# COMBINING RAW MATERIALS FOR COMPOSTING

*A guide to providing a suitable environment and source of nutrients to optimize the composting process.*

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COMPOSTING is a biological process in which biological wastes are stabilized and converted into a product to be used as a soil conditioner and organic fertilizer. This process depends upon the activity of microorganisms. To carry out these activities, the microorganisms must be provided with a suitable environment and a source of nutrients that should be present in proper proportions. The extent to which we supply those two needs and the way in which we do so, determine to a large degree our influence on the compost process and its optimization.

The major sources of nutrients for composting are organic waste materials. However, it is rare that a waste material in the condition in which it is available consistently possesses all of the characteristics essential for efficient composting. To compensate for this deficiency, it is usually necessary to blend in suitable proportions of another waste or low cost material. For example, in the U.S., the excessively high moisture content of sewage sludge usually is lowered by blending a "bulking" agent such as wood chips or sawdust. In Europe, municipal solid wastes often serves as the bulking agent. For farms, an excessively moist manure can be blended with crop residues, or perhaps with waste from a nearby lumber operation.

## REQUIRED FEEDSTOCK CHARACTERISTICS

Carbon (C), nitrogen (N), phosphorus (P), and potassium (K) are the primary nutrients for the microorganisms involved in composting. Because they also are the primary nutrients for plants, their concentrations in the compost product also influence the value of the compost. Generally, supplying C and N in the appropriate ratio (C/N) ensures the presence of required concentrations of other nutrient elements. Initial C/N's between 15 and 30 will consistently bring about good composting results. At ratios lower than about 15/1, nitrogen is lost—usually as ammonia, which can constitute an odor problem. Although ratios between 30 and 50 may be permissible, the required composting time is longer because of the additional time microorganisms need to oxidize the excess carbon and thereby lower the C/N to the desired level. Provided that the initial C/N was high, C/N can serve as an indicator of product stability.

C/N has an important bearing on the utility of the compost product. Incorporation of a product having an excessively high C/N into the soil leads to nitrogen deprivation for plants grown on that soil. To oxidize the excess carbon, the microorganisms need more nitrogen. To meet this need, they must compete with the crop plants for the insufficient supply of soluble nitrogen in the soil. Being more competitive than plants, the microorganisms flourish at the expense of the plants. The result is that plant growth is inhibited until the excess C has been oxidized. The nitrogen shortage is avoided by using a compost product that has C/N ratio of 15/1 or lower. In the case of sewage sludge bulked with wood chips, the sludge usually starts at a lower C/N than desired for composting. Adding the chips increases the ratio to the optimum range for composting. Finally, screening the large chips out for reuse usually lowers the C/N of the product to the desired range for nitrogen availability to plants.

The availability of the nutrients also influences the process. If the C is in a form that is

difficult to decompose, such as lignin or other woody forms, the rate of stabilization will be slow. It is important to note that fungi are the only type of organisms that can efficiently utilize woody materials and that they do not tolerate temperatures as high as some forms of bacteria or actinomycetes. Virtually no fungi survive above 60°C. Thus the rate of decomposition of materials, like municipal solid waste with its high content of paper (made from wood), slows rapidly above 55°C.

For practical purposes, because the mobility of the microorganisms is negligible, it is necessary to provide intimate contact between the microorganisms and the nutrient elements in the waste. This can be done by grinding the wastes and thoroughly mixing them.

A certain amount of moisture is necessary to support the metabolic processes of the microbes and to permit transport of the nutrients. Experience has shown that the process will not be inhibited if the moisture content is at least 40%.

The composting process is relatively insensitive to pH, probably due to the broad spectrum of organisms that is usually involved. The optimum is probably in the range of 6.5 to 8.5, however, the natural buffering capacity of the process permits a much wider range of initial values (5-12). Most well stabilized composts will have a pH between 6.5 and 7.5. Controlling the pH of the initial composting mix can become important with certain wastes that have large amounts of protein (N), as was found in a research project on composting crab wastes at the University of Maryland. Adjusting the pH downward to near neutral reduced volatilization of ammonia and other odorous compounds.

The porosity, texture, and structure also affect the process by their influence on the effectiveness of aeration and its functions. These factors can be adjusted by selection of the materials used and by grinding or shredding and mixing. (Materials added to adjust these properties are usually called bulking agents). Porosity determines the resistance to air flow and is a function of the particle size and size gradation of the materials. The voids must also be interconnected to permit air movement. Large particle size, and the more uniform size distribution, result in increased porosity. Structure is derived from the rigidity of the particles, and is measured by their ability to resist settling and by loss of porosity in the moist environment of the compost.

Texture controls the available area for aerobic activity. Most of the aerobic decomposition of composting occurs on the surface of particles, whereby aerobic microorganisms on the surface of particles utilize the available oxygen in a thin film at the surface, leaving the interior in an anaerobic state. Since the surface to volume ratio increases with decreasing particle size, the rate of aerobic decomposition will increase with decreasing particle size within limits. When the particles become too small, however, there is a loss of porosity, so a compromise is needed. Good results are usually obtained when the particle sizes range from 1/8 inch to 2 inch mean diameter.

Porosity, texture and structure are all influenced by moisture content. Loss of porosity can be caused by excessive moisture filling most of the voids. The excess moisture also eliminates any tendency for crumbling that would increase the effective surface area. Many wastes used for composting such as leaves and paper lose their structural rigidity when wet. The detrimental effects of moisture are not significant for most materials below 60% moisture content (wet basis)

**Table 1. Approximate Nitrogen Content and C/N Ratios of Some Compostable Materials, Dry Basis***

| Material | N | C/N |
|---|---|---|
| Poultry manure | 6.3 | — |
| Mixed slaughterhouse wastes | 7–10 | 2 |
| Night soil | 5.5–6.5 | 6–10 |
| Sheep manure | 3.75 | — |
| Pig manure | 3.75 | — |
| Horse manure | 2.3 | — |
| Sea weed | 1.9 | 19 |
| Cow manure | 1.7 | — |
| Potato tops | 1.5 | 25 |
| Combined refuse, Berkeley, CA | 1.05 | 34 |
| Oat straw | 1.05 | 48 |
| Wheat straw | 0.3 | 128 |
| Sawdust | 0.11 | 511 |
| Paper | nil | — |

*From Gotaas, H.B., Composting, Sanitary Disposal and Reclamation of Organic Wastes. World Health Organization, Geneva. 1956*

**Table 2. Nitrogen Content and C/N Ratio of Various Materials Used In Municipal or Industrial Compost***

| Material | %N | C/N ratio |
|---|---|---|
| | (Dry Wt) | (Wt/Wt) |
| Garbage: | | |
| Raleigh, NC | 1.92 | 15.4 |
| Louisville, KY | 2.90 | 14.9 |
| Total raw refuse (residential including garbage): | | |
| Savannah, GA | 1.30 | 38.5 |
| Johnson City, TN | 0.6 | 80 |
| Chandler, AZ | 0.57 | 65.8 |
| Sewage Sludge: | | |
| Activated | 5.60 | 6.3 |
| Digested | 1.88 | 15.7 |
| Fruit Wastes | 1.52 | 34.8 |
| Wood (pine) | 0.07 | 723 |
| Fish scraps | 6.50 | — |
| Paper | 0.25 | 173 |
| Grass clippings | 2.15 | 20.1 |
| Grass clippings/garden weeds | 2.03 | 19.3 |
| Leaves (freshly fallen) | 0.5-1.0 | 40-80 |
| Lumber mill wastes | 0.13 | 170 |
| Pharmaceutical wastes | 2.55 | 19 |

*From Poincelot, R.P., The Biochemistry and Methodology of Composting. Bulletin 754. The Connecticut Agricultural Experiment Station, New Haven. 1975.*

# SAMPLE CALCULATIONS

**Blending Materials to Correct a Moisture Problem:**

Assume that a farm has chicken manure that usually has a moisture content of 70% when removed from the buildings. Both the moisture and the N contents are too high for optimum composting and the manure needs greater porosity. Sawdust is available with a moisture content of 30%. Using values from the tables and assuming that the C/N ratio of the manure is no more than 10, the calculation is done as follows:

1# of wet manure will contain:

| | | |
|---|---|---|
| Water 1# × 0.7 | = | 0.7# |
| Dry matter 1# – 0.7 | = | 0.3# |
| N 0.3 × 0.06 | = | 0.018# |
| C 0.018 × 10 | = | 0.18 |

1# of damp sawdust will contain:

| | | |
|---|---|---|
| Water 1# × 0.3 | = | 0.3# |
| Dry matter 1# – 0.3 | = | 0.7# |
| N 0.7 × 0.0011 | = | 0.00077# |
| C 0.00077 × 500 | = | 0.39# |

The moisture content should not exceed 60% and stated in terms of 1# of wet mix:

$$MC = 60\% = 0.6 = \frac{\text{wt } H_2O \text{ in manure} + \text{wt } H_2O \text{ in sawdust}}{\text{total weight}}$$

$$MC = 0.6 = \frac{0.7 + 0.3x}{1 + x}$$ where x is the amount of sawdust needed

$$0.6(1 + x) = 0.7 + 0.3x$$

x = 0.33# sawdust/#manure

**To check the C/N ratio:**

$$C/N = \frac{\text{C manure} + \text{C sawdust}}{\text{N manure} + \text{N sawdust}}$$

$$C/N = \frac{0.18 + 0.33 \times 0.39}{0.018 + 0.33 \times 0.00077}$$

C/N = 16.9 OK

Since this is near the low end of the acceptable range, the amount of sawdust added should not be reduced even if drier materials are available.

**Blending Materials to Correct a C/N Ratio:**

Assume that wheat straw is available which has a moisture content of 15%:

1# of wheat straw will contain:

| | | |
|---|---|---|
| Water 1# × 0.15 | = | 0.15# |
| Dry matter 1# – 0.15 | = | 0.85# |
| N 0.3 × 0.003 | = | 0.0026# |
| C 0.0026 × 128 | = | 0.33# |

The amount of straw should be estimated on the basis of a C/N ratio of 20 instead of the minimum of 15, to reduce the possibility of loss of nitrogen and odor production.

$$C/N = 20 = \frac{\text{C in 1\# manure} + x(\text{C in 1\# straw})}{\text{N in 1\# manure} + x(\text{N in 1\# straw})}$$

where x is the amount of straw needed.

$$20 = \frac{0.18 + x(0.33)}{0.018 + x(0.0026)}$$

x = 0.65# straw/# manure

**To check the mix moisture content:**

$$MC = \frac{\text{wt } H_2O \text{ in 1\# manure} + \text{wt } H_2O \text{ in 0.65\# straw}}{\text{total weight}}$$

$$MC = \frac{0.7 + 0.65 \times 0.15}{1.65} = 48\% \text{ OK}$$

and a few materials may have higher or lower critical moisture contents.

Porosity cannot be predicted with accuracy from ingredient characteristics. Bulk density can be related to porosity and is easily measured so it is sometimes used to estimate the probably porosity. Bulk densities of the mixture with less than 35 to 40 pounds per cubic foot are usually adequate. Sometimes porosity is expressed as free air space, which should exceed 30%. Porosity, texture and structure are a function of moisture content, characteristics of the mixture of materials, and compaction.

As described above, a good feedstock for composting will have a C/N ratio of 15 to 30 and a moisture content of 40% to 60% on a wet basis. Although a few materials will fall in these ranges, it is usually necessary to blend materials. Tables 1 and 2 give typical values for the N content, and the C/N ratio. From them, appropriate mix ratios can be calculated for the C/N ratio. Moisture contents of waste materials are usually variable with time from most sources, so the ratio may need continuous adjustment to stay within the optimum moisture range. It generally will be possible to calculate an acceptable mix ratio from the typical analysis given in Tables 1 and 2. However, it is advisable to conduct pilot tests to verify the suitability of the computed mix ratios.

## TYPICAL INGREDIENTS AND CONDITIONING APPROACHES

**Sludge:** Sewage sludge has a C/N ratio on the low end of the acceptable range, is too wet and lacks porosity. It is usually conditioned by mixing with wood chips, sawdust, bark, or dry compost. Occasionally, fly-ash has been added to the mix to reduce the moisture content and the amount of other bulking material needed. Sometimes, the sludge has been mixed with municipal solid wastes or a fraction thereof, which have a low C/N ratio and moisture content.

**MSW:** Most plans for composting municipal solid wastes (MSW) are part of an overall resource recovery system which removes a variety of recyclable materials from the MSW. Thus it is difficult to generalize about its need for conditioning. However, fine grinding prior to composting should be avoided, if possible, to maintain porosity. The MSW and most of its fractions will need added water and will benefit from additional nitrogen.

**Yard Waste:** Leaves have a very high C/N ratio and tend to be dry. They benefit from added water and nitrogen. Shredding improves their porosity and exposes the interior of the leaf, which is more susceptible to decomposition than the outer surfaces. Lawn clippings lack the structure to maintain their porosity for aeration, but have a favorable C/N ratio and moisture content for decomposition. Thus the lawn clippings are likely to deplete the oxygen in a windrow and become anaerobic and generate odors. Brush and tree trimmings need shredding for size reduction. A combination of these yard wastes can make a good composting mix, if the leaves can be stored until the other materials are available. Research would be helpful to determine optimum preparation and proportions of these materials.

**Food Wastes:** Wastes from food and feed processing plants can vary widely in their characteristics. Many will be too wet to have the necessary porosity and so will need a bulking material. Dewatering could help reduce the amount of bulking material required. Others may need grinding to reduce particle size. The C/N ratio may need adjustment; fruits and vegetables are mostly deficient in N. By judiciously blending them with other wastes, most could be effectively composted.

Some waste materials, especially industrial and municipal wastes, will contain toxic substances that would make the compost unsuitable for the intended uses. Thus, it is important that the compost operator obtain copies of any analysis that may be required for disposal of the waste by pollution control authorities having jurisdiction over those wastes, and that metals concentrations be kept to levels acceptable to regulators for land application. If questionable materials are used, the compost must be analyzed.

Analysis of the nutrients contained in the compost will be useful for determining application rates and for marketing. Typical availability of nutrients for the first cropping season is 15% for N and 40% for P with lesser amounts in succeeding seasons.

If the initial mixture of materials has a C/N ratio of 15 to 40, a moisture content of 40%-60%, a pH of 5 to 12 and greater than 30% free air space, it will usually be possible to operate an effective composting process.

## CONCLUSIONS

Almost any organic waste material can be made into compost, if a market can be found that warrants the expense. It will usually be possible to operate an effective composting process if the initial mixture of materials has a C/N ratio of 15 to 40, a moisture content of 40% to 60%, a pH of 5 to 12, and porosity (free air space) of greater than 30%. ■

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# PROFESSIONAL SERVICES