Changes in the Spectral Characteristics of Hydrophilic Fraction in Compost Organic Matter

Zhang Zilong¹, Xiao Yu¹,²*

¹ College of environmental science and engineering, Guilin University of Technology, Guilin, Guangxi, China
² Guangdong University of Petrochemical Technology, Maoming, Guangdong, China

First author’s email: 1584125859@qq.com
*Corresponding author’s e-mail: xiaoyu@gdupt.edu.cn

Abstract. The hydrophilic fraction (HyI) is one of the important components of humus, and its structure and composition are important factors for evaluating the stability and maturity of compost. This study used spectroscopy to analyze the composition and structure of HyI. The results showed that with the passage of composting time, the UV–Vis curve had a red shift, indicating that the conjugated structure of the substance increased and the aromaticity is enhanced. The three-dimensional fluorescence excitation–emission spectrum (3D-EEM) showed that the fluorescence intensity of humus-like substances in HYI was significantly enhanced, and microbial metabolites such as protein-like substances, carbohydrates and other small molecules were continuously degraded, and the relative content decreased from 21% to 8%, the humus-like substances rose from 54% to 68%, which showed that the organic matter in the compost is continuously condensing and polymerizing, and the maturity and stability of the compost product are deepened.

1. Introduction

The sludge contains a lot of organic matter and nutrient elements such as nitrogen, phosphorus and potassium, Composting is one of the important ways to realize the resource utilization of sludge. Composting products can improve soil fertility and microbial community structure [1], and can be used for agricultural land, garden land and degraded soil remediation [2-3]. The material transformation of compost mainly occurs in the water phase. Dissolved organic matter (DOM) is the most active component of organic matter, which is regarded as the binding center of organic pollutants, heavy metals and other toxic substances [4], It is also an important interface of microbial metabolism and transformation, and its main components include humic acid, fulvic acid and HyI. HyI is a typical heterogeneous mixture, and its structure and composition are significantly different in each composting stage. At present, there are relatively few studies on the transformation of hydrophilic component in composting process. Based on this, this study separated and purified the hydrophilic components of the compost at different time periods, and used UV–Vis and 3D-EEM to explore the material structure of HyI, reveal their structural transformation characteristics during the composting process. It provides a new strategy for the use of spectroscopy to evaluate compost maturity, and also provides a scientific basis for the subsequent compost products entering the soil.
2. Materials and methods
The compost material used 15kg municipal sludge and 5kg auxiliary material rice bran, mixed evenly and put it into a 50L fermentation tank, the particle size is about 10~20mm, and the initial moisture content is 62%. 150g samples of upper, middle and lower layers were collected at 0, 3, 6, 9, 14, 19, 24 and 29 days. After freeze-drying, grinding and sieving, the samples were stored in the refrigerator for testing. For the separation and purification of HyI, refer to the literature [5], using NaOH+ Na4P2O7 mixed solution leaching, through alkaline extraction, acid precipitation, elution resin column and so on. The data are processed by Excel, the toolbox toolkit of Matlab software is used for parallel factor analysis, and the graph is drawn by Origin software.

3. Results & Discussion

3.1. Analysis of the UV–Vis spectra of HA
Diluted the DOC concentration of each hydrophilic component to 20 mg/L, eliminating the interference error of organic carbon, selected the data at the beginning and end of the compost, the high temperature period, and the maturity period to draw the graph. As shown in Figure 1, the UV–Vis curve has a red shift, and a shoulder peak appears at 270nm, which indicated that the humicity and aromaticity of the hydrophilic component are continuously increasing. Conjugated structures such as unsaturated aromatic substances absorb ultraviolet light [6], caused electrons to undergo a π→π* transition, this also showed that the content of humic substances in HyI, is increased, and the structure is more complex.

![Figure 1](image1.png)

Figure 1 UV-Visible spectra of hydrophilic components.

3.2. Evolution of HyI components based on fluorescence spectroscopy
The organic components change drastically during the composting process. 3D-EEM is often used to study the structural characteristics of mixtures such as humus, which can effectively reflect the composting process and maturity. The DOC concentration of HyI samples in different time periods was uniformly diluted to 2mg/L, and then the fluorescence spectrum was scanned with the F98 fluorophotometer. As shown in Figure 2, SONG divided the fluorescence image into 5 regions [7]. The HyI mainly include by-products of microbial metabolism in region IV and humus-like substances in region V. In addition, the fluorescence peak shows a tendency to move to the V region, and the fluorescence intensity continues to increase, indicated that the concentration of humus-like substances has increased significantly, the degree of humification of hydrophilic components has increased, and the structure of the substance has become more stable. This is consistent with the results of UV-Vis spectra.
The parallel factor analysis (PARAFAC) method can perform qualitative and quantitative analysis of organic matter, it also can effectively avoid the overlap of fluorescence peaks and identify a single fluorescent component by three-dimensional fluorescence data analysis. Each fluorescent component represents a class of substances. Therefore, this method is more representative and scientific in quantitative characterization [8]. As shown in Figure 3, the PARAFAC divided the hydrophilic component into three components. Component 1 has a fluorescence peak at Ex=340nm, Em=415nm, which is closely related to the humus-like substances in the organic matter. The structure of humus-like substances is complex and difficult to decompose, which can prolong the residence time of organic matter in the soil and strengthen the soil Fertility. Component 2 has a strong and weak double peak at Ex=360nm, 395nm, Em=475nm, which is caused by the fluorescent group of the humic acid substance. The fluorescence peak of Component 3 appeared at Ex=310nm, Em=380nm, which is caused by protein-like substances such as microbial metabolites and their residues.
The content of the three components of HyI during the composting process is shown in Figure 4. The content of each component presents different trends. With the passage of composting time, the content of humus of Component 1 increased from 54% to 68%, which indicated that the hydrophilic components in the compost organic matter are gradually humified, and the carbon skeleton continues to condense to form humus-like substances with more complex components and larger molecular weights [9]. The content of Component 2 decreases first and then increases. This indicated that the microbes are active in the first and middle stages of composting, and the macromolecular humic acid will also be mineralized and decomposed. During this period, the rate of generation of humic acid is less than the degradation rate. After the compost temperature drops and enters the decomposing period, Microbial activity declines, small molecular substances gradually polymerize into humic acid, and the relative content of the substance increases. Studies have shown that protein substances are precursors of synthetic humus-like substances [10], and the initial content of Component 3 has been reduced from 21% to 8%, indicated that microbial metabolites and their residues are easily degradable protein-like substances (such as tyrosine, tryptophan, carbohydrates, etc.) are gradually degraded and converted into humus-like substances that are more stable and more complex in structure.
4. Conclusion

The spectroscopy method can effectively characterize the change characteristics of organic matter during the composting process. With the progress of composting, the UV-Vis curve has a red shift, the conjugated structure of the substance increased, and the aromaticity enhanced. 3D-EEM combined with PARAFAC showed that HyI is continuously humified, and the protein-like substances in microbial residues and their metabolites are degraded in a large amount, and the relative content is reduced from 21% to 8%, while the high aromatization and high humus-like substances increased from 54% to 68% at the beginning, and the material structure became more stable and complicated, and the compost maturity was deepened.

Acknowledgments

Thanks for the scientific research funding of Guangxi Innovation Research Team Project (2018GXNSFGA281001) and Projects of Talents Recruitment of GDUPT 2020rc035.

References

[1] Awasthi S K, Sarsaiya S, Awasthi M K, et al. (2020) Changes in global trends in food waste composting: Research challenges and opportunities [J]. Bioresource Technology, 299: 122555.
[2] Titova J, Baltrenaite E. (2021) Physical and Chemical Properties of Biochar Produced from Sewage Sludge Compost and Plants Biomass, Fertilized with that Compost, Important for Soil Improvement [J]. Waste And Biomass Valorization, 12(7): 3781-3800.
[3] Pandey P K, Cao W, Biswas S, et al. (2016) A new closed loop heating system for composting of green and food wastes [J]. Journal of Cleaner Production, 133: 1252-1259.
[4] Zhao Y, Wei Y, Zhang Y, et al. (2017) Roles of composts in soil based on the assessment of humification degree of fulvic acids [J]. Ecological Indicators, 72: 473-480.
[5] Yu M, He X, Liu J, et al. (2018) Characterization of isolated fractions of dissolved organic matter derived from municipal solid waste compost [J]. Science Of the Total Environment, 635: 275-283.
[6] He X S, Xi B D, Jiang Y H, et al. (2013) Structural transformation study of water-extractable organic matter during the industrial composting of cattle manure [J]. Microchemical Journal, 106: 160-166.
[7] Song C, Li M, Wei Z, et al. (2016) Effect of inoculation with multiple composite microorganisms on characteristics of humic fractions and bacterial community structure during biogas residue and livestock manure co-composting [J]. Journal Of Chemical Technology And Biotechnology, 91(1): 155-164.
[8] Song C, Li M, Xi B, et al. (2015) Characterisation of dissolved organic matter extracted from the bio-oxidative phase of co-composting of biogas residues and livestock manure using spectroscopic techniques [J]. International Biodeterioration & Biodegradation, 103: 38-50.
[9] Yu G H, He P J, Shao L M. (2010) Novel insights into sludge dewaterability by fluorescence excitation-emission matrix combined with parallel factor analysis [J]. Water Research 44(3): 797-806.

[10] Che J, Lin W, Ye J, et al. (2020) Insights into compositional changes of dissolved organic matter during a full-scale vermicomposting of cow dung by combined spectroscopic and electrochemical techniques [J]. Bioresource Technology, 301:122757.