Developing a food waste-based volatile fatty acids platform using an immersed membrane bioreactor

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Abstract

Approximately 1.3 billion tons of food waste is produced globally every year. In principle, all the resources in the supply chain are lost (e.g. land, energy, and water) when the food is not consumed as intended. Anaerobic digestion is an established biological technology to treat food waste, and is mainly employed for recovery of energy in the form of biogas. Volatile fatty acids (VFAs) are formed as intermediate products of the anaerobic digestion process, and can be applied as precursors for various essential biomaterials. The manipulation of the anaerobic digestion process to synthesize these intermediates instead of biogas is considered to recover more value from food waste. However, some bottlenecks that prevent large-scale production and application of VFAs still exist. Among the key issues to be addressed are the difficulty in recovering the VFAs from the fermentation medium and the overall low product yields. The goals of the present thesis were: 1) to investigate methods to boost the production of VFAs from food waste; 2) to continuously recover VFAs from food waste fermentation medium; 3) to determine the changes in the microbial structure during high organic loading of food waste in membrane bioreactors; and 4) to study a novel approach for applying food waste-derived VFAs for cultivating edible filamentous fungi.

For continuous product recovery at high yields, an immersed membrane bioreactor was constructed with robust cleaning capabilities to withstand the complex anaerobic digestion medium. The membrane bioreactor was first operated without pH control and a yield of 0.54 g VFA/g VS_{added} was achieved when an organic loading rate of 2 gVS/L/d was applied. Moreover, only a 16.4% reduction in the permeate flux during a 40-day operation period was recorded. In the second experimental work, the immersed membrane bioreactor system was subjected to high organic loading rates of 4, 6, 8, and 10 g VS/L/d as a tool of manipulating the anaerobic digestion process towards high VFAs and hydrogen production. The highest yield of VFAs was attained at 6 g VS/L/d (0.52 g VFA/gVS_{added}), while at 8 g VS/L/d, a maximal hydrogen yield of 14.7 NmL/gVS_{added} was obtained. An analysis of the microbial structure revealed that the presence of *Clostridium* resulted in high production of acetate, butyrate and caproate. On the other hand, the relative abundance of *Lactobacillus* was found to influence lactate biosynthesis.

Cultivation of edible filamentous fungi presents a novel possibility for application of food waste-derived VFAs. Due to the growing demand of single-cell protein, one of the potential uses for the fungal biomass is the production of animal feed. In this thesis, an edible filamentous fungus, *Rhizopus oligosporus* was grown solely on the VFAs recovered from the membrane bioreactors. It was revealed that high concentrations could inhibit fungal growth; thus, the dilution of the VFAs solution used as substrate was necessary. Furthermore, when a fed-batch cultivation technique was applied, a four-fold improvement in the biomass production relative to standard batch cultivation was realized. A maximum biomass yield of 0.21 ± 0.01g dry biomass/ g $VFAs_{\text{COD eq. consumed}}$, containing 39.28 ± 1.54% crude protein, was obtained. With further improvements in the VFAs uptake and the biomass yield, this novel concept could be a fundamental step in converting anaerobic digestion facilities into biorefineries.

Keywords: food waste; anaerobic digestion, volatile fatty acids; immersed membrane bioreactor; edible filamentous fungi