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# Chemical Stability and Maturity of Compounds from Organic Solid Waste Treatment

Luciléia G. T. Colares[a]*, Daniele Seremeta[b], Sandro X. Campos[b]

[a]Federal University of Rio de Janeiro, Institute of Nutrition, Av. Brigadeiro Trompowski, s/n, Rio de Janeiro, Brazil
[b]Ponta Grossa State University, Chemistry Department, Av. General C. Cavalcanti, 4748, Ponta Grossa, Brazil
lucolares@nutricao.ufrj.br

Composting is a recycling method based on biological degradation of organic solid waste (OSW) by microorganisms under aerobic conditions, resulting in a stable and mature organic compound that can be used as organic fertilizer in agriculture. Several countries have invested in this technology as part of urban solid waste management, since it is considered simple and inexpensive, provided there are parameters controlled during the process such as temperature, humidity, pH, carbon / nitrogen ratio and particle size. The composting process in the reactor system presents some advantages when compared to the traditional process in piles or ponds, as the requirement of smaller area and labor. The objective of this work was to evaluate the chemical stability and maturity of compounds from organic solid waste treatment by composting process in a reactor system. The reactor was constructed and filled with 60 kg of material, being 58% of OSW, 28% of Wood waste-sawdust and 14% of dry leaves. To evaluate the chemical stability of the compound the following parameters were monitored for 120 days: Temperature (°C); pH in 0.01 mol$L^{-1}$ $CaCl_2$ solution; moist at 65°C; carbon/nitrogen Ratio; cation exchange capacity (CEC mmol $kg^{-1}$); Total Organic Carbon (TOC) and CEC/TOC ratio. Toevaluate the maturity of the compound the following parameters were monitored: Germination index (GI); Electric conductivity (EC); Spectroscopic characterization of humic acids in the ultraviolet-visible region (UV-Vis); Spectroscopic characterization of humic acids by Fourier transform infrared spectroscopy (FTIR) and ash content. It was observed that after 90 days the compound presented stability, with reduction of temperature, moist and Carbon / Nitrogen ratio, increase of pH, CEC and CEC / COT ratio; however, the maturity of the compound was reached at 120 days of the composting. The compound reached stability and maturity at the end of the composting process (90-120 days), indicating that it could be used as soil corrective in agriculture.
KEY WORDS: organic solid waste, composting, stability, maturity

## 1. Introduction

Population growth, urbanization, and lifestyle changes have contributed to increases in the generation of municipal solid waste (MSW), requiring investment by states and municipalities in strategies that can minimize social, economic, and environmental problems caused by inadequate management of solid waste (Mannarino et al., 2016, Kumar et al., 2017), as well as the serious health problems caused by volatile compounds (nitrogenous, oxygenated, aromatic, halogenated, among others) released during the decomposition of solid waste in treatment plants.(Wu et al., 2018, Rodriguez et al., 2018). According to the Brazilian Association of Public Cleaning and Special Waste Companies, Brazil generated 78.4 million tons of MSW in 2017 and of this amount, 6.9 million tons were not collected, and 40.9% of the total solid waste collected was disposed of in unsuitable places, without environmental protection. While efforts are being made to solve the problems arising from the generation of MSW in Brazil, these are concentrated in metropolitan regions and large cities, including the implementation of advanced technologies for waste management including reduction in source, and recycling and recovery of materials (Abrelpe, 2017).
When it comes to MSW management, research has focused on that generated in households (Pham Phu et al., 2018) while little has done on the solid waste generated by the food service industry and by food outside the home. In Brazil, food consumed outside of the home represents 31% of household food expenses. This

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sector is in rapid growth, being economically important in the generation of jobs and commercialization of food; however, this sector also uses important resources (water and energy) for the production of meals / food and generates a substantial amount of solid waste. The management of this waste therefore requires more attention.

Some researches show that approximately 80% of the solid residue generated by food services is organic solid waste (OSW), requiring management based on reducing generation at source using adequate management measures during meal production (Alves & Ueno, 2015; Zotesso et al., 2016). The composting treatment of OSW is still an underutilized solution, and this could contribute to efforts to minimize the amount of waste ending up in landfill (Abrelpe, 2017).

Composting is an effective and economical biotechnology widely used in the sanitation and treatment of OSW (Luo et al., 2018). It is based on the biological degradation of OSW by microorganisms under aerobic conditions, resulting in a stable and mature organic compound that can be used as an organic fertilizer in agriculture. This is a promising approach as it could utilize a significant proportion of waste entering landfill, and could minimize serious environmental problems arising from final disposal such as the emission of greenhouse gases. Several countries have been investing in this technology as part of MSW management initiatives, especially as it is considered simple and inexpensive—as long as key parameters are carefully controlled during the process such as temperature, humidity, pH, carbon/nitrogen ratio, and particle size. Composting in a reactor system presents some advantages compared to the traditional composting process in piles or windrows, notably lower area and labor requirements (Campos et al., 2017). A range of analytical techniques has been applied to evaluate the maturity and stability of compost products, and their physico-chemical and biological characteristics. This includes the use of molecular spectroscopy in the visible ultraviolet (UV-Vis) region and Fourier transform infrared absorption spectroscopy (FTIR) (Campos et al., 2017) to evaluate the quality of compost.

The terms "stability" and "maturity" are often used synonymously to describe the degree of decomposition and transformation of organic matter into humified compounds, however, according to Adani et al. (2004), the stability is strongly related to the microbial activity, that is, the degree of use of the organic matter by the microorganisms, while the maturity indicates an organic-chemical condition of presence or absence of phytotoxic organic acids in the compound. Stability is an important quality parameter for the use of the compound in the soil and the C/N ratio is a good indicator of the action of the microorganisms on the compound mass. A high C/N ratio means that microorganisms will still use the available carbon as energy and immobilize nitrogen and phosphorus to their metabolism. Likewise, the seed germination index (SGI) is a good indicator of maturity of the compound..

This study aims to evaluate the chemical stability and maturity of compounds resulting from OSW treatment by composting in a reactor system.

## 2. Materials and Methods

The composting process was studied from February to June 2017 (150 days), using the OSW generated at the restaurant of the State University of Ponta Grossa, Brazil. A reactor system was constructed, consisting of a plastic drum with space to receive the mixture of materials to be composted, leachate collection and aeration from holes made in the lid (Figure 1a). The 200-liter reactor was built based on Campos et al. (2014), and filled with 60 kg of material composed of 58% of OSW; 28% wood sawdust; and 14% dry leaves. The last two materials acted as bulking agents and were ground to reach a favorable particle size of 1 to 3 cm (Figure 1b). Before filling the reactor, sufficient water was added to the mixture to maintain an initial moisture of 70%. In addition, the starting temperature and pH were measured (23°C and 6.0, respectively).To evaluate the chemical stability of the compound produced, the following parameters were monitored: temperature (°C); pH (in 0.01 $molL^{-1}CaCl_2$ solution); moisture content (at 65°C); carbon/nitrogen ratio; cation exchange capacity (CEC mmol $kg^{-1}$); total organic carbon (TOC); and CEC/TOC ratio.

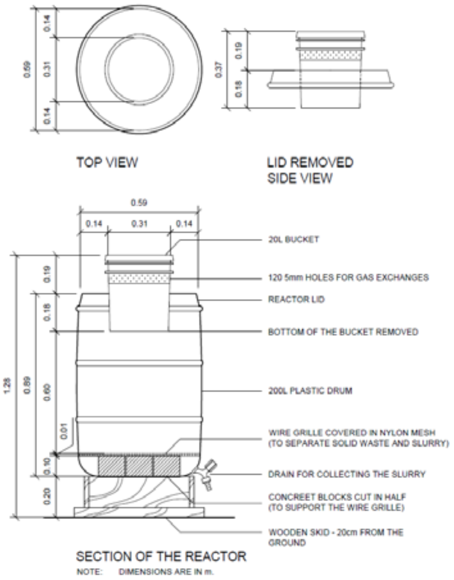
The maturity of the compound was evaluated according to the following parameters: seed germination index (SGI); electric conductivity (EC); spectroscopic characterization of humic acids (in the UV-Vis region); spectroscopic characterization of humic acids by FTIR spectroscopy; and ash content. Stability and maturity parameters were determined at 30, 60, 90, and 120 days, except for spectroscopic characterization which was performed up to 150 days.

The physico-chemical analyses (T, pH, moisture, C/N, EC, COT, ECC) and biological analyses (SGI) were performed following the manual of official analytical methods for fertilizers and corrective soils of the Ministry of Agriculture, Livestock and Supply, Brazil (Mapa, 2017). For the germination test, an aqueous extract of the compound was prepared, then cress (*Lepidium sativum*) seeds were incubated in the extract and in distilled water (control), and finally the calculation according to Equation 1 was performed (Luo et al., 2018).

GI % = (SGT x RLT)/(SGC x RLC) x 100 (1)

where SGT, SGC: number of seeds germinated in treatment and control, respectively; and RLT, RLC: root length in treatment and control, respectively.

(a)




(b)

*Figure 1: (a) Reactor section with top and side view (b) Waste submitted to composting treatment*

For the spectroscopy analyses (UV-Vis and FTIR), humic acid (HA) was extracted from the compound at 30, 60, 90, 120, and 150 days as recommended by the International Humic Substance Society (IHSS, 2014).
To obtain the UV-Vis spectra, 1.0 mg of HA sample was dissolved in 80 mL of a solution 0.05 mol $L^{-1}$ and pH 8.0 of sodium bicarbonate ($NaHCO_3$). Absorbance was measured in the working range of 400–700 nm using a Varian Cary 50 BIO spectrophotometer and the ratio E4/E6 was calculated from the absorbance at 465 and 665 nm (Zitel et al., 2018). To obtain the FTIR spectra, pellets containing 1.0 mg of HA sample and 100 mg of potassium bromide were subjected to vacuum pressure for 1 min. Samples were analyzed in the range 400–4000 $cm^{-1}$ using a Shimadzu IR PRESTIGE 21 spectrophotometer (Tahiri et al., 2016). The absorbance ratio at 1620 and 1030 $cm^{-1}$ was calculated to evaluate the initial (30 days) and final (150 days) humification degree of the composting process.
Maintaining a behavior pattern for the composting process is not an easy task, since it depends on several factors such as: type of material to be submitted to the process, initial conditions of temperature, pH, humidity, granulometry and mainly carbon / nitrogen ratio, as necessary to trigger the decomposition of the mass by microorganisms. According to Kiehl (1985) in up to 120 days of composting there is an increase in pH (40%), ash content (85%) and total nitrogen (50%). In addition, there is organic matter reduction (30-35%), TOC% (25%), and the process should be terminated with C/ N ratio below 20.

## 3. Results and Analysis of Results

### 3.1 Chemical stability parameters of the compound

Stability during the composting process indicates the resistance of organic material in the compound to decomposition by microorganisms, provided that other factors are not interfering with the process (Luo et al., 2018). The composting process started with the following parameters: 70% humidity; pH 6.5; a C/N ratio of 30; and 25 °C. From the third day to the eighth day, the temperature remained at thermophile levels (42–45°C), falling gradually until the thirtieth day. Table 1 presents the results of the stability parameters at day 30, 60, 90, and 120 of the composting process. There was a reduction in temperature, passing through the thermophilic, mesophilic, and cryophilic phases; a reduction in humidity and the C/N ratio was observed (although it has not reached less than 20 at the end of the process); pH was constant but favorable to the process; and CEC, TOC, and the CTC/COT ratio increased, suggesting that the product of the composting had characteristics stability. Similar results were found by Dores-Silva (2013).

*Table 1: Evolution of chemical stability parameters during composting*

| Chemical stability parameters | Days | | | |
|---|---|---|---|---|
| | 30 | 60 | 90 | 120 |
| Temperature ($^0$C) | 28,2 | 23,0 | 23,0 | 19,3 |
| pH in 0,01 molL$^{-1}$ $CaCl_2$ solution | 7,8 | 8,1 | 7,8 | 7,3 |
| Moist at 65$^0$C (%) | 69,7 | 67,3 | 66,0 | 65,0 |
| C/N ratio | 31,0 | 31,0 | 26,0 | 25,0 |
| CEC (mmol kg$^{-1}$) | 442,7 | 550,5 | 576,5 | 615,0 |
| TOC (mass %) | 29,0 | 26,0 | 25,0 | 23,0 |
| CEC/TOC ratio | 15,3 | 21,2 | 23,1 | 26,7 |

The composting process was maintained at a cryophilic temperature (19–28 °C) from the thirteenth day, possibly due to the low carbon content of the mixture; up until the thirtieth day the compost mass reached the thermophilic temperature required for the elimination of pathogenic and mesophilic microorganisms, which is necessary for the decomposition of organic matter by microorganisms; a stable pH (between 8.1 and 7.3) may have been related to the uniformity of aeration of the composting mass in the reactor; all other parameters indicated stability 90 days after the start of the process.

### 3.2 Maturity parameters of the compound

Maturity of the composting process has been studied since, when applied to soil, immature organic compounds can lead to the immobilization of nutrients and can cause phytotoxicity to the plants. The measurement of parameters that aid the evaluation of compost maturity is therefore very important (Komilis, 2015). Table 2 presents the results of the stability parameters at day 30, 60, 90, and 120 of the composting process.

*Table 2: Evolution of maturity parameters during composting*

| Maturity parameters | Days | | | |
|---|---|---|---|---|
| | 30 | 60 | 90 | 120 |
| Seed Germination Index - SGI (%) | 94,9 | 119,9 | 142,4 | 146,7 |
| Electric conductivity - EC (mS cm$^{-1}$) | 0,8 | 0,7 | 0,6 | 0,4 |
| Ash content (%) | 1,2 | 1,3 | 1,3 | 1,5 |
| UV-Vis (E4/E6 ratio) | 178,1 | 141,4 | 66,5 | 56,6 |

The evaluation of the phytotoxicity of organic compounds (using the germination test) has been applied as a good indicator in the degree of maturation in the treatments of organic residues by composting (Cotta et al., 2015). The increase of the seed germination index (SGI) throughout the process attests to a decrease in ammonia, short chain aliphatic acids, and other toxic substances in the composting mass, evidencing the decrease of the toxic potential of the compound. The compound is considered non-phytotoxic with SGI greater than 80%. An increasing SGI was observed throughout the composting process, showing the maturation of the compound and an absence of phytotoxicity.

An increase in EC during the composting process is associated with a reduction inorganic matter and the increase in the concentration of different minerals such as phosphate, ammonium, and potassium (Rajpal et al., 2014). A decline in EC (mS cm$^{-1}$) was observed in this study throughout the composting process. This may be associated with lower accumulation of organic acids towards the beginning of the process, and with the degradation of organic matter and elevation of pH values. This leads to a continued reduction in total ions and a corresponding decline in EC.

Ash content was observed to increase throughout the process, denoting mineralization of the compound, meaning that it can be assumed that the nitrogen content would be released more slowly when applied to the soil.

Spectroscopy methods are a very suitable tool in environmental analyses for characterizing the structure of complex organic compounds, such as humified compounds (Wang et al., 2013).

In this study, spectroscopic analysis was performed from the UV-Vis absorption curves, in the 400–700 nm range, because this reflects the characteristics of aromatic or unsaturated compounds (Li et al., 2010). The E4/E6 ratio, which correlates the absorption intensities at 465 nm and 665 nm during the composting process, declined during the composting process, showing the progression of humification with elevated condensation of the constituent aromatics (Dores-Silva et al., 2013).

Figure 2 shows FTIR spectra of HAs extracted from the compound at different stages of the composting process. FTIR is a qualitative method widely used in the analysis of soil organic matter because it allows the characterization of chemical groups (Carballo et al., 2008).

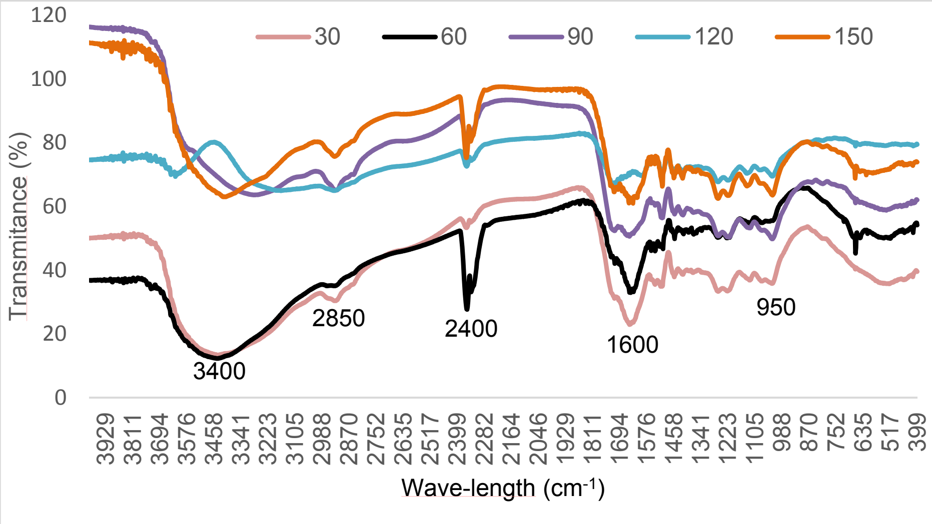



*Figure 2: FTIR) spectra of humic acids extracted from the compound at different stages of composting (30 to 150 days - range 4000-400 cm$^{-1}$).*

The spectra of the compound were interpreted on the basis of characteristic FTIR absorption bands for organic compounds as described by Carballo et al. (2008) as follows: 3,400 (OH of COOH and COH); 2,850 cm$^{-1}$(CH of aliphatic structures); 2,400 (OH strongly bound to COOH); 1,620 (C = O vibrations of ketones, quinones, carboxylic acids, and esters, as well as C = C vibrations of aromatic components); 1,430–1,455cm$^{-1}$ (OH in the carboxylic acid plane, $CO_2$ of carboxylates, and aliphatic $CH_2$ alkanes, as well as carbonate CO); 1,030 cm$^{-1}$ (polysaccharides). When calculating the ratio between peaks 1,620 and 1,030, the elevation of values between the initial (day 30) and final (day 150) period of the composting process could denote a reduction in carbohydrates via the degradation of organic matter, giving rise to compounds with carboxylic groups, and this confirming the humification of the compound, as shown by Zittel et al. (2018).

## 4. Conclusions

The compound reached stability and maturity at the end of the composting process (90-120 days), indicating that it could be used as soil corrective in agriculture. The stability parameters combined with those of maturity can contribute to evaluate the quality of the organic compound and indicate the best moment of application in the soil. Other studies with different mixtures of materials may contribute to optimize the composting process of organic residues generated in restaurants, since the evolution of stability and maturity parameters depend on the initial conditions.

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