UC Workshop on Compost Use for Pest Management

How agricultural end-users can assess compost quality

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Compost quality is a much debated topic by many producers and users of compost. This is a result of the numerous characteristics of compost that have been suggested to play a role in quality and the fact that much of the supporting scientific data for these suggestions is material and application specific. Although there may be disagreements on quantitative measures of quality, most will agree that the beneficial characteristics of compost, such as the suppression of plant diseases, are highly coupled to the composting process and in many cases ultimately defined by composting process management.

The goal of this presentation is to introduce some of the common measurements of compost quality and how to evaluate results from these measurements. Another goal is to present to you some strategies used in managing composting processes and how an assessment of quality can be gleaned from an analysis of process management.

Chemical and Biological Measurements of Quality

There are many chemical and biological measurements used to assess quality. A list of some common measurements and comments on these measurements are given below.

Chemical Measurements

Measurement	Comments
pH and alkalinity	pH plays a large role in the availability of plant nutrients. A basic pH can reduce phosphorous, manganese, and zinc availability, while an acidic pH can cause potassium, calcium, nitrogen, copper and molybdenum deficiency. An optimal pH value depends on the system to which compost is to be applied.
	A pH< 5 is a good indication that the compost measured is not stable and one which probably contains phytotoxic compounds.
	Very little is known about the effect of alkalinity in composts, except that a compost with high alkalinity may help buffer the system against large pH changes.
cation exchange capacity (CEC)	The CEC is a measure of the exchangeable cations that a compost can absorb. The higher the CEC of a compost, the more exchangeable cations it can hold. The CEC of compost tends to increase as maturity and humic substances increase.
	The CEC depends on the pH of the compost, thus care should be taken when comparing the CEC of composts with different pH.
salinity	The desired salinity of a compost will vary depending on the application. The salinity of manure composts is usually higher than composts from yard waste.
	The salinity is typically measured by preparing a water-based paste of the compost, thus this measurement is a function of the dilution ratio of compost to water. Caution should be taken when comparing salinity values of composts where dilution ratios are unknown or are different.

Carbon to Nitrogen ratio (C/N)	The C/N ratio is a measure of the ratio of the total carbon and nitrogen. This ratio is typically used to assess stability and maturity yet it provides no measure of the biological availability of carbon or nitrogen in a sample. For instance, a compost with a high C/N where lignin represents a large fraction of the carbon may have the same impact on a system as a compost with a lower C/N where cellulose represents a large fraction of the carbon. In general it has been suggested that composts with a large C/N may cause nitrogen immobilization, while composts with a small C/N may result in ammonia toxicity.
heavy metals	Measurement of heavy metal concentrations in composts produced at composting facilities is required by law and limits on specific metal concentrations are provided in the California Composting Operations Regulatory Requirements. Studies have shown composts to reduce leaching of heavy metals, but research is still needed to evaluate the extent of irreversibility of this process.

Plant nutrients such as N, P, and K are also commonly measured for composts. The importance of these values will again depend on the desired application.

Stability

Biological measurements such as stability and plant bioassays are often used to assess the quality of compost. Stability measurements will be mentioned below. Plant growth and disease suppression bioassays are discussed in other sections of these proceedings.

The stability of a compost is often measured to assess potential phytotoxic affects of compost. Stability has also been used in combination with other chemical measurements to assess the degree to which composts suppress plant pathogens. A stability measurement is defined here as a measure of the biological activity within a compost sample which has adequate moisture and oxygen and is not inhibited by high (>50 ^{o}C) or low (<20 ^{o}C) temperatures. A stability test essentially allows one to gain insight into the rate of decomposition and thus how "finished" a compost may be with respect to raw or mature composts.

Listed below are four common measurements of stability.

1. Heat production.

   This test relies on the fact that aerobic microorganisms decomposing the compost produce heat and the heat produced is proportional to microbial activity. This test is typically performed by placing the sample in an insulated container with a thermometer. The temperature rise in the sample is used to assess stability. An important note about this test is that the temperature rise is not only a function the heat generated from microbial activity, but also on the sample weight and moisture content.

2. Oxygen consumption.

   This test measures oxygen depletion by microbial activity. The test is usually performed in a controlled-temperature and sealed environment. The rate of oxygen depletion from the environment and/or the change in oxygen within the environment over a given period of time are used to assess stability.

3. Pressure change.

   If a biologically active compost sample is placed in a sealed container along with a solution which absorbs CO_2, the pressure in the container will drop. As oxygen is consumed by aerobic microbes, CO_2 is produced; absorbing the CO_2 from the gas in the container results in a pressure drop. Stability can be assessed by measuring the pressure drop in the container over a given period of time.

4. CO_2 production.

   This test measures the CO_2 produced by both anaerobic and aerobic microbial activity. The test is performed in a sealed environment and is usually done with some temperature control. The measured rate of CO_2 production and/or the change in

CO_2 within the environment over a given period of time are used to assess stability.

One issue common to the biological measurements of stability is that sufficient time is needed for the microbes within the compost to recover from the perturbation associated with material sampling. Most of the techniques listed above require at least two days for the microbial population within the sample to "adjust" to the new environmental conditions before an accurate assessment of stability can be obtained. The user should be wary of stability tests done in less than 48 hours.

Assessing the Process

Records that must be kept by a composting operation to be in compliance with the California Regulations include compost temperature measurements (temperature history), mixing frequency, and metal and fecal coliform concentrations of the final product. Other measurements often recorded include oxygen and carbon dioxide concentration, moisture and volatile solids content. These measurements can be very helpful to you in assessing compost quality.

Temperature

Temperature plays an important role in stability, pathogen (human and plant) destruction and weed seed inactivation. With respect to temperature the California Integrated Waste Management Regulations state: (1) for an enclosed or within-vessel composting operation, temperatures must equal or exceed 55^{o}C (131^{o}F) for a period of three days, (2) for a windrow operation, temperatures must equal or exceed 55^{o}C (131^{o}F) for a period of 15 days and the windrow must be turned at least 5 times during this period, and (3) for an aerated static pile operation, temperatures must equal or exceed 55^{o}C (131^{o}F) for a period of three days and the compost must be covered with 6-12 inches of insulating material during this period.

Temperatures and temperature histories required by the California regulations are sufficient for both pathogen and weed seed inactivation. This result will only hold when actions have been taken (such as mixing or enclosing the pile) to ensure all portions of the compost have been exposed to high temperatures. Thus, the user would want to verify by analysis of temperature histories at several locations in the process that the compost had been exposed to sufficiently high temperatures.

Some compost piles can reach temperatures as high as 70°C (158°F) if not controlled properly. Temperatures this high can significantly reduce microbial activity and the rate of decomposition. This can result in an unstable product and one which is potentially phytotoxic. The user would want to verify longer processing and curing times for a material exposed to temperatures greater than 65°C (150°F) for long periods of time.

One common rule of thumb regarding temperature and stability is that if the temperature difference between the compost and ambient air is greater than 10°C (15°F), the compost is still fairly unstable.

Oxygen and Aeration

Decomposition in composting is performed by both aerobic and anaerobic microorganisms. Aerobic microorganisms are favored because they decompose organic materials more rapidly than anaerobic organisms and they do not produce the nuisance odors typically associated with composting. Thus, one important management strategy in composting is to increase oxygen transfer within the pile. Oxygen transfer can be enhanced by increasing the porosity (volume fraction of air) and/or by forcing air through the compost. Porosity is increased by the addition of bulking agents, control of moisture and mixing of the pile. Overmixing, however, can reduce the particle size and subsequently the porosity of the compost.

Studies have shown that biological activity within a composting operation begins to decrease when oxygen concentration drops below 10% (CO_2>11%), and is significantly reduced when the oxygen concentration drops below 3% (CO_2>18%). Processes operated with a low oxygen concentration could produce an unstable compost. If records of a composting operation show low oxygen or high CO_2 concentrations for long periods of time, the user should verify that the material was composted and cured for an extended period to ensure the product is stable.

Moisture

The balance of moisture within the process is highly coupled to both temperature and oxygen control. Moisture is required by all organisms, yet too much moisture will reduce the amount of oxygen supplied to the process. Not enough oxygen will result in anaerobic activity and a decrease in the rate of decomposition. This decrease could result in an unstable product. Also, a large fraction of the heat generated during the composting process is removed by evaporative cooling. Significant amounts of water can be lost as a result of this cooling, so moisture management must be a key component to any composting process.

The moisture content at which moisture becomes limiting to microbial activity and oxygen transport varies among materials. The lower limit of moisture content is about 35-40% (weight of water x 100/total wet weight) and the upper is about 60-70%. The user would want to verify that if moisture content went below 35-40% during the process, measures were promptly taken to increase the moisture content. If moisture was never adjusted, the product could be unstable. If the moisture content of the material went above 60-70%, the user would want to verify that the material was composted longer to compensate for the reduced oxygen transfer, and thus aerobic microbial activity.

Other issues of importance are feedstocks and how they were processed prior to composting. The importance of these issues depends on how the compost is to be used. The extent to which contaminates such as glass, metals and lumber scraps are removed from the compost plays a large role in the quality of the product. The user would want to look closely at a compost for small pieces of plastic and other contaminants prior to accepting delivery.

Summary

A good composting facility should be able to provide the user with regulatory records as well as other monitored parameters upon request. Below is a summary of some questions the end-user would want to answer upon analysis of facility records.

1. *Were temperatures sufficiently high to ensure pathogen and weed seed destruction?*

   The user would check for temperatures greater than 55^{o}C (131^{o}F) at several locations in the pile for:

   - 3 days if the process is enclosed or within-vessel
   - 15 days if the process is a windrow (also check that the pile was mixed at least five time during the 55^{o}C phase)
   - 3 days if the process is an aerated static pile (also check that the pile was insulated)

   The user would also want to learn about when temperatures were monitored (time before or after mixing) and the depth at which temperatures were measured. Temperatures measured before mixing would generally be higher than if measured right after mixing. Temperatures measured at greater depths in the pile (> 2 ft) would typically be higher than if measured closer to the surface.

1. *Did temperatures exceed 65^{o}C (150^{o}F) for an extended period of time?*

   The user would review temperature records as stated above. If temperatures did exceed 65^{o}C (150^{o}F) for a few weeks, the user would want to check the stability of the final product.

2. *Was oxygen limiting to the process?*

If available, the user would review oxygen and CO_2 data. If the oxygen concentration dropped below 5% or the CO_2 rose above 15% for an extended period of time, the user would want to verify the stability of the product. The oxygen concentration can drop and CO_2 rise significantly with increasing distance into the pile, thus the user would want to ask at what depth oxygen and CO_2 were measured to make an accurate estimate of oxygen limitations.

3. *How was moisture controlled within the process?*

   If available, the user would review the moisture content and moisture addition records. If moisture content dropped below 30% for an extended period of time and was not adjusted or if moisture content rose above 70%, the user would want to verify the stability of the product.

4. *How were contaminants removed from the raw material and final product?*

   The user would request information from the facility operator on actions taken to prevent contaminants including metals, plastics, glass and waste lumber from entering the process and the methods used to remove contaminants from the process. S/he should also look at a few batches of compost for contaminants.