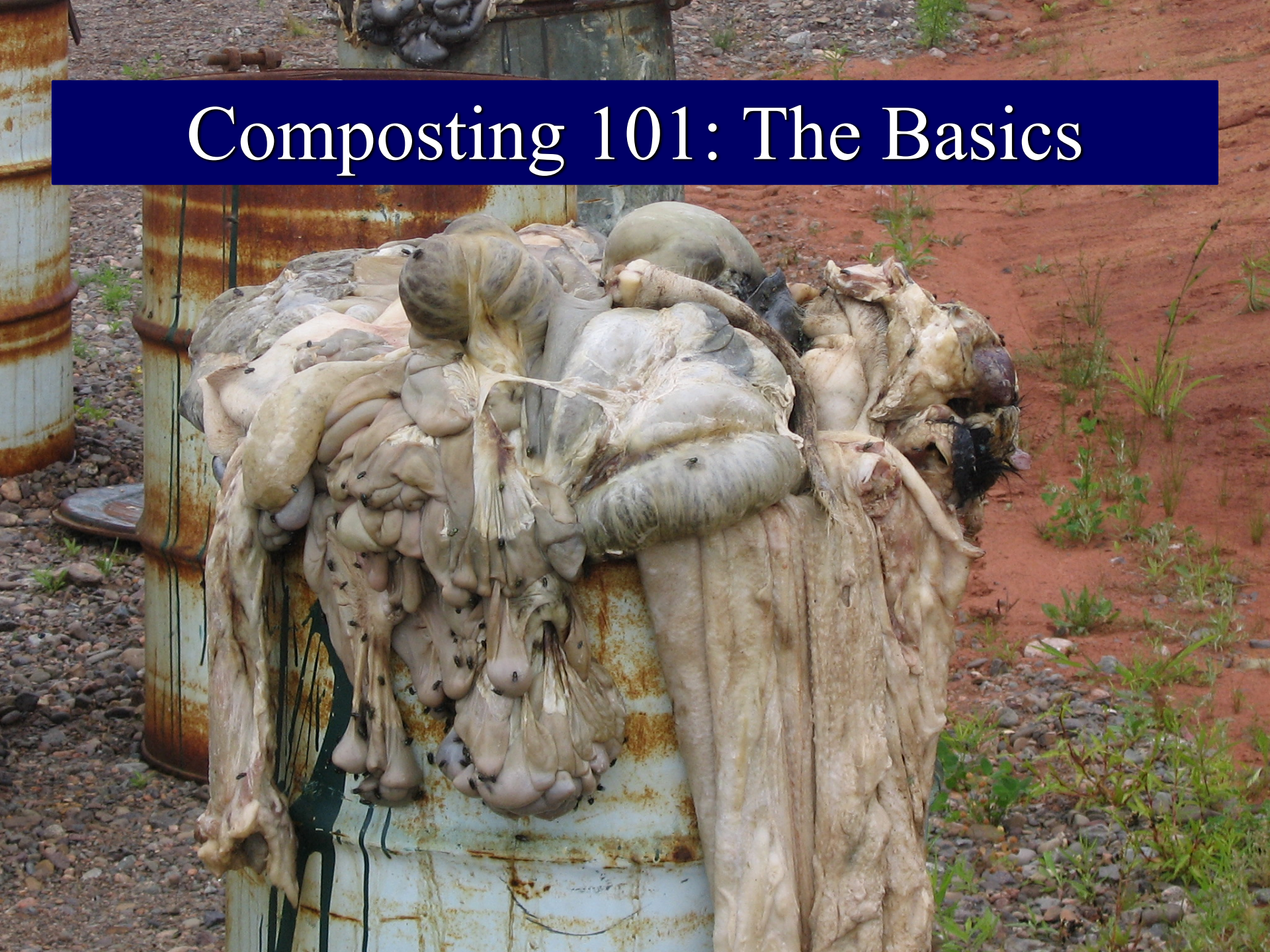
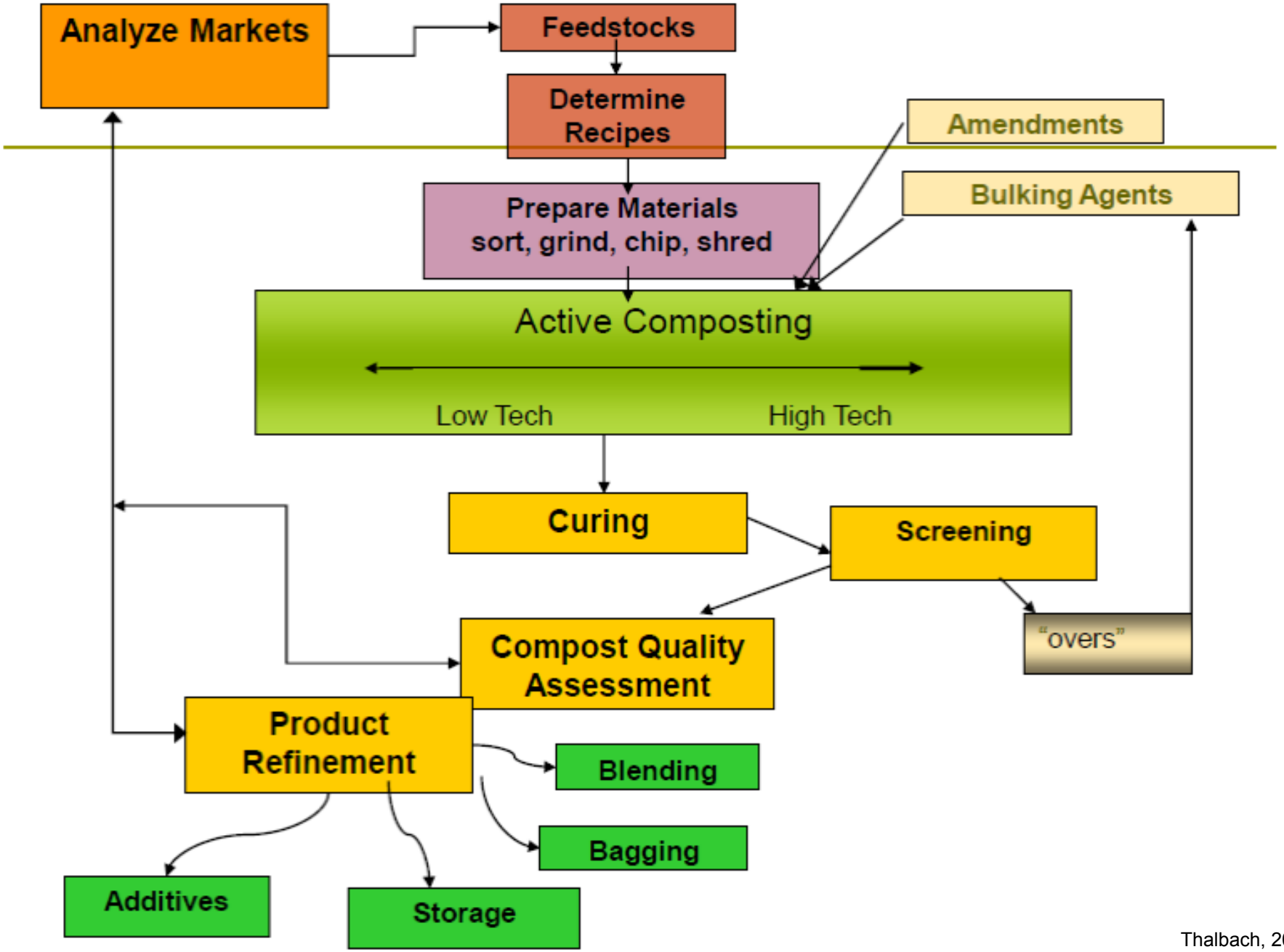

Composting 101: The Basics

Compost Process Flow Chart



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Introduction

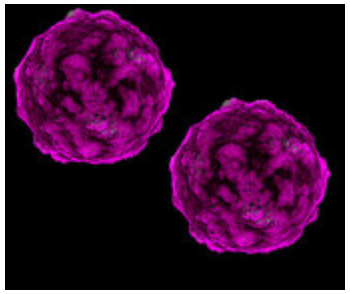
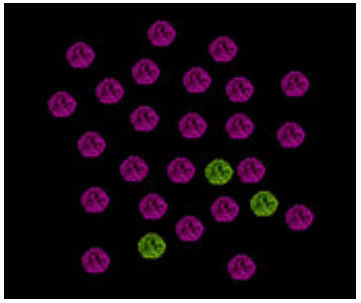
Compost:

- Well decomposed OM when added to soil improves soil health & plant productivity

Composting (Compost Manufacturing):

- Procedure to enhance the natural aerobic or anaerobic decomposition of OM to make the process more efficient

Composting Process

OM_b +  → OM_t + 

b = biodegradable

t = transformed (humus-like)

Composting Basics

Optimizing the microbial environment

- Nutrients
- Air (O_2)/porosity
- Moisture
- Particle size
- Bulk Density

Composting Basics

Optimizing the microbial environment

Nutrients: Carbon (C) & Nitrogen (N)

- C:N ~ 20-40 → 30
- > optimum = insufficient nitrogen
- < optimum = nitrogenous gas ($NH_3/N_2/N_2O$) losses

C:P ~ 100-150

C:S ~ 200-300

Material (feedstock)	C:N	Moisture %
Plant Residues		
Corn stalks	60-73	12
Fruit wastes	20-49	62-88
Vegetable produce	15-20	87
Animal Residues		
Crab wastes	5	47
Fish wastes	4	76
Poultry carcasses	5	65
Shrimp wastes	3	78
Manures		
Broiler litter	12-15	22-46
Beef	11-30	67-87
Dairy	13	83
Horse	22-50	59-79
Layers	3-10	62-75
Sheep	13-20	60-75
Swine	9-19	65-91
Straw, Hay, Silage		
Corn silage	38-43	65-68
Straw	48-150	4-27
Wood and Paper		
Sawdust	200-750	19-65

Composting Basics

Optimizing the microbial environment

Air (oxygen)

- < 5% oxygen = anaerobic conditions

- porosity ~ 35-50%
  - > 50% = high heat loss
  - < 35% = anaerobic conditions

> 40 lbs/ft^3 = anaerobic conditions

Composting Basics

Optimizing the microbial environment

Anaerobic (vs Aerobic)

- less efficient
- incomplete OM decomposition
- obnoxious odors
- toxics or toxin generation

Composting Basics

Optimizing the microbial environment

Moisture: ~ 40-60%

- > optimum = low O_2, compaction, slow decomposition & odors
- < optimum = inhibited decomposition

→ hand squeeze test & other methods

Material (feedstock)	C:N	Moisture %
Plant Residues		
Corn stalks	60-73	12
Fruit wastes	20-49	62-88
Vegetable produce	15-20	87
Animal Residues		
Crab wastes	5	47
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Sheep	13-20	60-75
Swine	9-19	65-91
Straw, Hay, Silage		
Corn silage	38-43	65-68
Straw	48-150	4-27
Wood and Paper		
Sawdust	200-750	19-65

Composting Basics

Optimizing the microbial environment

Particle size

- surface effects
- small particles = high surface area
- < 2” (ideal; mixed)

Composting Basics

Optimizing the microbial environment

Bulk density

> 40 lbs/ft^3 = anaerobic conditions

- 5 gallons of water weighs ~42 pounds

- Pounds of material in a 5-gallon pail multiplied by 40 equals bulk density of the material in units of pounds/$yard^3$

> 1080 lbs/yd^3 = anaerobic conditions

Feedstock Recipe Examples

Feedstock	Bulk Density (g/cm3)	Moisture Content (%)	C:N ratio
mature compost	0.74	42.89	638.00
active compost	0.53	84.64	117.71
2:1 sand:compost	1.22	18.92	12.41
bark product	0.35	58.75	47.82
wood chips	0.31	50.98	59.16
sand	1.51	2.86	226.00
grass	0.22	17.41	*12-25
weeds	0.23	237.24	*30-60
*fruit waste	*high	*75-95	*35
*vegetable waste	*high	*75-95	*13

*theoretical values

Formulas for Determining Composting Recipes by Weight

Formulas for an Individual Ingredient

Moisture content = % moisture content ÷ 100
Weight of water = total weight x moisture content
Dry weight = total weight – weight of water
= total weight x (1 – moisture content)
Nitrogen content = dry weight x (% N ÷ 100)
% carbon = % N x C:N ratio
Carbon content = dry weight x (% C ÷ 100)
= N content x C:N ratio

General Formulas for a Mix of Materials

$$\text{Moisture content} = \frac{\text{weight of water in ingredient a + water in b + water in c + ...}}{\text{total weight of all ingredients}}$$

$$\text{Moisture content} = \frac{(a \times m_a) + (b \times m_b) + (c \times m_c) + \ldots}{a + b + c + \ldots}$$

$$\text{C:N ratio} = \frac{\text{weight of C in ingredient a + weight of C in b + weight of C in c + ...}}{\text{weight of N in a + weight of N in b + weight of N in c + ...}}$$

$$\text{C:N ratio} = \frac{[\%C_a \times a \times (1-m_a)] + [\%C_b \times b \times (1-m_b)] + [\%C_c \times c \times (1-m_c)] + \ldots}{[\%N_a \times a \times (1-m_a)] + [\%N_b \times b \times (1-m_b)] + [\%N_c \times c \times (1-m_c)] + \ldots}$$

Symbols:

a = total weight of ingredient *a*
b = total weight of ingredient *b*
c = total weight of ingredient *c*
$m_a, m_b, m_c, \ldots$ = moisture content of ingredients *a, b, c, ...*
$\%N_a, N_b, N_c, \ldots$ = % nitrogen of ingredients *a, b, c, ...* (% of dry weight)
$\%C_a, C_b, C_c, \ldots$ = % carbon of ingredients *a, b, c, ...* (% of dry weight)

Shortcut Formulas for Only Two Ingredients
(For example, manure plus straw)

1. Required amount of ingredient *a* per pound of *b* based on the desired moisture content:

$$a = \frac{m_b - M}{M - m_a}$$

Then check the C:N ratio using the general formula.

2. Required amount of ingredient *a* per pound of *b* based on the desired C:N ratio:

$$a = \frac{\%N_b}{\%N_a} \times \frac{(R - R_b)}{(R_a - R)} \times \frac{(1 - m_b)}{(1 - m_a)}$$

Then check the moisture content using the general formula.

Symbols:

a = pounds of ingredient *a* per pound of ingredient *b*
M = desired mix moisture content
m_a = moisture content of ingredient *a*
m_b = moisture content of ingredient *b*
R = desired C:N ratio (by weight) of the mix
R_a = C:N ratio (by weight) of ingredient *a*
R_b = C:N ratio (by weight) of ingredient *b*

posting web pages. Information on how to obtain either of the programs can be found in the reference section at the end of t book.

Converting Weight Ratios to Volume Ratios

Unless all feedstock ingredients are weighed prior to mixing (wh is not usually the case), the recipe proportions calculated on a wei basis must be converted into volumes of material. Otherwise, buc operators (who handle materials on a volume basis) will not kn how many loads of each ingredient to mix. This weight-to-volu conversion is especially necessary when mixing materials w widely different bulk densities, such as when mixing liquid or se solid manures with loose, bulky materials such as straw or hay

A simplified table for converting weight ratios into volume rat for material mixing is presented in table 2-4 (page 42). In this tal a bulk density factor is used to convert the weight ratio of e ingredient in a compost recipe into a volume ratio. An illustrat example is presented below.

EXAMPLE: Converting Weight Ratios to Volume Ratios

Problem: What is the volume ratio of a compost recipe that ha calculated weight ratio of 1:3:2, with ingredients correspondin the following bulk densities?

Ingredient A (primary) — 900 pounds per cubic yard
Ingredient B (secondary) — 700 pounds per cubic yard
Ingredient C (third) — 1,900 pounds per cubic yard

Solution: The first ingredient listed in the weight ratio is alw the primary ingredient. Use table 2-4 (page 42) to convert all o ingredients to a volume basis based on the primary ingredient. conversion, set up the following worksheet:

Ingredient	Bulk density (lbs/cu yd)	Calculated recipe (weight basis)		Relative bulk density factor (from table 2-4)		Recipe ratio (volume ba
A (primary)	900	1.0	x	1.00	=	1.0
B (secondary)	700	3.0	x	1.29	=	3.87
C (third)	1,900	2.0	x	0.47	=	0.94

Answer: The volume recipe to be used for mixing ingredient B, and C is approximately 1:4:1.

Check: To field-verify the accuracy of a calculated recipe as mi reverse the above procedure by dividing the actual volume r used on-site by the relative bulk density factors from table 2-4 (p 42), as follows:

Ingredient	Bulk density (lbs/cu yd)	Volume ratio, as mixed		Relative bulk density factor (from table 2-4)		Actual reci as mixed (weight ba
A (primary)	900	1	÷	1.00	=	1.00
B (secondary)	700	4	÷	1.29	=	3.10
C (third)	1,900	1	÷	0.47	=	2.13

Table 3.3
Formulas for determining composting recipes

Formulas for an individual ingredient

Moisture content = % moisture content ÷ 100
Weight of water = total weight x moisture content
Dry weight = total weight – weight of water
= total weight x (1 – moisture content)
Nitrogen content = dry weight x (% N ÷ 100)
% carbon = % N x C:N ratio
Carbon content = dry weight x (% C ÷ 100)
= N content x C:N ratio

General formulas for a mix of materials

$$\text{Moisture content} = \frac{\text{weight of water in ingredient a + water in b + water in c + ...}}{\text{total weight of all ingredients}}$$

$$= \frac{(a \times m_a) + (b \times m_b) + (c \times m_c) + \ldots}{a + b + c + \ldots}$$

$$\text{C:N ratio} = \frac{\text{weight of C in ingredient a + weight of C in b + weight of C in c + ...}}{\text{weight of N in a + weight of N in b + weight of N in c + ...}}$$

$$= \frac{[\%\, C_a \times a \times (1 - m_a)] + [\%\, C_b \times b \times (1 - m_b)] + [\%\, C_c \times c \times (1 - m_c)] + \ldots}{[\%\, N_a \times a \times (1 - m_a)] + [\%\, N_b \times b \times (1 - m_b)] + [\%\, N_c \times c \times (1 - m_c)] + \ldots}$$

Symbols

a = total weight of ingredient *a*
b = total weight of ingredient *b*
c = total weight of ingredient *c*
$m_a, m_b, m_c, \ldots$ = moisture content of ingredients *a, b, c, ...*
$\%\, N_a, N_b, N_c, \ldots$ = % nitrogen of ingredients *a, b, c, ...* (% of dry weight)
$\%\, C_a, C_b, C_c, \ldots$ = % carbon of ingredients *a, b, c, ...* (% of dry weight)

Shortcut formulas for only two ingredients (for example, leaves plus grass clippings)

1. Required amount of ingredient *a* per pound of *b* based on the desired moisture content:

$$a = \frac{m_b - M}{M - m_a}$$

Then check the C:N ratio using the general formula.

2. Required amount of ingredient *a* per pound of *b* based on the desired C:N ratio:

$$a = \frac{\%\, N_b}{\%\, N_a} \times \frac{(R - R_b)}{(R_a - R)} \times \frac{(1 - m_b)}{(1 - m_a)}$$

Then check the moisture content using the general formula.

Symbols

a = pounds of ingredient *a* per pound of ingredient *b*
M = desired mix moisture content
m_a = moisture content of ingredient *a* (for example, amendment)
m_b = moisture content of ingredient *b* (for example, manure)
R = desired C:N ratio of the mix
R_a = C:N ratio of ingredient *a*
R_b = C:N ratio of ingredient *b*

Sample Calculation: Recipe Proportions, Moisture Content, and C:N Ratio

A farm has chicken manure that usually has a moisture content of 70% when removed from the buildings. Both the moisture and the nitrogen contents are too high for optimum composting, and the manure needs greater porosity. Sawdust is available with a moisture content of 35%. Assume that the C:N ratio of the manure is not more than 10:1 with a nitrogen content of 6% and that the sawdust has a C:N ratio of about 500:1 and a nitrogen content of 0.11%. Determine an appropriate composting recipe.

Blending materials to the desired moisture content

weight of water = total weight x moisture content
weight of *dry matter* = total weight – weight of water
weight of nitrogen *(N)* = weight of dry matter x (%N ÷ 100)
weight of carbon *(C)* = C:N ratio x weight of N

1 pound of wet manure contains

Water	1 pound x 0.7	=	0.7 pounds
Dry matter	1 pound – 0.7	=	0.3 pounds
N	0.3 x 0.06	=	0.018 pounds
C	0.018 x 10	=	0.18 pounds

1 pound of damp sawdust contains

Water	1 pound x 0.35	=	0.35 pounds
Dry matter	1 pound – 0.35	=	0.65 pounds
N	0.65 x 0.0011	=	0.00072 pounds
C	0.00072 x 500	=	0.36 pounds

The moisture content should not exceed 60%. For 1 pound of wet manure:

$$MC = \frac{\text{weight of water in manure + weight of water in sawdust}}{\text{total weight}}$$

$$MC = 60\% = 0.6 = \frac{0.7 + (0.35 \times \mathbf{S})}{1 + \mathbf{S}}$$

where **S** is the amount of sawdust needed

$$MC = 0.6\,(1 + \mathbf{S}) = 0.7 + 0.35 \times \mathbf{S}$$
$$0.25\,\mathbf{S} = .1$$
$$\mathbf{S} = 0.4 \text{ pounds sawdust per pound of manure}$$

Note: S is calculated from the above equation using a little algebra. Since there are only two ingredients, it is also possible to solve for S using the shortcut formulas in table 3.3 (page 19). In this case, S would be the same as *a* in table 3.3 (page 19). The manure would be represented by *b*. Therefore:

$$S = a = \frac{m_b - M}{M - m_a} = \frac{0.70 - 0.60}{0.60 - 0.35}$$

S = 0.4 pounds of sawdust per pound of manure

Check the C:N Ratio

$$C{:}N = \frac{C_{manure} + C_{sawdust}}{N_{manure} + N_{sawdust}} = \frac{0.18 + (0.4 \times 0.36)}{0.018 + (0.4 \times 0.00072)} = 17.7$$

Since this ratio is near the low end of the acceptable range and the moisture content is at the high end (60%), the amount of sawdust should be increased to raise the C:N ratio.

Blending materials to the desired C:N ratio

Assume that wheat straw is available which has a moisture content of 15%, a C:N ratio of 128:1, and a nitrogen content of 0.3%. Estimate the amount of straw needed with the chicken manure to obtain a mix C:N ratio of 25.

1 pound of wheat straw contains

Water	1 pound x 0.15	=	0.15 pounds
Dry matter	1 pound – 0.15	=	0.85 pounds
N	0.85 x 0.003	=	0.0026 pounds
C	0.0026 x 128	=	0.33 pounds

The desired C:N ratio is 25:1. For 1 pound of wet manure:

$$C{:}N = 25 = \frac{(\text{C in 1 pound manure}) + \mathbf{S} \times (\text{C in 1 pound straw})}{(\text{N in 1 pound manure}) + \mathbf{S} \times (\text{N in 1 pound straw})}$$

where **S** is the amount of straw needed

$$25 = \frac{0.18 + \mathbf{S} \times (0.33)}{0.018 + \mathbf{S} \times (0.0026)}$$

S = **1** pound of straw per pound manure

Note: Again, since only two ingredients are involved, the shortcut formulas of table 3.3 (page 19) can also be used to solve for S.

$$S = a = \frac{\%N_b}{\%N_a} \times \frac{(R - R_b)}{(R_a - R)} \times \frac{(1 - m_b)}{(1 - m_a)} = \frac{6\%}{0.3\%} \times \frac{(25 - 10)}{(128 - 25)} \times \frac{(1 - 0.70)}{(1 - 0.15)}$$

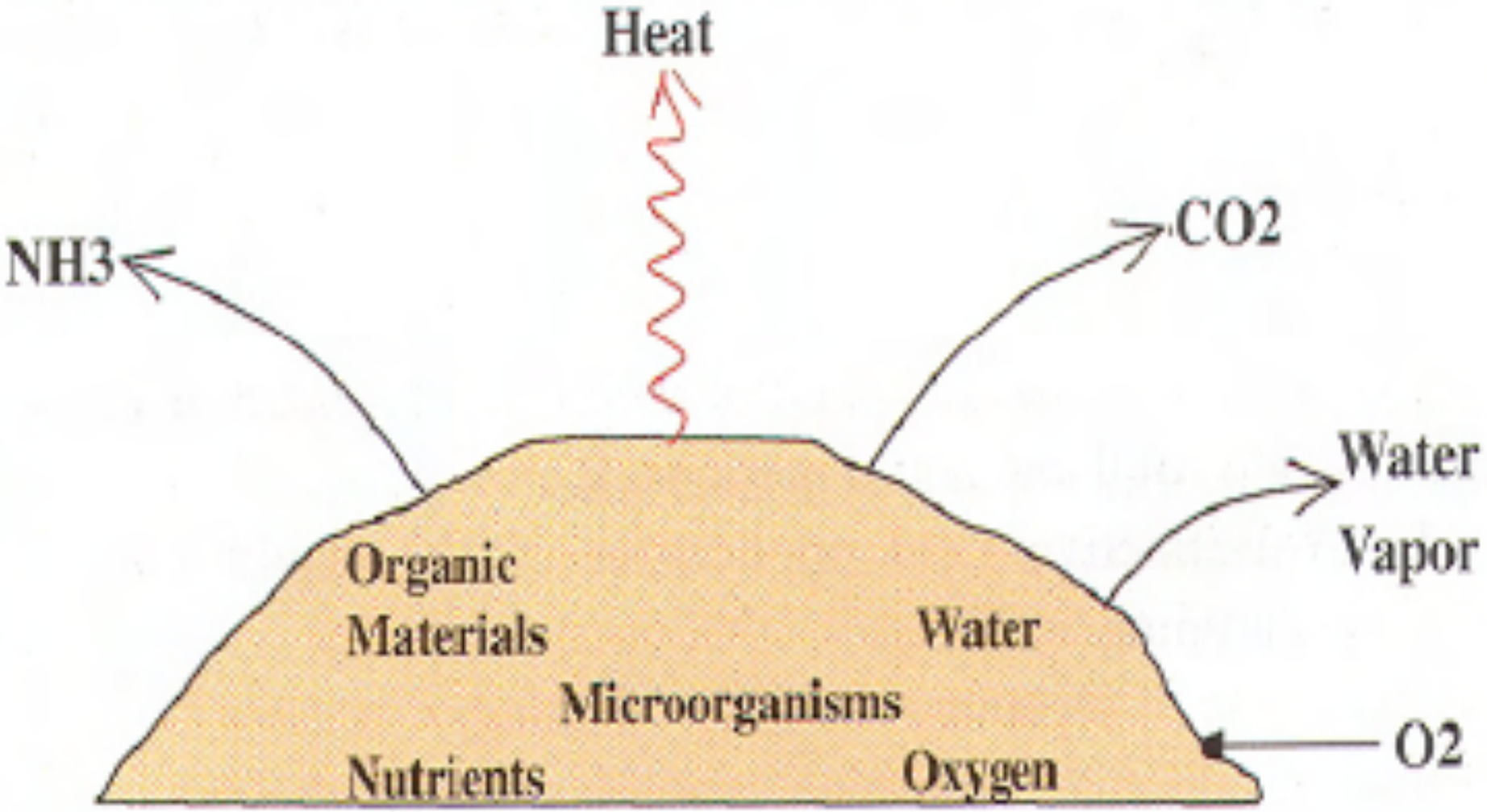
S = 1 pound

Check the mix moisture content

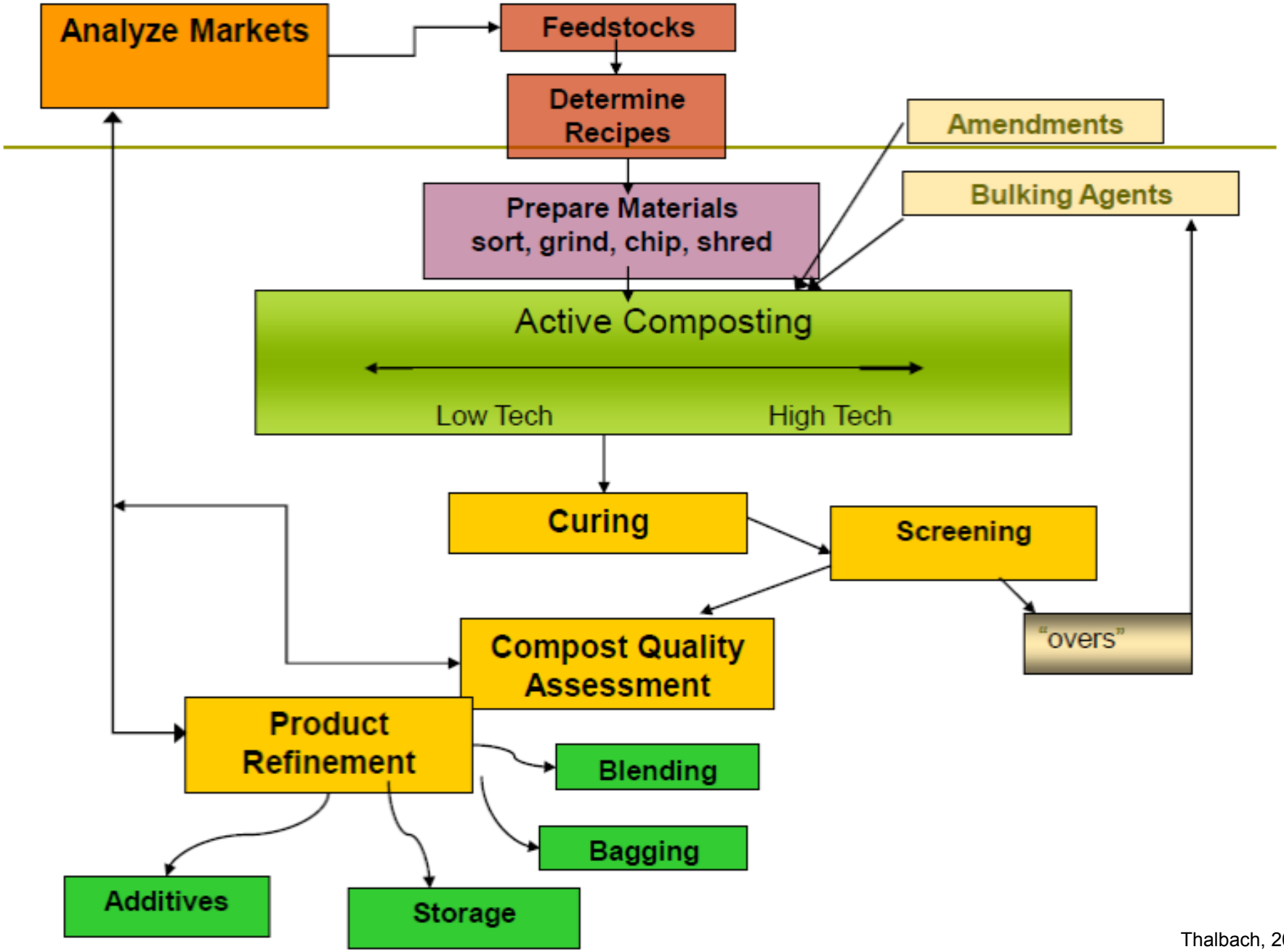
$$MC = \frac{\text{weight of water in 1 pound manure} + \text{weight of water in 1 pound straw}}{\text{total weight}}$$

$$MC = \frac{0.7 + (1 \times 0.15)}{2} = 0.425 = 42.5\%$$

This moisture content is low for a starting mix. Options: Use these proportions and hope for rain to wet the pile (risky); add water to the mix directly; decrease the amount of straw and accept a lower C:N ratio; add another damp material to the mix; or replace the straw with a wetter amendment.


Heat
NH3
CO2
Water
Vapor
Organic
Materials
Water
Microorganisms
O2
Nutrients
Oxygen

Compost Process Flow Chart



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It’s Trial and Error Sometimes!

Calculators

- https://puyallup.wsu.edu/soils/compost-mix-calculator/
- https://compostingtechnology.com/compost-calculator/
- https://compost.css.cornell.edu/download.html
- https://vtfoodcycle.com/news-resources/resource-library/compost-recipe-calculator