SEPARATION OF XYLOSE FROM GLUCOSE IN OIL PALM FROND (OPF) BAGASSE HYDROLYSATE USING NANOFILTRATION MEMBRANE SYSTEM

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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 in

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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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LIST OF SYMBOLS

A	Effective membrane area (m^2)
C_0	Total feed concentration
C_f	Concentration of sugar in tank (gL^{-1})
C_p	Concentration of sugar in permeate (g/100 g of solution)
$C_{f,glu}$	Concentration of glucose in feed (g/100 g of solution)
$C_{f,xyl}$	Concentration of xylose in feed (g/100 g of solution)
$C_{p,glu}$	Concentration of glucose in permeate (g/100 g of solution)
$C_{p,\,xyl}$	Concentration of xylose in permeate (g/100 g of solution)
J_w	Water flux ($L\ m^{-2}\ h^{-1}$)
N_{tot}	Total nitrogen
P_m	Pure water permeability ($L\ m^{-2}\ h^{-1}\ bar^{-1}$)
Q_R	Retentate flow
R_{obs}	Observed retention of respective solute
R_{xyl}	Observed retention of xylose
R_{gluc}	Observed retention of glucose
X_{xyl}	xylose separation factor
ΔP	Different operating pressure
Δt	Measured period of time
ΔV	Volume of ultrapure water collected

LIST OF ABBREVIATIONS

COD	Chemical oxygen demand
DEF	Dead-end filtration
DOE	Design of experiments
DP	Degree of polymerization
EFB	Empty fruit bunch
HMF	5-hydroxymethyl-furfural
HPLC	High performance liquid chromatography
LCB	Lignocellulosic biomass
LHW	Liquid hot water
MW	Molecular weight
MWCO	Molecular weight cut-off
NaOH	Sodium hydroxide
NF	Nanofiltration
NMSS	Nanofiltration membrane separation system
NREL	National renewable energy laboratory
MPOB	Malaysian palm oil board
OPF	Oil palm frond
POME	Palm oil mill effluent
RO	Reverse osmosis
TMP	Transmembrane pressure
UF	Ultrafiltration
VCR	Volume concentration ratio

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ABSTRAK

Pemisahan hirolisat biojisim mengandungi xilosa dan glukosa telah dilakukan dengan sistem aliran silang, menggunakan membran nanoturasan (NF) komersil dengan potongan berat molekul (MWCO) di antara 150-1000 g/mol. Xilosa merupakan produk perantaraan dalam pengeluaran xilitol, dan glukosa mengganggu dalam proses pemisahannya. Berat molekul glukosa adalah 1.2 kali ganda berat molekul xilosa dua jenis Kedua-dua jenis monosakarida ini berkemungkinan boleh dipisahkan menggunakan membran NF mengikut saiz molekul mereka berbanding keterserapan. Oleh itu kajian ini telah dilakukan bertujuan untuk menyelidik prestasi skala perintis membran komersil nanoturasan gulungan lingkar pilin iaitu Desal-5 DK, Desal-5 DL dan NF90 untuk pemisahan xilosa dari glukosa. Larutan yang digunakan adalah biojisim daripada hampas pelepah kelapa sawit. Hemiselulosa tersari daripada hampas pelepah kelapa sawit telah dihidrolisis kepada monomer dengan menggunakan cairan hidrolisis asid. Pemisahan gula telah dimulakan menggunakan model larutan xilosa-glukosa sebelum menjalankan hidrolisa OPF. Operasi penapisan dilakukan mod kitar semula pada 5 ke 10 bar. Kepekatan gula telah dianalisa menggunakan kromatografi cecair prestasi tinggi (HPLC). Daripada kajian ini, membran Desal-5 DK memberi faktor pemisahan xilosa yang lebih tinggi iaitu pada 1.17 berbanding dengan Desal-5 DL (0.81) dan membran NF90 (0.84) apabila menggunakan model larutan. Terdapat beberapa parameter operasi digunakan untuk mengkaji prestasi membran diantaranya tekanan tranmembran (TMP), jumlah kepekatan yang masuk (C_0) dan nisbah xilosa dan glukosa. Kesan aliran silang daripada parameter operasi telah diuji menggunakan model larutan dedua. Penolakan xilosa dan glukosa bergantung kepada keberkesanan tekanan pemisahan. Merujuk kepada keputusan kajian ini, penolakan glukosa sehingga 90 % dan penolakkan xilosa sehingga 80 % apabila tekanan dinaikkan. Faktor pemisah maksima 2.47 telah dicapai apabila pecahan kepekatan xilosa adalah 3.2 % dalam jumlah kepekatan yang masuk dengan 10 % glukosa. Ini adalah kerana lagi tinggi kepekatan molekul besar (glukosa) menolak molekul kecil (xilosa) melalui membran, meningkatkan penelapan xilosa. Sementara itu, nisbah xilosa kepada glukosa yang sama (50:50) pada kepekatan yang tinggi 10 % telah menggalakkan kepada kepekatan faktor pemisah yang tinggi iaitu 2.16. Pemisahan OPF hidrolisa dalam kajian ini memberi penolakan xilosa yang rendah antara 10 ke 30 %. Ini adalah kerana tekanan rendah pada 5 dan 10 bar telah diaplikasi semasa pemisahan. Faktor pemisah xilosa sehingga 1.63 apabila dinaikkan tekanan suap dan penghalang yang ada dalam hidrolisat hampas pelepah kelapa sawit tersekat lebih kerana faktor pemisah mereka yang rendah. Berkemungkinan tinggi perencat tidak dapat melalui membran kerana molekul xilosa yang besar dan menyekat mereka. Secara keseluruhan, dapat disimpulkan bahawa membran nanoturasan gulungan lingkar pilin boleh dijadikan sebagai pemisah alternatif kos rendah serta mudah diselenggarakan yang mana ianya mempunyai potensi besar dalam pemisahan xilosa-glukosa.

ABSTRACT

Separation of biomass hydrolysate that contain glucose and xylose was done in a cross-flow system, using a commercial spiral wound nanofiltration (NF) membrane with molecular weight cut off (MWCO) ranging from 150 to 1000 g/mol. Xylose is an intermediate product in xylitol production and glucose interferes in the process of separation. The molecular weight of glucose is 1.2 times higher than the molecular weight of xylose. These two different types of monosaccharides can possibly be separated using NF membrane according to their molecular size rather than diffusivities. Thus the aim of this study are to develop and evaluate the performance of pilot scale commercial spiral wound NF membrane namely Desal-5 DK, Desal-5 DL and NF90 for separation of xylose from glucose. The feedstock used was biomass from oil palm frond (OPF) bagasse. The separation of sugar was started using xylose-glucose model solution before run with OPF hydrolysate. The filtration was operated in total recycled mode at 5 to 10 bar. The sugar concentration was analyzed using high performance liquid chromatography (HPLC). From this study, Desal-5 DK membrane gave the higher xylose separation factor at 1.17 as compare to Desal-5 DL (0.81) and NF90 membranes (0.84) when using model solution. There are several operating parameter used to evaluate the performance of membrane, which are transmembrane pressure (TMP), total feed concentration (C_0) and ratio xylose to glucose. The crossflow effect from the operating parameter was tested using binary model solution. Xylose and glucose rejection are dependent on the effective filtration pressure. According to the result in this study, glucose rejection is up to 90 % and xylose rejections up to 80 % when pressure increased. Maximum separation factor 2.47 was achieved when xylose concentration ratio was 3.2 % in total feed concentration with 10 % of glucose. This is due to higher concentration of larger molecule (glucose) pushes smaller molecule (xylose) through the membrane, enhancing xylose permeation. Meanwhile, equal ratio of xylose to glucose (50:50) at high feed concentration, 10 % promoted to high separation factor which is 2.16. The separation of OPF hydrolysate in this present work gave low rejection of xylose between 10 to 30 %. This is due to low pressure at 5 to 10 bar was applied during the separation. The xylose separation factor was up to 1.63 when increased in feed pressure while inhibitors present in OPF bagasse hydrolysate are retained more due its lower separation factor. The inhibitors most probably cannot pass through the membrane due to xylose molecule size was bigger and block them. Overall, it can be concluded that the spiral wound nanofiltration membrane offers cost-effective and easy-maintenance, which has a potential in xylose-glucose separation.

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