CORRELATION OF FOULING MECHANISM WITH ENZYMATIC HYDROLYSIS IN AN ENZYME-MEMBRANE INTEGRATED SYSTEM FOR HIGH SUGAR PERMEATION FROM PINEAPPLE LEAVES

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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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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

Currently, a few initiatives have been made to incorporate and integrate enzymatic hydrolysis and membrane separation as one system in the depolymerization of hemicellulose. However, none of the researchers has reported on the correlation between membrane fouling and enzymatic hydrolysis that would actually influence both hydrolysis and separation performance. Therefore, this research correlates the operating conditions of pH, pressure, temperature, and agitation speed using 2 different xylanolytic enzymes and a multienzyme for the fouling mechanism with the yield of sugar production. The screening study on four factors (pH: 5-8, pressure: 5–10 bar, temperature: 50–80 °C, agitation speed: 200–500 rpm) that substantially influence the hydrolysis-separation performance of lignocellulosic liquid of pineapple residues was carried out via two-level factorial analysis (TLFA) by using Design Expert software. Design Expert recommended endo-xylanase at pH 5, 5 bar, 50 °C, 300 rpm; beta-xylosidase at pH 8, 5 bar, 65 °C, 500 rpm; and multienzyme at pH 8, 5 bar, 80 °C, 200 rpm as the best conditions for simultaneously maximizing sugar and minimizing furfural concentration. The experimental best condition indicates the enzyme-membrane integrated system was capable of producing 0.5, 0.2, and 0.3 g/L xylose with a yield of 367, 118, and 167 % using endo-xylanase, beta-xylosidase, and multienzyme, respectively. Consequently, the validation experiment for the suggested solutions shows the error was less than 10 % in comparison to the experimental results. Fouling studies show that temperatures of 80 °C used for multienzyme experiments have caused thermal fouling of the membrane, leading to sugar loss. Based on the FESEM morphology image, flux decline, and Mulders' model, it has been confirmed that pore blocking and cake formation are the major types of fouling observed in this study. Therefore, a successful fouling reduction technique is necessary in order for simultaneous filtration to be effective since fouling affects the purification step, which in turn affects the feasibility of the entire integrated system.

ABSTRAK

Pada masa ini, beberapa inisiatif telah dibuat untuk menggabungkan dan mengintegrasikan hidrolisis enzimatik dan pemisahan melalui membran sebagai satu sistem dalam depolimerisasi hemiselulosa. Walau bagaimanapun, tiada penyelidikan yang diketahui melaporkan korelasi antara pengotoran membran dan hidrolisis enzimatik yang mempengaruhi prestasi hidrolisis dan pemisahan. Oleh itu, penyelidikan ini menghubungkan kondisi operasi pH, tekanan, suhu, dan kelajuan pengadukan menggunakan 2 enzim xilanolitik yang berbeza dan multienzim untuk mekanisme pengotoran terhadap hasil pengeluaran gula. Kajian saringan mengenai empat factor (pH: 5-8, pressure: 5–10 bar, temperature: 50–80 °C, agitation speed: 200–500 rpm) yang secara substansial mempengaruhi prestasi pemisahan hidrolisis cecair lignoselulosa residu nanas dilakukan melalui analisis *two-level factorial analysis* (TLFA) dengan menggunakan perisian Design Expert. Perisian tersebut mengesyorkan *endo-xylanase* pada pH 5, 5 bar, 50 °C, 300 rpm; *beta-xylosidase* pada pH 8, 5 bar, 65 °C, 500 rpm; dan multienzim pada pH 8, 5 bar, 80 °C, 200 rpm sebagai kondisi terbaik untuk memaksimumkan gula dan meminimumkan kepekatan furfural secara serentak. Kondisi terbaik eksperimen menunjukkan sistem integrasi enzim-membran mampu menghasilkan 0.5, 0.2, dan 0.3 g/L xilosa dengan hasil 367, 118, dan 167 % menggunakan *endo-xylanase*, *beta-xylosidase*, dan multienzim, masing-masing. Manakala, solusi eksperimen pengesahan seperti yang dicadangkan dalam perisian menunjukkan ralat kurang daripada 10 % berbanding dengan hasil eksperimen. Kesan positif suhu (C+) adalah faktor penyumbang yang sama bagi kedua-dua respon bagi semua enzim. Untuk sistem multienzim, kesan interaksi negatif dari tekanan-agitasi (BD-) juga merupakan faktor penyumbang yang sama untuk kedua-dua respon. Kajian kotoran membran menunjukkan bahawa suhu 80 °C yang digunakan untuk eksperimen multienzim telah menyebabkan pengotoran termal membran, yang menyebabkan pengekalan gula yang rendah. Berdasarkan imej morfologi FESEM, penurunan fluks, dan model Mulders, telah disahkan bahawa penyekatan liang dan pembentukan kek adalah jenis pengotoran utama yang diperhatikan dalam kajian ini. Oleh itu, teknik pengurangan pengotoran yang cekap diperlukan agar penyaringan serentak lebih berkesan kerana pengotoran membran mempengaruhi penulenan gula yang akan mempengaruhi kebolehlaksanaan keseluruhan sistem berintegrasi.

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