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APPENDIX

APPENDIX A

SUPPORT PROPERTIES DETERMINATION

Apparent Porosity

$$p, \% = [(W-D)/V]*100$$

Water Absorption

$$A, \% = [(W-D)/D]*100$$

Bulk Density

$$B, g/cm^3 = D/V$$

where D is dry weight, g

W is saturated weight, g

S is suspended weight, g

V is exterior volume, cm^3 = W - S

Shrinkage

$$\text{shrinkage}, \% = [(L_B - L_A)/L_B] * 100$$

where L_B is the length of specimen before sintering, cm.

L_A is the length of specimen after sintering, cm.

Modulus of Rupture

$$M, \text{MPa} = 8PLD/\pi (D^4 - d^4)$$

where P is load at rupture, N

L is distance between supports, mm.

D is outside diameter of specimen, mm.

d is inside diameter of specimen, mm.

APPENDIX B

POLYVINYL ALCOHOL DETERMINATION [27]

Procedure

20 ml of sample is diluted to 25 ml and then treated with 15 ml of 4 % boric acid solution and 3 ml of iodine solution (prepared from 1.27 g of iodine and 25 g of KI/I). The resulting solution is diluted to 50 ml and kept at 25 °C and its absorbance measured at 690 nm.

Note

Beer's law applies in the concentration range of 0-20 mg of polyvinyl alcohol/l of solution.

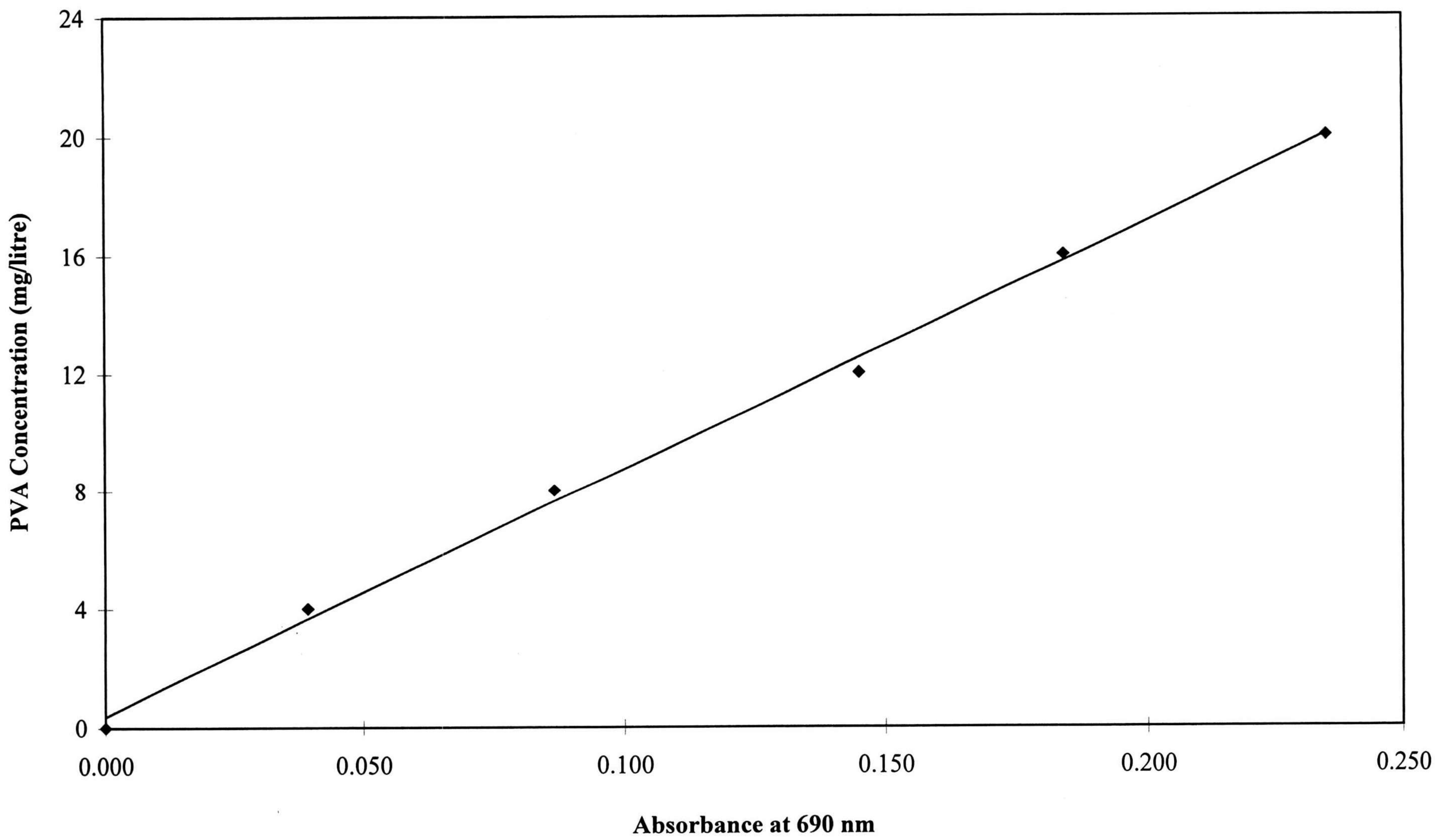

Figure B1 Polyvinyl Alcohol (MW 70,000-100,000) Standardization Curve

APPENDIX C

SACCHARIFYING AMYLASE DETERMINATION [28]

Reagents

0.02 M Phosphate buffer, pH 6.9

45.0 ml of 0.02 M sodium dihydrogen phosphate is mixed with 55.0 ml of 0.02 M disodium hydrogen phosphate. Store in the refrigerator.

Substrate solution

2 g of soluble starch is dissolved in 100 ml of 0.02 M phosphate buffer, pH 6.9

Dinitrosalicylic acid reagent

1 g of 3,5-dinitrosalicylic acid is dissolved in 20 ml of 2 M sodium hydroxide and 50 ml of distilled water, then 30 g sodium potassium tartrate is added, and diluted to 100 ml with distilled water. Keep this solution in the brown bottle.

Procedure

0.5 ml of properly diluted enzyme is incubated for 3 minutes at 50 °C with 0.5 ml of substrate solution. The enzyme reaction is interrupted by the addition of 1 ml of DNSA reagent. The tube containing this mixture is heated for 5 minutes in boiling water and then cooled in running tap water. After addition of 10 ml of H_2O, the absorbance of the solution is measured at 540 nm.

Note

The unit of enzyme is amount of enzyme saccharify 1 mg of glucose within 1 minute at 50 °C, pH 6.9.

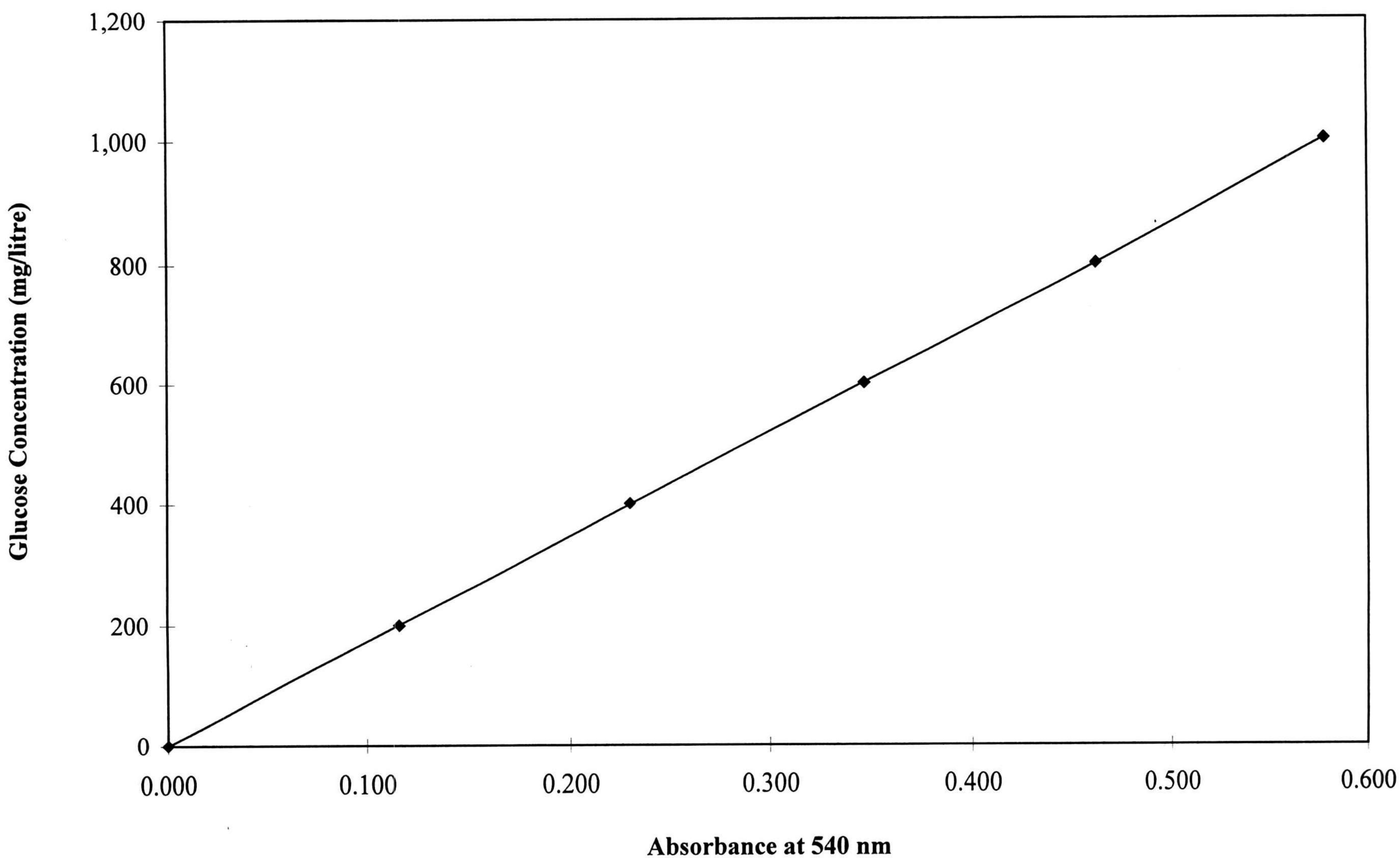

Figure C1 Glucose Standardization Curve

APPENDIX D

EXPERIMENTAL DATA

Table D1 Pore Size Distribution of Support Layers

Average Pore Diameter (A)	Pore Volume (cc/g)
839,279	0.0000
337,729	0.0000
187,484	0.0000
136,743	0.0019
92,287	0.0000
67,819	0.0000
53,134	0.0000
43,143	0.0000
35,240	0.0000
24,858	0.0000
16,946	0.0000
15,105	0.0013
13,047	0.0562
10,929	0.0264
9,494	0.0042
8,524	0.0065
7,508	0.0000
6,537	0.0035
5,269	0.0000
4,176	0.0004
3,242	0.0000
2,241	0.0054
1,748	0.0023
1,250	0.0078
902	0.0091
754	0.0002
652	0.0374
552	0.0000
452	0.0130
352	0.0107
251	0.0000
160	0.0000

Table D2 Membrane Thickness VS. Coating Time

Dipping Time (sec)	Membrane Thickness (micron)
10	4.50
20	8.10
30	12.14

Table D3 Properties of Membranes in Various Calcination Temperature

Calcination Temperature (C)	Avg. Pore Diameter (A)	Porosity (%)	Pore Volume (cc/g)
300	37.0989	41.94	0.066379
400	48.8029	45.96	0.092650
500	57.3716	47.20	0.112047
600	69.4301	48.21	0.132123
700	78.5873	46.74	0.118447
800	95.4350	46.65	0.113336

Table D4 Properties of Membranes in Various Calcination Time

Calcination Time (minute)	Avg. Pore Diameter (A)	Porosity (%)	Pore Volume (cc/g)
5	72.5049	48.02	0.132381
30	74.4301	48.21	0.132423
120	75.5479	46.70	0.125879
240	76.0133	45.61	0.123125

Table D5 Permeation Flux of Support and Intermediate at Recirculation Velocity 1.66 m/sec in Various Transmembrane Pressure

Transmembrane Pressure	Permeation Flux (cc/min-sq.cm)	
(bars)	Support	Intermediate
0.3	1.56	0.13
0.4	2.03	0.18
0.5	2.53	0.22

Table D6 Permeation Flux of Bi-Layer Membrane in Various Transmembrane Pressure

Transmembrane Pressure	Permeation Flux (cc/min-sq.cm)		
(bars)	v = 1.66 m.sec	v = 1.43 m/sec	v = 1.04 m/sec
0.3	0.016	0.014	0.010
0.4	0.022	0.018	0.013
0.5	0.028	0.023	0.016

Table D7 Pore Size Distribution of One and Bi-Layer Membrane

One-Layer Membrane			Bi-Layer Membrane		
Pore Diameter Range (A)	Pore Volume (cc/g)	Pore Volume (%)	Pore Diameter Range (A)	Pore Volume (cc/g)	Pore Volume (%)
10517.9-1650.1	0.008131	1.92	35117.7-1438.1	0.005126	1.22
1650.1-653.5	0.001211	0.29	1438.1-624.1	0.000794	0.19
653.5-348.4	0.001412	0.33	624.1-340.6	0.001010	0.24
348.4-256.3	0.001251	0.30	340.6-253.3	0.000916	0.22
256.3-184.3	0.002124	0.50	253.3-179.1	0.001558	0.37
184.3-134.8	0.003642	0.86	179.1-125.3	0.004732	1.13
134.8-100	0.003511	0.83	125.3-103	0.019137	4.55
100-79.4	0.105864	25.02	103-77.1	0.118647	28.23
79.4-58.2	0.132123	31.22	77.1-57.3	0.132215	31.46
58.2-43.9	0.066654	15.75	57.3-43.8	0.066517	15.83
43.9-33.7	0.033678	7.96	43.8-34.9	0.032091	7.64
33.7-27.3	0.015952	3.77	34.9-27.1	0.021374	5.09
27.3-22.4	0.009559	2.26	27.1-22.2	0.009644	2.29
22.4-17.4	0.006443	1.52	22.2-17.2	0.006499	1.55

Table D8 Experimental Datas of Filtration at Enzyme Concentration and Recirculation Velocity of 2.4 g/litre and 1.66 m/sec

Time	Pressure = 0.3 bar				Pressure = 0.4 bar				Pressure = 0.5 bar			
(min)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)
0	0.0	0.0000	3,634.22	0.00	0.0	0.0000	3,634.22	0.00	0.0	0.0000	4283.16	0.00
4	19.3	0.0144			25.7	0.0192			31.6	0.0236		
8	37.5	0.0136	1,644.14	54.76	49.3	0.0176	1,341.31	63.09	61.4	0.0222	1488.40	65.25
12	55.9	0.0137			73.2	0.0178			88.9	0.0205		
16	73.6	0.0132	1,678.75	53.81	95.4	0.0166	1,696.06	53.33	116.4	0.0205	1644.14	61.61
20	91.5	0.0134			118.6	0.0173			144.1	0.0207		
24	109.4	0.0134	1,747.97	51.90	141.6	0.0172	1,730.67	52.38	172.1	0.0209	1834.50	57.17
28	125.7	0.0122			163.3	0.0162			200.8	0.0214		
32	141.2	0.0116	1,817.19	50.00	185.5	0.0166	1,678.75	53.81	226.6	0.0192	1903.72	55.55
36	158.1	0.0126			207.5	0.0164			253.4	0.0200		
40	173.5	0.0115	1,782.58	50.95	230.6	0.0172	1,782.58	50.95	280.2	0.0200	1869.11	56.36
44	187.3	0.0103			250.7	0.0150			305.3	0.0187		
48	201.7	0.0107	1,851.80	49.05	270.3	0.0146	1,730.67	52.38	331.4	0.0195	1903.72	55.55
52	218.5	0.0125			291.0	0.0154			359.0	0.0206		
56	236.9	0.0137	1,799.89	50.47	311.6	0.0154	1,652.80	54.52	384.7	0.0192	1946.98	54.54
60	252.2	0.0114			333.8	0.0166			410.2	0.0190		
64	269.0	0.0125	1,817.19	50.00	353.9	0.0150	1,678.75	53.81	435.4	0.0188	1903.72	55.55
68	285.8	0.0125			373.8	0.0148			460.4	0.0186		
72	300.7	0.0111	1,817.19	50.00	395.7	0.0163	1,670.10	54.05	485.0	0.0184	1946.98	54.54
76	317.4	0.0125			415.2	0.0145			509.4	0.0182		
80	331.9	0.0108	1,869.11	48.57	431.7	0.0123	1,696.06	53.33	533.6	0.0181	1955.63	54.34
84	346.3	0.0107			450.4	0.0139			557.4	0.0178		
88	362.8	0.0123	1,834.50	49.52	468.9	0.0138	1,765.28	51.43	584.0	0.0198	1860.46	56.56
92	376.2	0.0100			490.3	0.0160			607.4	0.0175		
96	392.5	0.0122	1,782.58	50.95	511.6	0.0159	1,730.67	52.38	633.8	0.0197	1817.19	57.57
100	408.9	0.0122			532.9	0.0159			656.9	0.0172		
104	425.2	0.0122	1,678.75	53.81	554.2	0.0159	1,687.41	53.57	683.2	0.0196	1799.89	57.98
108	441.6	0.0122			575.5	0.0159			709.4	0.0195		
112	457.9	0.0122	1,678.75	53.81	596.8	0.0159	1,644.14	54.76	735.7	0.0196	1730.67	59.59
116	474.3	0.0122			618.1	0.0159			762.0	0.0196		
120	490.7	0.0122	1,644.14	54.76	639.4	0.0159	1,644.14	54.76	788.3	0.0196	1730.67	59.59

Table D9 Experimental Datas of Filtration at Enzyme Concentration and Recirculation Velocity of 2.4 g/litre and 1.43 m/sec

Time	Pressure = 0.3 bar				Pressure = 0.4 bar				Pressure = 0.5 bar			
(min)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)
0	0.0	0.0000	4079.72	0.00	0.0	0.0000	4105.83	0.00	0.0	0.0000	3986.45	0.00
4	17.5	0.0131			23.5	0.0175			29.9	0.0223		
8	34.6	0.0128	1835.06	55.02	46.1	0.0169	1887.86	54.02	57.9	0.0209	1880.41	52.83
12	49.9	0.0114			68.4	0.0166			86.5	0.0213		
16	65.4	0.0116	1908.90	53.21	89.2	0.0155	1812.31	55.86	113.1	0.0198	1848.92	53.62
20	80.4	0.0112			111.3	0.0165			140.8	0.0207		
24	94.9	0.0108	1827.31	55.21	131.9	0.0154	1861.58	54.66	167.3	0.0198	1800.68	54.83
28	108.9	0.0104			151.1	0.0143			193.3	0.0194		
32	123.3	0.0107	1910.53	53.17	171.6	0.0153	1890.32	53.96	219.9	0.0198	1848.12	53.64
36	136.3	0.0097			191.8	0.0151			246.1	0.0195		
40	150.1	0.0103	2039.86	50.00	210.5	0.0139	1762.22	57.08	272.1	0.0194	1882.80	52.77
44	163.7	0.0101			230.0	0.0145			297.9	0.0192		
48	177.0	0.0099	2048.84	49.78	249.3	0.0144	1809.44	55.93	321.7	0.0178	2018.34	49.37
52	191.7	0.0110			270.1	0.0155			346.8	0.0187		
56	204.6	0.0096	2039.86	50.00	289.0	0.0141	1560.22	62.00	373.5	0.0199	1975.29	50.45
60	217.2	0.0094			307.7	0.0139			398.2	0.0184		
64	231.7	0.0108	2261.80	44.56	328.2	0.0153	1690.37	58.83	422.6	0.0182	1884.79	52.72
68	243.9	0.0091			346.4	0.0136			449.0	0.0197		
72	255.8	0.0089	2216.92	45.66	364.4	0.0134	1985.17	51.65	473.0	0.0179	1884.79	52.72
76	270.0	0.0106			384.6	0.0151			499.2	0.0195		
80	284.2	0.0106	2249.15	44.87	404.9	0.0151	1949.04	52.53	522.8	0.0176	1926.65	51.67
84	295.6	0.0085			422.3	0.0130			549.0	0.0195		
88	309.7	0.0105	2249.15	44.87	442.4	0.0150	2092.74	49.03	572.2	0.0173	2031.10	49.05
92	320.7	0.0082			459.4	0.0127			598.2	0.0194		
96	334.6	0.0104	2182.24	46.51	479.4	0.0149	2113.68	48.52	621.0	0.0170	2060.20	48.32
100	348.6	0.0104			499.4	0.0149			646.8	0.0192		
104	362.5	0.0104	2249.15	44.87	519.3	0.0148	2092.74	49.03	672.7	0.0193	1926.65	51.67
108	376.4	0.0104			539.3	0.0149			698.6	0.0193		
112	390.4	0.0104	2182.24	46.51	559.3	0.0149	2092.74	49.03	724.4	0.0192	1926.65	51.67
116	404.3	0.0104			579.3	0.0149			750.3	0.0193		
120	418.3	0.0104	2182.24	46.51	599.3	0.0149	2092.74	49.03	776.2	0.0193	1926.65	51.67

Table D10 Experimental Datas of Filtration at Enzyme Concentration and Recirculation Velocity of 2.4 g/litre and 1.04 m/sec

Time	Pressure = 0.3 bar				Pressure = 0.4 bar				Pressure = 0.5 bar			
(min)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)
0	0.0	0.0000	3634.22	0.00	0.0	0.0000	4085.67	0.00	0.0	0.0000	4389.63	0.00
4	12.9	0.0096			16.2	0.0121			20.5	0.0153		
8	24.7	0.0088	372.14	89.76	31.1	0.0111	1488.00	63.58	39.7	0.0143	1628.11	62.91
12	37.0	0.0092			45.4	0.0107			57.1	0.0130		
16	47.9	0.0081	1445.33	60.23	58.9	0.0101	1603.63	60.75	75.0	0.0134	1718.10	62.91
20	59.3	0.0085			73.1	0.0106			92.6	0.0131		
24	70.8	0.0086	1471.13	59.52	88.4	0.0114	1556.64	61.9	109.4	0.0125	2560.91	60.86
28	82.6	0.0088			102.3	0.0104			127.2	0.0133		
32	93.1	0.0078	1502.02	58.67	116.9	0.0109	1680.84	58.86	145.3	0.0135	2175.06	41.66
36	105.0	0.0089			128.5	0.0087			161.4	0.0120		
40	115.3	0.0077	1471.13	59.52	142.8	0.0107	1551.74	62.02	177.1	0.0117	2560.91	50.45
44	126.8	0.0086			155.7	0.0096			196.1	0.0142		
48	138.3	0.0086	1502.02	58.67	169.9	0.0106	1682.07	58.83	211.1	0.0112	2202.72	41.66
52	149.9	0.0087			184.0	0.0105			227.3	0.0121		
56	161.4	0.0086	1471.13	59.52	196.7	0.0095	1887.99	53.79	242.1	0.0110	2103.51	49.82
60	172.9	0.0086			207.1	0.0078			257.4	0.0114		
64	184.5	0.0087	1471.13	59.52	220.9	0.0103	1847.95	54.77	274.6	0.0128	2103.51	52.08
68	196.0	0.0086			234.7	0.0103			291.7	0.0128		
72	207.5	0.0086	1644.12	54.76	248.5	0.0103	1847.95	54.77	306.5	0.0110	2194.82	52.08
76	216.5	0.0067			259.8	0.0084			323.5	0.0127		
80	227.9	0.0085	1676.83	53.86	273.5	0.0102	1887.99	53.79	340.5	0.0127	2113.17	50.00
84	239.3	0.0085			287.2	0.0102			357.5	0.0127		
88	250.7	0.0085	1773.86	51.19	300.8	0.0101	1810.36	55.69	374.6	0.0128	2542.47	51.86
92	262.1	0.0085			314.5	0.0102			391.6	0.0127		
96	273.5	0.0085	1618.32	55.47	328.2	0.0102	1861.84	54.43	405.4	0.0103	1810.72	42.08
100	284.9	0.0085			341.8	0.0101			422.3	0.0126		
104	296.3	0.0085	1618.32	55.47	355.5	0.0102	1810.36	55.69	439.2	0.0126	1810.72	58.75
108	307.7	0.0085			369.2	0.0102			456.1	0.0126		
112	319.1	0.0085	1618.32	55.47	382.9	0.0102	1810.36	55.69	473.0	0.0126	1810.72	58.75
116	330.5	0.0085			396.5	0.0101			489.8	0.0125		
120	341.9	0.0085	1618.32	55.47	410.2	0.0102	1810.36	55.69	506.7	0.0126	1810.72	58.75

Table D11 Experimental Datas of Filtration at Transmembrane Pressure and Recirculation Velocity of 0.5 bar and 1.66 m/sec

Time	Enzyme Concentration = 1.2 g/litre				Enzyme Concentration = 1.8 g/litre				Enzyme Concentration = 2.4 g/litre			
(min)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)	ACC. Volume (cc)	Flux (cc/min-sq.cm)	Glucose Conc. (mg/litre)	Rejection (%)
0	0.0	0.0000	1176.91	0.00	0.0	0.0000	2215.21	0.00	0.0	0.0000	4283.16	0.00
4	42.1	0.0314			35.7	0.0266			31.6	0.0236		
8	82.0	0.0298	10.55	99.10	68.1	0.0242	69.39	96.87	61.4	0.0222	1488.40	65.25
12	120.3	0.0286			100.5	0.0242			88.9	0.0205		
16	156.6	0.0271	0.17	99.99	129.2	0.0214	173.22	92.18	116.4	0.0205	1644.14	61.61
20	193.0	0.0272			158.2	0.0216			144.1	0.0207		
24	230.8	0.0282	27.86	97.63	189.0	0.0230	294.35	86.71	172.1	0.0209	1834.50	57.17
28	268.4	0.0280			219.6	0.0228			200.8	0.0214		
32	305.7	0.0278	138.61	88.22	248.8	0.0218	346.27	84.37	226.6	0.0192	1903.72	55.55
36	343.9	0.0285			277.5	0.0214			253.4	0.0200		
40	380.7	0.0275	173.22	85.28	307.0	0.0220	581.62	73.74	280.2	0.0200	1869.11	56.36
44	415.8	0.0262			337.7	0.0229			305.3	0.0187		
48	453.7	0.0283	180.14	84.69	366.8	0.0217	605.84	72.65	331.4	0.0195	1903.72	55.55
52	491.5	0.0282			399.1	0.0241			359.0	0.0206		
56	527.4	0.0268	173.22	85.28	429.8	0.0229	640.45	71.09	384.7	0.0192	1946.98	54.54
60	565.1	0.0281			458.5	0.0214			410.2	0.0190		
64	600.6	0.0265	148.99	87.34	489.0	0.0228	778.89	64.84	435.4	0.0188	1903.72	55.55
68	638.1	0.0280			519.6	0.0228			460.4	0.0186		
72	675.7	0.0280	166.30	85.87	550.2	0.0228	796.20	64.06	485.0	0.0184	1946.98	54.54
76	713.2	0.0280			578.2	0.0209			509.4	0.0182		
80	748.0	0.0260	242.44	79.40	608.6	0.0227	813.50	63.28	533.6	0.0181	1955.63	54.34
84	785.4	0.0279			639.1	0.0228			557.4	0.0178		
88	822.8	0.0279	277.05	76.46	669.5	0.0227	830.81	62.50	584.0	0.0198	1860.46	56.56
92	857.2	0.0257			699.9	0.0227			607.4	0.0175		
96	894.4	0.0277	277.05	76.46	727.1	0.0203	796.20	64.06	633.8	0.0197	1817.19	57.57
100	931.7	0.0278			757.4	0.0226			656.9	0.0172		
104	969.0	0.0278	277.05	76.46	787.7	0.0226	761.59	65.62	683.2	0.0196	1799.89	57.98
108	1006.2	0.0277			818.0	0.0226			709.4	0.0195		
112	1043.5	0.0278	259.74	77.93	848.3	0.0226	761.59	65.62	735.7	0.0196	1730.67	59.59
116	1080.8	0.0278			878.6	0.0226			762.0	0.0196		
120	1118.1	0.0278	277.05	76.46	908.9	0.0226	761.59	65.62	788.3	0.0196	1730.67	59.59

BIOGRAPHY

Miss Veerawan Vajanapornsan was born on August 26, 1971 in Bangkok, Thailand. In 1990, she graduated high school level from St. Joseph Convent. She received her Bachelor Degree in Chemical Engineering, Khon Kaen University in May 1994. She continued her Master's Study at Chulalongkorn University in June 1994.