Short Communication

Qualitative analysis of the stability of a continuous vermicomposting system

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HIGHLIGHTS

► A mathematical model describing the ecological relationship of a continuous vermicomposting system was established.
► Stability of continuous vermicomposting system was analyzed.
► Initial amounts of microbes and earthworms did not influence system stability.
► Stability depended on the species of microorganism and earthworm, dilution rate and initial amount of organic matter.

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ABSTRACT

A mathematical model was established to describe ecological relationships in a continuous vermicomposting system. The distributions of organic matter, microbes and earthworms on non-dimensional specific growth rates were simulated. The range of specific growth rates were visualized utilizing three-dimensional reconstruction technology. The stability of a vermicomposting system was not influenced by the initial concentrations of microbes and earthworms, only their species. The coordinates of the stable point depended on the dilution rate and initial amount of organic matter. The method described could be help for establishing a stable continuous vermicomposting system.

1. Introduction

Vermicompost is considered to be excellent culture substrate or soil additive, which has significant beneficial effects on plant growth (Ali et al., 2007; Bachman and Metzger, 2008; Gutiérrez-Miceli et al., 2007; Singh et al., 2008). It has also been suggested as a promising waste treatment technology for manned space stations due to its ability to increase the closure of material circulation (Liu et al., 2008). The basic principle of vermicomposting is to decompose the organic solid waste and humify it into nutrient-rich organic fertilizer under the synergetic action of earthworms and microorganisms. The quality of vermicompost depends on several factors, such as type of organic matter (Manna et al., 1996; Warman and AngLopez, 2010), earthworm species (Reinecke et al., 1992; Suthar and Singh, 2008), and microorganism inoculants (Pramanik et al., 2007, 2009). However, less attention has been paid to the evaluation of the stability of such a system under long-term continuous conditions, which would be encountered in space-related applications.

In this article, a mathematical model of continuous vermicomposting system was established. The theoretical analyses and numerical simulations of this model were made to help obtaining the proper species of biological components.

2. Methods

The ecological relationships among organic matter, microbes and earthworms in the continuous vermicomposting system can be illustrated as depicted in Fig. 1. The microbes live on the organic matter exclusively, while earthworms feed on organic matter and microbes simultaneously. The mathematical model describing this relationship could be established based on the classical Chemostat and Lotka-Volterra models:

\[
\begin{align*}
\frac{dS}{dt} &= D(S_0 - S) - \mu_1(S)X - \mu_2(S)Y \\
\frac{dX}{dt} &= \mu_1(S)X - DX - \mu_3(X)Y \\
\frac{dY}{dt} &= \mu_2(S)Y + \mu_3(X)Y - DY
\end{align*}
\]

where \(S(t), X(t), Y(t)\) denote the concentrations of organic matter, microbes and earthworms at time \(t\), respectively; \(S_0\) denotes the input concentration of the organic matter; and \(D\) is the dilution rate. The functions \(\mu_1(S)\) and \(\mu_2(S)\) denote the specific growth rates of microbes and earthworms using organic matter, respectively;