Composting – Waste Alternatives

M.J. Depaz

University of Florida Soil and Water Science Department

Disposal of organic waste generated by humans is becoming a problem due to increasing population and rising standards of living (Gray et al., 1971). Florida, in particular, has had rapidly increasing population throughout the past 20 years, thus generating large quantities of waste (Muchovej and Obreza, 2001). From 1990 to 2000, the population increased by 4 million people (Department of Heath, 2009). Traditional disposal methods are no longer adequate to handle the increase in waste. Alternative means of handling wastes need to focus on utilization rather than disposal (e.g. land application). For example, municipal solid waste, animal manure, and vegetable and yard waste have proven by research to be suitable for land application, especially after composting these source materials (Muchovej and Obreza, 2001). The beneficial alternatives to traditional disposal are applying composted solid municipal and yard wastes to agricultural fields. Agricultural soils in Florida have low residual fertility due to erosion, nutrient run-off, leaching, and organic matter loss (Crecchio et al., 2001). Low residual fertility has lead to the recognition that there is a great need for improved soil quality to promote sustainable plant growth (Crecchio et al., 2001).

Composting organic wastes is a low external energy input microbial decomposition process that produces CO_2, water, mineral ions, and stabilized humus-like material (Inbar et al., 1993; Ozores-Hampton et al., 1998; Huang et al., 2000; Stocks et al., 2002). The composting process improves handling by lowering the volume of feedstock to be transported, thus lowering transportation costs. Other benefits of composting wastes for land applications are reduced particle size allowing for uniform field application, increased nutrients, and decreased phytotoxic substances, i.e. high concentrations of

NH_4+ (Roe and Cornforth, 2000; Loecke et al., 2004; Gil et al., 2007). Recently, composts have been produced from waste material such as municipal solid waste (MSW), manure, and yard waste (Pandey and Shukla, 2006). Manure that has been composted allows for a reduction of weed seed content, deodorization, and suppressed insect population, all of which are a potential nuisance to neighboring areas (Gil et al., 2007; Loecke et al., 2004; Eghball et al., 1997). Composts used in agricultural areas can increase soil structure, water storage capacity, and nutrient retention (Pandey and Shukla, 2006). Compost application reduced plant diseases and subsequently reduced pesticide use (Keener et al., 2001). For a manure compost to be compatible with agriculture application, the manure must be transformed into a stabilized humus-like product and applied directly in the field to be a good source of nutritional elements (Inbar et al, 1993). Available nutritional elements such as potassium (K), calcium (Ca), magnesium (Mg), and phosphorus (P) increased when compost was applied (Courtney and Mullen, 2008).

Compost Sources in Florida

Municipal Solid Wastes

In Florida alone, about 37 tons of municipal solid waste was collected for recycling in 2005 (Li et al., 2010). In 1988, Florida produced 15.8 million tons of MSW. From 1997 to 2001 the total municipal solid waste increased from 23 to 28 million tons (Department of Environmental Protection, 2009). An alternative to landfills and incineration is composting and land application. MSW has been shown to provide organic matter as well as be a source of nutrients that increase fertility (Mylavarapu and Zinati, 2009). Banuelos et al. (2004) found that MSW is a natural resource that contains essential plant nutrients including N, S, Fe, Mn, Cu and Zn. The addition of MSW compost not only improves soil properties but also reduces environmental problems associated with disposal of various refuses. MSW is rich in organic matter and nutrients such as organic and inorganic N (Weber et al., 2006; Creechio et al., 2001). When MSW is composted, it can produce a substance similar to soil humus providing organic material that improves soil fertility (Weber et al., 2006). Municipal solid waste compost improved water penetration, increased soil porosity, and increased water retention (Weber et al., 2006).

Manures

Manure nutrients and decaying organic matter are both natural components of the environment and can add to the production of more plant and animal tissues (Van Horn et al., 1990). Manure produced by livestock has been used in agriculture systems for centuries as a soil amendment (McAndrews et al., 2006). Land application of manure to crops is a method of recycling plant nutrients. The plant nutrients are taken from the soil when harvested, given to the animals as feed, and then returned to the soil as manure (Coudhary et al., 1996). The land application of organic wastes is not only economical but an environmentally acceptable disposal method (Muchovej and Obreza, 2001).

Manure can be a solid, liquid, or slurry, each of which requires different management practices (Eghball and Power, 1994). Hogs produced, on average, about 2 tons of manure per year per animal (Choudhary et al., 1996). About 1 million head of swine are finished each year. This swine manure can then be applied directly to the field or piled for additional composting (Loecke et al., 2004). Other swine facilities use slotted floors and liquid storage under the slats. A new system uses slotted floors, however a system beneath the floor dries the manure allowing the manure to be handled as a solid and used for land application or composting (Keener et al., 2001).

About 26.4 tons of bovine manure is collected each year from feedlots in the US. Feedlot manure is usually cleaned about once a year, having time to stabilize from sitting on the floor surface for a long period of time. Eghball et al. (1997) found that manure from animal feeding units are a resource for crop production because of the important macro and micro nutrients. However, long-term storage and inappropriate use of raw manures can cause leaching of nitrates and other contaminants into the groundwater as well as odors, health risks, and difficulty of handling (Gil et al., 2007; Inbar et al., 1993). The excessive use or storage of manure can cause accumulation of nitrates and P in surface water that can limit land application (Keener et al., 2001; Roe and Cornforth, 2000).

Vegetable and Yard wastes

Other alternatives for compost materials are crop wastes and yard trimmings. Vegetable wastes are non-edible debris and discarded during collection, handling, transportation, and processing of agricultural corps that can be an option for composting. Composting of the crop waste is an old and inexpensive way to convert the unusable organic waste into useful compost that can be used as an organic fertilizer or soil amendment (Change et al., 2006). Applying compost to high value vegetable crops such as tomatoes may be more affordable and practical than applying the compost to pastures and grasses (Roe and Cornforth, 2000). Growers are more apt to use yard trimming compost rather than biosolids and municipal solid waste due to fewer regulatory restrictions for yard trimming compost use (Maynard and Hill, 2000). Recently, yard waste has been banned from landfills in many states, and more specifically, Florida has banned yard waste since 1992 (Maynard et al., 1997; Barkdoll et al., 2002).

In 1997 the USDA reported that ten million tons of tomatoes were processed in the United States and 1 to 3 million of that was not used for human consumption (Persia et al., 2002). In Florida alone, tomato packinghouses produced between 149,000 and 399,000 tons, which is only 1.5 to 4% of the total production in the US (Sargent, personal communication). In four districts that comprise the Florida Tomato Committee, culled tomatoes accounted for 256, 502 tons, which cost $648,300 for disposal per year. Typical greenhouses burn about 40 to 60 ton of vegetable waste or pile it near the greenhouses and let the plant material decompose (Alkoaik and Ghaly, 2006). The costs of landfills and concerns about solid wastes have increased interest in finding a new economical outlets for tomato by-products (Weiss et al., 1997). Composting provides a safe disposal method for the waste produced each year (Ozores-Hampton, 1998).

Composting

The Process

During decomposition, microorganisms such as facultative and strict aerobic bacteria, fungi, and actinomycetes, will assimilate complex organic substances and release inorganic nutrients (Ozores-Hampton et al., 1998; Huang et al., 2000). Proper composting stabilizes the composted organic carbon, as well as killing potential crop pathogens before the resulting compost is applied in the field (Ozores-Hampton et al., 1998).

Successfully composting of wastes requires certain conditions be met.

C:N Ratio

1. The C:N ration should be between 25:1 and 35:1 for most compost organisms to thrive and have a high degree of efficiency of N assimilation into microbial biomass. When the C:N ratio is too low, N is lost through ammonia volatilization (Maynard, 2000). A C:N ratio greater than 40:1 promotes immobilization of plant-available nitrogen and slows the decomposition process because of limited N (Zibilzke, 2005).

Moisture Content

2. The optimum moisture content for compost is between 50% and 70% (Stocks et al., 2002). If the compost is more than 70% moisture, it is too moist and the air spaces are filled with water

limiting the amount of oxygen that the organisms can obtain (Maynard, 2000; Chang et al., 2006).

Oxygen

3. Adequate oxygen supply is needed and should be above 5% (v/v) (Stocks et al., 2002). Inadequate oxygen supply less than 15% leads to anaerobic conditions, which decrease the rate of decomposition and increase odors (Grays et al., 1971; Chang et al., 2006). To ensure oxygen supply to microorganisms, the compost pile must be turned or put into a rolling drum (Levy and Taylor, 2003), manually aerated, or mixed continually throughout the composting process (Ozores-Hampton et al., 1998; Change et al., 2006; Maynard, 2000). Agitation of a pile can speed up the composting process by improving aeration (Gray et al., 1971). The movement of material allows fresh air into the middle of the pile where diffusion alone is insufficient to maintain high oxygen and low carbon dioxide levels. Agitation aids homogeneity of organic materials and nutrients, causes abrasion of materials and size reduction, and allows exposure of fresh material that has not yet been decomposed. Agitation also prevents overheating of the center of the pile and cooling of the outside of the pile. Too much agitation of the compost can be detrimental and lead to excess heat loss and moisture (Gray et al., 1971).

pH

4. A compost pH of 5.0 to 8.0 is needed for vegetable crops (Ozores-Hampton et al., 1998; Chang et al., 2006).

Particle Size

5. Small particle size aids in decomposition because smaller particles have greater surface area for microbes to attack (Gray et al., 1971). Compost material passing through a screen or sieve of 7.6 cm or smaller is needed to minimize large particles but many studies use screens with openings that are between 2 and 9 mm (Chang et al., 2006; Huang et al., 2000; Wu and Ma, 2001; Ozenc, 2006). Particle size that is too small will prevent oxygen diffusion into the pile and carbon dioxide out of the pile at a point when oxygen consumption is highest (Gray et al., 1971).

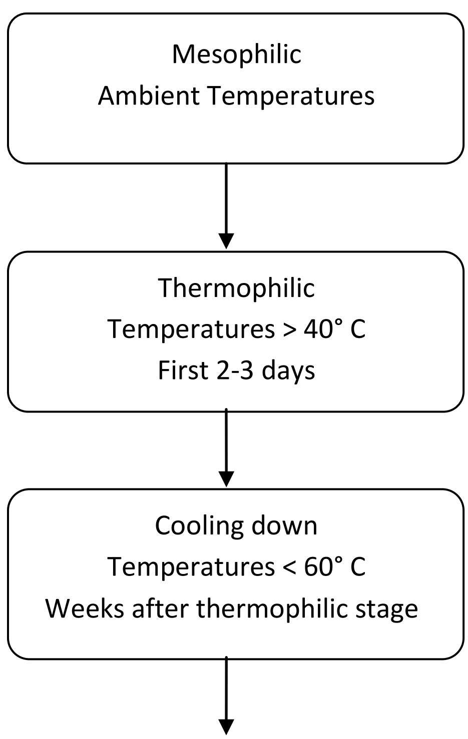
Microbial activity during the composting process has four stages, mesophilic, thermophilic, cooling down, and maturing (see Figure 1).

1. The beginning mesophilic stage has ambient temperature usually between 15 C and 4 C and the organic waste is slightly acidic (Zibilzke, 2005). Common microbes that degrade compost material are *Pseudamonas spp., Bacillus spp., and Achromobacter spp.* (Zibilzke, 2005). These microbes require not only oxygen and moisture for their growth and reproduction, but a source of carbon, N, P and K. The biological oxidation of carbon from the waste material gives the microbes energy (Gray et al., 1971). Readily available substrates such as proteins, sugars, and starch are oxidized rapidly (Zibilzke, 2005).

2. The thermophilic stage begins when temperatures greater than 40 C (104 F) are reached and thermophiles take over the degradation process (Gray et al., 1971). A constant temperature in excess of 40 C (105 F) is needed (see figure 2). Common thermophiles include *Bacillus* spp., *Steptomyces* spp., and *Thermoactinomyces* spp (Zibilzke, 2005). The thermophilic stage at 40 C begins the first 2-3 days of composting. The center of the pile then stabilizes at 60 – 70 C for 3 to 15 days (Gray et al., 1971; Maynard, 2000). When air temperature inside the pile falls, the compost should be turned to ensure not

only aeration but also that fresh, undecomposed material is introduced into the middle of the pile (Maynard, 2000). The thermophilic temperatures ensure the elimination of harmful organisms, rapid stabilization of compost material, and pasteurization of the compost (Zibilzke, 2005).

3. The cooling down phase or curing phase occurs as the pile temperature drops to less than 60 C and approaches ambient temperatures. When the temperature reaches 40 C the mesophilic organisms reappear. The maturing phase is the longest phase and requires a period of months. This phase takes place when temperatures are ambient, the mesophilic organisms dominate, and condensation and polymerization take place (Gray et al., 1971). By allowing time for curing the mesophilic microbes are able to break down deleterious metabolic intermediates like acetic acid and phenolic compounds. The final end product is mature compost that is a stable and complex humic acid (Zibizke, 2005).



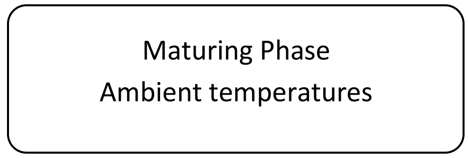


Figure 1. Stages of Composting Process

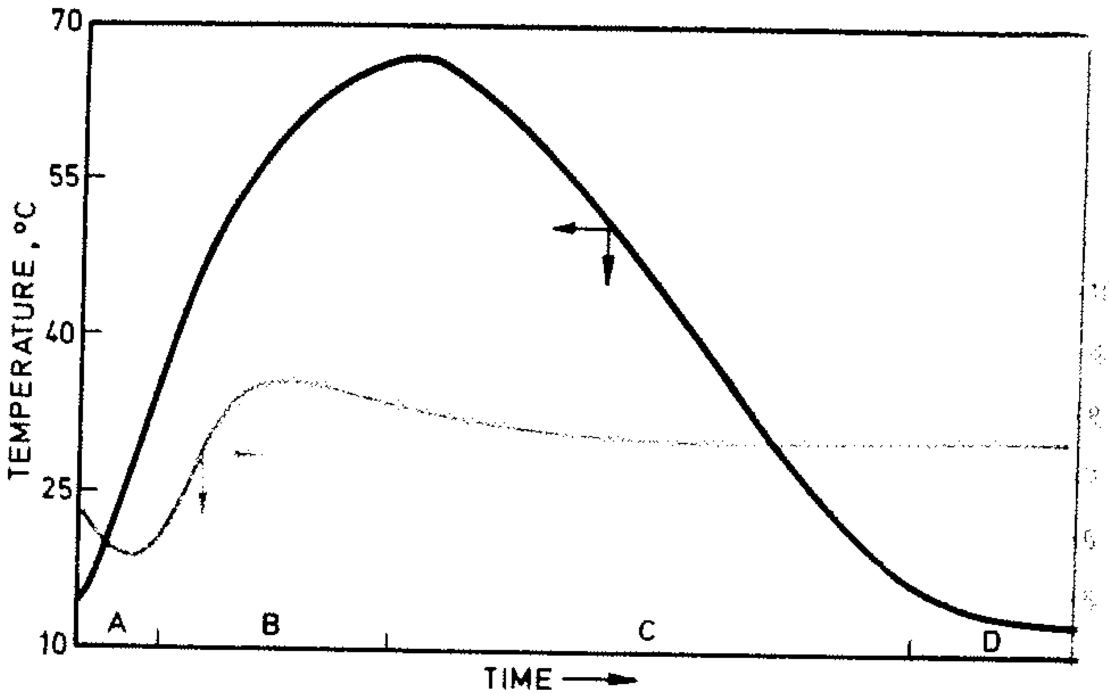


Fig. 1 (left). *The composting process*

Fig. 2 (above). *Temperature and pH variation with time indicating the phases of microbial activity*

A—mesophilic, *B*—thermophilic, *C*—cooling
D—maturing

Figure 2. Temperature and pH throughout the composting process (Gray et al., 1971)

Types of Composting Methods

The main difference between compost operations is in the methods of composting. Passive piles, turned or aerated piles, and in-vessel systems are the three general types of methods. All these composting methods are relatively low in capital costs especially if these methods can be carried out in the open air (Schaub and Leonard, 1996). This process is time consuming and takes place at a much slower rate than any other method (Fernandez and Sartaj, 1997). Passive piles are compost materials that are piled into a heap and left undisturbed, relying on natural airflow for aeration. Windrow piles are similar except the piles are laid out into rows (Shaub and Leonard, 1996). Composting using passive piles can be accelerated by employing aeration systems that draw air through the pile and into perforated pipes to aid in oxygen delivery within the pile. Convection air currents are established by temperature gradients from the point where the air enters the pipes and center of pile containing the warm decomposing material (Fernandez and Sartaj, 1997).

Turned or aerated piles allow air to be mixed into the decomposing material through the use of the mechanical action of front loaders or manually by pitchforks. This method also allows for monitoring the conditions within the composting material (Schaub and Leonard, 1996).

The in-vessel composting method relies on containing the material in drums, bins, or channels to promote the optimum conditions for quick decomposition. The vessels have a means of turning, or stirring of the contents, and allow for control of aeration, moisture content, and temperature as well as containing odors. The benefit of the in-vessel system compared to the passive or turned pile method is that this system reduces the amount of time needed for the active composting phase from 3-5 weeks to 10-14 days. The disadvantage of the in-vessel system is the initial high capital cost and intense management (Schaub and Leonard, 1996).

Plant Available Nutrients from Biosolids, Manure, and Compost Amendments

Methods of Nutrient Availability

Application of biosolids directly to the field increase nutrient content of the soil by increasing organic matter and essential macro/micro elements to the soil. The availability of essential elements depends on soil properties, biosolid decomposition rate, and organic matter content (Banuelos et al., 2004). Applied biosolids are subject to changes by weathering and microbial processes that reduce leaching and allow for the elemental forms to be available for plant uptake (Banuelos et al., 2004).

Composting municipal solid wastes is beneficial because the unstablilized organic matter in uncomposted wastes has a high C:N ratio. The microbial decomposition can then affect the N mobility and cause it to become unavailable for the plant (Busby et. al., 2007). Applications of pig slurry, dairy manure, wastewater effluent and biosolids also affect the plant nutrient availability in the soil through microbial transformations of the nutrients. Nitrogen mineralization as well as nitrification rates have been found to increase through additions of sheep manure, dairy effluent, and cattle slurry (Habteselassie et al., 2006). Mineralization of N increases as temperatures increase and is greatest when the soil moisture is close to field capacity of the compost (Eghball et al., 2009).

The products of soil mineralization and nitrification are NH_4^+ and NO_3^- which comprise the majority of N available for crops (Shi et al., 2004). Nitrification is the process where ammonium ions in the soil are enzymatically oxidized to nitrates (Brady and Weil, 2008). Manure compost provides soils nutrients that are beneficial to crops for many years. A study done by Eghball et al. (2000) found 12% of compost N was mineralized the first year, 12% the second year, and 8% the third year.

Benefits of Compost Use

Composts change the soil chemical and physical properties. As surface mulches it increases organic matter, suppresses weeds, improves water holding capacity and provides plant nutrients (Levy and Taylor, 2002; Roe, 1998; Stofella ad Graetz, 2000). It can also be used as a means of reducing the frequency and rate of irrigation and inorganic fertilizer used on Florida sandy soils, and increase yields (Ozores-Hampton et al., 1998; Maynard, 2000).

Organic amendments such as MSW, increases K, Ca, and organic matter of sandy soils, promotes plant health, increases yields and increases soil pH (Courtney and Mullen, 2008; Roe, 1998). Ozores-Hampton et al. (1994) found that amending calcareous soils with municipal solid waste increase yields and growth of tomatoes compared to unamended soils. A different study conducted on barley growth by Courtney and Mullen (2008), showed that plant available K, Ca, Mg, Na, and P increased when spent mushroom compost was applied to the soil.

Multiple studies have found that using a combination of compost and fertilizer increases yields (Roe, 1998). Togun and Akanbi (2003) found that the use of compost alone or compost with mineral fertilizer was better than the control. The fortification of compost with a small amount of mineral fertilizer almost doubled the number of tomato fruits per plant compared to the control. The control in their 1997 trial produced 9.5 fruits per plant, the maize-stover with poultry manure compost produce 19.8 fruits per plant, and the maize-stover with poultry manure compost with 30 kg N/ha produced 18.1 fruits per plant. Maynard (2000) found that a combination of leaf compost and a reduced rate of 10-10-10 fertilizer produced optimum yields of most vegetables including tomatoes.

Applications of yard compost had a cumulative effect on yields of onions (Maynard and Hill, 2000) and have higher yields of tomatoes than with unamended soils (Maynard, 1997; Maynard, 1999;

Maynard, 2000). Tomatoes that have been amended with leaf composts have shown a cumulative effect as well and have higher yields than with unamended soils showing positive results on tomato plants (Togun and Akanbi, 2003; Maynard, 1997). Sugar cane (Stoffella and Graetz, 2000) and hazelnut husk (Ozenc, 2006) composts have been used as alternative compost to traditional compost (such as yard waste and MSW) and have increased tomato yields by 1.8 and 1.74 times higher than the control. The study by Stoffella and Graetz (2000) on sugar cane compost found higher marketable tomato fruit yield and fruit size in compost amended plots than unamended. The control was not amended with fertilizer or compost and produced a total of 2,156 kg/ha with an average fruit size of 108 g/fruit and the compost amended plots without fertilizer produced a total of 36,656 kg/ha with a fruit size of 177 g/fruit.

Affects on Weed Control

In the past, composts have been used in place of polyethylene mulch, inorganic fertilizers, and weed control in alley ways (Stofella and Graetz, 2000). Immature compost can even be used in weed control because it possess phytotoxic compounds (acetic acid and propionic acid) that prevent weed growth (Leroy et al., 2008).

Soil Characteristics

In sandy soils, the composted organic matter acts like a sponge, helping to retain water that drains down and out of the root zone (Golabi et al., 2007). In a study by Tambone et al. (2007), plots treated with compost showed a higher total organic carbon content than the control from the beginning to the end of the experiment. These researchers also found that the cation exchange capacity (CEC), which is the amount of exchange sites that are able to adsorb and release cations, correlated with the total organic carbon soil contents exhibiting the role that organic carbon plays in CEC determination.

Courtney and Mullen (2008) found that with the addition of spent mushroom compost, the organic carbon content increased with increasing application rates whereas, the application of inorganic fertilizer had no effect on soil organic carbon. Pandey and Shukla (2006) found that the repeated application of composted yard waste resulted in the increase of soil moisture, indicating increased organic matter increased soil water retention in the soil as well as increased the capillary rise from the water table.

In a study done by Leroy et al. (2008), application of fruit and garden waste (VFG) compost and raw cattle slurry maintained aggregate size and distribution and the combined application of both VFG and slurry resulted in the highest aggregate size and distribution. The hydraulic conductivity, which is the ease that water flows through the soil pores in response to a potential gradient, increased when both VFG and slurry were applied (Brady and Weil, 2008; Leroy et al., 2008). Both the aggregate stability and hydraulic conductivity can be attributed to an increase in soil organic matter which forms larger and more stable aggregates and increases the total pore volume. Organic matter can also prevent leaching by retaining water that would normally drain down beyond the root zone allowing sufficient residence time within the root zone for plant uptake of available nutrients (Golabi et al., 2007).

Composting is a low energy input decomposition process that is easy and cost-effective. Types of composting materials include municipal solid waste, manure, and vegetable and yard waste. Studies show that adding compost to Florida sandy soils can provide benefits to crops and soil for many years by reducing the amount of irrigation and application rates of inorganic fertilizer required to maintain or increase growth and yields. Florida has very sandy soils with little residual fertility due to nutrient run-off and leaching, organic matter loss, and erosion. Adding composts to soils in Florida is beneficial by increasing the macro/micro nutrient content and organic matter content of the soil. The addition of compost can also suppress weeds, increase water holding capacity, and reduce leaching of essential plant nutrients.

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