Volatile Fatty Acids as a Key to Sustainability and Circularity in Polyhydroxyalkanoates Production

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Thesis for the degree of Doctor of Philosophy at the University of Borås to be publicly defended on **May 26th 2023, 10:00 a.m**. in room **C203**, University of Borås, Allégatan 1, Borås, Sweden.

Language: English

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Abstract

The negative consequences of plastic pollution on both environmental and socio-economic aspects have motivated the development of sustainable and renewable materials to replace the petroleum-based plastic. Polyhydroxyalkanoates (PHAs), which are bioplastics, having an outstanding biodegradability and rather comparable thermal and mechanical properties, are potential alternatives for the replacement of conventional plastics. However, one of the hurdles on the way to PHA commercial production is the cost of conventional feedstock, which can constitute up to 50% of the production cost. In this regard, volatile fatty acids (VFAs) derived from acidogenic fermentation of organic waste can be a promising substrate to increase the cost-competitiveness of PHA production. Therefore, in this thesis, VFAs were utilized and developed to be a key carbon feedstock for the sustainable and economically feasible production of PHAs.

The applicability of individual and mixed VFAs as potential substrates was initially investigated through the cultivation of two different PHA-bearing bacteria of *Bacillus megaterium* and *Cupriavidus necator*, providing an average PHA yield on biomass of 10 and 55%, respectively. Further thorough studies, in terms of VFAs loading and inhibition thresholds and operating parameters, were conducted to improve the conversion efficiency of VFAs by *C. necator*. Consequently, a biomass yield on VFAs of up to 82% was obtained, rendering a PHA accumulation of 1 g/L using actual waste derived VFA effluent. In addition, in order to tackle the inherent issue of low productivity in batch and/or fed-batch cultivations under high VFA containing feed, a novel approach of immersed membrane reactor (iMBR) was introduced and applied in this thesis. With the assistance of membrane filtration, the PHA production was conducted in semi-continuous mode (up to 128 h), yielding a maximum biomass and PHA production of 6.6 and 2.8 g/L, respectively. The outcomes achieved, furthermore, were 32.1 and 28.5%, respectively, higher than that from a continuous stirred tank (CSTR), in which the cultivation was affected by the washout effect. Moreover, considering the insufficiency of the current recycling methods of PHA-based products in terms of resource recovery, a novel attempt of acidogenic fermentation has been conducted to valorize the PHA-based composites through conversion into precursor VFAs. Afterwards, the recovered VFAs could be recirculated into PHA production, fulfilling the concept of a circular bioeconomy.

Keywords: bioplastics, food waste, polyhydroxyalkanoates, volatile fatty acids, immersed membrane bioreactor, acidogenic fermentation