Highfields Center for Composting

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Recipe Development Worksheet

Overview

Recipe development is employed by composters to develop compost recipes that are well-suited for the decomposer microorganisms who will drive the process – approximately 60% moisture, a ratio of 25 -30 parts carbon per part nitrogen, and a bulk density of 1000 pounds per cubic yard or less. Since the compost recipe will create the habitat and diet for your decomposer populations, developing good recipes is a critical aspect of the composting process that cannot be overlooked.

In developing recipes, we tend to emphasize balancing the moisture content (M.C.) and the C:N because these issues exert a significant level of influence on the pile conditions for microbial decomposition, nitrogen retention during the composting process, odor potential, the ability of the pile to obtain thermaphillic temperatures, and the rate of decomposition, as well as the generation of Volatile Organic Acids (VOAs) and other potential phytotoxins. When developing a recipe you will first try to obtain the proper C:N ratio or moisture content (M.C.). Once this is achieved you will calculate the remaining factor. We generally recommend beginning your calculations by solving for M.C. Once this is done, the factor for the second ingredient is applied to the C:N equation and then evaluated for its suitability from that standpoint. Often one must work between the moisture and C:N equations to establish a recipe that suits both sufficiently. In many cases a suitable recipe for two specific ingredients cannot be established. In such a case, an operator will need to search for an additional feedstock to address a specific issue or several various feedstocks to achieve seemingly divergent goals. Once the baseline recipe is established, its bulk density should be assessed and adjusted as needed. Recipes with bulk densities greater than 1000 pounds per cubic yard are too dense for passive aeration and additional "bulking materials" should be incorporated to compensate.

The following worksheet was created to assist you in developing your own composting recipes. The worksheet is designed to provide you with an example for each step, followed by space for you to enter your own information. As the worksheet guides you through the recipe development process it simultaneously develops a theoretical compost recipe for managing the manure generated by 100 sheep. This worksheet is structured to develop a recipe around a primary feedstock that will direct the composting activities on your farm. For example, the primary feedstock on a dairy farm is likely to be manure generated daily, while on a vegetable farm it may be food scraps delivered weekly. On either farm the use of wood chips (the secondary ingredient) in the recipe, for example, will be proportional to the amount of the primary feedstock (manure or food scraps) being composted. During the calculations we can therefore make the process more manageable and consider the amounts of our ingredients as being in a ratio with one pound of manure. Doing this and then converting the ratio from weight to volume, we are able to create functional recipes that are easily implemented from the seat of your tractor (i.e. two tractor buckets of wood chips to every one bucket of bedded manure).

Note that the pH of feedstocks can exert significant influences on the composting process, however evaluating recipe pH is not covered in this worksheet. If you have feedstocks with a pH of less than 4.5 or greater than 8, seek technical assistance for moderating the recipe pH.

Theoretical Compost Mix for Managing Manure of 100 Sheep

Note: remember percents must be translated into decimal form in calculations. For example, 85% becomes 0.85 in the calculation.

1. Determine how much manure are you managing

Example -

Assumed average yield of manure from a 100-pound sheep per day – 4 #s per day
100 head of sheep x 4 pounds of manure = 400 #s of manure per day
400 #s x 365days = 146,000 #s per year

- In a real application, take into consideration the amount of time the animals actually spend in the barn. For example, animals on summer pasture may generate anywhere from no manure in the barn to a quarter of their winter generation. The seasonal discrepancy of time spent in the barn will significantly impact your generation estimates and should be accounted for.

YOUR ENTRY –

Average yield of manure per animal per day: ___________ pounds per day
Number of animals _____ x pounds per animal per day ___ = Total pounds manure per day_______
Pounds manure per day _____ x number of days = Pounds of manure generated per year ______

What is the make-up of your manure?

*****Doing an analysis of your manure is important for developing a good recipe and cannot be replaced with general figures. Be sure to ask that the lab analyze the carbon content of your manure or provide you with the carbon to nitrogen ratio (C:N), preferably both, as well as percent nitrogen (total and, organic or nitrate), moisture content (or percent solids), pH and bulk density.

Example -

Moisture Content – 72.5%
%N – 2.7%
C:N – 16:1
%C – 43.2%
Bulk Density – 1,730#s/ cubic yard

YOUR ENTRY –

Moisture Content - ___%
%N - ___%
C:N - _____
%C - _____

2. What is the make-up of your bedding material?

*Doing an analysis of your bedding material is important for developing a good recipe and cannot be replaced with general figures. Be sure to ask that the lab analyze the carbon content of your bedding and provide you with its bulk density.

***Example* -**

Bedding Material: Straw
Moisture Content – 21.5%
%N – 0.98%
%C – 43.7%
C:N – 44.6:1
Bulk Density – 92#s/ cubic yard

YOUR ENTRY –
Bedding Material - _______
Moisture Content - ____%
%N - ___ %
%C - ____
C:N - ____
Bulk Density - ____

3. Determine ratio of manure to straw to obtain ideal Moisture Content of mix

Moisture content (M.C.) is critical to pile health and it exercises significant influence over the composting process. Commonly, excessive pile moisture is a limiting factor in agricultural composting operations. Therefore, we generally recommend approaching recipe development by first calculating the M.C. The calculations below will help you develop recipes around targeted M.C.s.

When beginning your M.C. calculations, you do an initial assessment of the mix by simply looking over their M.C.s. If you are targeting 60% M.C. and you have two materials, you have limited options to achieve the targeted M.C. If your "dry" ingredient is itself 58% moisture and your wet ingredient is 80% moisture (say a green sawdust and a dairy manure), it may be nearly impossible, or at least not very practical, to obtain 60%MC since your dry material itself doesn't provide much of a buffer with the desired M.C. In this case an additional or alternative dry material should be sought.

In doing these calculations, keep in mind that we are trying to establish a ratio of our second ingredient (straw in the example) and our manure. Therefore, the weight of manure for the purpose of determining that ratio will be one pound. Two methods of calculating moisture content, one for two materials and one for two or more materials, are shown below.

Example –

MC = moisture content
S = weight of straw
Total weight = 1 pound of manure + **S** (1 pound of straw)

MC for two ingredients:

$$\text{Target MC} = \frac{\text{MC of manure} + \mathbf{S}(\text{MC of straw})}{\text{Total weight}}$$

$$0.6 = \frac{0.725 + \mathbf{S}(0.215)}{1 + \mathbf{S}(1)}$$

$0.6\ (1 + \mathbf{S}) = 0.725 + 0.215\mathbf{S}$

$0.6 + .6\mathbf{S} = 0.725 + 0.215\mathbf{S}$

$0.6\mathbf{S} = 0.125 + 0.215\mathbf{S}$

$0.385\mathbf{S} = 0.125$

$\mathbf{S} = 0.32$ pounds of straw

Therefore, for every pound of manure we have to compost, we need 0.32 pounds of straw.

--OR--

MC for two or more ingredients:

$$\frac{\%\text{M of A} \times \text{weight of A} + \%\text{M of B} \times \text{weight of B}\ldots\ldots}{\text{weight of A} + \text{weight of B}\ \ldots\ldots..}$$

0.725 x 1 + 0.215 x 0.32*/ 1+0.32* =
0.7938/ 1.32 = .6 = **60% moisture**

*Generally when using this formula a "guess and check" approach is used to determine the MC. In such a case, the figure of 0.32 pounds of straw per pound of manure would not be available and one would need to insert an estimate, check the resulting value and adjust the calculation to compensate as needed.

YOUR ENTRY –

Moisture Content (MC) for two ingredients:
S = weight of second ingredient

Target MC* = (MC of manure) + **S**(MC of second ingredient) / 1 pound manure + **S**(1 pound of second ingredient)

*Can use a different target MC, such as 55%, if desired

0.6 = ____+ **S**(___) / 1 + **S**(1) → insert MC of ingredients

0.6 (1 + **S**) = ____ + ____**S** → multiply both sides by total weight

0.6 + .6**S** = ____ + ____**S** → subtract 0.6 from both sides

0.6**S** = ____ + ____**S** → consolidate **S** on left side of the equation by subtracting your "___ **S**" figure from both sides

____ **S** = ____ → Solve for **S** - divide by remaining amount on opposite side or equation

S = ____ pounds of second ingredient per 1 pound of primary ingredient

4. Check C:N of mix

Example –

[%C in manure x weight of manure x (1 – MC of manure)] + [%C in straw x weight of straw x (1 – MC of straw)]
[%N in manure x weight of manure x (1 – MC of manure)] + [%N in straw x weight of straw x (1 – MC of straw)]

[0.432 x 1 x (1 – 0.725)] + [0.437 x 0.32 x (1 – 0.215)]
[0.027 x 1 x (1 – 0.725)] + [0.0098 x 0.32 x (1 – 0.215)]

[(0.1188 + 0.1098) / (0.007425 + 0.00246)] = 0.2286/ 0.009887 = 23 = **23C: 1N**

This mix of manure to bedding works relatively well on a 1:0.32 basis for both the moisture and the C:N ratio – the C:N is a bit low, but still within a tolerable range. In this case fiddling with the numbers could bring the C:N up to roughly 25:1, dropping the MC to roughly 55%. Since it would be desirable to have a C:N of at least 25:1 if possible, and working with a moisture content of 55% instead of 60% is generally fine (and possibly preferred in the winter), it would be wise to recalculate the recipe to 55% MC. See below.

YOUR ENTRY –

m = manure
si = second ingredient
S = pounds of second ingredient per pound of manure

[%Cm ______ x 1 x (1 – MCm ___)] + [%Csi _______ x **S** ___ x (1 – MCsi ___)]
____ → solve each set of brackets [ ]

[%Nm _____ x 1 x (1 – MCm ___)] + [%Nsi ___ x **S** ___ x (1 – MCsi ___)]

(_____ + _____) / (____ + ____) = _____ **C: 1N**

4. Adjust Recipe if needed

If your C:N calculation does not provide you with your desired C:N, but it is close enough that you feel adjusting your target moisture content (MC) will create a satisfactory result, you can apply the "guess and check" approach. You will essentially repeat steps 3 and 4. Remember that it is possible that obtaining a desirable mix with two ingredients may be entirely impossible. If your first calculations provided an unsatisfactory recipe, you must look at the results and assess how feasible more acceptable results will be. For instance, a recipe that generates a perfect 60% MC with a C:N of 150:1 is unlikely to be salvaged by revisiting the calculations alone. In this case additional feedstocks should be considered to keep the recipe largely moisture neutral and drop the C:N if possible (such a large drop in the C:N without impacting MC would be difficult and may require multiple ingredients). For the purpose of this work sheet these adjusted calculations will be provided as examples only. In this case, we will try working with an M.C. of 55% in order to increase the C:N to roughly 25:1. If you require making an adjustment to your calculation, use the calculations provided in the preceding steps above.

Moisture Content -

$$0.55 = \frac{0.725 + \mathbf{S}(0.215)}{1 + \mathbf{S}(1)}$$

$0.55 (1 + \mathbf{S}) = 0.725 + 0.215\mathbf{S}$

$0.335\mathbf{S} = 0.175$

$\mathbf{S} = 0.52$ pounds of straw per pound of manure

Carbon: Nitrogen Ratio -

[0.432 x 1 x (1 – 0.725)] + [0.437 x **0.52** x (1 – 0.215)] / [0.027 x 1 x (1 – 0.725)] + [0.0098 x **0.52** x (1 – 0.215)]

0.1188 + 0.1269 / 0.007425 + 0.002846 = **26C: 1N**

In this case, the adjusted recipe has afforded us a substantial increase in our C:N while keeping our MC at a good level. As a result, we should expect to see a more effective mix.

6. Translate weight of feedstocks into volume

REMEMBER…this ratio of manure to bedding is still in terms of weight, which is difficult to gauge when you are sitting on a tractor. We still need to convert these proportions to volume. The bulk density of each ingredient will help us translate this ratio into a recipe that is easily applied on a per-bucket basis when you are handling materials with the tractor. The bulk density of a given material is the pounds in one cubic yard of that material.

Bulk Density-
***Example* -**

Bulk Density of Manure: 1,730 #s/ cubic yard
Bulk Density of Straw: 92 #s/ cubic yard

Pounds per day:
Manure: 2800 #s
Straw: 400 x 0.32 = 128 #s (60% moisture content)
400 x 0.52 = 208 #s (55% moisture content)

Cubic Yards per day:
Manure: 400/ 1730 = 0.23 yards/ day
Straw: 128/ 92 = <u>1.39</u> yards/ day (MC = 60%)
208/ 92 = <u>2.26</u> yards/ day (MC = 55%)

As you can see, the increase in straw to achieve the adjusted recipe is significant. Recipe development is a dynamic process that often comes down to balancing what is needed and what is possible. Remember that our first calculation based on 60% M.C. was entirely suitable. Therefore, if the amount of straw required by the adjusted recipe is not practical, because of cost for instance, the original proportions could be used or a proportion between the two could be sought. Additionally, if there is a limitation, such as availability or cost, in meeting even the outer perimeters of recipe requirements, alternative feedstocks should be sought and integrated into the recipe.

YOUR ENTRY –

Bulk Density of Manure: ______ #s/ cubic yard
Bulk Density of second ingredient: ____ #s/ cubic yard

Pounds per day:
Manure: _____ #s
Second ingredient: Pounds of manure per day _____ x pounds of second ingredient per pound of manure ____ = _____ pounds of second ingredient per day

Cubic Yards per day:
Manure: Pounds of manure per day______/ Bulk density of manure _____ = _____ Yards of manure per day
Second ingredient: Pounds of second ingredient per day ____ / Bulk density of second ingredient ____ = ____Yards of second ingredient per day

If this mix can be achieved in the barn when bedding is put down, this eliminates one step of mixing in additional bulking agents outside the barn. Additionally, given other conditions are appropriate, some decomposition will begin in the barn. As the barn is cleaned out, this mix becomes more adequately and thoroughly mixed and aerated, preparing it to be composted when it is brought out of the barn. Also note, this recipe does not account for the presence of rejected hay, which, in small ruminant barns, is often significant. In a real calculation, this rejected hay should be estimated in volume and integrated into the recipe. This will significantly reduce the need for purchased carbon materials, such as straw. Given the significant increase in straw required to meet the 55% MC, 26:1 C:N recipe and the likelihood that in a real scenario rejected hay would contribute significantly to the carbon content of the mix, we will use the 0.32 pounds of straw per pound of manure ratio (60% MC, 23:1 C:N) for the remaining calculations.

Note: if significant quantities of any other organic materials, such as spent hay, feed or silage is added to this mix, adjustments in the proportions and recipe may be required.

7. Factoring Bulk Density

The bulk density (B.D.) of a compost mix is important for the operator to be generally aware of because of its impact on the movement of air into and through the pile. While our efforts to balance the M.C. to targeted levels of moisture will prevent a saturation of pore space, this does not account for the overall size of the pore spaces. Air must be able to move through the pile. The particle size and density of your feedstocks will affect the overall density of the mix, determining how freely air is able to move through the pile. We generally do not get very specific with our bulk density goals, unless there are specific processing factors that need to be accounted for, however it is recommended that your pile bulk density does not exceed 1000 pounds per cubic yard. Bulk density calculations are below.

Example –

(Yards of manure x bulk density of manure) + (yards of second ingredient x bulk density of second ingredient)
Total number of yards

[(1.87 x 1730) + (9.7 x 92)] / 1.87 + 9.7 = (3235 + 892.4) / 11.57 = **356.7 pounds per cubic yard**

YOUR ENTRY –

[(Yards manure _____ x BD manure ______) + (Yards second ingredient _____ x BD second ingredient_____)]
Yards of manure _____ + yards of second ingredient _____

= ______ pounds per cubic yard of mix

If your bulk density exceeds 1000 pounds per yard, additional bulking agents should be factored in. If the rest of your recipe is good, an effort to source a C:N and MC neutral material can be made, however it is likely that you will have to start the calculation process over from the beginning to account for the characteristics of the bulking agent, such as wood chip.

8. Create Recipe

If you are satisfied with your mix, the last and final step is to create your recipe. In order to create the recipe that you will be able to utilize while operating the tractor and combining materials, we need to return to establishing a ratio of our second ingredient to one unit of our primary ingredient.

Yards of Second Ingredient per day = Yards of second ingredient per yard of primary ingredient
Yards of Primary Ingredient per day

Ex. - 1.39 / 0.23 = 6

YOUR ENTRY -

Yards of second ingredient per day ______ / Yards of primary ingredient per day ______ =
______ **yards of second ingredient per yard of primary ingredient**

You should now have the ratio of the yards of the second ingredient per yard of the primary ingredient. With this volume ratio you will be able to apply your recipe in practical terms with any unit of volume, such as on a per bucket basis. With your recipe established, you now know how much material you need to manage over a given period of time. This information will be critical in your site development process and can be used in the Determining Your Composting Pad Size worksheet.