Developing a Recipe for Composting Livestock Manure

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Composting is the controlled breakdown of organic material by microorganisms that results in the production of carbon dioxide, water, heat and a relatively stable organic end-product. Microbes and weather breakdown organic materials naturally, although in nature this process is slow and may stop and start many times before decomposition is complete. The composting process, on the other hand, is accelerated and should generally progress at a predictable rate to produce a high-quality product in the least amount of time to meet product requirements.

Composting is an aerobic process meaning it requires oxygen. In addition to air, the microorganisms involved in composting also require water and nutrients, particularly carbon and nitrogen, and a hospitable environment. Under optimal conditions, composting proceeds through 3 phases: 1) the mesophilic, or moderate temperature phase that lasts for a couple of days; 2) the thermophilic, or high-temperature phase that lasts for a few days to several months; and 3) a cooling and maturation phase that lasts for several months.

The first task in developing a successful composting program is getting the right combination of ingredients – or the right recipe. This paper and presentation will focus on the development of a compost recipe. Also briefly discussed will be the management of the composting process.

Building the Compost Pile

There are five basic steps in building a compost pile. They are:

1. setting the particle size
2. setting the initial C:N ratio
3. setting the moisture content
4. blending the ingredients together
5. establishing the air-filled pore space

1. <u>Setting the Particle Size</u>

The first step in building a compost pile is establishing an optimum and uniform particle size for the compost mix. This is achieved during feedstock preparation. The purpose of setting the particle size is to ensure that all of the particles in the compost pile will be exposed to the correct mixture of air, nutrients and water. This will promote vigorous microbial activity by balancing the microbes' need for air with their need for food and water.

Small, uniform particles decompose more rapidly and at the same rate relative to each other compared to large particles. However, particles that are too small will pack together tightly and obstruct the movement of air through the material. Particles that are too large will decompose slowly and unevenly (if at all) and are hard to wet evenly. The target initial particle size is about 1-2 inches (25 to 50 mm). This is small enough to promote vigorous microbial activity, but still large enough to provide some structure to the pile and allow for proper aeration and wetting.

2. <u>Setting the Initial Carbon to Nitrogen Ratio (C:N Ratio)</u>

The second step in building a compost pile is establishing the correct proportions of each of the feedstocks that are required to achieve an optimum ***initial*** C:N ratio. Microbes require carbon (C) for energy and cell development and nitrogen (N) is needed for protein synthesis. The balance between carbon and nitrogen is critical in determining whether a material will decompose readily or not.
The initial C:N ratio can be set using the following formula:

$$\text{C:N Ratio} = \frac{\text{weight of biodegradable C}}{\text{weight of organic N + ammonium N + nitrate N}}$$

Carbon is measured as the weight of C in the biodegradable fraction of a feedstock. Nitrogen is the organic N, ammonium N and nitrate N.

The ideal ***initial*** C:N ratio should target about 30:1, however, initial C:N ratios can range from 25:1 to 40:1 depending on the characteristics of the feedstocks. Low C:N ratio compost is high in nitrogen – too much N may result in the loss of N through ammonia volatilization and may produce unwanted odours. High C:N ratio compost is high in carbon – too much carbon will result in slower decomposition and may result in a final product that immobilizes N when added to the soil.

The C:N ratio at the end of the process (or the final C:N ratio) is an indicator of product stability. Mature compost has a C:N ratio approaching 20:1 or less. This ensures that immobilization of nitrogen does not occur when added to soil. Soil has a C:N ratio of about 10:1.

The following example demonstrates how to calculate the proportions of each feedstock in order to achieve an initial C:N ratio of 30. The feedstocks that are available include chicken manure and sawdust.

In order to establish the blending rate of chicken manure to sawdust, the quantity of nitrogen in the feedstock and the C:N ratio of the feedstock must be known. This can be obtained from a basic compost analysis of a representative sample of each feedstock.

Feedstock Analyses Results:

	Chicken Manure	Sawdust
Moisture Content (%)	60	35
Nitrogen (%) dry weight basis	5	0.11
C:N Ratio	12:1	400:1

From the above basic feedstock analyses, the amount of water, dry matter, nitrogen and carbon can be calculated per pound of feedstock.

	Chicken Manure		Sawdust	
	Analyses	lb / lb manure	Analyses	lb / lb sawdust
Moisture	70	0.60	35	0.35
Dry Matter		0.4		0.65
Nitrogen	5	0.4 x 0.05 = 0.02	0.11	0.65 x 0.0011 = 0.000715
C:N Ratio	12:1		400:1	
Carbon		12 x 0.02 = 0.24		400 x 0.000715 = 0.286

Using the above analyses, the initial C:N ratio can be set at 30 and the quantity of each of the feedstocks required can be calculated as follows:

$$\text{C:N Ratio} = \frac{\text{weight of biodegradable C}}{\text{weight of organic N + ammonium N + nitrate N}}$$

$$\text{C:N Ratio} = \frac{\text{X lb manure x C(manure) + X lb sawdust x C(sawdust)}}{\text{X lb manure x N(manure) + X lb sawdust x N(sawdust)}}$$

How much sawdust is required per pound of manure?

$$30 = \frac{1 \times 0.24 + X \text{ lb sawdust} \times 0.286}{1 \times 0.02 + X \text{ lb sawdust} \times 0.000715}$$

30 x (0.02 + 0.000715X) = 0.24 + 0.286 X
0.60 + 0.02145X = 0.24 + 0.286X
0.60 – 0.24 = 0.286X – 0.02145X
0.36 = 0.26455X
X = 1.36

Therefore, to build a compost mix with an initial C:N ratio of 30, 1.36 lbs sawdust should be blended with each pound of manure.

3. Setting the Moisture Content

In addition to C and N, microbes require water and air for efficient metabolism. Both air and water compete for the pore spaces in the compost pile. Maintaining optimum moisture in the pile is necessary to provide both water and air to the microbes. If the compost pile is too dry, biological activity will slow down or stop due to a lack of water. If the pile is too wet, the pile will become anaerobic due to a lack of oxygen. A lack of oxygen can result in anaerobic decomposition which can cause odours, slow the rate of decomposition and produce phyto-toxic compounds.

The initial moisture content should target 55% with an optimum range between 45 and 60%. Continuing with the above example, the initial moisture content can be calculated as follows:

[weight(manure) x moist(manure)] + [weight(sawdust) x moist(sawdust)] = moist(mix) x [weight(manure) + weight(sawdust)]

Recall that 1.36 lbs of sawdust should be blended with each lb of manure to achieve an initial C:N ratio of 30.

1x0.60 + 1.36x0.35 = moist(mix) x (1 + 1.36)
0.60 + 0.476 = moist(mix) x (2.36)
moist(mix) = 0.45

Therefore, in this example, the moisture content of the mix would be 0.45 or 45%. To achieve an ideal, initial moisture content of 55%, water must be added. If the initial mix had been too wet (>65% moisture), additional measures would be required to ensure that the microbes receive adequate air and the mix does not go anaerobic. If drier, suitable feedstocks are not available, an alternative method would be to add a bulking agent to increase the air-filled pore space (see step 5).

Continuing with the above example, to determine how much additional water is required per lb of chicken manure, the following formula can be used:

$$\text{Moisture Content} = \frac{\text{weight of water}}{\text{total weight (water + solids)}}$$

$$0.55 = \frac{[\text{weight(mix) x moist(mix)}] + \text{additional water}}{\text{weight (mix)} + \text{additional water}}$$

$$0.55 = \frac{[2.36 \times 0.45] + \text{additional water}}{2.36 + \text{additional water}}$$

$$0.55 = \frac{1.062 + \text{additional water}}{2.36 + \text{additional water}}$$

0.55 x (2.36 + additional water) = 1.062 + additional water
1.298 + 0.55(additional water) = 1.062 + additional water
1.298 – 1.062 = (1-0.55) additional water
additional water = 0.52

Therefore, 0.52 lb water must be added for each pound of manure to achieve an initial ideal moisture content of 55%.

4. Blending the Ingredients Together

Once the quantities of feedstocks and water have been established, they must be blended together to form the compost pile. Turning and mixing will distribute the feedstocks evenly, blend the added water throughout the mix and physically breakdown any clumps.

5. Establishing the Air-filled Pore Space

Porosity is a critical factor for biological stability, pile and product uniformity, composting retention time, and odour prevention. The air-filled pore space determines how well air circulates through the pile to supply the needs of the microbes for oxygen and removal of carbon dioxide. It is determined by the particle size and bulking material.

Bulking materials are inert, are not involved in the composting process (i.e. they do not supply carbon to the microbes) and can be sieved out at the end of the composting process. Bulking materials commonly include chunks of wood or strips of bark but can be any inert material that can be removed when the composting process is complete. Bulking materials that have been sieved out of active compost can be used to kick-start the next compost mix by inoculating it with composting microbes.

The initial air-filled pore space should target between 45-60%. The following "Quick Test for Air-filled Pore Space" can be used after the pile has been turned and mixed:

1. Weigh empty 5-gallon pail (5 US gallons = 18.925 litres).
2. Fill 5-gallon pail one-third full with uncomposted material. Drop the pail, from a 6-inch height, ten times.
3. Add more uncomposted material to fill the pail until two-thirds full. Drop ten times from a 6-inch height.
4. Fill pail and drop 10 times from a 6-inch height.
5. Fill pail to brim.
6. Weigh. (Example: 13.5 kg)
7. Fill pail with water (to replace the air-filled pore space) and weigh. (Example: 20.5 kg)

$$\text{Volume water } (m^3) = \frac{\text{Wt of pail with material and water (kg)} - \text{Wt of pail with uncomposted material (kg)}}{\text{Density of water } (kg/\ m^3)}$$

$$\text{Volume water} = \frac{20.5 - 13.5}{1000}$$

Volume water = 0.007 m^3 or 7 litres

$$\text{\% Air-filled Pore Space} = \frac{\text{Volume of Water}}{\text{Total Volume}} \times 100$$

$$\text{\% Air-filled Pore Space} = \frac{7}{18.925} \times 100$$

Air-filled Pore Space = 37%

In this example, there is not enough free airspace. Therefore, add bulking material, turn and mix the pile to distribute the bulking material and repeat the test for air-filled pore space.

Managing the Composting Process

Once the compost pile has been established, it must be managed to optimize composting conditions. The management of the compost pile will affect the generation of odours during the composting process, the retention time of the compost and the quality of the final product. During the high rate composting phase microbial activity is high and the decomposition of the composting materials is accelerated. During this phase, aeration, moisture and temperature must all be managed.

Aeration

Aeration must be just enough to provide enough oxygen to the microbes to keep the composting process aerobic and to control the temperature -- but should not be so high as to blow off nitrogen or moisture from the pile. Oxygen levels in the pile should be maintained above 16%. Air can be added to the pile by turning and mixing or through forced aeration. Turning and mixing will also break up clumps and channels and expose all materials to aerobic conditions and higher temperatures. During the winter, it may be necessary to limit turning and mixing due to cooling of the pile.

Moisture

Water must often be added to the pile during high rate composting, as moisture loss is greatest during this phase. Moisture loss is a result of microbial activity and evaporation. Evaporative losses increase with turning and mixing and forced aeration. If moisture falls below 40%, microbial activity will slow or stop.

Care must also be taken to ensure that moisture levels do not get too high. If the moisture content exceeds 60%, the microbes cannot get enough air. Without air, anaerobic conditions develop and composting slows, odours are generated, and phyto-toxic compounds may be created. During high rate composting, an estimated optimum range of about 50 to 55% moisture will provide the most effective pore space for air and water. The best time to add water is just prior to or during turning and mixing operations so that the water will be distributed throughout the pile.

Temperature

Small changes in temperature have a greater affect on microbial activity than small changes in other parameters such as moisture, pH, organic matter or C:N ratios. Temperature can be controlled by turning and mixing, forced aeration (in high technology composting systems) and pile size. Smaller piles will lose more heat naturally. Similarly, larger piles can be created to retain heat. Because temperature is easy to monitor, it is often used to manage aeration. This is because correct temperatures imply adequate oxygen levels in the pile.

Increased temperatures indicate a high level of microbial activity associated with rapid decomposition. Ideal temperatures during the normal high rate composting phase should be between 40°C (104°F) and 50°C (122°F). Very high temperature composting can be used to reduce human and animal fecal pathogens to below background levels, kill weed seeds and fly larvae, as well as destroy plant pathogens. The very high temperature pathogen control stage should last from 3 to 15 days depending on the type of system used (static pile versus windrow, respectively). Temperatures during the pathogen control stage should be maintained between 55°C (131°F) and 60°C (140°F). It should be noted that although temperatures can reach 80°C or greater, microbial activity will have slowed at these temperatures. The pile remains HOT because it is very well insulated – in this case, a very hot pile does not mean a very active pile.

In lower technology composting (without forced aeration) heat is removed from the pile by turning and mixing. In addition to temporarily cooling the pile, turning and mixing can be used to expose all materials to high temperatures. The latter is very important during the pathogen reduction stage and as a means of fly control. Fly larvae can grow on the surface of the pile, but are destroyed when exposed to the higher temperatures on the inside of the pile.

Compost Curing

The final stage of the composting process includes a curing phase. Curing stabilizes the compost by aging or maturing the product and ensures that there are no organic phyto-toxins present in the final product. Although curing still requires aerobic conditions, not as much oxygen is required as in high rate composting and temperatures should be maintained below 50°C (122°F). The curing process involves microorganisms such as fungi that thrive at these lower temperatures. The fungi slowly decompose the more resistant carbon compounds in the compost (such as lignin) to produce a stable, humus-like end product.

Reference Materials:

Cornell Composting Website
http://compost.css.cornell.edu/Composting_Homepage.html

Compost Facility Operating Guide
Developed by the U.S. Composting Council
http://www.compostingcouncil.org/index.cfm