THIN FILM COMPOSITE HOLLOW FIBER MEMBRANE FOR SEPARATION IN BIOREFINERY

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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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ABSTRAK

Sisa biojisim kelapa sawit dalam bentuk pelepah, batang, tandan buah kosong, cengkerang, serat, dan efluen kilang kelapa sawit boleh diproses untuk menghasilkan produk bernilai tinggi seperti bioethanol dan bahan kimia berasaskan bio. Teknologi membran telah diakui dengan baik untuk memekatkan gula dan penyingkiran perencat semasa pemprosesan biojisim di biorefinery. Walau bagaimanapun, kebanyakan membran yang digunakan dibeli secara komersil dan tidak khusus untuk pemprosesan hidrolisat biojisim. Dalam kajian semasa, satu siri membran filem komposit nipis (TFC) gentian berongga direka untuk menyesuaikan prestasi ke arah kepekatan gula dan penyingkiran asid asetik dalam pemprosesan biojisim. Tiga parameter penting disiasat iaitu jenis monomer berair dalam proses pempolimeran antaramuka (IP), jarak jurang udara semasa proses pintalan kering-basah untuk fabrikasi substrat membran, dan kepekatan m-phenylenediamine (MPD) monomer dalam IP. Membran telah dinilai oleh kebolehtelapan dan ujian penolakan larut, mikroskopi pengimbasan elektron, dan jelmaan Fourier spectroskopi inframerah. Monomer akueus yang terbaik yang diperoleh untuk membekalkan membran serat TFC berongga adalah monomer MPD. Serat Hollow berputar pada jarak jurang udara 6 cm menunjukkan substrat membran terbaik untuk menghasilkan membran TFC. Kepekatan MPD 2.0 wt. % dipilih sebagai kepekatan terbaik untuk bertindak balas dengan monomer organik trimesoyl klorida untuk menyediakan membran serat TFC berongga. Membran serat berongga TFC yang disediakan pada keadaan terbaik ini menunjukkan nilai penolakan 91.66 ± 0.09% xilosa, 67.28 ± 13.97% glukosa, dan 13.08 ± 3.00% asid asetik. Ini adalah sama dengan faktor pemisahan yang ideal iaitu 3.20 ± 1.27 untuk asid asetik/glukosa dan 10.42 ± 0.25 untuk asid asetik/xilosa. Walaupun demikian, membran ini boleh digunakan untuk penyingkiran asid asetik dan kepekatan gula secara serentak dalam hidrolisis lignoselulosa tetapi prestasinya masih rendah dibandingkan dengan membran komersil. Sebagai contoh, membran komersil RO98pHt mempunyai faktor pemisahan yang ideal iaitu 223.16 untuk asid asetik/glukosa dan 348.69 untuk asid asetik/xilosa, dan faktor pemisahan membran RO99 sebanyak 209.96 untuk asid asetik/glukosa dan 194.41 untuk asid asetik/xilosa. Penyiasatan lanjut mengenai penghasilan bahan membran dengan kombinasi sifat mekanik dan fizikokimia yang baik diperlukan dalam kajian masa depan. Selain itu, pengoptimuman serentak pada parameter putaran membran dan parameter proses IP dapat meningkatkan prestasi membran serat TFC berongga. Ujian membran TFC dengan hidrolyzate biomassa sebenar juga penting untuk menilai prestasi membran gentian TFC sebenar.

ABSTRACT

Membrane technology has been well-recognized for sugar concentration and inhibitor removal during biomass processing in biorefinery. However, most of the membranes used were commercially purchased and not specifically customize for the biomass hydrolysate processing. In the current study, a series of thin film composite (TFC) hollow fiber membranes were fabricated to tailor the performance toward sugar concentration and acetic acid removal in biomass processing. Three important parameters were investigated which were type of aqueous monomer in interfacial polymerization (IP) process, air gap distance during dry-wet spinning process for fabrication of membrane substrate, and the concentration of aqueous m-phenylenediamine (MPD) monomer in IP. The membranes were evaluated by permeability and solute rejection tests, scanning electron microscopy, and Fourier transform infrared spectroscopy. The best aqueous monomer obtained to prepare TFC hollow fiber membrane was MPD monomer. Hollow fiber spun at 6 cm air gap distance showed the best membrane substrate to produce TFC membrane. MPD concentration of 2.0 wt. % was selected as the best concentration to react with trimesoyl chloride organic monomer to prepare TFC hollow fiber membrane. TFC hollow fiber membrane prepared at this best condition showed the rejection value of 91.66 ± 0.09 % xylose, 67.28 ± 13.97 % glucose, and 13.08 ± 3.00 % acetic acid. This is corresponding to the ideal separation factor of 3.20 ± 1.27 for acetic acid/glucose and 10.42 ± 0.25 for acetic acid/xylose. Although, the membrane is feasible for simultaneous acetic acid removal and sugar concentration in lignocellulosic hydrolysates but its performance is still low compares to the commercial membrane. As an example, commercial RO98pHt membrane had an ideal separation factor of 223.16 for acetic acid/glucose and 348.69 for acetic acid/xylose, and RO99 membrane separation factor of 209.96 for acetic acid/glucose and 194.41 for acetic acid/xylose. Further investigation on producing membrane material with good combination of mechanical and physicochemical properties is necessary in the future study. In addition, simultaneous optimization on the membrane spinning parameters and IP process parameters can improve the performance of the TFC hollow fiber membrane. Testing the TFC membrane with real biomass hydrolysate also important to evaluate the actual TFC hollow fiber membrane performance.

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LIST OF SYMBOLS

A	Effective membrane area
C_f	Concentration of respective solute in feed
C_p	Concentration of respective solute in permeate
Da	Dalton
ε	Porosity (%)
J	Flux (L/m^2 h)
ΔP	Operating pressure (Pa)
ρ_w	Density of water at 25 ºC
Q	Volumetric flow rate of permeate pure water (m^3/s)
R	Rejection of respective solute (%)
r_m	Mean pore radius (nm)
s	Solute
Δt	Measured period of time of collected flux (h)
μ	Viscosity of water at 25 ºC
ΔV	Volume of collected flux (L)
w_1	Weight of wet membrane (kg)
w_2	Weight of dry membrane (kg)
X	Separation factor

LIST OF ABBREVIATIONS

AA	Acetic acid
AR	Analytical reagent
Na_3PO_4	Sodium phosphate
DMF	Dimethylformamide
DNS	Dinitrosalicylic acid
EFB	Empty fruit bunch
FTIR	Fourier transform infrared
GFC	Gel filtration chromatography
Glu	Glucose
HPLC	High performance liquid chromatography
IP	Interfacial polymerization
LS	Light scattering
MDF	Medium density fiberboard
MF	Microfiltration
MPD	M-phenylenediamine
MW	Molecular weight
MWCO	Molecular weight cut-off
NaOH	Sodium hydroxide
NF	Nanofiltration
OPA	Oil palm ash
OPF	Oil palm frond
OPT	Oil palm trunk
PEG	Polyethylene glycol
PEI	Polyethylenimine
PEO	Polyethylene oxide
PIP	Piperazine
PKS	Palm kernel shell
POME	Palm oil mill effluent
PSf	Polysulfone
PVP	Polyvinylpyrrolidone
PWP	Pure water permeability

RI	Refractive index
RO	Reverse osmosis
SEM	Scanning electron microscope
TEOA	Triethanolamine
TMC	Trimesoyl chloride
UF	Ultrafiltration
UPLC	Ultra performance liquid chromatography
Xyl	Xylose

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