DILUTE ACID HYDROLYSIS PRETREATMENT PROCESS OF MERANTI WOOD SAWDUST USING ASPEN PLUS

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MASTER OF SCIENCE

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRACT

The conversion of the hemicellulose and cellulose fractions to fermentable sugar hydrolysate is a crucial step for its use in various biochemical processes. The high yields of end products, such as ethanol and xylitol, are highly dependent on the recovery of intermediate products, such as xylose and glucose. The process models for dilute acid hydrolysis have been extensively published in the literature to study the behaviour of the process based on stoichiometric reaction simulation. However, the stoichiometric reaction failed to predict the operability of the process under different operational conditions. To date, only a few studies have been conducted to simulate the kinetic-based reaction of complete dilute acid hydrolysis using Aspen Plus. However, those studies used different pretreatment operational conditions and raw materials to simulate the production of intermediate products. In this study, a process model of dilute sulfuric acid hydrolysis for xylose production was developed and simulated for comparison with experimental results (Rafique and Sakinah, 2012). The process considered in this study consists of a mixer, a heat exchanger, a continuous stirred tank reactor, a stoichiometric reactor, and a solid-liquid separator. Detailed kinetic parameters and input data for each process unit considered in this process were determined from the experimental study (Rafique and Sakinah, 2012). The comparison results showed the percentage differences of 2.47%, 4.66%, and 15.29% for xylose, glucose, and furfural, respectively. The process parameters, such as temperature, reaction time, and acid concentration, were manipulated and discussed in this study. The results from sensitivity analysis showed that the response of xylose, glucose, and furfural concentration was directly influenced by those three parameters. The sensitivity analysis results revealed that an increase in acid concentration, temperature, and reaction time increased the xylose, glucose, and furfural concentrations. However, xylose concentration dropped remarkably a few minutes after the reaction started. The maximum xylose concentration of 34.62 g/L was obtained at 160 °C, 2% H_2SO_4 concentration, and 20 min reaction time. On the other hand, the glucose and furfural concentrations increased constantly with increased acid concentration, temperature, and reaction time. The highest glucose and furfural concentrations of 35.28 and 14.63 g/L, respectively, were obtained at 140 °C, 6% H_2SO_4 concentration, and 160 min reaction time. The optimum conditions for maximum xylose and minimum furfural concentrations were obtained at 150 °C, 4% H_2SO_4 concentration, and 40 min reaction time using central composite design. Based on the obtained results, the simulation of dilute acid hydrolysis of Meranti wood sawdust can be potentially used as an efficient and practical tool that can provide insight regarding the steady-state operation of hydrolysis. The simulation process developed in this study can also be used as a basis to develop other studies related to the controllability, operability, and flexibility of this process.

ABSTRAK

Penukaran pecahan hemiselulose dan selulosa melalui proses penapain gula hidrolisis adalah langkah penting untuk digunakan dalam pelbagai proses biokimia. Penghasilan produk akhir yang banyak seperti etanol dan xylitol sangat bergantung kepada pemilihan produk perantaraan seperti xylose dan glukosa. Pembangunan model proses hidrolisis asid cair telah diterbitkan secara meluas untuk mengkaji tingkah laku proses ini berdasarkan simulasi tindak balas stoikiometrik. Walaubagaimanapun, tindak balas stoikiometrik tidak dapat meramalkan operasi proses di bawah keadaan operasi yang berbeza. Sehingga kini, hanya beberapa kajian telah dilakukan untuk mensimulasikan proses hidrolisis asid yang lengkap berdasarkan tindak balas kinetik dengan menggunakan Aspen Plus. Walaubagaimanapun, kajian – kajian ini menggunakan operasi pra- rawatan dan bahan mentah yang berbeza untuk mensimulasikan pengeluaran produk perantaraan. Dalam kajian ini, model simulasi hidrolisis asid cair untuk penghasilan xylose telah dibangunkan dan disimulasikan untuk dibandingkan dengan keputusan eksperimen (Rafique and Sakinah, 2012). Proses simulasi yang dipertimbangkan dalam kajian ini terdiri daripada pengadun, penukar haba, reaktor tangki pancaran berterusan, reaktor stoikiometrik dan pemisah cecair pepejal. Parameter kinetik yang terperinci dan data untuk setiap unit proses yang dipertimbangkan dalam proses ini telah ditentukan daripada kajian eksperimen (Rafique and Sakinah, 2012). Hasil perbandingan menunjukkan bahawa perbezaan peratusan bagi xylose, glukosa, dan furfural masing – masing adalah 2.47%, 4.66% dan 15. 29%. Proces parameter seperti, suhu, masa dan kepekatan asid dimanipulasi dan dibincangkan dalam kajian ini. Hasil daripada analisis sensitiviti ini menujukkan bahawa tindak balas kepekatan xylose, glukosa dan furfural secara langsung dipengaruhi oleh tiga pembolehubah proses tersebut. Analisis sensitiviti mendedahkan bahawa peningkatan kepekatan asid, suhu dan masa tindak balas meninggikan penghasilan xylose, glukosa dan furfural. Walaubagaimanapun kepekatan xylose sangat merosot setelah beberapa minit tindak balas bermula. Maximum kepekatan xylose ialah 34.62 g/L terhasil pada 160°C dengan 2 % kepekatan H_2SO_4 s dan 20 minit masa tindak balas. Sebaliknya, kepekatan glukosa dan furfural sentiasa meningkat dengan peningkatan kepekatan asid, suhu dan masa tindak balas. Glukosa dan furfural tertinggi yang dilepaskan ialah ialah 35.28 g/L dan 14.63 g/L pada 140°C dengan 6% kepekatan H_2SO_4 selama 160 minit masa tindak balas. Sitiuasi optimum yng diperoleh dari kaedah “central composite design” (CCD) adalah pada 150°C, 4% kepekatan H_2SO_4 s dan 40 minit masa tindak balas bagi penghasilan xylose yang optimum disamping furfural yang minimal. Berdasarkan keputusan yang diperolehi, simulasi hidrolisis asid cair terhadap habuk kayu Meranti berpotensi digunakan sebagai alat yang efisien dan praktikal yang dapat memberi gambaran mengenai operasi keadaan tetap proses hidrolisis. Proses simulasi yang dibangunkan dalam kajian ini juga boleh digunakan sebagai asas untuk membangunkan kajian lain yang berkaitan dengan pengendalian, pengoperasian dan fleksibiliti process ini.

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