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Appendix

ศูนย์วิทยทรัพยากร  
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## Appendix A : Feed Solution Preparation

### Appendix A1 : Acetone-Butanol-Ethanol-Acetic Acid-Butyric Acid-Water Mixtures

Concentrations of each component were :

Butanol	7 g/l
Acetone	6 g/l
Ethanol	0.25 g/l
Acetic Acid	0.50 g/l
Butyric Acid	0.20 g/l

### Appendix A2 : Acetone-Butanol Fermentation Broth

Acetone-butanol fermentation broth was obtained from a fermentation process of *Clostridium acetobutylicum* ATCC 824. Fermentation medium that has been described by Petitdemange; for 1 L,  $K_2HPO_4$  0.5 g,  $KH_2PO_4$  0.5 g,  $MgSO_4 \cdot 7H_2O$  0.2 g,  $MnSO_4 \cdot H_2O$  0.01 g,  $FeSO_4 \cdot 7H_2O$  0.01 g, NaCl 0.01 g, yeast extract 6.0 g, D(+) glucose anhydrous variable. The fermenter was coupled with recycling system, ceramic filter for cell recovery in continuous process. Temperature and pH were controlled at the desired conditions. Vegetable oil were added as a foam reducing agent.

Concentration of the main components in the cell free fermentation broth were adjusted to the values shown in Appendix A1.

## Appendix B : Experimental Calculations

### 1. Sorption Analysis

#### 1.1 Sorption Percentage (%wt.)

$$\% \text{ Sorption} = \frac{(W_1 - W_2) * 100}{W_1}$$

#### 1.2 Concentration of each components in silicone rubber membrane

(% by wt)

$$X_m = \frac{FX_{ii} - (F - (W_2 - W_1))X_{i2}}{W_1}$$

#### 1.3 Distribution Coefficient

$$S_i = \frac{X_m}{X_{i2}}$$

### 2. Pervaporation Analysis

#### 2.1 Permeate Flux

$$J = \frac{W}{A.t}$$

#### 2.2 Flux of component i

$$J_i = y_i J$$

#### 2.3 Permeate concentration

$$C_i = W_i / W$$

#### 2.4 Separation Factor

$$\beta = \frac{y_i / y_1}{x_i / x_1} = \frac{y_i / (1 - y_i)}{x_i / (1 - x_i)}$$

#### 2.5 Permeability and Diffusivity

The permeation flux is analyzed on the basis of the solution-diffusion model. From this assumption, the permeation flux at steady state is represented as follow:

$$J_i = -D_i \frac{dc_i}{dx} = -D_i K_i \frac{dc_i}{dx}$$

and the boundary conditions are given as :

$$\text{at } x = 0 \quad c_i = c_{fi}$$

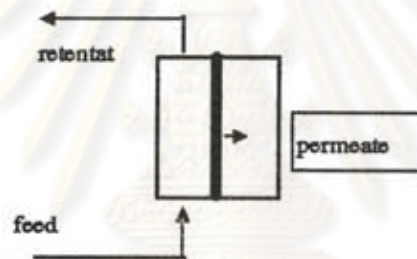
$$\text{at } x = \delta \quad c_i = 0$$

Integrating with the boundary conditions yields

$$J_i = D_i K_i c_i / \delta$$

where;  $D_i K_i = P = \text{Permeability}$

### 3. Mass balace at steady state



Assumptions :

1. Mass balance were calculated from the permeate collected in 1 hour.
2. Solution flow rate was kept constant at 1 l/hr.
3. No accumulation of any composition in membrane at steady state.

Mass balace :

Mass flow in the unit = Mass flow rate out of the unit +  
Mass accumulation

$$c_{fi} V_f = C_n V_r + w_{pi}$$

where;

$c_{fi}$  = concentration of i component in feed



$c_{ri}$  = concentration of i component in retentate

$v_f = v_r$  = flow rate of solution

$w_{pi}$  = mass of i component in permeate



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## Appendix C : Experimental Data

### Sorption Experiments

Table C1 Distribution coefficient of synthetic mixtures mixtures.

Temperature (°c)	Butanol	Acetone	Ethanol	Acetic acid	Butyric acid	Water
40	0.4088	0.1642	0.1467	0.0257	0.0297	0.0561
50	0.5842	0.4200	0.2802	0.0310	0.0276	0.0435
60	0.6300	0.6031	0.3010	0.0360	0.0301	0.0394
70	0.6416	0.6133	0.4691	0.0227	0.0366	0.0406

Table C2 Distribution coefficient of acetone-butanol fermentation broth.

Temperature (°c)	Butanol	Acetone	Ethanol	Acetic acid	Butyric acid	Water
40	0.2980	0.1020	0.0980	0.0211	0.0198	0.0550
50	0.4360	0.2390	0.1060	0.0297	0.0300	0.0501
60	0.5100	0.4460	0.1130	0.0286	0.0306	0.0229
70	0.5390	0.4630	0.2670	0.0340	0.0376	0.0267

Table C3 Distribution coefficient of butanol in various mixtures.

Mixtures	Distribution Coefficient of Butanol
Butanol	0.4930
Butanol-Ethanol	0.4860
Butanol-Acetone	0.4379
Butanol-Ethanol-Acetone	0.4172
Butanol-Ethanol-Acetic Acid-Butyric Acid	0.4793
Butanol-Ethanol-Acetone-Acetic Acid-Butyric Acid	0.4088

Table C4 Distribution coefficient of acetone in various mixtures.

Mixture	Distribution Coefficient of Acetone
Acetone	0.1712
Acetone-Butanol	0.1689
Acetone-Ethanol	0.1694
Acetone-Butanol-Ethanol	0.1660
Acetone-Acetic Acid-Butyric Acid	0.1691
Acetone-Butanol-Ethanol-Acetic Acid-Butyric Acid	0.1642

Table C5 Distribution coefficient of ethanol in various mixtures

Mixtures	Distribution Coefficient of Ethanol
Ethanol	0.1769
Ethanol-Butanol	0.1501
Ethanol-Acetone	0.1638
Ethanol-Butanol-Acetone	0.1498
Ethanol-Butanol-Acetic Acid-Butyric Acid	0.1703
Ethanol-Butanol-Acetone-Acetic Acid-Butyric Acid	0.167

Table C6 Distribution coefficient of acetic acid in various mixtures.

Mixtures	Distribution Coefficient of Acetic Acid
Acetic Acid-Butyric Acid	0.0273
Acetic Acid-Butyric Acid-Butanol-Ethanol	0.0326
Acetic Acid-Butyric Acid-Acetone	0.0301
Acetic Acid-Butyric Acid-Butanol-Ethanol-Acetone	0.0257

Table C7 Distribution coefficient of butyric acid in various mixtures.

Mixtures	Distribution Coefficient of Butyric Acid
Butyric Acid-Acetic Acid	0.0290
Butyric Acid-Acetic Acid-Butanol-Ethanol	0.0321
Butyric Acid-Acetic Acid-Acetone	0.0307
Butyric Acid-Acetic Acid-Butanol-Ethanol-Acetone	0.0297

Table C8 Distribution coefficient of water in various mixtures.

Mixtures	Distribution Coefficient of Water
Butanol-Ethanol	0.0366
Acetone	0.0486
Acetic Acid-Butyric Acid	0.0796
Butanol-Ethanol-Acetone	0.0437
Butanol-Acetone-Acetic Acid-Butyric Acid	0.0439
Acetone-Acetic Acid-Butyric Acid	0.0539
Butanol-Ethanol-Acetone-Acetic Acid-Butyric Acid	0.0561

### Pervaporation Process

Permeation Area :

$$\text{Membrane thickness 0.25 mm.} = 0.0565 \text{ m}^2$$

$$\text{Membrane thickness 0.50 mm.} = 0.0457 \text{ m}^2$$

$$\text{Membrane thickness 1.00 mm.} = 0.0321 \text{ m}^2$$



Membrane Thickness 0.25 mm.

Table C9 Permeation weight of synthetic mixtures and acetone-butanol fermentation broth

Temperature (°C)	Synthetic Mixtures			Acetone-Butanol Fermentation Broth		
	2 torr	10 torr	30 torr	2 torr	10 torr	30 torr
40	1.2873	0.8652	0.1551	0.9009	0.2891	0.1329
50	2.2161	1.4862	0.5223	1.6319	0.3692	0.1688
60	2.5616	1.8208	1.1788	2.1503	1.1305	0.9279
70	4.1448	2.6996	1.6426	2.6938	2.1569	1.1745
80	5.2718	3.1443	2.0482	-	-	-





Water	2.2118	7.5581	13.6404	20.5897	27.0346	2.1221	2.4778	11.4414	18.0244
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Table C13 Permeation concentration of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 2 torr

Component	Synthetic Mixtures (%)					Acetone-Butanol Fermentation Broth (%)			
	40	50	60	70	80	40	50	60	70
Butanol	15.97	17.77	24.99	20.66	17.63	25.46	11.06	23.02	21.68
Acetone	6.98	7.92	8.67	10.68	6.43	8.64	6.52	8.00	7.85
Ethanol	0.59	0.64	0.87	0.64	0.30	0.76	0.27	0.74	0.62
Acetic Acid	0.05	0.06	0.06	0.06	0.05	0.04	0	0.03	0.10
Butyric Acid	0	0	0.04	0.05	0.04	0	0	0.03	0.04
Water	76.9	72.7	75.75	68.04	75.52	71.15	78.07	68.17	69.69

Table 14 Permeation concentration of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 10 torr

Component	Synthetic Mixtures					Acetone-Butanol Fermentation Broth			
	40	50	60	70	80	40	50	60	70
Butanol	11.01	15.39	21.61	20.47	17.45	7.10	9.76	23.02	21.68
Acetone	6.27	7.91	9.53	7.45	7.25	6.04	7.26	7.76	6.32
Ethanol	0.40	0.48	0.61	0.44	0.38	0.46	0.55	0.59	0.42
Acetic Acid	0.03	0.04	0.06	0.08	0.08	0	0	0.05	0.06
Butyric Acid	0	0	0	0	0	0	0	0	0
Water	81.52	61.50	64.48	71.55	74.89	86.37	82.38	72.74	74.95

Table C15 Permeation concentration of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 30 torr

Component	Synthetic Mixtures					Acetone-Butanol Fermentation Broth			
	40	50	60	70	80	40	50	60	70
Butanol	9.49	11.06	25.46	22.32	19.49	5.55	9.47	24.58	24.72
Acetone	6.01	6.52	8.64	6.37	5.57	3.38	5.16	8.48	7.24
Ethanol	0.19	0.027	0.76	0.59	0.44	0.09	0.09	0.52	5.41



Acetic Acid	0	0	0.06	0.04	0.04	0	0	0.01	0.32
Butyric Acid	0	0	0	0	0	0	0	0	0.02
Water	80.52	81.73	65.36	70.80	74.55	90.16	82.93	66.28	86.68

Table C16 Membrane Selectivity of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 2 torr

Component	Synthetic Mixtures					Acetone-Butanol Fermentation Broth			
	40	50	60	70	80	40	50	60	70
Butanol	26.9601	30.6555	47.2605	36.9393	30.3622	22.3863	24.6809	43.8683	39.2679
Acetone	12.4312	14.2493	15.7268	19.8087	11.3844	9.8462	11.5358	14.4057	14.1126
Ethanol	23.7341	25.7584	35.0966	25.7584	12.0330	22.6013	23.3295	29.8132	24.9484
Acetic Acid	1	3.0012	3.0012	3.0012	1	0	0	0.5998	4.0030
Butyric Acid	0	0	2.0004	3.0012	2.0004	0	0	1.5002	2.0004
Water	0.0457	0.0376	0.0271	0.0361	0.0436	0.0348	0.0503	0.0303	0.0325

Table C17 Membrane Selectivity of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 10 torr

Component	Synthetic Mixtures					Acetone-Butanol Fermentation Broth			
	40	50	60	70	80	40	50	60	70
Butanol	17.5508	25.8082	48.8366	36.5122	29.9867	10.8416	15.3427	32.6933	31.6047
Acetone	10.7133	15.2298	17.4511	13.3356	12.9496	10.6495	12.9686	13.9295	11.1765
Ethanol	16.0603	19.2878	24.5436	17.6734	15.2542	18.4804	22.1666	23.7341	16.8666
Acetic Acid	0.5998	0.7999	1.2001	1.6005	1.6005	0	0	1	1.2001
Butyric Acid	0	0	0	0	0	0	0	0	0
Water	0.0624	0.0452	0.0257	0.0355	0.0422	0.0986	0.0896	0.0377	0.0423

Table C18 Membrane Selectivity of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 30 torr

Component	Synthetic Mixtures					Acetone-Butanol Fermentation Broth			
	40	50	60	70	80	40	50	60	70
Butanol	14.8737	17.6404	48.4529	40.7602	34.3410	8.3357	14.8391	39.8246	46.5822

Acetone	10.5932	11.5548	15.6672	11.2709	9.7719	5.7954	9.0135	15.3502	12.9304
Ethanol	7.6125	10.8863	30.6200	11.6308	9.6207	3.6023	8.4155	20.9035	10.4245
Acetic Acid	0	0	1.2001	0.7999	0.7999	0	0	0.1999	0.3998
Butyric Acid	0	0	0	0	0	0	0	0	0
Water	0.0584	0.0632	0.0266	0.0343	0.0414	0.1296	0.0687	0.0278	0.0920

Table C19 Mass recovery of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 2 torr

Component	Synthetic Mixtures					Acetone-Butanol Fermentation Broth			
	40	50	60	70	80	40	50	60	70
Butanol	2.94	5.63	9.11	12.23	13.28	1.75	3.45	7.01	8.34
Acetone	1.49	2.76	3.69	7.38	5.65	0.84	1.77	2.87	3.53
Ethanol	2.85	5.35	8.82	10.71	6.52	1.59	3.33	6.35	6.71
Acetic Acid	0.13	0.25	0.26	0.50	0.63	0	0	0.12	0.57
Butyric Acid	0	0	0.51	1.07	1.05	0	0	0.35	0.53
Water	0.09	0.15	0.17	0.28	0.40	0.07	0.13	0.14	0.19

Table C20 Mass recovery of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 10 torr

Component	Synthetic Mixtures					Acetone-Butanol Fermentation Broth			
	40	50	60	70	80	40	50	60	70
Butanol	1.45	3.27	6.66	7.89	7.92	0.29	0.52	3.02	5.61
Acetone	0.91	1.96	2.89	3.53	3.80	0.29	0.45	1.46	2.27
Ethanol	1.53	2.89	4.47	4.93	6.25	0.54	0.96	3.23	3.64
Acetic Acid	0.05	0.13	0.23	0.47	0.48	0	0	0.013	0.57
Butyric Acid	0	0	0	0	0	0	0	0	0
Water	0.07	0.12	0.13	0.19	0.24	0.02	0.03	0.08	0.16





Water	3.8833	6.6708	8.4708	12.1174	14.1132	1.2975	1.6573	5.0741	9.6813
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Table C24 Permeability of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 30 torr

Component	Synthetic Mixtures					Acetone-Butanol Fermentation Broth			
	40	50	60	70	80	40	50	60	70
Butanol	0.0931	0.3653	1.8979	2.3190	2.5241	0.0467	0.1050	1.4426	1.8363
Acetone	0.0688	0.2514	0.7518	0.7708	0.8416	0.0331	0.0643	0.5804	0.6280
Ethanol	0.0800	0.1624	1.5870	1.6320	1.8090	0.0211	0.0614	1.0670	1.1680
Acetic Acid	0	0	0.0600	0.0700	0.0950	0	0	0.0110	0.0160
Butyric Acid	0	0	0	0	0	0	0	0	0
Water	0.5608	1.9144	3.4583	5.2202	6.8542	0.5380	0.6282	2.7602	4.5698

Table C25 Diffusivity of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 2 torr

Component	40	50	60	70	40	50	60	70
Butanol	3.1847	4.2622	6.4007	8.4390	2.6057	3.5082	5.1315	5.7792
Acetone	2.5098	2.9042	3.2448	5.3269	1.8748	2.1931	2.7068	3.0976
Ethanol	8.6025	9.4604	10.6376	11.5844	6.9215	6.1924	9.3421	9.8804
Acetic Acid	2.1595	3.5645	3.5450	5.9151	0	0	2.5221	5.6648
Butyric Acid	0	0	3.1158	5.8458	0	0	2.3941	3.2472
Water	10.5164	15.8360	16.7380	28.7711	8.1192	13.9580	16.4240	21.0660

Table C26 Diffusivity of synthetic mixtures and acetone-butanol fermentation broth at permeation pressure 10 torr

Component	Synthetic Mixtures				Acetone-Butanol Fermentation Broth			
	40	50	60	70	40	50	60	70
Butanol	1.5732	2.9659	4.6793	5.4462	0.4362	0.5229	2.1934	3.8895
Acetone	1.5155	2.0671	2.5458	2.4192	0.6480	0.6794	1.3791	1.9976
Ethanol	4.6216	5.1067	5.3896	5.9410	2.3235	2.9497	4.0831	5.3521
Acetic Acid	0.9338	1.8064	3.1212	5.5437	0	0	2.4115	3.8663



Butyric Acid	0	0	0	0	0	0	0	0
Water	9.2459	15.5134	18.8240	27.5395	3.2437	4.0421	12.6852	24.2033

Table C27 Diffusivity of synthetic mixtures and acetone-butanol fermentation broth at per meation pressure 30 torr

Component	Synthetic Mixtures				Acetone-Butanol Fermentation Broth			
	40	50	60	70	40	50	60	70
Butanol	0.2281	0.6252	3.0125	3.6144	0.1566	0.2408	2.3649	2.8732
Acetone	0.2603	0.5985	1.4943	1.6580	0.1664	0.2209	1.2375	1.2477
Ethanol	0.5453	0.6490	4.3242	3.9892	0.2068	0.2569	3.5448	3.8804
Acetic Acid	0	0	1.8181	1.8567	0	0	0.4867	0.4992
Butyric Acid	0	0	0	0	0	0	0	0
Water	1.3352	4.4520	7.6851	11.6044	1.3450	1.5321	6.9005	11.4245

Membrane Thickness 0.50, and 1.00 mm.

Operating Condition : Feed Temperature 60° c

Permeation Pressure 2 torr

Table C28 Permeation weight of synthetic mixtures and acetone-butanol fermentation broth for membrane thickness 0.5 and 1.0 mm.

Membrane Thickness (mm.)	Synthetic Mixtures	Acetone-Butanol Fermentation Broth
0.50	0.7625	0.6661
1.00	0.2263	0.1824

Table C29 Permeation flux of synthetic mixtures and acetone-butanol fermentation broth for membrnae thickness 0.5, and 1.0 mm.

Component	Synthetic Mixtures		Acetone-Butanol Fermentation Broth	
	0.50 mm.	1.00 mm.	0.50 mm.	1.00 mm.
Butanol	5.5759	2.6664	4.8554	2.0776
Acetone	2.1291	1.0917	1.7506	0.7895

Ethanol	0.1641	0.0886	0.1352	0.0658
Acetic Acid	0	0	0	0
Butyric Acid	0	0	0	0
Water	9.2470	3.2565	8.4947	2.7591

Table C30 Permeation concentration of synthetic mixtures and acetone-butanol fermentation broth membrae thickness 0.5, and 1.0 mm.

Component	Synthetic Mixtures		Acetone-Butanol Fermentation Broth	
	0.50 mm.	1.00 mm.	0.50 mm.	1.00 mm.
Butanol	33.45	37.75	29.91	35.27
Acetone	12.77	15.46	12.06	13.87
Ethanol	0.98	1.25	0.92	0.99
Acetic Acid	0	0	0	0
Butyric Acid	0	0	0	0
Water	55.47	46.10	58.33	48.47

Table C31 Membrane selectivity of synthetic mixtures and acetone-butanol fermentation broth membrae thickness 0.5, and 1.0 mm.

Component	Synthetic Mixtures		Acetone-Butanol Fermentation Broth	
	0.50 mm.	1.00 mm.	0.50 mm.	1.00 mm.
Butanol	71.3015	86.0258	60.5356	77.2949
Acetone	24.2527	30.2957	22.7193	26.6782
Ethanol	39.5780	50.7842	37.1324	39.9859
Acetic Acid	0	0	0	0
Butyric Acid	0	0	0	0
Water	0.0176	0.0121	0.0198	0.0133



Table C32 Mass recovery of synthetic mixtures and acetone-butanol fermentation broth membrae thickness 0.5, and 1.0 mm.

Component	Synthetic Mixtures		Acetone-Butanol Fermentation Broth	
	0.50 mm.	1.00 mm.	0.50 mm.	1.00 mm.
Butanol	3.64	1.22	3.17	0.95
Acetone	1.62	0.58	1.33	0.42
Ethanol	3.00	1.43	2.47	0.84
Acetic Acid	0	0	0	0
Butyric Acid	0	0	0	0
Water	0.04	0.01	0.04	0.01

Table C33 Permeability of synthetic mixtures and acetone-butanol fermentation broth membrae thickness 0.5, and 1.0 mm.

Component	Synthetic Mixtures		Acetone-Butanol Fermentation Broth	
	0.50 mm.	1.00 mm.	0.50 mm.	1.00 mm.
Butanol	3.9827	3.8091	3.1110	2.9680
Acetone	1.7743	1.8195	1.4633	1.3158
Ethanol	3.2820	3.5440	2.7040	2.6320
Acetic Acid	0	0	0	0
Butyric Acid	0	0	0	0
Water	0.0469	0.0331	0.0401	0.0279

Table C34 Diffusivity of synthetic mixtures and acetone-butanol fermentation broth membrae thickness 0.5, and 1.0 mm.

Component	Synthetic Mixtures		Acetone-Butanol Fermentation Broth	
	0.50 mm.	1.00 mm.	0.50 mm.	1.00 mm.
Butanol	6.3217	6.0461	5.1000	4.8655
Acetone	3.5267	3.6185	3.1200	2.8055
Ethanol	8.9427	9.6566	8.4500	8.1993
Acetic Acid	0	0	0	0
Butyric Acid	0	0	0	0

Water	10.4197	7.3386	10.0185	6.9953
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### Experimental Results of Solutes in Various Mixtures

Operating Condition : Feed Temperature 60<sup>o</sup>c

Permeation Pressure 2 torr

Membrane Thickness 0.25 mm

Table C35 Pervaporation results of butanol in various mixtures

Mixtures	Flux (g/m <sup>2</sup> .hr.)	Concentration (%)	Selectivity	Permeability (x10 <sup>7</sup> , m <sup>2</sup> /hr)
Butanol	13.0028	28.21	55.7430	4.6438
Butanol-Ethanol	12.1100	26.82	51.9367	4.3250
Bautanol-Acetone	12.0619	25.84	49.4281	4.3078
Butanol-Acetone-Ethanol	11.4871	25.07	47.4624	4.1025

Table C36 Pervaporation results of acetone in various mixtures

Mixtures	Flux (g/m <sup>2</sup> .hr.)	Concentration (%)	Selectivity	Permeability (x10 <sup>7</sup> , m <sup>2</sup> /hr)
Acetone	5.9843	15.00	29.2353	2.4934
Acetone-Bautanol	4.1168	8.82	16.0252	1.7153
Acetone-Ethanol	5.0691	13.51	25.8776	2.1121
Butanol-Acetone-Ethanol	4.0061	8.74	15.8737	1.6692

Table C37 Pervaporation results of ethanol in various mixtures

Mixtures	Flux (g/m <sup>2</sup> .hr.)	Concentration (%)	Selectivity	Permeability (x10 <sup>7</sup> , m <sup>2</sup> /hr)
Ethanol	0.5169	1.41	57.2334	5.1690
Ethanol-Bautanol	0.4291	0.97	39.2518	4.2910
Ethanol-Acetone	0.4609	1.16	47.1375	4.6090
Butanol-Acetone-Ethanol	0.3991	0.87	35.1414	3.9910

Table C38 Pervaporation results of water in various mixtures

Mixtures	Flux (g/m <sup>2</sup> .hr.)	Concentration (%)	Selectivity	Permeability (x10 <sup>7</sup> , m <sup>2</sup> /hr)
Butanol	33.0890	71.79	0.0179	8.3306
Acetone	33.9018	84.99	0.0342	8.5266
Ethanol	36.1117	98.58	0.0174	9.0302
Butanol-Acetone	30.4986	65.34	0.0114	7.6707
Butanol-Ethanol	33.0690	73.19	0.0199	8.3276
Acetone-Ethanol	33.0016	83.48	0.0317	8.3023
Butanol-Acetone-Ethanol	29.9211	65.31	0.0262	7.5807



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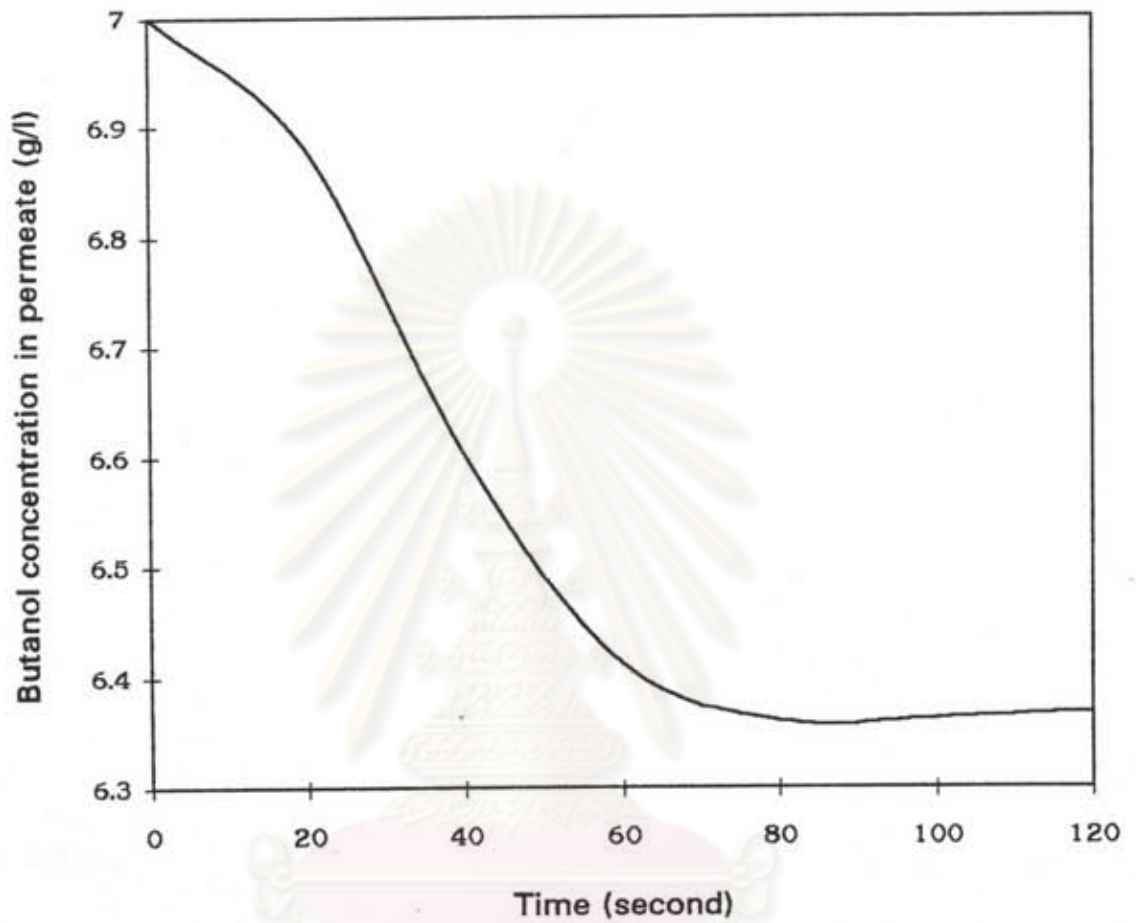


Figure C1 Correlation between butanol concentration in permeate at permeation pressure 2 torr, feed temperature 60°C, and membrane thickness 0.25 mm.

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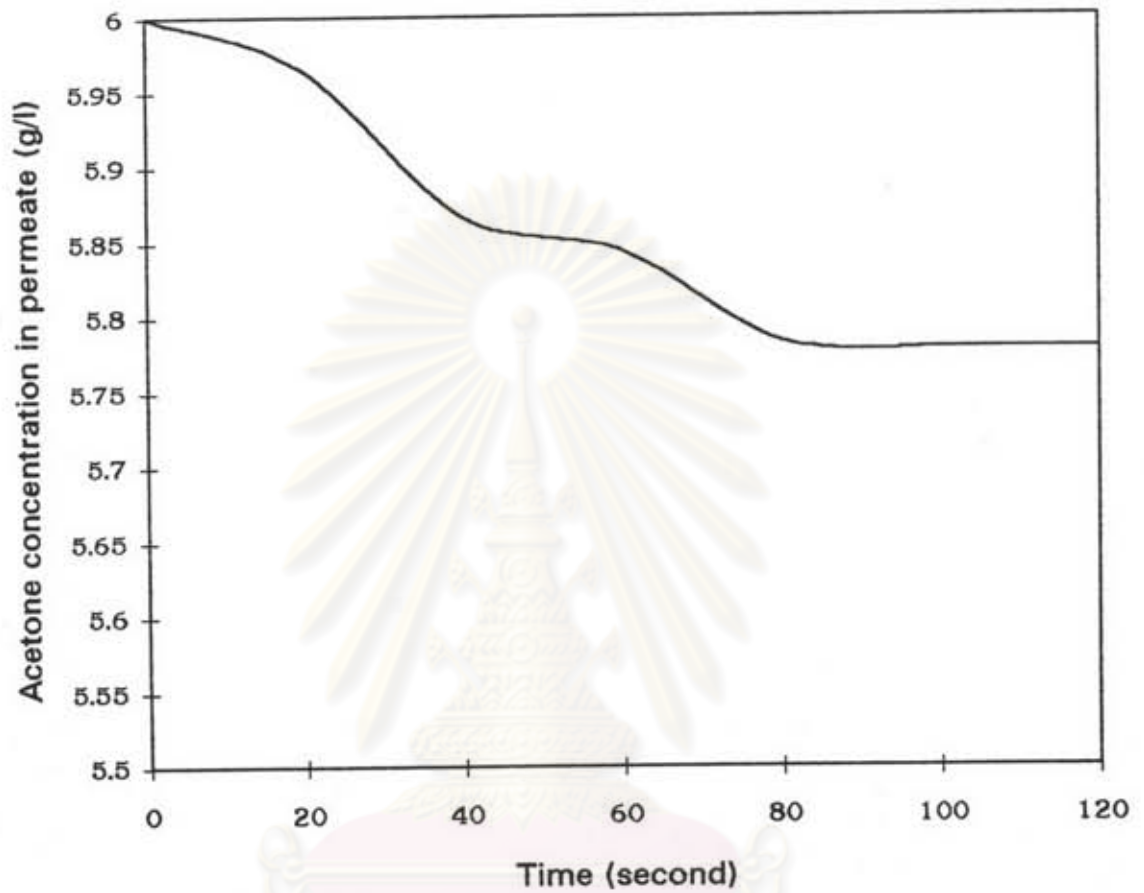


Figure C2 Correlation between acetone concentration in permeate at permeation pressure 2 torr, feed temperature 60<sup>o</sup>c and membrane thickness 0.25 mm.

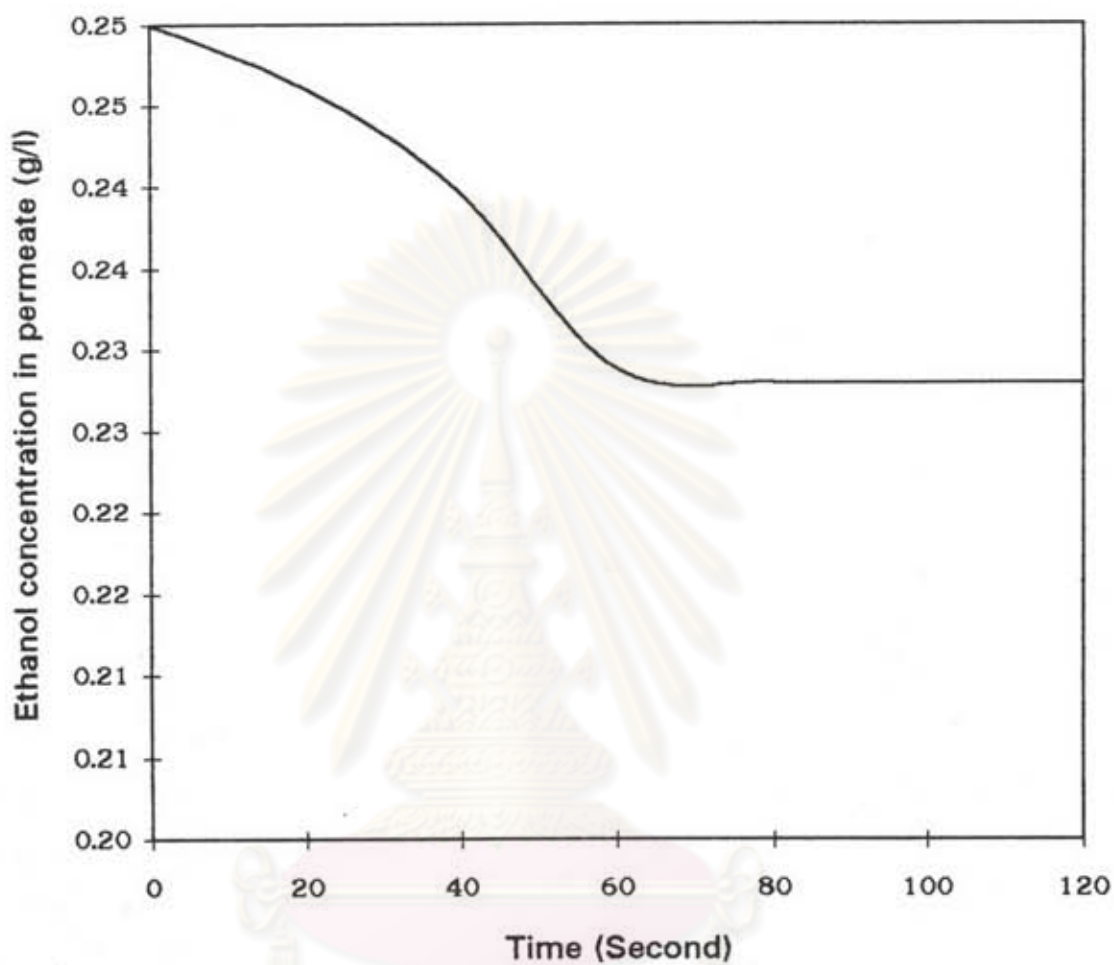


Figure C3 Correlation between time and ethanol concentration in permeate at permeation pressure 2 torr, feed temperature  $60^{\circ}\text{C}$ , and membrane thickness 0.25mm.

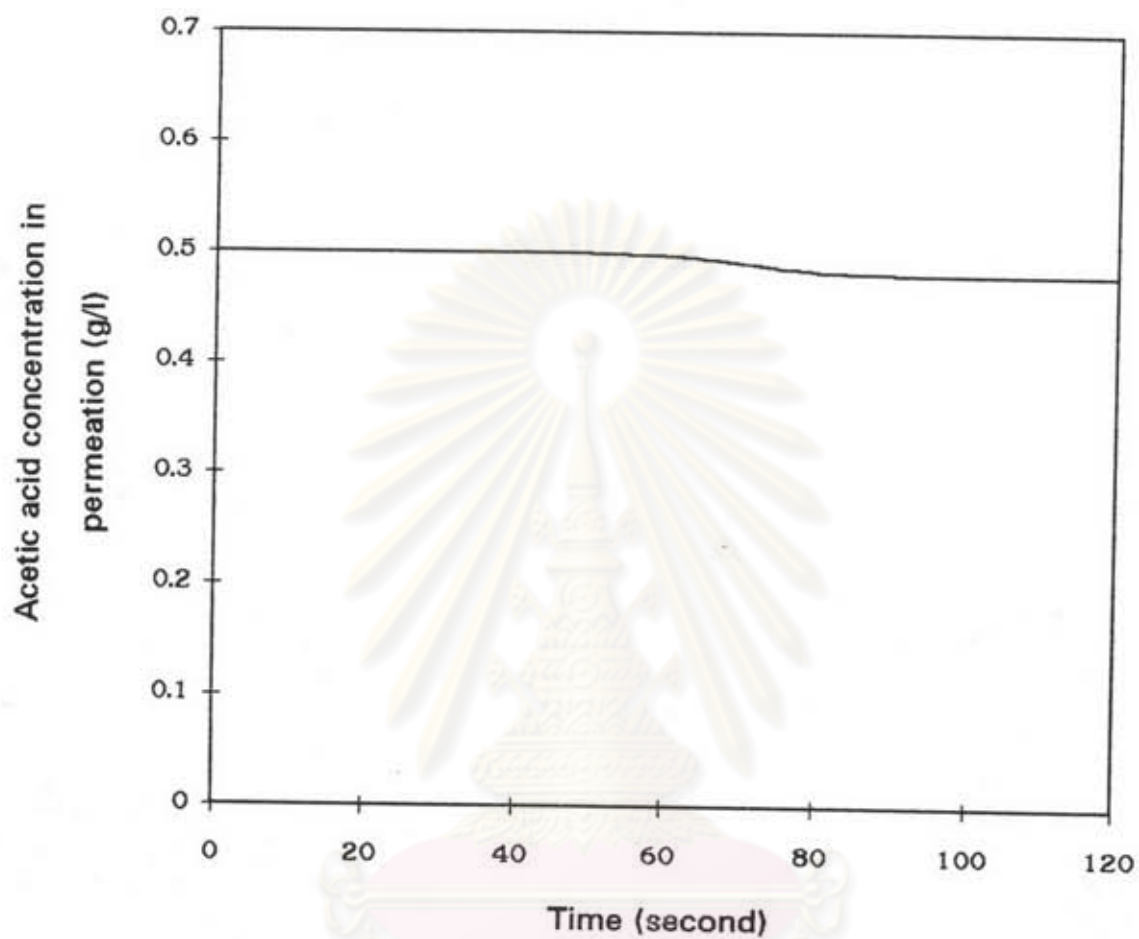


Figure C4 Correlation between time and acetic acid concentration in permeation at permeate pressure 2 torr, feed temperature  $60^{\circ}\text{c}$  and membrane thickness 0.25 mm.

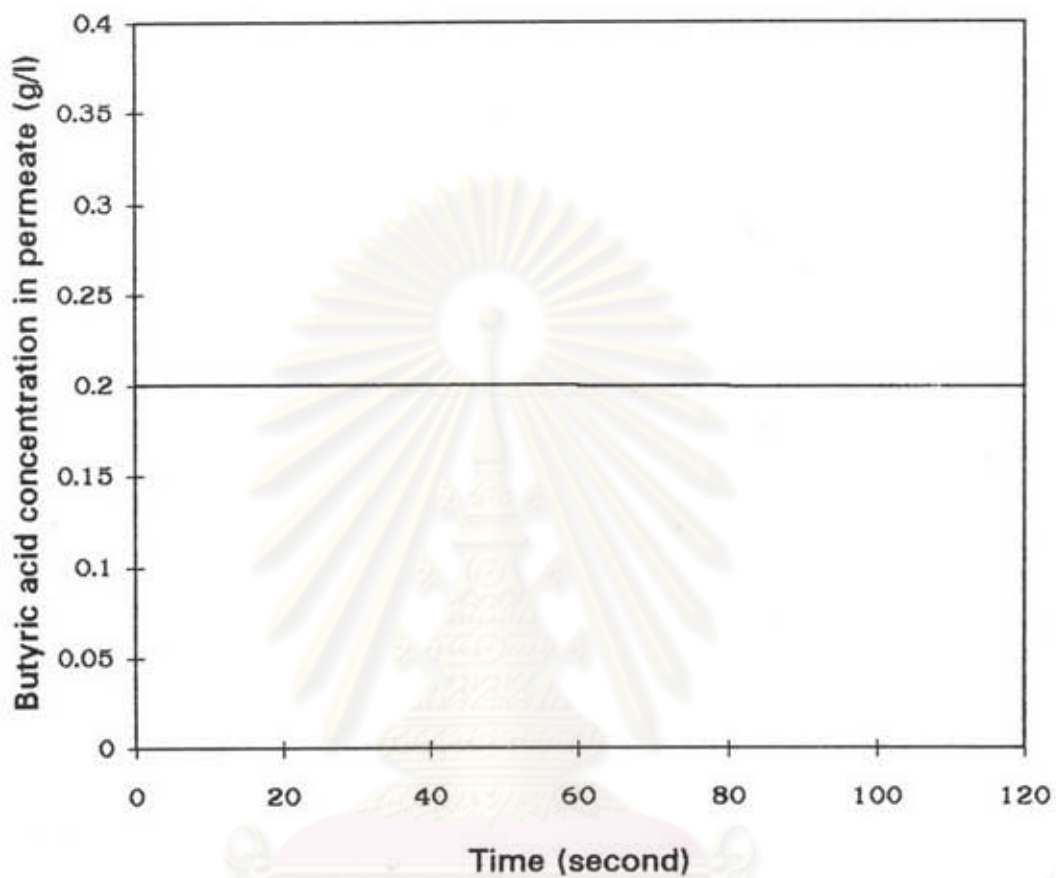


Figure C5 Correlation between time and butyric acid concentration in permeation at permeate pressure 2 torr, feed temperature  $60^{\circ}\text{C}$ , and membrane thickness 0.25 mm.





## Autobiography



Narongchai Prapakornwiriya was born on December 4, 1970 in Bangkok, Thailand. In 1988, he graduated high school level from Amnuay Silpa School. He received his Bachelor Degree in Biotechnology, King Mongkut's Institute of Technology Ladkrabang in March 1993. He continued his Master's Study at Chulalongkorn in June 1993.

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