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Enhanced polyhydroxyalkanoate production from organic wastes via process control

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HIGHLIGHTS

- Polyhydroxyalkanoate (PHA) production was investigated for a two-stage system.
- Optimal conditions for PHA production are 3.0 mgDO/L and S_0 = 100–500 mgCOD/L of VFA.
- A model-based feedback controller for VFA pulse addition was proposed and tested.
- Additional information can be used to determine when to stop the cultivation phase.

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ABSTRACT

This work explores the use of a model-based control scheme to enhance the productivity of polyhroxyalkanoate (PHA) production in a mixed culture two-stage system fed with synthetic wastewater. The controller supplies pulses of substrate while regulating the dissolved oxygen (DO) concentration and uses the data to fit a dynamic mathematical model, which in turn is used to predict the time until the next pulse addition. Experiments in a bench scale system first determined the optimal DO set-point and initial substrate concentration. Then the proposed feedback control strategy was compared with a simpler empiric algorithm. The results show that a substrate conversion rate of 1.370 ± 0.598 mgPHA/mgCOD/d was achieved. The proposed strategy can also indicate when to stop the accumulation of PHA upon saturation, which occurred with a PHA content of 71.0 ± 7.2 wt.%.

1. Introduction

Polyhydroxyalkanoates (PHA) are biodegradable polymers that can be accumulated by several types of bacteria as carbon and energy reserves under stress conditions (Akaraonye et al., 2010). They have received attention recently because they are suitable candidates for the substitution of some petroleum-based plastics and have several properties that make them attractive, including their nontoxicity and biocompatibility (Amache et al., 2013). However, the production cost of pure culture PHA is still too high to become a competitive commodity plastic material (Gurieff and Lant, 2007).

While pure cultures of specialized microorganisms such as *Azotobacter vinelandii* or recombinant *Escherichia coli* have achieved up to 90 wt.% accumulation capacity (Akaraonye et al., 2010), the need for sterile conditions and the use of relatively expensive substrates such as glucose or some volatile fatty acids (VFA) contribute to elevate the PHA production cost. Among the numerous approaches to lower production costs is the use of mixed cultures and organic wastes as a carbon source, for example glycerol as a by-product of biodiesel production (Dobroth et al., 2011), palm oil (Sudesh et al., 2011), fermented molasses (Carvalho et al., 2013), and olive oil mill pomace (Waller et al., 2012). Wastewater has also been shown to be a suitable resource for PHA production (Arcos-Hernandez et al., 2013; Bengtsson et al., 2008) and a recent life cycle assessment of the process confirms its potential (Gurieff and Lant, 2007). However, little has been reported on the development of process control strategies to optimize the production system.

The usual PHA production scheme using mixed cultures consists of sludge enrichment in a first stage using aerobic dynamic feeding (Dionisi et al., 2004; Serafim et al., 2004), followed by PHA production in a fed-batch bioreactor, where the substrate availability is intermittent (Johnson et al., 2010; Jiang et al., 2012). Nevertheless, other schemes have also been investigated with promising results; for example, the direct use of the excess sludge from a wastewater treatment plant without enrichment (Arcos-Hernandez et al., 2013), the continuous operation as a CSTR

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