COMPOSTING FUNDAMENTALS

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INTRODUCTION

Composting of organic waste has been used for centuries. Its use in biosolid stabilization increased in the 1970's and 80's as alternatives to land fill, ocean dumping and incineration. As municipalities face disposal problems for their organic materials, so do food processors and farmers. In addition to stabilizing organic materials, compost has some additional benefits. Reynk, et al., 1992 suggest some potential benefits are as follows:

- Enhanced soil fertility and tilth
- Destruction of undesirable microorganisms
- Reduce or eliminate unpleasant odors
- Environmental risk reduction

This presentation will be limited to discussing the fundamentals of composting.

WHY COMPOST WORKS

Composting is a biological process of decomposing organic materials into a humus like product. The process will occur naturally, but can be "speeded up" and controlled if proper ingredients are blended together. The controlled composting process is usually considered an aerobic process, which requires oxygen. The decomposition process is a "slow cooking" process and not a rotting process. Microorganisms are considered the "work horses" of the composting process.

HOW COMPOST WORKS

In order to generate a healthy compost process, some key inputs elements are as follows: a proper nutrient mix; moisture; oxygen; temperature; pH control; particle size; porosity; and time.
A proper nutrient mix is often referred to as the recipe; this is a blending of carbonaceous and nitrogenous materials together to form a desired carbon:nitrogen ratio (C:N). The ratio may vary from 20 to 35:1. Lower C:N ratios will produce rapid activity at the beginning, however, more odors will be given off in the process. A C:N ratio of 20:1 should be considered the minimum in formulating compost mix recipes. To assist in "recipe making" Brodie, 1994, at the University of Maryland, developed a computer spreadsheet. The spreadsheet allows the user to select the organic material(s) to be composted, then the program will indicate least cost recipe(s) based on the carbon sources available. Many scenarios can be evaluated, and a compost mix selection made in a very short period of time. In addition to the C:N ratio, Rubin and Sheldon (1993) suggest a C:P ratio of 100:1 to 150:1. A proper recipe is very important to successful composting. The end product is no better than the feedstocks used to make the recipe.

Moisture in the range of 40-60 percent is acceptable for composting. There are times when the moisture will be at the extremes of the range. In research at Maryland, 50 percent moisture has worked well in our composting efforts. Without a scale and convective or microwave oven, how can the moisture be estimated in a compost mix? One field method is the hand squeeze test. In the hand squeeze test, a hand full of the compost mix is obtained and squeezed into a ball by forming a fist. One or two drops of water may be squeezed from the ball. As the fist is released, the ball should expand but remain intact. The hand will be moist by not too wet. The squeeze test, as described, will approximate 50 percent moisture in the compost mix. Moisture levels greater than 60 percent may also cause a supernate (liquid) to leach from the compost mix and cause anaerobic (odor-causing) and other undesirable situations. Moisture is a key ingredient. If the moisture is too low or too high, the composting process will not function properly.

Oxygen is required to maintain the composting process in an aerobic state. It is desirable to maintain aerobic conditions for odor control and multiplication of thermophilic bacteria associated with this process. As the oxygen is depleted, one of the indicators may be the lowering of temperature in the compost mix. However, measuring the oxygen content of the compost mix is a more reliable way to determine oxygen depletion. In compost mixes having very high BOD₅ loads, oxygen requirements will be great. It may not be possible to supply the oxygen requirements by just turning. To overcome this situation some systems may be aerated with a fan and piping system or a combination of mechanical and aerated systems.

Temperature is generated in a compost mix by the metabolism of the microorganisms (bacteria, fungi and actinomycete). If the recipe, including proper moisture and oxygen, has been blended together correctly, the microbes will begin the metabolism process. The bacteria associated with process are mesophilic (moderate heat loving) and thermophilic (high heat loving) species. Mesophilic bacteria operate at temperatures less than 110° F.; thermophilic bacteria operate at temperatures ranging from 110 to 150° F. Good composting temperatures range from 135°-140° F.
Composting temperatures of 150° F. for organics from animal, poultry or seafood origin are desirable to assure the destruction of pathogenic bacterial and viral organisms.

**pH** is another item that may be critical at times, particular if it exceeds 8. If a compost mix has a pH of 8 or greater, ammonia (NH₃) volatilization may become a problem as it will cause odors. The desirable pH range is between 5.5 and 7.5. In some processes, depending upon the material, the pH will decrease over time to approximately 7; in others the pH will increase. You have to be on the guard for shifts in pH. If the pH is out of the desirable range, appropriate chemical action to alter the pH may be desirable. If the pH is too high, blending ferrous sulfate into the compost mix has been found to be an effective pH control agent (Carr and Brodie, 1992).

**Particle size** for the carbonaceous materials should range in size from 1/4 to 1 inch (Rubin and Shelton, 1993). For good bio-oxidation, the smaller particles are desirable because the surface-to-volume ratio is greater than in larger particles. Bio-oxidation occurs on the particle surface thus better decomposition. Sawdust is an excellent material to use in a recipe.

**Porosity** as defined by Rynk, et al. 1992 is as follows: "a measure of the pore space of a material or pile of materials. Porosity is equal to the volume of the pores divided by the total volume. In composting, the term porosity is sometimes used loosely, referring to the volume of the pores occupied by air only (without including the pore space occupied by water)." Particles greater than 1-inch in size used as bulking agents can assist in creating pore space and are not usually part of the C:N ratio determination.

**Time** for compost to mature is dependent on the mix recipe, moisture, feedstocks used, particle size, turning frequency, temperature and end use of the product. A compost requiring only pathogen reduction and can be utilized as a green compost will require much less time to process than a mature compost. Check with your state regulators concerning their requirements you have to follow as a compost site operator.

**COMPOSTING TECHNIQUES**

Four composting techniques will be discussed. These techniques will "speed up" the composting process over natural composting. The techniques are: static pile; aerated static pile; windrow and in-channel.

**Static pile** is where the compost mix is piled and not disturbed for a long period of time. It may be turned, but not frequently. To assist in natural aeration, the initial compost mix should have a porosity of approximately 30 percent or use a bulk density of approximately 900 lb./yd³.

**Aerated static piles** can be active or passive in mode of operation. The active piles normally draw air through the compost mix by using pipes or plenums placed in the
compost mix and fans attached to the duct system. Air discharge from the fan system can be filtered through a biofilter for odor control. Another aerated pile system is passive in operation. The passive system uses a series of perforated 4 or 5 inch plastic pipes underneath the compost pile. The pipe ends are left open and a natural convective process provides oxygen to the compost mix. A porosity of approximately 30 percent or use a bulk density of approximately 900 lb./yd³ is also desirable for the aerated pile system.

**Windrow** composting can be accomplished outside or in a large, covered structure. Windrows are normally turned with some type of turning equipment. The equipment can be as simple as a front-end loader or self-propelled equipment that straddles the windrow and turns it in one pass or equipment that requires 2 passes. However, good mixing may not be as effective with the front-end loader as the turning device. A porosity of approximately 30 percent is desirable or use a bulk density of approximately 900 lb./yd³.

**In-channel** techniques primarily use a turning device that runs down a rail of some type. It is possible to have parallel bays with common walls so the turning device can be moved from bay to bay. This type system is expensive, but may be a better system for long term composting. The in-channel system may also be used in conjunction with an aerated system. Fans and air ducts are placed throughout the system and will speed up the composting process by continuously providing oxygen in the compost mix. This may be of great benefit if the compost mix is highly volatile. Air from the fans can be discharged into a biofilter for odor control. A 30 percent porosity or use a bulk density of approximately 900 lb./yd³ will also assist in this process.

**QUALITY CONTROL**

Thought must be given to the compost product use before developing the initial compost mix. The end product will be no better than the feed stock used to make the initial mix. Therefore, it is very important to have a reasonably current nutrient analysis of each feedstock used in "recipe making". Tables 1 and 2 illustrate nutrient parameters associated with crab compost ingredients and the final compost, respectively. (Brodie, et al., 1994).

<table>
<thead>
<tr>
<th>Product Parameter</th>
<th>Crab Waste</th>
<th>Pine Sawdust</th>
<th>5 wk-Old Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Carbon</td>
<td>29.8</td>
<td>46.6</td>
<td>47</td>
</tr>
<tr>
<td>% Nitrogen</td>
<td>5.7</td>
<td>&lt;0.06</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**Table 1. Analysis of Compost Ingredients**
<table>
<thead>
<tr>
<th>Chemical Parameter</th>
<th>Compost - 1</th>
<th>Compost - 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>C:N</td>
<td>5.2</td>
<td>&gt;750</td>
</tr>
<tr>
<td>Bulk density lb/yd³ (wb)</td>
<td>540</td>
<td>675</td>
</tr>
</tbody>
</table>

Table 2. Crab Scrap-Sawdust Compost Nutrient Analysis

<table>
<thead>
<tr>
<th>Chemical Parameter</th>
<th>Compost - 1</th>
<th>Compost - 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>0.59</td>
<td>0.72</td>
</tr>
<tr>
<td>NH₄ - N</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>P₂O₅ %</td>
<td>0.99</td>
<td>1.5</td>
</tr>
<tr>
<td>K₂O %</td>
<td>0.20</td>
<td>0.25</td>
</tr>
<tr>
<td>Ca %</td>
<td>5.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Mg %</td>
<td>0.28</td>
<td>0.51</td>
</tr>
<tr>
<td>S %</td>
<td>0.12</td>
<td>0.14</td>
</tr>
<tr>
<td>MN ppm</td>
<td>86.2</td>
<td>104.1</td>
</tr>
<tr>
<td>Zn ppm</td>
<td>49.7</td>
<td>189.4</td>
</tr>
<tr>
<td>Cu ppm</td>
<td>13.7</td>
<td>19.5</td>
</tr>
</tbody>
</table>

a Compost-1: 35 days old; sawdust mix with crab once at a total volume ratio of 1 part crab to 1 part sawdust.

b Compost -2: 60 days old; compost-1 mixed with crab two times at a mix volume ratio of 2 parts crab to 5 parts compost-1 resulting in a total volume ratio of 1.8 parts crab to 1 part sawdust.

A decision has to be made concerning end use and compost quality. If the compost is going to be used as a field fertility source, the refinement or quality of feedstocks does not have to be as great as that used in home landscaping.
To assist in determining if compost is cured, respiration rates of the compost can be determined by laboratory procedures. A field determination can be made by collecting a compost sample, saturating it with water (but not soaking, dripping wet), place in a sealed plastic bag and store in a warm place (70 - 85 F) for one week. After one week open the bag, if there are no bad odors, the compost has stabilized.

Quality compost will have a C:N ratio of about 15:1. The time to achieve quality compost will depend on the technique used to compost. It may take one year or more to achieve a quality compost using static piles, whereas, a quality compost may be achieved in 2-3 months using mechanical systems.

**SUMMARY**

A brief overview of composting fundamentals has been presented in this paper. The final compost will be no better than the initial mix of feedstocks and the practices utilized during the process. Current nutrient analyses of the feedstocks are necessary in formulating the initial mix recipe. Refinement of feedstock quality of a compost mixture will be determined by its end use.

**REFERENCES**


A COMMERCIAL COMPOSTING FACILITY SERVING
THE FARM AND FOOD PROCESSING INDUSTRIES
OF THE DELMARVA PENINSULA

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The purpose of this paper is to describe the operation and evolution of a rural compost facility by New Earth Services, Inc. A 30 acre site is operated in rural Dorchester County Maryland near Hurlock. The facility is located adjacent to the county landfill; county officials hoped to divert organics from the landfill. The primary feedstock which caused the creation of the site was the waste shell generated by the county’s crab meat packing industry. Dorchester County picks and packs one million pounds of crabmeat every year; this results in several million pounds of “chum” needing disposal. Throughout the years various solutions were tried, but to no avail. Returning waste shell to the Bay created a loading problem at the point of discharge, creating a green “paint” along the bottom. Landfilling was awkward and created odors difficult to control. In the summer of 1992, New Earth began composting the tons of chum, turning it into an odor free humus, a composted garden product, “Chesapeake Blue” now bagged and sold in six states.

With the success of composting as a solution to the crab chum problem, New Earth turned its attention to other food processing by-products. Traditional disposal methods for these by-products had been land application. But with increasing demands on the land mass and the development of farmland it has become increasingly difficult to access this solution except for the most benign waste (i.e. vegetable cuttings). New Earth’s next feedstock was clam processing waste. This is the solid portion of the processing water that is belt pressed into cake. The clam residue has a high pH due to addition of lime as a floc. The clam residue was another difficult to handle waste due to its clay like consistency, high pH, and ready to rot clam protein. The task was made easier when our next feedstock was introduced. All of the Grey Poupon mustard in the country is made in Cambridge, Maryland. The waste from this product amounts to several tons a day, just about the same as the clam. The mustard bran however has entirely different physical characteristics. The bran has a low pH, is very viscous, and has a rather pleasant odor, reminiscent of a day at the ballpark. This then became a
perfect match to blend with the clams, helping us overcome all of the problems associated with them. Ordinarily, we compost feedstocks separately, unless there is good reason to mix.

In addition to these two seafood based by-products the facility handles some of the waste from the poultry processing industry. Waste solids from poultry processing water is known as DAF, derived from the practice of floating the solids from the waste water. This material is sludge like and may be thick or thin, it makes an excellent source of moisture into the compost recipe. We also receive feathers, which the industry normally processes into chicken feed, but due to the high volume and occasional breakdown of rendering equipment, the feathers sometimes find their way to our site in sporadic bursts. They are a good source of nitrogen into the recipe.

Some years ago, New Earth began working with poultry litter. This was well before _pfisteria_ precipitated a hard look at manure disposal practices. Although initial work that included time and motion studies showed that it cost almost $30/ton to compost litter, New Earth continued improving that equation until composting litter became economically viable.

Although some of our feedstocks present unique handling challenges, the economics of a composting facility is probably the most difficult aspect of a successful operation. All organic material can be composted, but at what cost? There are a lot of good sources of ingredients that will make good composted products, but the collection of a tipping fee is necessary. The compost process takes time, up to a year in a lot of instances; equipment and labor are expensive; we often need to pay for components of the recipe that may be in short supply (in our case woodchips); and the process results in a loss of approximately half the mass. The last example is illustrated by the realization that you can only sell half of what you take in, although your expenses are based on the latter. This means front end dollars are twice as important as back end.

Our facility regularly turns away good compostables from food processors that have good alternatives. A vegetable processor has an easier time sending material to a hog farm or to land application than does a clam shucker or crab packer. We believe that more difficult access to land application is a trend that will continue and works in favor of the compost alternative.

This is not to diminish the importance of receiving good value for the finished product. There are many obstacles to this however. The main problem is consumer education; an uneducated consumer is less likely to buy your product at a price that you may ask. Other obstacles include competition from municipally, or otherwise, subsidized compost operations. This can include a county grass and leaf compost facility that practices recycling of these materials via composting, but often lacks the appreciation of value in the finished product. The product is often given away or sold at a price unrelated to the cost of production. Similarly, biosolids compost facilities can command a tipping fee beyond that of a food residue facility. These products too find their way into the market at lower prices.
It is probable that a small facility must always be able to compete on quality. Our operation starts with good science. Analyses are taken on all potential incoming materials. A recipe is then formed that will indicate to us what our expenses will be, this then determines the fee. The beginning is also a good place to stop problems before they occur. This is the time to have an understanding with the generator that the material needs to come in fresh and devoid of contaminants. Pieces of glass and/or plastic can drastically diminish the value of your compost.

After the recipe is determined, the physical handling routine is established. Will the material go directly to mixing or will it be drained onto a bed of woodchips for incorporation later? Typically we spend a couple of months saturating woodchips with our food processing liquids; we then mix wet woodchips with drier nitrogenous materials. This prevents leachate that might occur were you to saturate the poultry litter or crab chum. Once the mix is right the compost process begins. We take care to monitor its process, primarily by way of temperature recordings. Temperatures are a guide to when to turn the material and are an indicator of when the process is nearing completion. It is required by the state that we document a pathogen kill that entails reaching certain temperatures over a certain time with a number of turnings. This ensures a safe product in the marketplace.

When the compost is finished, we usually prefer to give it time to mature; this is as simple as letting it sit for another couple of months. There are some advantages to that, although some applications do not require it. We seek to establish our composts as superior to others by quality control, consistency, and creating brand names. Chesapeake Blue was our first compost and was named for the Chesapeake Blue Crab. Chesapeake Green later was able to capitalized on that and was named because it turns grass green. Other names such as Chesapeake Clam Bake and Chesapeake Chicken are used informally to test market reaction.

Most of our markets do require it and most are higher end. These include the bagged goods and bulk homeowner market, landscapers, horticultural growers, golf courses, and state DOTs. In addition to the type of compost produced, we have the ability to blend finished products when the market calls for it. As an example, the state of Maryland composted biosolids that over time developed quite a loyalty as a turf dressing. The product was high in iron (for green) and high in lime (providing the pH preferred by turf). When the state closed the facility, New Earth was able to blend composts that resulted in this analysis, thus capturing market share. Another instance is to blend composts as a horticultural media. University tests reveal performance of blended composts as superior to any one compost. As a final example of blending products to achieve performance, the company is currently blending a compost based organic fertilizer to be crop and soil specific.