Chemical Alteration of Substrates During Initial Thermophilic Phase of Composting

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1. Introduction

Composting technologies has been used successfully for treatment of organic waste from agriculture, industrial process and urban activities. Some examples of organic waste are food waste, orange juice process, swine and cattle manure, poultry, sugar cane mill waste, bio-solids (sludge). These represent a valuable reservoir of plant nutrients in organic forms, particularly nitrogen (N), phosphorus (P) and sulphur (S). However, before the use of such materials as fertilizers, they must be converted into a stable product free of odours and pathogens, and in a physical form that is suitable for soil application. Aerobic-thermophilic (35-65 ºC) composting is a proven technology that can achieve these objectives. Composting as a process involves the biological decomposition of organic matter under controlled, aerobic conditions into a humus-like stable product [1]. The value of a compost as a soil ameliorant can be due to several factors: (i) to improve the chemical composition of soil through the supply of plant nutrients; (ii) to improve the physical condition of soil through lower bulk density, resulting in improved aeration and water holding capacity. Biochemical manifestations occurring during composting process include an increase in humic substances over time, specifically, humic acids. Carbohydrates are the primary source of energy for microorganisms in the process, following by cellulose and hemicellulose. Lignin is degraded through microbial action to smaller polyphenolic compounds and intermediate phenols. The enzymatic action turns these compounds in quinines and later condensed humic acids [1].

The purpose of this work was to study the effects of Eucalyptus charcoal fines on composting process. Although charcoal fines are available residues they are barely used in composting process of wastes. The use of charcoal can improve air diffusion in composting windrows, prevent anaerobic conditions and odor and greenhouse gas emissions (CH_4 and N_2O), and produce a high quality final product to use in agriculture. To evaluate this, Eucalyptus charcoal fines was used on composting process during the initial thermophilic phase under controlled conditions.

2. Materials and Methods

Bench scale experiment: A 5-days composting experiment (thermophilic phase) was carry out under controlled conditions using a 3 L bench scale bioreactors. These bioreactors had an air supply and controlled temperature difference system [2, 3], including insulation. This kind of control of temperature difference reduces heat looses of bench scale reactor and can provide and extend duration of thermophilic temperatures similar to those in full-scale.

Nine bioreactors were used in a completely randomized experiment with tree repetitions of treatments. The experiment includes three treatments: horse manure (T0); horse manure + charcoal, 3:1 net weight (T1); horse manure + charcoal + orange waste, 1:1:2 net weight (T2). Each bioreactor was filled with 1 Kg of mixtures. Initial humidity was adjusted for 80% for all substrates using distilled water. Aeration rate was maintained in 1.25 L min^{-1} for each bioreactor, approximately.

Substrate preparation: Horse manure from Race Track is a fairly uniform mixture with straw. Alfalfa and oat residues used to feeding the animals are present in this substrate. Certified commercial charcoal was grounded and sieved at 2 mm. Orange bagasse (juice processing) was size-reduced and homogenized on a blender. Experimental mixtures (treatments) were homogenized by hand before to fill bioreactors.

Sampling and measurements: Samples of each material and mixture were collected before experiment beginning and at 5 days of composting process. Samples were dried at 110 ºC in an air forced drier. Temperatures of composting process in the centre and axial distance inside each bioreactor were collected and stored by a computer system every 5 minutes.

The FTIR analyses were performed on a spectrophotometer model Perkin Elmer Spectrum 400 FTIR Spectrometer with the spectra resolution of 4 cm^{-1} in the region from 4000 to 400 cm^{-1}. The sample pellets for analyses were made using approximately 1 mg of sample and 100 mg of KBr spectroscopic grade and submitting the homogenized mixture to pressure. For each spectrum 4 scans were summed.

Principal Component Analysis (PCA) was carried out using the obtained spectra. The spectra pre-processing includes: multiplicative scatter correction; second derivative calculation and; mean-centering of the data.

3. Results and Discussion

The used bioreactors are prototypes under development and the presented results are preliminary. Probably due to the drying of the substrates, caused by the forced aeration and heating during the initial thermophilic phase the operation was ceased after 5 days and the internal temperature dropped to room temperature. Due to this, the experiment was interrupted. Additionally, a great variability of the internal temperature was observed among the repetitions and because of this some improvements of the bioreactors will be carried out. On the other hand, this variability created different composting situation that could be accessed by the FTIR analysis and it facilitated the evaluation of the chemical changes in the substrates in the initial phase of the composting.

After varimax rotation of the loadings, the scores of the first PC, that accounted by 68% of the total variance, clearly grouped the different substrates (Fig. 1a), with lower values for horse manure (T0) and higher for the treatment with orange bagasse (T2).

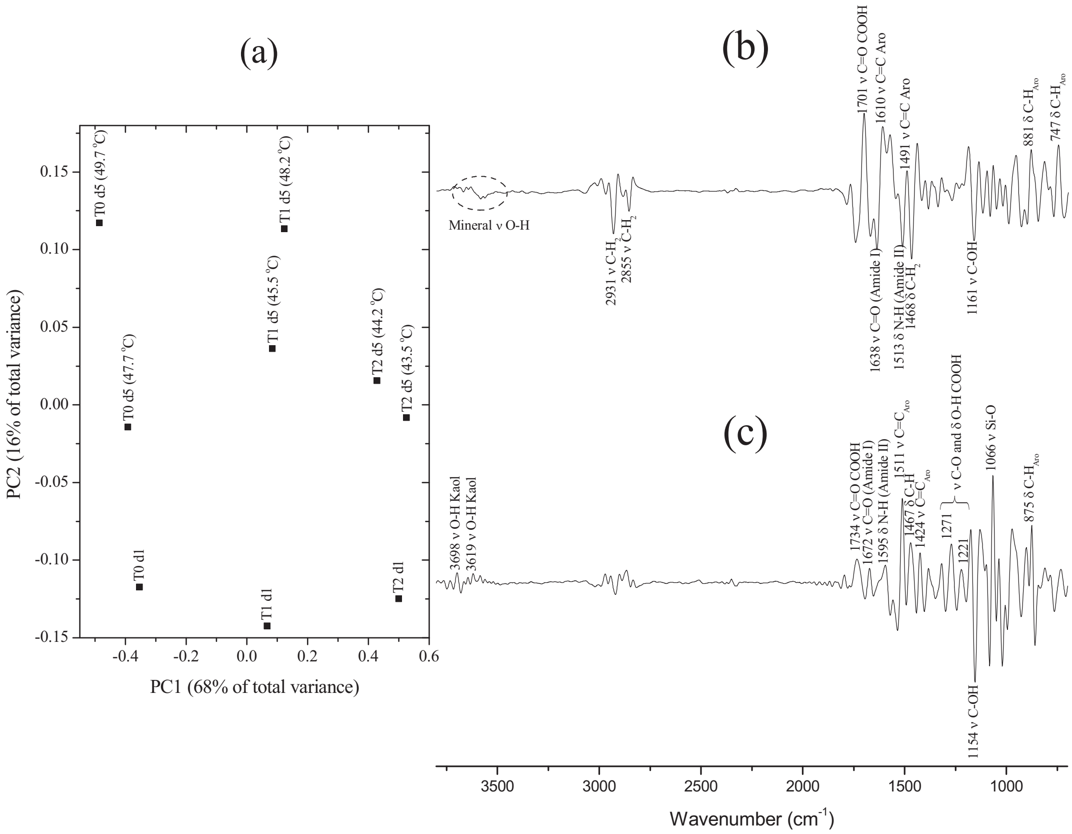

Figure 1: (a) Rotated scores of PCA from FTIR spectra. (b) Rotated loadings of the first PC from FTIR spectra. (c) Rotated loadings of the second PC from FTIR spectra. T0: horse manure; T1: horse manure + charcoal, 3:1 net weight; T1: horse manure + charcoal + orange waste, 1:1:2. d1: initial sampling (feedstocks); d5: five days of composting. The maximum temperature reached in each bioreactor is indicated in parenthesis

This First PC is characterized by positive loadings for bands attributable to aromatic moieties (Fig. 1b), due to the presence of charcoal in the T1 and T2 samples, and stretching of C=O from carboxylic, probably from the orange bagasse. And negative loadings in regions attributable to amide, polysaccharides (probably cellulose), methilene aliphatic and mineral contaminants, these chemical groups were expected in the horse's manure.

The second PC (16% of the total variance) showed a gradient from the feedstocks (initial substrates) towards the higher reached temperature in each bioreactor (Fig. 1a). In this way, the analysis of the loadings could help to trace the evolution of the material during the composting. The loadings of this PC presented positive values for the chemical groups that accumulate, or are formed, during the initial phase of the composting (Fig. 1c), such as: aromatic moieties, carboxylic groups and amides. Probably these amides aren't from the manure, which wouldn't be preserved during the initial phase of the composting, but the nitrogen probably is incorporated into the microbial tissues. Additionally, the silicates, probably kaolinite, are accumulated. The more important negative loading is from polysaccharides, confirming the easy decomposition of this class of compounds.

4. Conclusions

During the initial phase of the composting several chemical alterations occurs in the substrates, such as accumulation of the recalcitrant charcoal; alteration of the substrates by the partial oxidation to carboxylic groups; mineralization of the carbohydrates and increase of the amides groups, probably by the nitrogen incorporation into microbial biomass.

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