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Odor in Commercial Scale Compost: Literature Review and Critical Analysis

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Odor in Commercial Scale Compost

Literature Review and Critical Analysis

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incorporated from the atmosphere). Instead, the interest has been as an indicator of microbial respiration and the time it takes for compost to reach maturity. Steiner et al. (2011) found that respiration peaked more quickly, and at a higher level, with 20% biochar additions. This result was not found in a treatment with 5% biochar. Tanaka et al. (2006) studied the influence of charcoal additions on the proliferation of microorganisms in a mixture of charcoal and rice bran and found that both the rate of increase and the total extent of microbes were dependent on the amount of charcoal added to the mix. Ogawa et al. (2010) said that his years of practical experience using biochar in compost in Japan confirmed that the more charcoal is used, the faster decomposition progresses.

Charting compost temperature over time is another way to gauge respiration (and therefore CO_2). When composting sewage sludge with varying percentages of bamboo biochar (0 to 9%), Hua et al. (2009) found very little difference in time and temperature curves over 42 days and little difference in total organic matter over time, except during the first few days. Jindo et al. (2012) found that while the time vs. temperature plot was similar for compost with and without 2% biochar, the biochar treatment increased the pile temperature during the thermophilic phase.

Nutrient balance and the C:N ratio can either promote or delay compost activity and respiration. Most biochars will not contribute much degradable carbon (Steiner et al., 2011) to the compost. This means that while biochar increases the total C:N ratio of the compost mix, the functional C:N may not be changed much at all.

As discussed in the next section, biochar promotes humification of the degradable carbon in the compost, leaving open the possibility of sequestering additional biomass carbon and reducing CO_2 emissions during composting. This potential could be tested by trying different "recipes" with different forms of degradable carbon combined with different amounts and types of biochar.

Biochar and compost quality

The quality of industrial compost is an ongoing issue. In a review of synergisms between compost and biochar, Fischer and Glaser (2012) state, "In spite of the potential and observed beneficial effects of compost application to agricultural soils, this technique is not widespread across Europe and especially in Germany, [where] low quality composts are produced due to inefficient waste management regulations." The authors propose improving compost quality through the addition of biochar. The benefits they suggest include "enhanced nutrient use efficiency, biological activation of biochar and better material flow management and a higher and long-term C sequestration potential compared to individual compost and biochar applications (negative priming effect)." Some of the C sequestration potential results from the long-term stability of biochar. The "negative priming effect" they refer to is the observation that total CO_2 emissions are lower from biochar-amended soils. One characteristic of the native *terra preta* soils of the Amazon is lower respiration combined with higher microbial biomass and greater microbial diversity. The implication is that biochar helps improve the metabolic efficiency of soil life forms, lowering CO_2 emissions (Thies and Rillig, 2009).

Fischer and Glaser propose an ideal modern biochar compost system (Figure 5.1) by looking at the genesis of the *terra preta* soils in the Amazon. The work of many scientists suggests that these blackened, fertile soils were human-created, not formed by natural forest fires or other processes (Glaser and Birk, 2012). Most likely they began as kitchen waste with the accidental accumulation of food scraps, ashes and manure, but as the populations grew (perhaps attracted by the newly created soil fertility of kitchen material), they began to organize and deliberately manage the material flows of plant biomass, mammal and fish bones, ash, biochar, and human excreta that resulted in the *terra preta* soils we see today. Based on this history, Fischer and Glaser propose the modern material flow management scheme diagramed in Figure 5.1 for producing high quality compost that will replenish carbon, nutrients and beneficial microbes in agricultural soils.

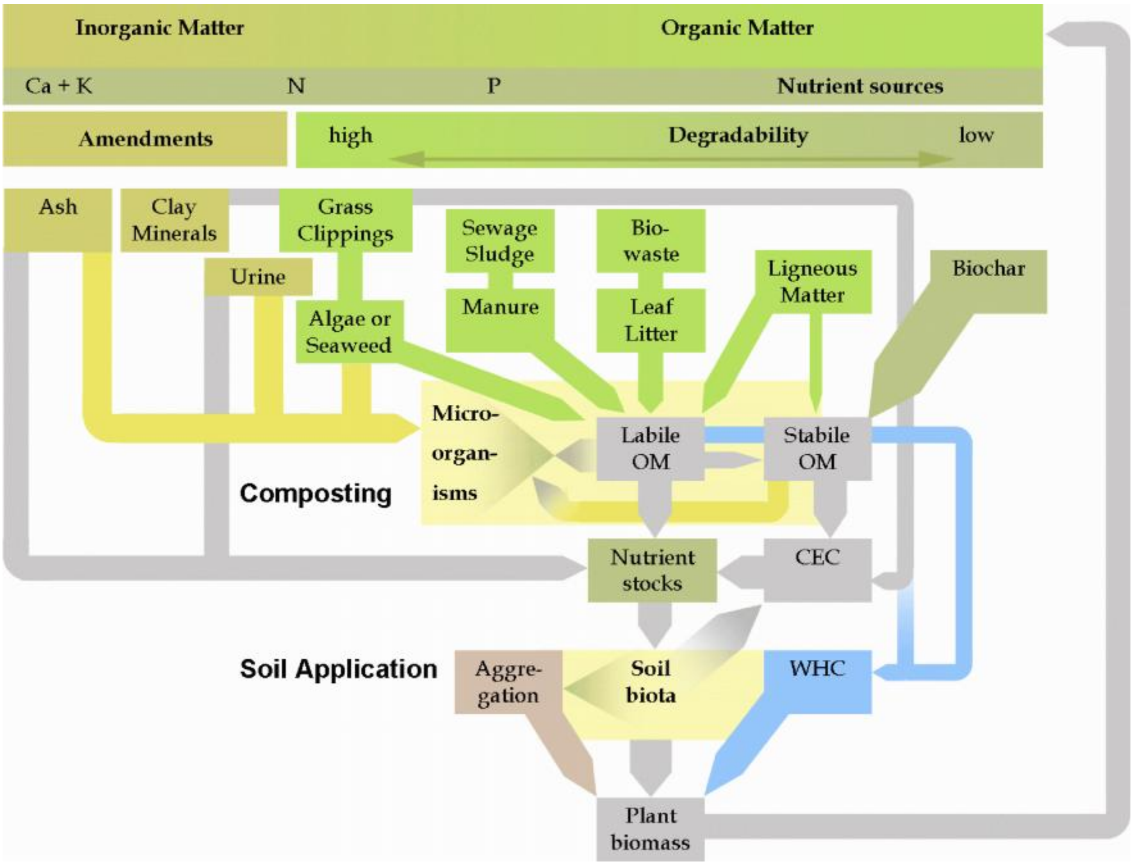

Figure 5.1: Sustainable management of natural resources by combining biochar with organic and inorganic wastes in compost processing (Fischer and Glaser, 2012)

Compost nitrogen content

Compost can lose nitrogen by volatilization of ammonia or other nitrogen-containing gases, or by leaching. As discussed previously, biochar can help retain ammonia. It also holds water, so can reduce leaching. Several authors (Spokas et al., 2011; Clough et al., 2013) have suggested biochar could be used to produce a new type of slow-release fertilizer, based on its ability to sorb nitrogen. Composting biochar with high-nitrogen feedstocks would be one way of accomplishing this. Results on nitrogen retention in biochar and compost have already been discussed, but they are summarized here: Steiner et al. (2010) found 20% biochar added to poultry litter compost reduced N loss by 52%. Chen et al. (2010) found that adding 9% bamboo biochar to pig manure compost reduced total nitrogen loss by 65% compared to the control. Hua et al. (2009) found that adding 9% bamboo charcoal to sewage sludge compost reduced total nitrogen loss by 64.1%.

Compost maturity and humic content

Several studies have looked at the effects of biochar on the stability and quality of final compost products. These studies have found that adding biochar to compost reduced the amount of dissolved organic carbon in mature compost while increasing the fraction of humic materials (Jindo et al., 2012; Dias et al., 2010; Tu et al., 2013). Following the addition of 2% biochar to compost, Jindo et al. (2012) recorded a 10% increase in carbon captured by humic substance extraction and a 30% decrease in water-soluble C. They also found an increase of fungal species diversity and proposed that these fungi were responsible for the increased humification.

Biochar property alteration through composting

Biochar has been shown to change compost properties, but the reverse is also true: composting can change biochar properties. Specifically, composting makes the surfaces of biochar more reactive and increases sorption properties. Prost et al. (2013) placed litterbags of biochar within active compost piles. They found clear increases in sorption properties from composting over a 6-month period. Borchard et al. (2012) also used litterbags of biochar in compost to assess two different biochars. They found that composting increased the sorption affinity coefficient of the biochars by 3 to 5 times for copper in a copper sulfite solution. This could be a concern where copper is needed as a trace element nutrient in soils. On the other hand, this could help immobilize metals present in sewage in China (Hua et al., 2009), producing a safer compost.

Plant growth response to biochar compost

Biochar amended compost has been found to improve several indicators of plant growth. At the conclusion of their experiment on biochar compost and CH_4 generation, Sonoki et al. (2012) performed a germination test on both the biochar compost and the control. They found a slight improvement of seed germination in the biochar compost. At the field level, Lashari et al. (2013) conducted a two-year field trial using poultry manure composted with biochar on a salt-stressed wheat field in China and found a significant decrease in salt stress along with crop yield improvement. The effect was increased during the second year of the trial.

Several studies (Fischer and Glaser, 2012; Schultz and Glaser, 2012; Liu et al., 2012; Steiner et al., 2008) have experimented with various combinations of compost and biochar soil amendments. All of these studies found improved plant growth when biochar was added to soil along with compost. A 2013 study (Schulz et al., 2013) looked instead at biochar composted together with other materials (including sewage sludge and green waste). They tested six different amounts of biochar in the compost (0 to 50% by weight), and also three different compost application rates. Using oats in greenhouse pots on two different soils (sandy and loamy), they discovered that plant growth was improved as the amount of biochar in the compost increased. They also found that growth improved with increasing application rates of each type of biochar compost.

Conclusion

Biochar is a promising ingredient for compost with the potential to improve the composting processes and reduce odor emissions. It can also create finished compost with greater value as a soil amendment and fertilizer. This is an expanding area of scientific and agricultural research and additional literature will be forthcoming. Further research and pilot projects are needed to achieve the following:

- Determine optimum application rates for biochar in composting, and minimum application rates to achieve desired effects.
- Test different biochar materials to determine the effects of properties such as surface area, ash content and volatile matter on compost processes and quality.
- Trial the use of different inoculants with biochar to assess their effects on odor control and other composting processes. Test the use of inoculants and biochar at food scrap collection points for the most effective odor control.
- Experiment with different combinations of feedstocks and biochar to determine impacts on odor generation, GHG emissions, nutrient retention and humification. Different "recipes" may be invented for composts with specific properties (e.g. slow release fertilizer).
- Carry out comparative field-testing of compost with and without biochar in different applications including agriculture, forestry and remediation.
- Assess different systems for economical production of biochar including installations at compost facilities that can use excess lignocellulosic material as biochar feedstocks.

Investigators should also evaluate the use of carbon-based materials at various points in the waste collection and process flow. Potential areas of biochar application include:

- Collection bins. Since these are unavoidably anaerobic, biochar inoculated with bokashi or similar microbial cultures could reduce odor.
- Receiving area. Adding biochar as a cover immediately after reception of waste could help control odor.
- Bulking agent. Biochar as a bulking agent in compost could help with aeration, leachate and moisture management and it can sorb odorous gases and in some cases prevent their formation.
- Add to cover. When biochar supplies are limited, it may be effective to add a layer of biochar as a cover on piles. This can be renewed after piles are turned, and the old cover will get incorporated with the compost.
- Add to biofilters. Biochar can help improve the adsorptive and odor-neutralizing function of biofilters. It can also reduce biofilter compaction and extend their life.

Finally, the comparative economics of biochar versus other odor control measures needs to be analyzed. This analysis should include not only the cost of acquiring (whether generated on site or purchased) and applying biochar, but also the potential for increased income from a higher quality compost product.

Conclusion

Food scrap collection is growing in importance with numerous municipalities in the US initiating residential or industrial programs in the last decade. This trend has the potential to contribute enormously to sustainable waste management in the US, with nearly one-third of all produced food wasted. However, this increased organics recovery has also had drawbacks. It has increased the processing burden on existing waste management infrastructure, particularly within the compost industry. In addition, the increasing percentages of putrescent material represented by food scraps have led to emerging odor concerns communities near compost facilities.

Composting is a biological process utilizing controlled, aerobic conditions within a mixed ecology to produce compost, a valued soil amendment. Finished compost has undergone an initial, rapid stage of decomposition; a longer stage of stabilization; and ultimately an incomplete process of humification (Insam and de Bertoldi, 2007). Odors are a result of compounds produced during the degradation processes, and can be produced before food scraps arrive at the facility, during compost handling and preparation, or during actual composting. Compounds primarily responsible for odors appear to be organic sulfides, mercaptans, amines, and VFAs. Terpenes, ammonia, alcohols, and hydrogen sulfide also contribute.

The composting literature indicates that composting of highly biodegradable material such as food scraps and fresh-cut green waste is highly prone to both low pH and shifts from aerobic to anaerobic conditioning. These risks are particularly acute during the first stage of processing. It is also a particular danger at compost operations with high flow rates and excessively large piles. In severe cases, these anaerobic cultures are also capable of producing VFA, lowering the pH, and continuing the shift in microbial population—reinforcing the negative cycle.

A large number of strategies can be used to limit odor generation and dissipate or treat odors before they impact the surrounding communities. Strategies fall generally within four categories:

- Enhancing emissions control infrastructure,
- Biological optimization of compost piles,
- Adding anaerobic pre-processing of highly biodegradable wastes, and
- Amending compost materials with carbon-based products.

First, non-biological structures, technologies and controls can be implemented throughout the compost production process. Some of the most important for controlling odors include next generation negative-air tipping buildings, covered structures as well as covered piles for the actual compost operation, use of multiple, staged biofilters and more rigorous design and engineering of facilities. Real-time process controls that monitor pile conditions and respond by adjusting aeration or other mechanisms are also likely to be important. It is important to note that each of these strategies increases costs and complexity of the operation.

Second, biological approaches can be used to enhance the composting process and improve biological control of odor. These methods are particularly important for ensuring that the first phase of composting proceeds quickly, and that aerobic processing is maintained. A summary of essential infrastructural and biological parameters and their optimal targets during composting of high fractions of biodegradable material are provided in Table 6.1. Some moderate to smaller size operations have also had success with high-value treatment, be it BCS, mushroom, or vermiculture.

Table 6.1: Suggested BMP parameters

BMP Parameters	Suggestions
Plan/Footprint	Size to handle flow rate; 2,000-3,500 ft^3 set back; 2-4% slope
Structures	Large NA tipping building, covered structures, biofilters
Composting Type	Micro-pore covers; aerated static pile
Process Controls	Complex, real-time monitoring many parameters & feedback
Aeration	Variable drive, phased 2,000+ to 200-500 cfh/dt
Oxygen Content	> 10-18%, but preferred on high end
Moisture	< 60%, more between 50-55%, pre-controls on food scraps
Temperature	Variable drive, phased 35ºC then 50-55ºC, no > 65ºC
Pile Size	No greater than 25' by 10' (width x height)
Mix/Nutrients/C-N Ratio	C/N 20-25; optimal Biodegradable C; 10-15% seed rate
Bulk Density/Porosity	2-3" particles; > 1,000 lb/yd^3 bulk; 40-60% air capacity

Third, a small but clear body of literature indicates important economic and environmental benefits that could result from integrating anaerobic digestion prior to composting, specifically for the treatment of highly biodegradable food scraps and fresh grass clippings. This could reduce odors, improve air quality, enhance organic recycling processing quality and performance, and reduce GHG emissions. Because the process also generates energy in the form of a biogas, it could help offset the energy needs of the composting operation. Remaining hurdles include improving technical performance for digestion of highly biodegradable wastes, and added costs and complexity of such facilities. Most importantly, less than optimal received electricity prices in the US have made it a challenge to develop economically viable projects, though researchers and project developers continue to make progress in this area. Further research could lead to advances in AD technology that could reduce costs, increase performance, or develop value-added co-products. Additional development of auxiliary technology, such as biogas conditioning and compression technology for generation of compressed CH_4 fuel, may create additional economic incentives. This may be a particularly appealing match for organics recycling facilities, as they could use the fuel in their waste management fleets.

The fourth major odor-control strategy includes incorporation of carbon-based materials to piles, including AC, high carbon wood ash, and biochar. Among these, AC is generally understood to be technically effective but too expensive for widespread use in compost odor control. High carbon wood ash is a waste product from biomass energy combustion, and is therefore obtainable at relatively low cost. Biochar, on the other hand, is expected to have costs somewhere between wood ash and AC.

The existing small amount of scientific literature on high carbon wood ash indicates mixed results. The product may provide some composting process benefits (e.g. faster processing, higher initial temperatures), and may reduce some odors, but may have no impact on, or may even increase others. In addition, at higher quantities, the ash may compromise the quality of the compost as a plant growth medium.

Meanwhile, research results are beginning to show how biochar can improve compost processes and reduce CH_4 emissions. Biochar can hold air and water at the same time, encouraging aerobic bacteria and reducing the number of anaerobic pockets that produce CH_4. Biochar also appears to support denitrifying organisms in ways that reduce the production of N_2O. Biochar can improve compost quality by retaining nitrogen and other nutrients and minerals. It promotes compost maturity and increased humification and may have positive climate impacts as more carbon is converted to stable humic substances. Recent studies suggest that biochar compost may have positive effects on plant growth. There are a number of ways that biochar could be used in current composting systems to reduce the generation and propagation of odors. These include adding it to anaerobic collection bins to suppress VFA generation, using it in compost receiving areas for immediate odor control, and using it as cover or a bulking agent in windrows. Biochar may also work to extend the life of biofilters and control leachate in compost yards. Any economic analysis of using biochar in compost should balance the cost of using biochar against increased returns from the sale of higher quality compost than is obtainable without biochar.

This study and literature review has summarized and detailed many of the areas and approaches that could be used by the industry to improve upon present aerobic compost treatment of organics enriched in large fractions of highly biodegradable waste such as food scraps and fresh yard clippings. While promising strategies for improving composting and controlling odors exist, it is important to recognize that each of these strategies involves greater levels of complexity, control and training, as well as increased capital and operating costs. Regulatory agencies will undoubtedly play a role as continued occurrences of odors come to the fore, with roles potentially including enhanced design criteria, regular reporting of on-line monitoring with feedback control, and establishment of maximum flow rates and processing times. They may also play a key role in facilitating agreements as well as education/outreach to make viable business plans placed under these new regulatory or capital structures. Addressing these issues may help ensure that communities can successfully and sustainably manage their organic wastes, while generating an invaluable soil resource.