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Modeling of hydrodynamics and mixing in a submerged membrane bioreactor

Zaineb TRAD[a,b,c], Christophe VIAL[b,c*], Jean-Pierre FONTAINE[b,c], Christian LARROCHE[b,c]

[a]*Clermont Université, Université Blaise Pascal, LABEX IMobS[3], BP 10448, F-63000 F-63171 Clermont-Ferrand, France*
[b]*Clermont Université, Université Blaise Pascal, Institut Pascal, BP 20206, F-63174 Aubière cedex, France*
[c]*CNRS, UMR 6602, IP, F-63171 Aubière, France*
Corresponding author: Zaineb.TRAD@univ-bpclermont.fr
Tel: +33(0)473405266 - Fax: +33(0)473407829

ABSTRACT

This work deals with the optimization of mixing in an anaerobic submerged membrane bioreactor (AnMBR) devoted to the production of biohydrogen as a 2nd generation biofuel using the dark fermentation process from lignocellulosic waste. The AnMBR consists of an unbaffled mechanically-stirred tank equipped with a two-stage radial impeller which is coupled to an external hollow fibre membrane module placed in a forced circulation loop with permeate suction. In the tank, mixing conditions must enable the suspension of solid waste, homogenize local concentrations, and enhance hydrogen desorption simultaneously. For optimizing reactor design, mixing was investigated both experimentally and numerically. The computational strategy consisted in the combination of 1D and 3D methodologies including single-phase and two-fluid CFD models. The experimental approach encompassed RTD and mixing time measurements, the analysis of vortex formation and the description of solid suspension using straw as waste. The results showed that a laminar flow pattern prevailed in the recirculation loop and the membrane unit, while turbulent flow was observed in the stirred tank in which mixing time was far smaller than residence time in single-phase flow. A compromise was defined using CFD, which prevented vortex formation and promoted homogeneous suspension, by optimizing impeller position and rotation speed. The positions of the inlet and the outlet of the forced circulation loop in the tank were deduced from CFD simulations and validated by experimental data. Finally, this work confirms the potential interest of AnMBR for biohydrogen production and the applicability of CFD for the optimization of abiotic factors.

Keywords: anaerobic membrane bioreactor, biohydrogen, CFD, hydrodynamics.

1. Introduction

Biohydrogen ($BioH_2$) is a 2^{nd} and a 3^{rd} generation biofuel. It constitutes undoubtedly a promising renewable and sustainable alternative to fossil fuels and combines the advantages to face with the issue of mobility of the future and to reduce greenhouse gas emissions [1]. Second generation $BioH_2$ can be obtained through anaerobic digestion of agricultural and food waste in the liquid phase, provided methanogenesis is prevented. This technology has been the subject of intensive research in the recent years, as this process can use solid waste as a raw material to produce $BioH_2$ using either pure [2] or mixed cultures [3]. Mixed cultures present the advantage to avoid aseptic conditions, but with a lower yield. However, the production of $BioH_2$ is necessarily coupled with that of volatile fatty acids (VFA), while soluble hydrogen, H_2 partial pressure and VFA are all able to inhibit $BioH_2$ production; this means that VFA must be removed continuously. As a result, $BioH_2$ production relies not only on