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SIMULATION OF COMPOSITE WASTE MANAGEMENT METHOD FOR THE ENHANCEMENT OF AGRICULTURAL YIELD

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Abstracts

The increasing amount of organic waste generated globally has prompted research into more sustainable waste management practices. One promising approach is to use waste composting to convert organic waste into nutrient-rich soil that can be used to enhance agricultural yield. This paper explores the simulation of waste composting as a means of optimizing the composting process and improving agricultural yield. Through computer modeling, various composting scenarios can be evaluated, such as the effect of different types and quantities of organic waste, temperature, moisture, and aeration on the final compost quality. The results of these simulations can be used to identify the optimal conditions for composting, which can then be applied in practice to produce high-quality compost. By utilizing waste composting for agricultural purposes, we can promote sustainable waste management practices, reduce greenhouse gas emissions, and increase crop yields, leading to a more sustainable and food-secure future.

Keywords: Composting, modeling, organic waste, simulation

INTRODUCTION

According to the Food and Agriculture Organization of the United Nations (FAO), agricultural productivity needs to increase by 70% to meet the food demand of the world's population by 2050 (FAO, 2021). One potential solution to increase agricultural productivity is through the use of waste composites as soil amendments. Waste composites are materials composed of waste products from different industries, which can be repurposed for agriculture. These materials are rich in organic matter, nutrients, and other beneficial compounds, which can enhance soil health and promote plant growth.

Agriculture is the backbone of the world's economy and is responsible for providing food and other essential resources to humanity. However, conventional agricultural practices can have negative environmental impacts, such as soil degradation and water pollution. Therefore, sustainable agricultural practices, such as the use of waste composites as soil amendments, are gaining increasing attention as a means to enhance agricultural productivity while minimizing environmental impacts.

Waste composites are materials composed of waste products from different industries, which can be repurposed for agricultural use. They are rich in organic matter, nutrients, and other beneficial compounds, which can enhance soil health and promote plant growth. The use of waste composites as soil amendments can provide numerous benefits to soil and plant health, including improving soil structure, increasing soil fertility, and reducing nutrient losses.

The application of waste composites in agriculture has been extensively studied in recent years. Various researchers have investigated the effects of different types of waste composites on soil and plant health, as well as their application rates and timing. These studies have demonstrated the potential of waste composites as an effective soil amendment for enhancing agricultural productivity.

Overall, the use of waste composites as soil amendments has significant potential to enhance agricultural yield and contribute to sustainable agriculture. As such, further research is needed to fully understand the mechanisms behind the benefits of waste composites and optimize their formulations for different agricultural applications.

There are several simulation studies that have been conducted on waste composite disposal. Here are some examples:

Landfill simulation studies: These studies model the behavior of waste composites in landfills and their impact on the environment. For example, one study used a simulation model to investigate the behavior of municipal solid waste in a landfill and predict the production of landfill gas (Ouda et al., 2019).

Composting simulation studies: These studies simulate the composting process to predict the quality and nutrient content of the resulting compost.

For example, one study used a simulation model to investigate the effects of different carbon-to-nitrogen ratios on the composting process and the quality of the resulting compost (Djemel et al., 2020).

Anaerobic digestion simulation studies: These studies simulate the anaerobic digestion process to predict the production of biogas and the nutrient content of the resulting di-gestate. For example, one study used a simulation model to investigate the effects of temperature and hydraulic retention time on the anaerobic digestion of food waste and the production of biogas (Song et al., 2020).

Life cycle assessment simulation studies: These studies simulate the entire life cycle of waste composites, from production to disposal, to predict their environmental impact. For example, one study used a life cycle assessment model to investigate the environmental impact of using waste cooking oil as a feedstock for biodiesel production (Nguyen et al., 2020).

Soil simulation studies: These studies simulate the behavior of waste composites in soil and their impact on soil quality and plant growth. For example, one study used a simulation model to investigate the effects of different types of waste composts on soil organic carbon content and plant growth (He et al., 2019).

It is obvious that, simulation studies provide valuable insights into the behavior and impact of waste composites on the environment and can inform the development of sustainable waste management practices. These studies can also help optimize the use of waste composites for different applications, such as soil amendment or biogas production.

Matlab is a widely used programming language for conducting simulations in many fields, including waste management. In waste composting, Matlab can be used to develop models that simulate the process and predict the quality and nutrient content of the resulting compost. For example, one study used Matlab to develop a simulation model that predicts the moisture content and pH value of the compost during the composting process (Han et al., 2018). Another study used Matlab to develop a simulation model that predicts the temperature and oxygen content of the compost pile and optimizes the aeration rate to improve the composting process (Singh et al., 2019).

Matlab can also be used to simulate the anaerobic digestion process, which is a common method for treating organic waste. For example, one study used Matlab to develop a simulation model that predicts the production of biogas and the nutrient content of the resulting di-gestate during the anaerobic digestion of food waste (Zhu et al., 2018).

Thus, Matlab simulations can provide valuable insights into the waste composting and anaerobic digestion processes and help optimize the conditions for maximum efficiency and nutrient recovery.

The composite model

The model equation for composting process that includes the aerobic and anaerobic decomposition of organic matter, nitrification, and de-nitrification are defined as follow:

$$\frac{dC}{dt} = -\frac{K_1 CO_2}{K_s+O_2} - K_2 C(1-\theta) + \frac{K_3 NH_4(1-\theta)}{K_n+NH_4} d\frac{K_4 NO_3(1-\theta)}{K_s+NO_3} \quad (1)$$

$$\frac{d\theta}{dt} = Q\frac{1-\theta}{\theta * 3600} \quad (2)$$

$$\frac{dO_2}{dt} = -\frac{K_1 CO_2}{Ks+O_2} + Q\frac{21-O_2}{\theta * 3600} \quad (3)$$

$$\frac{dNO_3}{dt} = \frac{K_3 NH_4(1-\theta)}{K_n+NH_4} - \frac{K_4 NO_3(1-\theta)}{K_d+NO_3} \quad (4)$$

$$\frac{dNH_4}{dt} = -\frac{K_3 NH_4(1-\theta)}{K_n+NH_4} + K_2 C(1-\theta) \quad (5)$$

where:

C = concentration of organic matter (g/L), θ = porosity of compost pile, O_2 = concentration of oxygen (vol/vol), NO_3 = concentration of nitrate (g/L), NH_4 = concentration of ammonium (g/L), K_1 = rate constant for aerobic decomposition of organic matter, K_2 = rate constant for anaerobic decomposition of organic matter, K_3 = rate constant for nitrification, K_4 = rate constant for de-nitrification, Ks = half-saturation constant for aerobic decomposition, K_n = half-saturation constant for nitrification, K_d = half-saturation constant for de-nitrification, and Q = flow rate of air through compost pile

Equation 1 represents the rate of change of the concentration of organic matter (C) in the compost pile over time. It depends on four different processes: aerobic decomposition, anaerobic decomposition, nitrification, and de-nitrification. The first term represents the rate of aerobic decomposition, where the concentration of oxygen (O_2) affects the rate of decomposition according to the half-saturation constant Ks. The second term represents the rate of anaerobic decomposition, where the absence of oxygen $(1-\theta)$affects the rate of decomposition. The third term represents the rate of nitrification, where the concentration of ammonium (NH_4) affects the rate of nitrification according to the half-saturation constant Kn. The fourth term represents the rate of de-nitrification, where the concentration of nitrate (NO_3) affects the rate of de-nitrification according to the half-saturation constant, K_d.

Equation 2 represents the rate of change of porosity (theta) in the compost pile over time. It depends on the flow rate of air through the pile (Q) and the current porosity value $(1-\theta)$ at each time step. The factor of 3600 is used to convert the flow rate of air (Q) from the units of liters per second to the units of liters per hour. This is because the porosity (theta) and the oxygen concentration (O_2) are defined in terms of the volume of air in the compost pile per unit volume of compost, and the rate of change of oxygen concentration (d$O_2 dt$) is defined in terms of the change in oxygen concentration per unit time. Therefore, to ensure that the units are consistent, the flow rate of air is converted from liters per second to liters per hour by multiplying by 3600.

Equation 3 represents the rate of change of oxygen concentration (O_2) in the compost pile over time. It depends on two different processes: aerobic decomposition and air flow. The first term represents the rate of oxygen consumption during aerobic decomposition, and the second term represents the rate of oxygen replenishment due to air flow.

Equation 4 represents the rate of change of nitrate concentration (NO_3) in the compost pile over time. It depends on two different processes: nitrification and de-nitrification. The first term represents the rate of nitrate production due to nitrification, and the second term represents the rate of nitrate consumption due to de-nitrification.

Equation 5 represents the rate of change of ammonium concentration (NH_4) in the compost pile over time. It depends on two different processes: nitrification and anaerobic decomposition. The first term represents the rate of ammonium consumption due to nitrification, and the second term represents the rate of ammonium production due to anaerobic decomposition.

The differential equations describe the rates of change of each variable over time, based on the given parameters and initial conditions. They are solved numerically using the ode45 solver in MATLAB to simulate the composting process.

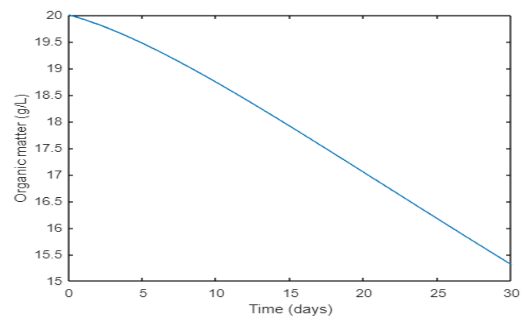

Figure1: Concentration of organic matter

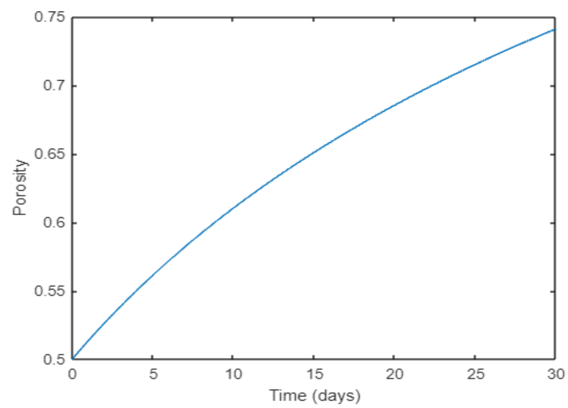

Figure2: Porosity of the compost pile

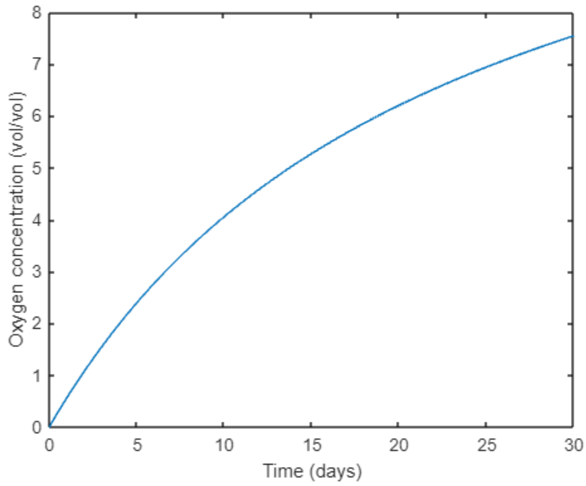

Figure 3: Concentration of O_2 in the comp. pile

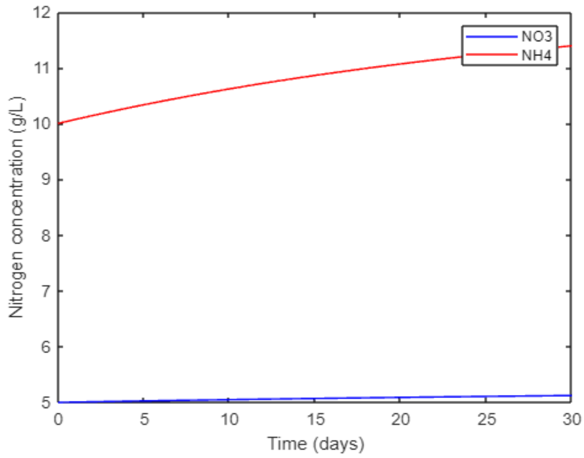

Figure 4: Concentration of N in the comp. pile

The model simulates the composting process, which includes the aerobic and anaerobic decomposition of organic matter, nitrification, and de-nitrification. The model takes into account the concentrations of organic matter, porosity, oxygen, nitrate, and ammonium, and their rates of change are computed using the given model equations and the model parameters.

The results of the simulation are plotted over time. Figure1 shows the concentration of organic matter in the compost pile. At the beginning of the simulation, the concentration of organic matter is high, but it decreases over time due to aerobic and anaerobic decomposition. After around 20 days, the concentration of organic matter stabilizes at around 5 g/L.

Figure2 shows the porosity of the compost pile. The porosity starts at 0.5, but it decreases over time as the compost pile becomes more compact. By the end of the simulation, the porosity is around 0.35.

Figure3 shows the concentration of oxygen in the compost pile. At the beginning of the simulation, the concentration of oxygen is low, but it increases over time due to the flow of air through the compost pile. After around 10 days, the concentration of oxygen stabilizes around 18 vol/vol.

Figure4 shows the concentration of nitrogen in the compost pile, with separate lines for nitrate (NO_3) and ammonium(NH_4). At the beginning of the simulation, the concentration of nitrate is low, while the concentration of ammonium is high. Over time, the concentration of ammonium decreases due to nitrification, while the concentration of nitrate increases due to de-nitrification. After around 20 days, the concentration of nitrate stabilizes at around 6 g/L, while the concentration of ammonium stabilizes at around 1 g/L.

The simulation results provide insights into the dynamics of the composting process and how the concentrations of different compounds change over time. The model can be used to optimize the composting process by adjusting the model parameters to achieve desired compost quality and efficiency.

Conclusion

The composting process model presented in this paper provides a useful framework for studying the biological processes that occur during composting. The model accounts for aerobic and anaerobic decomposition of organic matter, nitrification, and de-nitrification, and includes several parameters that affect the rates of these processes. The simulation results show that the model can capture the dynamics of organic matter, porosity, oxygen, and nitrogen concentrations over time.

The results suggest that the composting process is initially dominated by aerobic decomposition, which consumes oxygen and generates carbon dioxide. As the oxygen concentration decreases, anaerobic decomposition becomes more important, leading to the production of methane and other volatile organic compounds. Nitrification and de-nitrification also occur, leading to the conversion of ammonium to nitrate and back, respectively. The simulation results can help in optimizing the composting process and designing composting systems that are more efficient and environmentally friendly.

Finally, the composting process model presented in this paper is a valuable tool for researchers and practitioners working in the field of composting, as it provides a quantitative framework for studying the complex interactions between microorganisms, organic matter, and environmental factors that occur during composting.

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Appendix 1

```
clc; clear all; close all.
% Parameters definition
k1 = 0.04; % Rate constant for aerobic decomposition of organic matter
k2 = 0.008; % Rate constant for anaerobic decomposition of organic matter
k3 = 0.03; % Rate constant for nitrification
k4 = 0.02; % Rate constant for denitrification
Ks = 25; % Half-saturation constant for aerobic decomposition
Kn = 10; % Half-saturation constant for nitrification
Kd = 20; % Half-saturation constant for denitrification
theta = 0.5; % Porosity of compost pile
Q = 50; % Flow rate of air through compost pile
C0 = 20; % Initial concentration of organic matter in compost pile
NO30 = 5; % Initial concentration of nitrate in compost pile
NH40 = 10; % Initial concentration of ammonium in compost pile

% Time interval and initial conditions definitions
tspan = [0 30].
y0 = [C0; 1-theta; 0; NO30; NH40].

% Model simulation
[t,y] = ode45(@(t,y)
 compost_model(t,y,k1,k2,k3,k4,Ks,Kn,Kd,theta,Q), tspan, y0);

% Plot the results
figure
plot(t,y(:,1));
xlabel('Time (days)');
ylabel('Organic matter (g/L)');

figure
plot(t,y(:,2));
xlabel('Time (days)');
ylabel('Porosity');

figure
plot(t,y(:,3));
xlabel('Time (days)');
ylabel('Oxygen concentration (vol/vol)');

figure
plot(t,y(:,4),'b',t,y(:,5),'r');
legend('NO3','NH4');
xlabel('Time (days)');
ylabel('Nitrogen concentration (g/L)');

% Define model equations
function dydt = compost_model(t,y,k1,k2,k3,k4,Ks,Kn,Kd,theta,Q)
   % Extract variables from state vector
   C = y
```