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Noise-induced stochastic transition: a novel stochastic chemostat model with flocculation effect

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The continuous culture of microorganisms is extensively used to produce some important commercial products. Hence, the collection of continuously cultured microorganisms is one important topic in the applications of microbial engineering. In this research work, we present a novel stochastic chemostat model with two complementary nutrients and flocculation effect to provide control strategies. At microscopic scale the accumulation of small perturbations in the chemostat could not be neglected. In order to capture the fluctuations caused by environmental heterogeneity, we extend a deterministic model to the case with some stochastic perturbation in the form of white noise and then study the influence of stochastic perturbation on the global dynamics of such model. We obtain some theoretical results including sufficient conditions for the existence of a unique ergodic stationary distribution and persistence of the stochastic model. In biology, the existence of unique stationary distribution of stochastic model means that microorganisms can be collected continuously. Based on usual sensitivity analysis method, some control strategies are discussed. Therefore, in order to achieve continuous collection of microorganisms, it is feasible to adopt the following strategies, (i) increasing the maximum growth rate of microorganisms, or the input concentration or of carbon source or nitrogen source; (ii) reducing the dilution rate, or the flocculation rate, or the input concentration of flocculants; (iii) reducing the intensities of white noise as much as possible. Further numerical simulations using MATLAB2019 were carried out to validate the analytical predictions and those show that the random fluctuation may have positive biological effects.

Keywords: Stochastic chemostat model, Flocculation effect, Stationary distribution, Extinction and persistence, Noise-induced stochastic transition

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