

Supporting information for:
Technical Performance and Economic
Evaluation of Evaporative and
Membrane-based Concentration for
Biomass-derived Sugars

David A. Sievers,* Jonathan J. Stickel, Nicholas J. Grundl, and Ling Tao

*National Bioenergy Center, National Renewable Energy Laboratory, Golden, Colorado, 80401,
United States of America*

E-mail: david.sievers@nrel.gov

Phone: +1 (303) 384 7748. Fax: +1 (303) 384 6877

1 Detailed analysis of membrane-concentration data

The measured water permeance of the three membranes during conditioning is shown in Fig. S1. The water permeance of the RO90 and NF270 membranes appear to still be approaching steady state but were considered sufficiently conditioned for use.

Detailed results for the concentration of hydrolysate with the RO90 membrane are shown in Fig. S2. Water flow rate is obtained by taking the numerical derivative of the recorded permeate mass, $Q_p \approx \frac{1}{\rho} \frac{\Delta m}{\Delta t}$ (density, ρ , is assumed to be ~ 1 g/ml). The experimental noise in the mass signal is magnified when dividing by closely spaced time-points, i.e., when Δt is small. Data smoothing[?] was applied to the permeate mass signal (Fig. S2a), and the calculated permeance using the smoothed signal exhibits much less noise (Fig. S2b). Smoothed permeate mass signals were used for all subsequent analysis. The empirical model for permeance (Eq. 5) was fit to the data and is shown as a dashed blue line in Fig. S2d.

As run-time retentate samples were not taken, it was not possible to calculate rejection directly for each permeate sample. Therefore an empirical model for rejection (Eq. 4) and an iterative method was used to evaluate rejection. The model is effectively a power-law model, but the second form given in Eq. 4 has improved numerical stability and was used for the numerical analysis. A mass balance of the batch-concentration experimental system provides a relationship for the rate change of retentate concentration:

$$\frac{dc}{dt} = \frac{Q_p cr}{V}, \quad (\text{S1})$$

where V is the retentate volume. Using $Q_p = dV_p/dt$ and $V = V_0 - V_p$, where V_0 is the initial retentate volume (L), gives

$$\frac{dc}{dV_p} = \frac{cr}{V_0 - V_p}. \quad (\text{S2})$$

Given a set of model coefficients for rejection, Eq. S2 was solved numerically for retentate concentration, followed by calculation of predicted permeate concentration by $c_p = c(1 - r)$. An iterative minimization routine followed these steps to find the best fit for the rejection model, using the least-squared difference between the predicted and measured permeate concentrations as the ob-

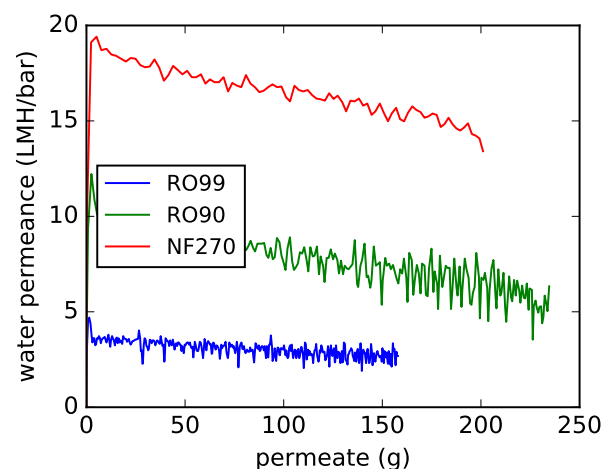


Figure S1: Water permeance during conditioning of the membranes tested.

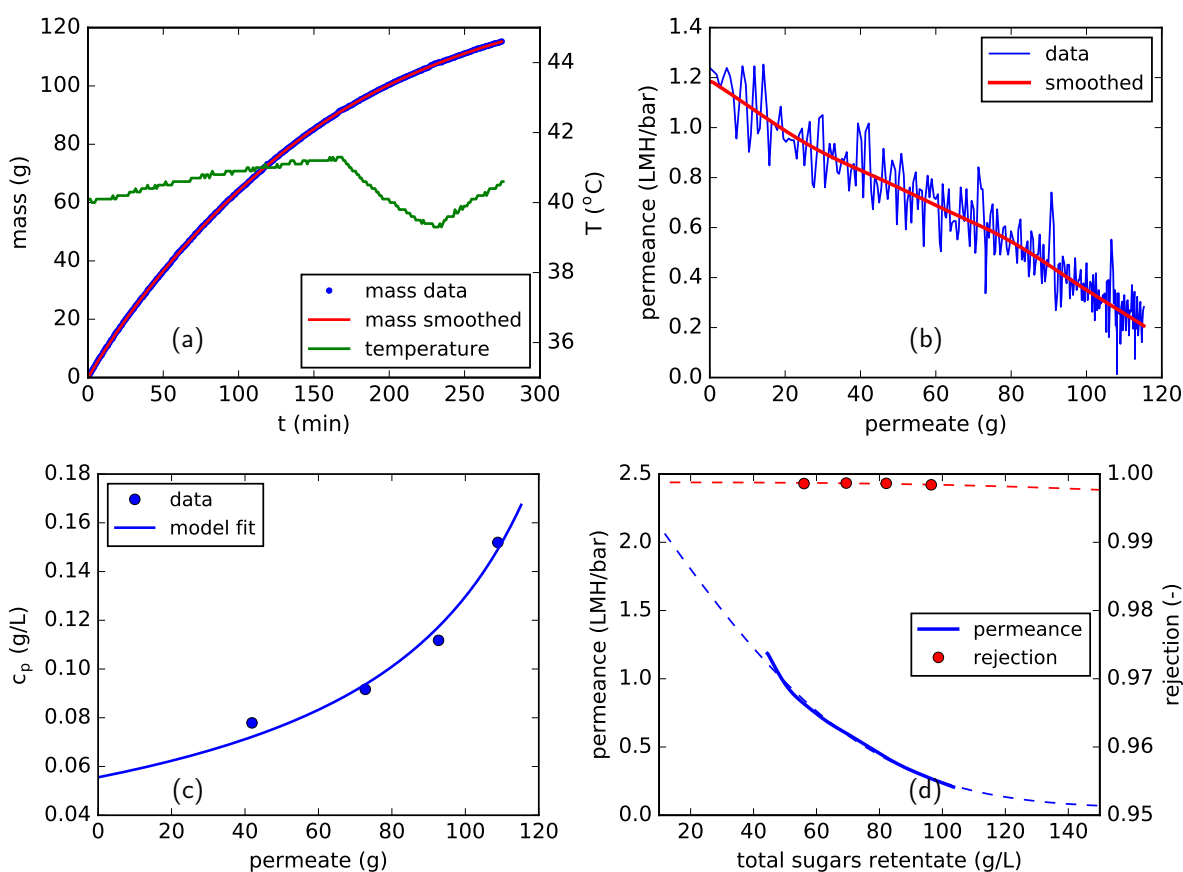


Figure S2: Detailed results for the concentration of hydrolysate with the RO90 membrane: (a) mass of permeate collected and temperature; (b) permeance vs. collected permeate; (c) instantaneous permeate concentration; (d) permeance and rejection vs. retentate sugar concentration (dashed lines are model fits).

Table S1: Rejection and Permeance model parameters

	a_0	a_1	a_2	b_0	b_1	b_2	b_3
RO99 glucose	0.999	42.4	8	14.5	0.0139	4.45	0.05
RO90 glucose	0.997	20.2	3.07	24.7	0.0142	4.45	0.05
RO90 hydrolysate	0.999	20.3	2.69	5.13	0.0128	4.45	0.05
NF270 hydrolysate	0.938	31.9	6	-508	0.00486	3.35e+04	0.117
NF270 glucose	0.892	14	2.56	-308	0.00614	2.11e+03	0.257

jective function. The best-fit rejection model is shown as the dashed red line in Fig. S2d, and the resulting agreement to the permeate concentration is shown in Fig. S2c. Best-fit model coefficients for both the permeance and rejection models for each membrane and solution combination are given in Table S1. As the models are empirical and only intended to reproduce the experimental trend lines, their form and coefficient values should not be used to infer any physical significance. The coefficient values are provided so that the reader may reproduce the permeance and rejection curves, if desired.