Novel Application of Membrane Bioreactors in Lignocellulosic Ethanol Production: Simultaneous Saccharification, Filtration and Fermentation (SSFF)

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Abstract

Biofuels production and utilisation can reduce the emission of greenhouse gases, dependence on fossil fuels and also improve energy security. Ethanol is the most important biofuel in the transportation sector; however, its production from lignocelluloses faces some challenges. Conventionally, lignocellulosic hydrolysis and fermentation has mostly been performed by separate hydrolysis and fermentation (SHF) or simultaneous saccharification and fermentation (SSF). SHF results in product inhibition during enzymatic hydrolysis and increased contamination risk. During SSF, suboptimal conditions are used and the fermenting organism cannot be reused. Bacterial contamination is another major concern in ethanol production, which usually results in low ethanol yield.

In these studies, the above-mentioned challenges have been addressed. A novel method for lignocellulosic ethanol production 'Simultaneous saccharification filtration and fermentation (SSFF)' was developed. It circumvents the disadvantages of SSF and SHF; specifically, it uses a membrane for filtration and allows both the hydrolysis and fermentation to be carried out at different optimum conditions. SSFF also offers the possibility of cell reuse for several cultivations. The method was initially applied to pretreated spruce, with a flocculating strain of yeast *Saccharomyces cerevisiae*. SSFF was further developed and applied to pretreated wheat straw, a xylose rich lignocellulosic material, using encapsulated xylose fermenting strain of *S. cerevisiae*. High solids loading of 12% suspended solids (SS) was used to combat bacterial contamination and improve ethanol yield. Oil palm empty fruit bunch (OPEFB) was pretreated with fungal and phosphoric acid in order to improve its ethanol yield. An evaluation of biofuel production in Nigeria was also carried out.

SSFF resulted in ethanol yield of 85% of the theoretical yield from pretreated spruce with the flocculating strain. Combination of SSFF with encapsulated xylose fermenting strain facilitated simultaneous glucose and xylose utilisation when applied to pretreated wheat straw; this resulted in complete glucose consumption and 80% xylose utilisation and consequently, 90% ethanol yield of the theoretical level. High solids loading of 12% SS of pretreated birch resulted in 47.2 g/L ethanol concentration and kept bacterial infection under control; only 2.9 g/L of lactic acid was produced at the end of fermentation, which lasted for 160 h while high lactic acid concentrations of 42.6 g/L and 35.5 g/L were produced from 10% SS and 8% SS, respectively. Phosphoric acid pretreatment as well as combination of fungal and phosphoric pretreatment improved the ethanol yield of raw OPEFB from 15% to 89% and 63% of the theoretical value, respectively.

In conclusion, these studies show that SSFF can potentially replace the conventional methods of lignocellulosic ethanol production and that high solids loading can be used to suppress bacterial infections during ethanol productions, as well as that phosphoric acid pretreatment can improve ethanol yield from lignocellulosic biomass.

Keywords: Biofuel, Ethanol, Membrane bioreactors, High solids loading, Lignocellulose, Nigeria, Pretreatment, SSFF, *Saccharomyces cerevisiae*