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Techno-Economic Analysis (TEA) of Different Pretreatment and Product Separation Technologies for Cellulosic Butanol Production from Oil Palm Frond

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Abstract: Among the driving factors for the high production cost of cellulosic butanol lies the pretreatment and product separation sections, which often demand high amounts of energy, chemicals, and water. In this study, techno-economic analysis of several pretreatments and product separation technologies were conducted and compared. Among the pretreatment technologies evaluated, low-moisture anhydrous ammonia (LMAA) pretreatment has shown notable potential with a pretreatment cost of \$0.16/L butanol. Other pretreatment technologies evaluated were autohydrolysis, soaking in aqueous ammonia (SAA), and soaking in sodium hydroxide solution (NaOH) with pretreatment costs of \$1.98/L, \$3.77/L, and \$0.61/L, respectively. Evaluation of different product separation technologies for acetone-butanol-ethanol (ABE) fermentation process have shown that in situ stripping has the lowest separation cost, which was \$0.21/L. Other product separation technologies tested were dual extraction, adsorption, and membrane pervaporation, with the separation costs of \$0.38/L, \$2.25/L, and \$0.45/L, respectively. The evaluations have shown that production of cellulosic butanol using combined LMAA pretreatment and in situ stripping or with dual extraction recorded among the lowest butanol production cost. However, dual extraction model has a total solvent productivity of approximately 6% higher than those of in situ stripping model.

Keywords: ABE fermentation; LMAA pretreatment; techno-economic analysis; cellulosic butanol

1. Introduction

The potential of large-scale cellulosic butanol production is limited by the low efficiency of the pretreatment process as well as the extensive downstream processing requirement. Studies have revealed both operations as potentially driving the production cost of cellulosic butanol [1–4]. Pretreatment is essential to reduce the recalcitrant structure of lignocellulosic materials and therefore results in better sugar yield after the enzyme hydrolysis process [5]. Nevertheless, the process often requires harsh processing conditions (high temperature and pressure) as well as a high amount of chemical and water [6], which makes it unfeasible for commercial application.

Similarly, downstream processing in biobutanol production also entails considerable cost because of low productivity of the fermentation process (acetone-butanol-ethanol (ABE) fermentation) due to the toxic and inhibition effect given by the fermentation products to the microorganisms used. The known approach, capable of solving this problem, is to use the inline separation method which reduces the product concentration in the fermentation broth through the