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APPENDICES

Appendix A Weight loss behavior of bionanocomposite sponges

Table A1 Weight loss behavior of non-methanol treated SF sponge

Time (hour)	Initial weight W_0 (g)	Dried weight W_d (g)	Weight loss (%)	Average	SD
3	0.0257	0.0053	79.3774	76.9041	2.29596
	0.0314	0.0079	74.8408		
	0.0251	0.0059	76.4940		
6	0.0258	0.0067	74.0310	77.9387	3.71894
	0.0237	0.0044	81.4346		
	0.0194	0.0042	78.3505		
12	0.0254	0.0032	87.4016	88.8059	3.85142
	0.0234	0.0016	93.1624		
	0.0205	0.0029	85.8537		

* after 12 hours, the SF sponge cannot retain its shape.

Table A2 Weight loss behavior of non-methanol treated 90/10 SF/CLWs bionanocomposite sponge

Time (hour)	Initial weight W_0 (g)	Dried weight W_d (g)	Weight loss (%)	Average	SD
3	0.0245	0.0099	59.5918	56.6314	2.7060
	0.0245	0.0112	54.2857		
	0.0241	0.0106	56.0166		
6	0.0250	0.0102	59.2000	56.6999	4.7609
	0.0248	0.0121	51.2097		
	0.0258	0.0104	59.6899		
12	0.0252	0.0098	60.4000	58.0511	2.8795
	0.0232	0.0103	54.8387		
	0.0249	0.0114	58.9147		
24	0.0231	0.0053	77.0563	63.7984	14.3642
	0.0231	0.0079	65.8009		
	0.0171	0.0088	48.5380		
48	0.0252	0.0053	78.9683	67.5444	11.5985
	0.0246	0.0079	67.8862		
	0.0199	0.0088	55.7789		
72	0.0195	0.0011	94.3590	85.3038	8.4660
	0.0232	0.0052	77.5862		
	0.0237	0.0038	83.9662		

Table A3 Weight loss behavior of non-methanol treated 80/20 SF/CLWs bionanocomposite sponge

Time (hour)	Initial weight W_0 (g)	Dried weight W_d (g)	Weight loss (%)	Average	SD
3	0.0202	0.0101	50.0000	48.7795	4.8571
	0.0175	0.0099	43.4286		
	0.0189	0.0089	52.9101		
6	0.0184	0.0101	45.1087	49.4233	3.9660
	0.0199	0.0099	50.2513		
	0.0186	0.0083	52.9101		
12	0.0194	0.0098	49.4845	51.5094	2.6103
	0.017	0.0084	50.5882		
	0.0202	0.0092	54.4554		
24	0.0185	0.0077	58.3784	54.4658	3.7942
	0.0166	0.0076	54.2169		
	0.0187	0.0092	50.8021		
48	0.0193	0.0059	69.4301	67.8881	3.2154
	0.0237	0.0071	70.0422		
	0.0229	0.0082	64.1921		
72	0.0194	0.0049	74.7423	80.1284	4.7437
	0.0194	0.0035	81.9588		
	0.0190	0.0031	83.6842		

Table A4 Weight loss behavior of non-methanol treated 70/30 SF/CLWs bionanocomposite sponge

Time (hour)	Initial weight W_0 (g)	Dried weight W_d (g)	Weight loss (%)	Average	SD
3	0.0170	0.0090	47.0588	48.6473	4.1278
	0.0191	0.0104	45.5497		
	0.0180	0.0084	53.3333		
6	0.0164	0.0077	53.0488	51.0820	5.8437
	0.0173	0.0096	44.5087		
	0.0167	0.0074	55.6886		
12	0.0131	0.0059	54.9618	52.1447	5.1264
	0.0143	0.0064	55.2448		
	0.0167	0.0090	46.2275		
24	0.0149	0.0077	48.3221	56.6081	7.1765
	0.0244	0.0096	60.6557		
	0.0189	0.0074	60.8465		
48	0.0165	0.0063	61.8182	58.4711	2.9042
	0.0172	0.0074	56.9767		
	0.0207	0.0090	56.6184		
72	0.0165	0.0072	56.3636	60.8758	3.9225
	0.0172	0.0064	62.7907		
	0.0167	0.0061	63.4731		

Table A5 Weight loss behavior of non-methanol treated 60/40 SF/CLWs bionanocomposite sponge

Time (hour)	Initial weight W_0 (g)	Dried weight W_d (g)	Weight loss (%)	Average	SD
3	0.0204	0.0136	33.3333	36.9994	3.4940
	0.0206	0.0123	40.2913		
	0.0198	0.0124	37.3737		
6	0.0195	0.0104	46.6667	40.6966	5.9649
	0.0204	0.0121	40.6863		
	0.0190	0.0124	34.7368		
12	0.0203	0.0104	48.7685	42.2797	6.6837
	0.0211	0.0121	42.6540		
	0.0192	0.0124	35.4167		
24	0.0272	0.0152	44.1176	44.3930	5.2157
	0.0193	0.0097	49.7409		
	0.0206	0.0125	39.3204		
48	0.0202	0.00988	51.0891	49.8719	4.2353
	0.0208	0.0097	53.3654		
	0.0186	0.0102	45.1613		
72	0.0191	0.0084	56.0209	55.6181	2.1123
	0.0210	0.0098	53.3333		
	0.0200	0.0085	57.5000		

Table A6 Weight loss behavior of non-methanol treated 50/50 SF/CLWs bionanocomposite sponge

Time (hour)	Initial weight W_0 (g)	Dried weight W_d (g)	Weight loss (%)	Average	SD
3	0.0176	0.013	26.1364	25.5886	2.9291
	0.0165	0.0128	22.4242		
	0.0195	0.014	28.2051		
6	0.0150	0.0095	36.6666	35.7215	3.7307
	0.0174	0.0119	31.6092		
	0.018	0.011	38.8888		
12	0.0171	0.0113	33.9181	35.5214	1.4641
	0.0198	0.0127	35.8585		
	0.0193	0.0122	36.7875		
24	0.0205	0.0113	44.8780	37.5174	6.7087
	0.0167	0.0107	35.9281		
	0.0189	0.0129	31.7460		
48	0.0188	0.0095	49.4680	49.0660	2.4419
	0.0183	0.0098	46.4480		
	0.0156	0.0076	51.2820		
72	0.0176	0.0089	49.4318	49.7618	2.8149
	0.0165	0.0078	52.7272		
	0.0174	0.0092	47.1264		

Appendix B Shrinkage of bionanocomposite sponges after treated with methanol

shrinkage (%) = $(V_i - V_f) / V_i \times 100$; where V_i and V_f represent the volume of the sponges before and after methanol treatment, respectively.

Table B1 Volume of bionanocomposite sponges before methanol treatment (V_i)

Bionanocomposite sponges	volume of bionanocomposite sponges before methanol treatment (V_i)		
	radius (mm)	height (mm)	$V = \pi r^2 h$ (mm ³)
SF	7.439	4.818	1675.909
	7.165	4.394	1417.905
	7.406	5.001	1723.933
	7.280	4.992	1662.771
	7.301	3.795	1271.369
90/10	7.396	4.787	1646.069
	7.478	4.764	1674.547
	7.443	4.732	1647.766
	7.616	4.643	1692.584
	7.475	4.599	1615.253
80/20	7.471	4.066	1426.525
	7.471	4.767	1672.242
	7.592	4.570	1655.488
	7.312	4.575	1537.511
	7.291	4.984	1665.355
70/30	7.327	4.972	1677.792
	7.243	4.608	1519.512
	7.404	4.692	1616.541
	7.317	4.016	1351.310
	7.315	3.666	1233.036
60/40	7.447	4.620	1610.495
	7.395	4.802	1650.420
	7.182	4.191	1358.634
	7.206	3.821	1246.981
	7.218	5.149	1686.209

Table B1(Cont) Volume of bionanocomposite sponges before methanol treatment (V_i)

Bionanocomposite sponges	volume of bionanocomposite sponges before methanol treatment (V_i)		
	radius (mm)	height (mm)	$V = \pi r^2 h$ (mm ³)
50/50	7.457	4.718	1648.856
	7.182	4.649	1507.318
	7.471	4.561	1599.978
	7.432	4.096	1422.086
	7.206	3.821	1246.981

Table B2 Volume of bionanocomposite sponges after methanol treatment (V_f)

Bionanocomposite sponges	volume of bionanocomposite sponges after methanol treatment (V_f)		
	radius (mm)	height (mm)	$V = \pi r^2 h$ (mm ³)
MSF	6.383	3.571	914.379
	6.333	3.533	890.671
	6.572	4.031	1094.199
	6.606	3.823	1048.505
	6.438	3.219	838.514
M90/10	6.626	4.128	1139.021
	6.382	4.179	1069.726
	6.689	3.893	1094.703
	6.426	4.323	1122.074
	6.532	4.189	1123.287
M80/20	6.511	3.625	965.809
	6.734	4.094	1166.767
	6.606	4.352	1193.589
	6.528	3.912	1047.885
	6.543	4.560	1227.081
M70/30	6.646	4.400	1221.597
	6.598	4.070	1113.545
	6.649	4.041	1122.939
	6.017	4.280	973.999
	6.429	3.379	877.869

Table B2 (Cont) Volume of bionanocomposite sponges before methanol treatment (V_i)

Bionanocomposite sponges	volume of bionanocomposite sponges after methanol treatment (V_f)		
	radius (mm)	height (mm)	$V = \pi r^2 h$ (mm ³)
M60/40	6.744	4.215	1204.822
	6.676	4.428	1240.309
	6.666	3.933	1098.358
	6.655	3.561	991.340
	6.564	4.623	1251.842
M50/50	6.952	4.298	1305.504
	6.757	4.301	1234.332
	6.830	4.538	1330.445
	6.717	4.431	1256.629
	6.655	3.561	991.340

Table B3 Shrinkage (%) of bionanocomposite sponges

Bionanocomposite sponges	Shrinkage (%)	Average shrinkage (%)	SD
MSF	45.4398	38.0282	4.3280
	37.1840		
	36.5288		
	36.9423		
	34.0464		
M90/10	30.8036	32.9300	2.3348
	36.1185		
	33.5644		
	33.7065		
	30.4575		

Table B3 (cont) Shrinkage (%) of bionanocomposite sponges

Bionanocomposite sponges	Shrinkage (%)	Average shrinkage (%)	SD
M80/20	32.2964 30.2274 27.9011 31.8453 26.3171	29.7174	2.56418
M70/30	27.1902 26.7169 30.5345 27.9219 28.8043	28.2335	1.50879
M60/40	25.1893 24.8489 19.1572 20.5008 25.7600	23.0912	3.0331
M50/50	20.8236 18.1107 16.8460 11.6348 20.5008	17.5832	3.71542

Appendix C Cell in bionanocomposite sponges/ Cell leakage (/g sponge)

Table C1 Methanol-treated bionanocomposite sponges at weight ratio of 100/0 SF/CLWs (MSF)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
6	8	6	2	4	26	0.00002	200	2.60 x 10 ⁸	0.0223	1.17x10 ¹⁰
6	3	2	9	6	26	0.00002	200	2.60 x 10 ⁸	0.0223	1.17x10 ¹⁰
9	9	14	8	5	45	0.00002	200	4.50 x 10 ⁸	0.0223	2.02x10 ¹⁰
									Average	1.45x10¹⁰
									SD	4.92x10⁹

Table C2 Methanol-treated bionanocomposite sponges at weight ratio of 90/10 SF/CLWs (M90/10)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
4	4	4	5	10	27	0.00002	200	2.70 x 10 ⁸	0.0214	1.26 x10 ¹⁰
10	11	12	4	8	45	0.00002	200	4.50 x 10 ⁸	0.0214	2.10 x10 ¹⁰
2	10	8	10	4	34	0.00002	200	3.40 x 10 ⁸	0.0214	1.59 x10 ¹⁰
									Average	1.65 x10¹⁰
									SD	4.24 x10⁹

Table C3 Methanol-treated bionanocomposite sponges at weight ratio of 80/20 SF/CLWs (M80/20)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
10	5	8	14	12	49	0.00002	200	4.90 x 10 ⁸	0.0209	2.34x10 ¹⁰
3	11	3	6	6	29	0.00002	200	2.90 x 10 ⁸	0.0209	1.39x10 ¹⁰
5	6	8	4	10	33	0.00002	200	3.30 x 10 ⁸	0.0209	1.58x10 ¹⁰
									Average	1.77x10¹⁰
									SD	5.06x10⁹

Table C4 Methanol-treated bionanocomposite sponges at weight ratio of 70/30 SF/CLWs (M70/30)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
12	9	7	8	8	44	0.00002	200	4.40 x 10 ⁸	0.0201	2.19x10 ¹⁰
4	9	11	13	5	42	0.00002	200	4.20 x 10 ⁸	0.0201	2.09x10 ¹⁰
13	5	7	12	9	46	0.00002	200	4.60 x 10 ⁸	0.0201	2.29x10 ¹⁰
									Average	2.19x10¹⁰
									SD	9.95x10⁸

Table C5 Methanol-treated bionanocomposite sponges at weight ratio of 60/40 SF/CLWs (M60/40)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
15	2	10	9	7	43	0.00002	200	4.30 x 10 ⁸	0.0196	2.19x10 ¹⁰
11	6	11	8	15	51	0.00002	200	5.10 x 10 ⁸	0.0196	2.60x10 ¹⁰
13	7	10	12	16	58	0.00002	200	5.80 x 10 ⁸	0.0196	2.96x10 ¹⁰
									Average	2.59x10¹⁰
									SD	3.83x10⁹

Table C6 Methanol-treated bionanocomposite sponges at weight ratio of 50/50 SF/CLWs (50/50)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
10	9	12	7	19	57	0.00002	200	5.70 x 10 ⁸	0.0189	3.02x10 ¹⁰
10	14	16	11	18	69	0.00002	200	6.90 x 10 ⁸	0.0189	3.65x10 ¹⁰
21	11	12	10	13	67	0.00002	200	6.70 x 10 ⁸	0.0189	3.54x10 ¹⁰
									Average	3.40x10¹⁰
									SD	3.40x10⁹

Appendix D Cell leakage of methanol-treated bionanocomposite sponges after immersed in distilled water with 150 rpm shaking at 30°C for 48 hours.

Table D1 Cell leakage of methanol-treated bionanocomposite sponges at weight ratio of 100/0 SF/CLWs (MSF)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
13	14	14	13	17	71	0.00002	20	7.10x10 ⁷	0.0223	3.18 x10 ⁹
16	19	20	20	18	93	0.00002	20	9.30x10 ⁷	0.0223	4.17 x10 ⁹
10	25	27	17	18	97	0.00002	20	9.70x10 ⁷	0.0223	4.35 x10 ⁹
									Average	3.90 x10⁹
									SD	6.28 x10⁸

Table D2 Cell leakage of methanol-treated bionanocomposite sponges at weight ratio of 90/10 SF/CLWs (M90/10)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
5	11	15	20	13	64	0.00002	20	6.40x10 ⁷	0.0214	2.99 x10 ⁹
13	13	8	9	10	53	0.00002	20	5.30x10 ⁷	0.0214	2.48 x10 ⁹
14	9	19	15	24	81	0.00002	20	8.10x10 ⁷	0.0214	3.79 x10 ⁹
									Average	3.08 x10⁹
									SD	6.59 x10⁸

Table D3 Cell leakage of methanol-treated bionanocomposite sponges at weight ratio of 80/20 SF/CLWs (M80/20)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
9	11	12	12	13	57	0.00002	20	5.70x10 ⁷	0.0209	2.73x10 ⁹
8	10	11	8	3	40	0.00002	20	4.00x10 ⁷	0.0209	1.91x10 ⁹
10	13	9	29	10	71	0.00002	20	7.10x10 ⁷	0.0209	3.40x10 ⁹
									Average	2.68 x10⁹
									SD	7.43 x10⁸

Table D4 Cell leakage of methanol-treated bionanocomposite sponges at weight ratio of 70/30 SF/CLWs (M70/30)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
10	5	9	14	9	47	0.00002	20	4.70x10 ⁷	0.0201	2.34 x10 ⁹
9	17	13	11	11	61	0.00002	20	6.10x10 ⁷	0.0201	3.03 x10 ⁹
11	9	11	8	15	54	0.00002	20	5.40x10 ⁷	0.0201	2.69 x10 ⁹
									Average	2.69 x10⁹
									SD	3.48 x10⁸

Table D5 Cell leakage of methanol treated bionanocomposite sponges at weight ratio of 60/40 SF/CLWs (M60/40)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
8	16	20	7	6	57	0.00002	20	5.70x10 ⁷	0.0196	2.91x10 ⁹
5	4	9	13	10	41	0.00002	20	4.10x10 ⁷	0.0196	2.09x10 ⁹
5	6	6	10	7	34	0.00002	20	3.40x10 ⁷	0.0196	1.73x10 ⁹
									Average	2.24x10⁹
									SD	6.02x10⁸

Table D6 Cell leakage of methanol treated bionanocomposite sponges at weight ratio of 50/50 SF/CLWs (M50/50)

Yeast cells in bionanocomposite sponge						volume (cm ³)	dilution	Cells/ml	Average weight of sponge (g)	Cells/g sponge
1	2	3	4	5	total					
6	11	7	5	11	40	0.00002	20	4.00x10 ⁷	0.0189	2.12x10 ⁹
19	15	17	10	9	70	0.00002	20	7.00x10 ⁷	0.0189	3.70x10 ⁹
5	5	7	14	11	42	0.00002	20	4.20x10 ⁷	0.0189	2.22x10 ⁹
									Average	2.68x10⁹
									SD	8.87x10⁸

Table D7 Yeast cell leakage of various weight ratio of methanol treated SF/CLWs bionanocomposite sponge after immersion in distilled water with shaking at 150 rpm 30°C for 48 hours.

Bionanocomposite sponge	Immobilized cells / g sponge	Cell in medium / g sponge	Cell leakage (%)	Average cell leakage (%)	SD
MSF	1.17×10^{10}	3.18×10^9	27.31	28.21	7.15
	1.17×10^{10}	4.17×10^9	35.77		
	2.02×10^{10}	4.35×10^9	21.56		
M90/10	1.26×10^{10}	2.99×10^9	23.70	19.77	6.92
	2.10×10^{10}	2.48×10^9	11.78		
	1.59×10^{10}	3.79×10^9	23.82		
M80/20	2.34×10^{10}	2.73×10^9	11.63	15.65	5.20
	1.39×10^{10}	1.91×10^9	13.79		
	1.58×10^{10}	3.40×10^9	21.52		
M70/30	2.19×10^{10}	2.34×10^9	10.68	12.31	1.98
	2.09×10^{10}	3.03×10^9	14.52		
	2.29×10^{10}	2.69×10^9	11.74		
M60/40	2.19×10^{10}	2.91×10^9	13.26	9.05	3.80
	2.60×10^{10}	2.09×10^9	8.04		
	2.96×10^{10}	1.73×10^9	5.86		
M50/50	3.02×10^{10}	2.12×10^9	7.02	7.81	2.06
	3.65×10^{10}	3.70×10^9	10.14		
	3.54×10^{10}	2.22×10^9	6.27		

Appendix E Growth curve of *S. cerevisiae burgundy* KY11

Table E Yeast cell at difference fermentation time

Time (h)	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Total cell	Total volume	cell/ml	diltution	actual cell/ml
0	4	10	5	11	8	38	0.00002	1900000	20	3.80×10^7
2	4	13	7	11	5	40	0.00002	2000000	20	4.00×10^7
4	8	7	10	13	12	50	0.00002	2500000	20	5.00×10^7
6	24	33	37	25	37	156	0.00002	7800000	20	1.56×10^8
8	66	62	64	55	61	308	0.00002	15400000	20	3.08×10^8
10	8	6	8	6	11	39	0.00002	1950000	200	3.90×10^8
12	18	11	12	16	19	76	0.00002	3800000	200	7.60×10^8
16	20	16	19	15	16	86	0.00002	4300000	200	8.60×10^8
20	21	23	13	12	16	85	0.00002	4250000	200	8.50×10^8
24	18	17	18	10	19	82	0.00002	4100000	200	8.20×10^8
28	16	13	19	14	16	78	0.00002	3900000	200	7.80×10^8
32	10	18	18	14	16	76	0.00002	3800000	200	7.60×10^8
40	12	10	21	14	11	68	0.00002	3400000	200	6.80×10^8
44	17	8	19	13	11	68	0.00002	3400000	200	6.80×10^8
48	6	13	19	10	16	64	0.00002	3200000	200	6.40×10^8

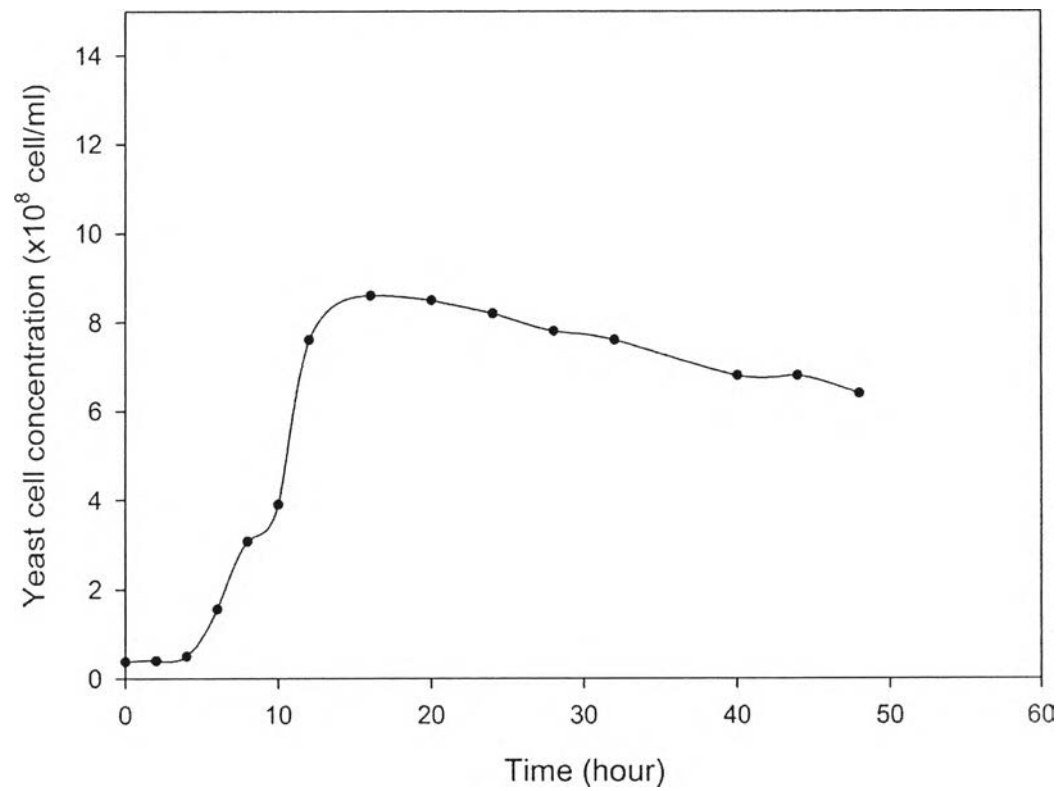


Figure E Growth curve of *S. cerevisiae burgundy* KY11

Appendix F Compression modulus of methanol- treated bionanocomposite sponges at different SF/CLWs weight ratio

Table F1 Compression modulus of methanol – treated sponges at different SF/CLWs weight ratio

Methanol-treated Sponges at different SF/CLWs ratios	Compression modulus (MPa)					Average (x 10 ⁻² MPa)	SD
MSF	0.075	0.060	0.080	0.055	0.071	6.82	1.04
M90/10	0.071	0.062	0.103	0.070	0.070	7.52	1.60
M80/20	0.062	0.192	0.079	0.190	0.059	11.64	6.85
M70/30	0.262	0.166	0.194	0.097	0.262	19.62	6.97
M60/40	0.389	0.221	0.207	0.265	0.257	26.78	7.19
M50/50	0.322	0.214	0.272	0.295	0.263	27.32	4.02

Table F2 Compression modulus of 50/50 weight ratio of methanol – treated sponges at different SF/CLWs weight ratio

Methanol-treated Sponges at different SF/CLWs ratios	Compression modulus (MPa)					Average (x 10 ⁻² MPa)	SD
M50/50	0.3759	0.2551	0.3075	0.3108	0.2392	29.77	2.39

Appendice G Determination of ethanol concentration in fermentation by using free cell, immobilized cell and crosslinked cell by using glucose concentration of 10-40% (w/v)

Table G Raw data of standard curve of ethanol concentration

Ethanol concentration (% v/v)	Peak area
0	0
0.01	10700
0.1	86937
0.5	412908
1	796397
5	3926959
10	7588181
15	11996300
20	13484737

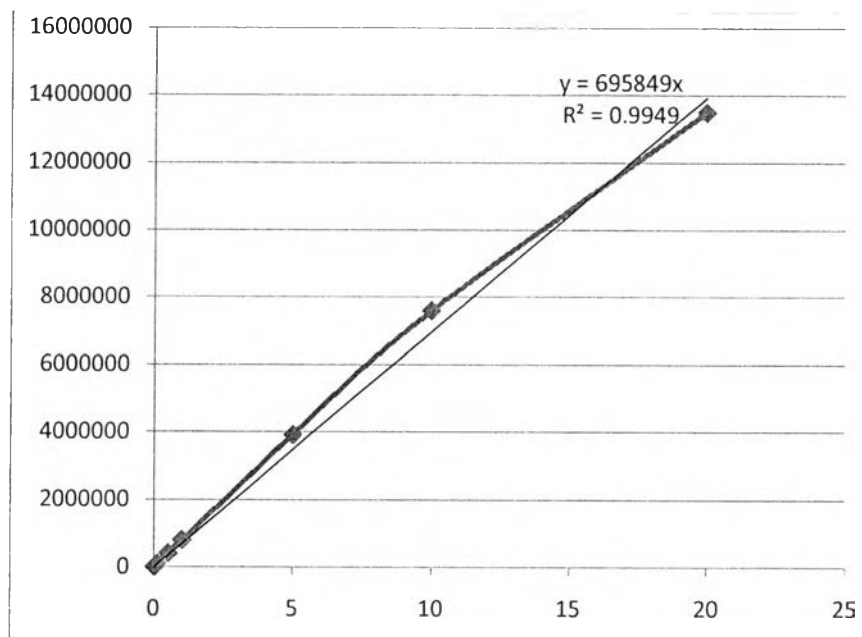


Figure G Standard curve of ethanol

Table G2 Determination of ethanol production in free yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
10%	8	222469.2000	0.1027	0.8103	0.8524	0.1013
		236156.4000	0.1227	0.9679		
		219729.6000	0.0987	0.7788		
	16	577454.4000	0.6207	4.8975	4.7844	0.1061
		566238.6000	0.6044	4.7684		
		559184.4000	0.5941	4.6872		
	24	990666.0000	1.2237	9.6551	9.6086	0.0795
		978647.4000	1.2062	9.5168		
		990561.6000	1.2236	9.6539		
	36	1393138.8000	1.8110	14.2891	14.3566	0.4798
		1360560.6000	1.7635	13.9140		
		1443290.4000	1.8842	14.8665		
	48	1930881.6000	2.5958	20.4805	20.4221	0.0861
		1929322.8000	2.5935	20.4626		
		1917226.8000	2.5758	20.3233		

Table G3 Determination of ethanol production in free yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
20%	8	331561.4000	0.2619	1.5990	1.8910	0.2546
		326463.7000	0.2545	2.0664		
		829496.3000	0.9885	2.0077		
	16	894898.1000	1.0840	7.7995	8.1372	0.3824
		852096.8000	1.0215	8.5525		
		1359201.1000	1.7615	8.0597		
	24	1390249.0000	1.8068	13.8984	13.7354	0.6183
		1285686.3000	1.6542	14.2558		
		2131835.5000	2.8890	13.0519		
	36	2004658.7000	2.7034	22.7943	22.4720	1.0191
		2175053.7000	2.9521	21.3300		
		2736336.3000	3.7711	23.2919		
	48	2859794.5000	3.9513	29.7543	30.2535	0.7996
		2742944.5000	3.7808	31.1758		
		331561.4000	0.2619	29.8304		

Table G4 Determination of ethanol production in free yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
40%	8	288696.6000	0.1993	1.5729	1.7417	0.1468
		309605.0000	0.2299	1.8136		
		311791.9000	0.2331	1.8388		
	16	743483.3000	0.8630	6.8092	6.5011	0.3496
		683722.6000	0.7758	6.1211		
		722970.9000	0.8331	6.5730		
	24	1357215.6000	1.7586	13.8755	13.5755	0.2603
		1316722.8000	1.6995	13.4093		
		1319551.9000	1.7037	13.4418		
	36	1830974.9000	2.4500	19.3302	18.6859	0.5590
		1749812.6000	2.3315	18.3958		
		1744238.0000	2.3234	18.3316		
	48	2237517.9000	3.0432	24.0111	22.8341	1.1113
		2122645.8000	2.8756	22.6885		
		2045735.7000	2.7634	21.8029		

Table G5 Determination of ethanol production in free yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
40%	8	183871.8000	0.0464	0.3659	0.4530	0.1504
		206516.7000	0.0794	0.6267		
		183908.6000	0.0464	0.3664		
	16	587348.9000	0.6352	5.0115	4.8983	0.2253
		590225.5000	0.6394	5.0446		
		554990.0000	0.5879	4.6389		
	24	1000300.6000	1.2378	9.7661	10.9265	1.0734
		1184233.9000	1.5062	11.8838		
		1118733.3000	1.4106	11.1297		
	36	1747564.9000	2.3282	18.3699	18.5128	0.2743
		1787449.7000	2.3865	18.8291		
		1744923.9000	2.3244	18.3395		
	48	1972914.9000	2.6571	20.9645	21.1935	0.3128
		2023750.5000	2.7313	21.5498		
		1981736.6000	2.6700	21.0661		

Table G7 Determination of ethanol production in immobilized yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
10%	8	317083.0000	0.2408	1.8997	2.0027	0.1521
		341201.0000	0.2760	2.1774		
		319791.0000	0.2447	1.9309		
	16	655750.0000	0.7350	5.7990	5.7171	0.1419
		634405.0000	0.7038	5.5533		
		655750.0000	0.7350	5.7990		
	24	1287749.0000	1.6572	13.0757	12.5075	0.7855
		1160551.0000	1.4716	11.6112		
		1266902.0000	1.6268	12.8357		
	36	1762358.0000	2.3498	18.5402	18.8278	0.4858
		1763594.0000	2.3516	18.5544		
		1836047.0000	2.4574	19.3886		
	48	2057960.0000	2.7812	21.9437	21.7771	0.1803
		2045646.0000	2.7632	21.8019		
		2026865.0000	2.7358	21.5857		

Table G8 Determination of ethanol production in immobilized yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
20%	8	531798.0000	0.5541	4.3719	4.1244	0.2196
		495385.0000	0.5010	3.9526		
		503744.0000	0.5132	4.0489		
	16	1043943.0000	1.3015	10.2686	10.3803	0.1006
		1056103.0000	1.3192	10.4086		
		1060887.0000	1.3262	10.4637		
	24	1682479.0000	2.2333	17.6205	18.4015	0.7604
		1814399.0000	2.4258	19.1394		
		1754069.0000	2.3377	18.4448		
	36	2265262.0000	3.0837	24.3305	24.3302	0.9409
		2346933.0000	3.2029	25.2708		
		2183501.0000	2.9644	23.3891		
	48	3429487.0000	4.7826	37.7351	39.1748	1.4362
		3678964.0000	5.1467	40.6075		
		3555139.0000	4.9660	39.1818		

Table G9 Determination of ethanol production in immobilized yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
30%	8	553653.0000	0.5860	4.6235	4.5144	0.1761
		526536.0000	0.5464	4.3113		
		552339.0000	0.5841	4.6084		
	16	1205013.0000	1.5365	12.1231	12.5214	0.4064
		1238242.0000	1.5850	12.5057		
		1275560.0000	1.6395	12.9353		
	24	2232962.0000	3.0366	23.9586	24.8415	0.7672
		2353430.0000	3.2124	25.3456		
		2342541.0000	3.1965	25.2203		
	36	2932267.0000	4.0571	32.0102	31.8941	1.4670
		3044253.0000	4.2205	33.2996		
		2790028.0000	3.8495	30.3725		
	48	3986288.0000	5.5952	44.1459	45.3165	1.4409
		4227718.0000	5.9475	46.9257		
		4049861.0000	5.6879	44.8779		

Table G10 Determination of ethanol production in immobilized yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
40%	8	413957.0000	0.3821	3.0151	2.7954	0.1911
		386839.0000	0.3426	2.7028		
		383830.0000	0.3382	2.6682		
	16	1160633.0000	1.4717	11.6121	11.4447	0.1472
		1141040.0000	1.4432	11.3865		
		1136605.0000	1.4367	11.3354		
	24	2064158.0000	2.7902	22.0150	21.7138	0.2777
		2033174.0000	2.7450	21.6583		
		2016642.0000	2.7209	21.4680		
	36	2612120.0000	3.5899	28.3241	29.8516	1.3234
		2807716.0000	3.8753	30.5762		
		2814510.0000	3.8852	30.6544		
	48	3935412.0000	5.5209	43.5601	42.4883	0.9284
		3797014.0000	5.3190	41.9667		
		3794531.0000	5.3153	41.9381		

Table G11 Determination of ethanol production in crosslinked yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
10%	8	199701.0000	0.0695	0.5482	0.6803	0.1175
		214588.5000	0.0912	0.7196		
		219235.5000	0.0980	0.7731		
	16	580390.5000	0.6250	4.9313	5.1654	0.2402
		622075.5000	0.6858	5.4113		
		599677.5000	0.6532	5.1534		
	24	1023938.5000	1.2723	10.0382	10.2113	0.1577
		1050729.5000	1.3114	10.3467		
		1042250.5000	1.2990	10.2491		
	36	1613916.0000	2.1332	16.8311	17.0756	0.5408
		1688996.0000	2.2428	17.6955		
		1602550.0000	2.1166	16.7002		
	48	1950022.5000	2.6237	20.7009	20.6777	0.1341
		1935479.5000	2.6025	20.5335		
		1958511.0000	2.6361	20.7986		

Table G12 Determination of ethanol production in crosslinked yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
20%	8	286902.0000	0.1967	1.5522	1.5111	0.0596
		285693.0000	0.1950	1.5383		
		277392.0000	0.1829	1.4427		
	16	716476.5000	0.8236	6.4982	6.6456	0.1894
		723514.5000	0.8339	6.5792		
		747831.0000	0.8694	6.8592		
	24	1021686.0000	1.2690	10.0123	10.9357	0.8064
		1151023.5000	1.4577	11.5015		
		1132948.5000	1.4313	11.2933		
	36	1906887.0000	2.5607	20.2043	21.0780	1.4392
		2127039.0000	2.8820	22.7390		
		1914387.0000	2.5717	20.2906		
	48	3129293.0000	4.3446	34.2787	33.7062	0.5232
		3069225.5000	4.2569	33.5871		
		3040187.0000	4.2145	33.2528		

Table G13 Determination of ethanol production in crosslinked yeast cell fermentation system

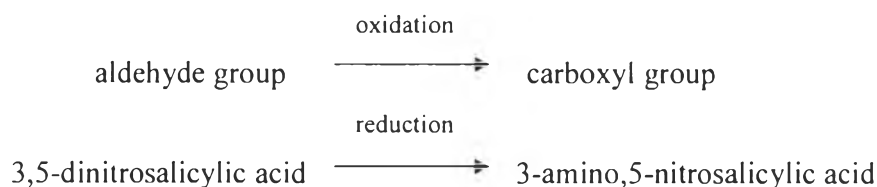
Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
30%	8	297037.5000	0.2115	1.6689	1.5823	0.2213
		267669.0000	0.1687	1.3308		
		303841.5000	0.2214	1.7472		
	16	994204.5000	1.2289	9.6959	10.5172	0.7630
		1125192.0000	1.4200	11.2040		
		1077216.0000	1.3500	10.6517		
	24	1762672.5000	2.3503	18.5438	19.1292	0.5186
		1829444.5000	2.4477	19.3126		
		1848418.0000	2.4754	19.5311		
	36	2997322.0000	4.1520	32.7592	31.7863	0.8431
		2873035.5000	3.9706	31.3282		
		2868091.0000	3.9634	31.2713		
	48	3481248.0000	4.8582	38.3310	37.1163	1.0533
		3327718.0000	4.6341	36.5633		
		3318281.5000	4.6204	36.4547		

Table G14 Determination of ethanol production in crosslinked yeast cell fermentation system

Substrate concentration (% w/v)	Time	Graph area	Ethanol (% v/v)	Ethanol g/l	Average	SD
40%	8	299200.0000	0.2147	1.6938	1.5837	0.1063
		288925.0000	0.1997	1.5755		
		280777.0000	0.1878	1.4817		
	16	907897.0000	1.1029	8.7022	8.7690	0.2903
		941304.0000	1.1517	9.0868		
		891891.0000	1.0796	8.5179		
	24	1519163.0000	1.9949	15.7401	15.4775	0.2806
		1470677.0000	1.9242	15.1819		
		1499221.0000	1.9658	15.5105		
	36	2276412.0000	3.1000	24.4589	23.8413	0.5791
		2215244.0000	3.0107	23.7546		
		2176665.0000	2.9544	23.3104		
	48	3284988.0000	4.5718	36.0713	35.9423	0.1292
		3262543.0000	4.5390	35.8129		
		3273804.0000	4.5555	35.9426		

Appendix H Determination of reducing sugar by dinitrosalicylic (DNS) colorimetric method

Reducing sugars content was analyzed by dinitrosalicylic (DNS) colorimetric method (Miller, 1959). This DNS assay tests for the presence of free carbonyl group (C=O), which consists in reducing sugar molecules. This involves the oxidation of the aldehyde functional group in reducing sugar. Then 3,5-dinitrosalicylic acid (DNS) is reduced to 3-amino,5-nitrosalicylic acid under alkaline conditions which developed the redbrown colour.



This experiment used D-glucose as a standard. 3 mL DNS reagent was added to 3 mL of sample. The mixture was heat in boiling water for 5 minutes which the redbrown color was developed. Then the mixture was cooled in an ice bath for 5 minutes. Measured the absorbance at 575 nm by using UV-visible spectroscopy.

Table H Determination standard curve of reducing sugar

Glucose concentration (mg/mL)	Absorbance at 575 nm				
	1	2	3	average	SD
0	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.0754	0.0733	0.0659	0.0715	0.0050
0.4	0.1458	0.1293	0.1427	0.1392	0.0088
0.6	0.2421	0.1981	0.2224	0.2208	0.0220
0.8	0.3020	0.3027	0.2993	0.3013	0.0018
1	0.3888	0.3431	0.3728	0.3682	0.0232

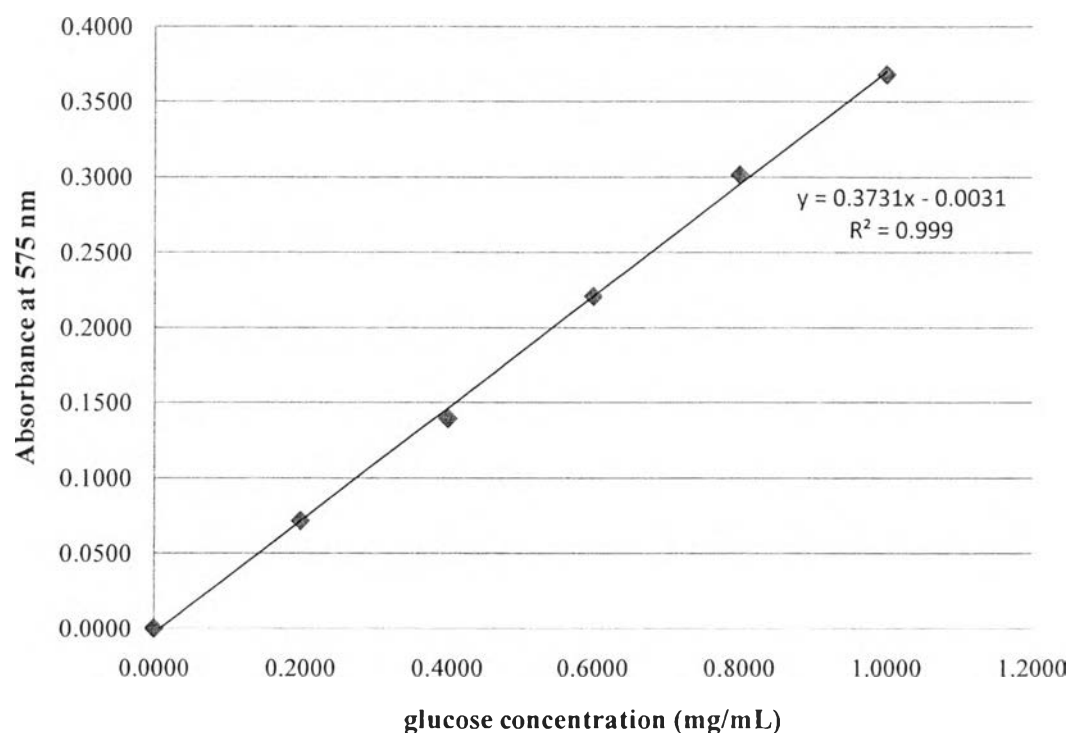


Figure H Standard curve of glucose

Table H1 Determination of glucose concentration (mg/mL) in suspended yeast cell

Substrate concentration (w/v)	Time (h)	Absorbance at 575 nm			Glucose concentration (mg/mL)				
		1	2	3	1	2	3	average	SD
10%	0	0.4560	0.4622	0.4684	121.7006	123.3361	124.9715	123.3361	1.6354
	8	0.4580	0.4369	0.4382	122.2282	116.6624	117.0053	118.6319	3.1192
	16	0.3625	0.3139	0.3633	97.0456	84.2258	97.2567	92.8427	7.4632
	24	0.2408	0.2376	0.2469	64.9433	64.0992	66.5524	65.1983	1.2463
	48	0.1525	0.1454	0.1603	41.6690	39.7961	43.7265	41.7305	1.9659

fermentation system (cont)

Substrate concentration (w/v)	Time (h)	Absorbance at 575 nm			Glucose concentration (mg/mL)				
		1	2	3	1	2	3	average	SD
20%	0	0.3865	0.4251	0.4005	206.7354	227.0995	214.1213	215.9854	10.3092
	8	0.3098	0.3399	0.3400	166.2712	182.1509	182.2036	176.8752	9.1834
	16	0.2748	0.2852	0.2631	147.8238	153.3105	141.6513	147.5952	5.8330
	24	0.2498	0.2664	0.2412	134.6347	143.3922	130.0976	136.0415	6.7581
	36	0.2022	0.2005	0.2104	109.5051	108.6083	113.8312	110.6482	2.7928
	48	0.1121	0.1087	0.1798	61.9715	60.1778	97.6877	73.2790	21.1576
30%	0	0.4030	0.3989	0.4065	323.1525	319.9475	325.9301	323.0100	2.9938
	8	0.3098	0.3399	0.3400	249.4068	273.2263	273.3055	265.3129	13.7751
	16	0.3088	0.2966	0.3054	248.6415	238.9871	245.9509	244.5265	4.9823
	24	0.2607	0.2735	0.2780	210.5777	220.7069	224.2680	218.5175	7.1029
	36	0.1886	0.1880	0.1807	153.4954	153.0206	147.2437	151.2532	3.4804
	48	0.2156	0.2109	0.2064	116.5745	114.0950	111.7209	114.1301	2.4270
40%	0	0.3940	0.3721	0.3670	421.4191	398.3118	392.9306	404.2205	15.1355
	8	0.3358	0.3525	0.3075	359.9757	377.5964	330.1156	355.8959	24.0019
	16	0.3350	0.3277	0.2534	359.1665	351.4323	273.0678	327.8889	47.6337
	24	0.2682	0.2467	0.2718	288.6837	265.9984	292.4822	282.3881	14.3204
	36	0.2144	0.2054	0.2127	231.8829	222.3867	230.0891	228.1196	5.0452
	48	0.2095	0.2060	0.1895	226.7127	223.0198	205.6101	218.4476	11.2698

Table H2 Determination of glucose concentration (mg/mL) in immobilized yeast cell in bionanocomposite sponges fermentation system

Substrate concentration (w/v)	Time (h)	Absorbance at 575 nm			Glucose concentration (mg/mL)				
		1	2	3	1	2	3	average	SD
10%	0	0.4507	0.4606	0.4525	120.3026	122.9140	120.7774	121.3313	1.1358
	8	0.2731	0.2941	0.2710	73.4548	78.9942	72.9008	75.1166	2.7512
	16	0.2335	0.2267	0.2463	63.0177	61.2239	66.3941	63.5452	2.1434
	24	0.1624	0.1692	0.1606	44.2627	46.0565	43.7879	44.7024	0.9769
	36	0.0633	0.0607	0.0492	18.1132	17.4273	14.3938	16.6448	1.6161
	48	0.0399	0.0300	0.0340	11.9406	9.3292	10.3843	10.5514	1.0726
20%	0	0.4381	0.3694	0.3752	233.9578	197.7141	200.7739	210.8153	16.4119
	8	0.3679	0.3360	0.3385	196.9227	180.0934	181.4123	186.1428	7.6415
	16	0.2616	0.2724	0.2784	140.8599	146.5576	149.7230	145.7135	3.6672
	24	0.2462	0.2346	0.2250	132.7354	126.6157	121.5510	126.9674	4.5728
	36	0.1973	0.1844	0.1837	106.9201	100.1145	99.7452	102.2599	3.2987
	48	0.0699	0.0861	0.0819	39.7083	48.2548	46.0390	44.6674	3.6214
30%	0	0.4014	0.4009	0.3873	321.8942	321.4986	310.7362	318.0430	5.1692
	8	0.3679	0.3360	0.3385	295.3841	270.1401	272.1184	279.2142	11.4623
	16	0.2835	0.2924	0.2836	228.6204	235.6634	228.7312	231.0050	3.2943
	24	0.1971	0.2036	0.1898	160.2480	165.3917	154.4711	160.0369	4.4608
	36	0.1531	0.1468	0.1597	125.4025	120.4170	130.6254	125.4817	4.1679
	48	0.1015	0.0982	0.1064	84.5690	81.9575	88.4466	84.9910	2.6659

Table H2 (cont) Determination of glucose concentration (mg/mL) in immobilized yeast cell in bionanocomposite sponges fermentation system

Substrate concentration (w/v)	Time (h)	Absorbance at 575 nm			Glucose concentration (mg/mL)				
		1	2	3	1	2	3	average	SD
40%	0	0.3835	0.3916	0.3898	410.3403	418.8868	416.9876	415.4049	3.6642
	8	0.3310	0.3286	0.3294	354.9111	352.4101	353.2226	353.5146	1.0417
	16	0.2804	0.2878	0.2856	301.5563	309.3643	307.0430	305.9879	3.2737
	24	0.2485	0.2496	0.2452	267.8977	269.0583	264.4157	267.1239	1.9727
	36	0.1531	0.1532	0.1398	167.2034	167.3089	153.1701	162.5608	6.6403
	48	0.0745	0.0689	0.0706	84.2701	78.3614	80.1551	80.9289	2.4735

Table H3 Determination of glucose concentration (mg/mL) in crosslinked yeast cell fermentation system

Substrate concentration (w/v)	Time (h)	Absorbance at 575 nm			Glucose concentration (mg/mL)				
		1	2	3	1	2	3	average	SD
10%	0	0.4637	0.3969	0.4254	123.7317	106.1111	113.6289	114.4905	8.8419
	8	0.3482	0.3289	0.3540	93.2648	88.1738	94.7948	92.0778	3.4664
	16	0.2863	0.2954	0.3026	76.9454	79.3458	81.2451	79.1788	2.1547
	24	0.2254	0.2059	0.2172	60.8810	55.7373	58.7180	58.4454	2.5827
	36	0.1391	0.1260	0.1209	38.1079	34.6523	33.3070	35.3558	2.4765
	48	0.1327	0.1458	0.1170	36.4197	39.8752	32.2783	36.1911	3.8036

Table H3 (cont) Determination of glucose concentration (mg/mL) in crosslinked yeast cell fermentation system

Substrate concentration (w/v)	Time (h)	Absorbance at 575 nm			Glucose concentration (mg/mL)				
		1	2	3	1	2	3	average	SD
20%	0	0.3812	0.3750	0.3503	203.9393	200.6684	187.6376	197.4151	8.6241
	8	0.3200	0.3313	0.3163	171.6523	177.6138	169.7004	172.9888	4.1226
	16	0.3032	0.3118	0.2984	162.7892	167.3263	160.2569	163.4575	3.5818
	24	0.2630	0.2376	0.2508	141.5985	128.1984	135.1622	134.9864	6.7018
	36	0.2563	0.2420	0.2457	138.0638	130.5197	132.4716	133.6850	3.9157
	48	0.2643	0.2183	0.2198	142.2669	117.9989	118.7903	126.3521	13.7884
30%	0	0.4129	0.3983	0.3983	330.9947	319.4410	319.4962	323.3107	6.6546
	8	0.3200	0.3313	0.3163	257.4785	266.4207	254.5505	259.4833	6.1838
	16	0.3160	0.2905	0.3314	254.3392	234.1836	266.5260	251.6829	16.3340
	24	0.2892	0.2732	0.2752	233.1311	220.4695	222.0522	225.2176	6.8988
	36	0.2219	0.2392	0.2246	179.8473	193.5376	181.9839	185.1229	7.3652
	48	0.3070	0.3158	0.3147	164.7940	169.4366	168.8562	167.6956	2.5296
40%	0	0.3814	0.3932	0.3825	408.1245	420.5751	409.2851	412.6616	6.8778
	8	0.3358	0.3066	0.3192	359.9757	329.1659	342.4606	343.8674	15.4530
	16	0.2649	0.2540	0.2503	285.2018	273.7009	269.7969	276.2332	8.0086
	24	0.2503	0.2394	0.2426	269.7969	258.2960	261.6724	263.2551	5.9116
	36	0.2224	0.2229	0.1949	240.3239	240.8515	211.3078	230.8277	16.9068
	48	0.2054	0.1900	0.1946	222.3867	206.1377	210.9913	213.1719	8.3411

APPENDIX I Immobilization efficiency between immobilized cell and glyoxal crosslink- immobilized cell

Table II Immobilization efficiency of immobilized yeast cell without glyoxal crosslinked

Glucose concentration (% w/v)	Cell in medium $X_f (x10^9)$	Cell in Sponge $X_i (x10^9)$	Total cell $X_t (x10^9)$	Immobilization efficiency (%)	AVERAGE	SD
10%	1.78	5.22	7.00	74.62	70.55	3.57
	2.13	4.50	6.63	67.92		
	1.85	4.14	5.99	69.12		
20%	2.28	5.76	8.04	71.69	68.93	2.55
	2.58	5.58	8.16	68.42		
	2.25	4.50	6.75	66.67		
30%	1.88	4.50	6.38	70.59	67.97	3.35
	2.23	4.98	7.21	69.12		
	1.98	3.54	5.52	64.19		
40%	1.83	4.80	6.63	72.45	67.77	4.33
	2.00	3.54	5.54	63.90		
	1.93	3.90	5.83	66.95		

Table 12 Immobilization efficiency of immobilized yeast cell with glyoxal crosslinked

Glucose concentration (% w/v)	Cell in medium $X_f (x10^9)$	Cell in Sponge $X_i (x10^9)$	Total cell $X_t (x10^9)$	Immobilization efficiency (%)	AVERAGE	SD
10%	0.95	5.40	6.35	85.04	87.14	1.84
	0.83	6.30	7.13	88.42		
	0.88	6.40	7.28	87.97		
20%	1.00	7.60	8.60	88.37	88.87	0.55
	1.03	8.70	9.73	89.46		
	1.00	7.90	8.90	88.76		
30%	1.18	6.80	7.98	85.27	84.65	1.67
	1.38	6.60	7.98	82.76		
	1.43	8.70	1.01	85.93		
40%	1.63	6.90	8.53	80.94	80.80	0.13
	1.50	6.30	7.80	80.77		
	1.46	6.10	7.56	80.69		

APPENDIX J Ethanol production in 5 cycle repeated batch

Table J1 Ethanol production of free cell fermentation (1st batch)

Batch number	Fermentation time (hour)	Peak area	Ethanol (%v/v)	Ethanol (g/l)	Average	SD
1	4.00	280033.00	0.19	1.47	1.27	0.19
		247290.00	0.14	1.10		
		260012.00	0.16	1.24		
	8.00	807274.00	0.96	7.54	7.69	0.16
		817551.00	0.97	7.66		
		835513.00	1.00	7.87		
	16.00	1859504.00	2.49	19.66	19.87	0.25
		1871677.00	2.51	19.80		
		1901481.00	2.55	20.14		
	24.00	4048513.00	5.69	44.86	44.75	1.13
		3935353.00	5.52	43.56		
		4131195.00	5.81	45.81		
	32.00	5659295.00	8.04	63.41	60.89	2.23
		5371935.00	7.62	60.10		
		5290837.00	7.50	59.17		
	48.00	5912786.00	8.41	66.33	63.40	3.85
		5783770.00	8.22	64.84		
		5279388.00	7.48	59.03		

Table J2 Ethanol production of free cell fermentation (2nd batch)

Batch number	Fermentation time (hour)	Peak area	Ethanol (%v/v)	Ethanol (g/l)	Average	SD
2	8.00	599738.00	0.65	5.15	5.10	0.36
		623271.00	0.69	5.43		
		561664.00	0.60	4.72		
	16.00	589187.00	0.64	5.03	5.24	0.25
		631814.00	0.70	5.52		
		600809.00	0.65	5.17		
	24.00	2427126.00	3.32	26.19	27.44	1.15
		2552726.00	3.50	27.64		
		2624910.00	3.61	28.47		
	32.00	4151156.00	5.84	46.04	46.48	2.47
		4420123.00	6.23	49.14		
		3995676.00	5.61	44.25		
	48.00	5820877.00	8.27	65.27	63.74	1.93
		5500252.00	7.80	61.58		
		5742836.00	8.16	64.37		

Table J3 Ethanol production of free cell fermentation (3rd batch)

Batch number	Fermentation time (hour)	Peak area	Ethanol (%v/v)	Ethanol (g/l)	Average	SD
3	8.00	599738.00	0.65	5.15	5.10	0.36
		623271.00	0.69	5.43		
		561664.00	0.60	4.72		
	16.00	589187.00	0.64	5.03	5.24	0.25
		631814.00	0.70	5.52		
		600809.00	0.65	5.17		
	24.00	2427126.00	3.32	26.19	27.44	1.15
		2552726.00	3.50	27.64		
		2624910.00	3.61	28.47		
	32.00	5820877.00	8.27	65.27	63.74	1.93
		5500252.00	7.80	61.58		
		5742836.00	8.16	64.37		
	48.00	5912786.00	8.41	66.33	66.96	0.55
		5993770.00	8.52	67.26		
		5997388.00	8.53	67.30		

Table J5 Ethanol production of immobilized cell fermentation

Batch number	Fermentation time (hour)	Peak area	Ethanol (%v/v)	Ethanol (g/l)	Average	SD
i	4.00	262211.00	0.16	1.27	1.58	0.28
		308351.00	0.23	1.80		
		296707.00	0.21	1.67		
	8.00	1043943.00	1.30	10.27	10.38	0.10
		1056103.00	1.32	10.41		
		1060887.00	1.33	10.46		
	16.00	3694590.00	5.17	40.79	39.57	1.06
		3522197.00	4.92	38.80		
		3550329.00	4.96	39.13		
	24.00	5557540.00	7.89	62.24	61.24	2.25
		5607567.00	7.96	62.81		
		5246475.00	7.43	58.66		
	32.00	6025809.00	8.57	67.63	72.76	5.35
		6952726.00	9.92	78.30		
		6435363.00	9.17	72.34		
	48.00	7148215.00	10.21	80.55	81.39	3.55
		7558818.00	10.81	85.28		
		6954932.00	9.93	78.33		

Table J5 Ethanol production of immobilized cell fermentation

Batch number	Fermentation time (hour)	Peak area	Ethanol (%v/v)	Ethanol (g/l)	Average	SD
2	8.00	4173694.00	5.87	46.30	47.88	1.78
		4280868.00	6.03	47.54		
		4478100.00	6.31	49.81		
	16.00	6590348.00	9.40	74.13	75.38	1.62
		6858178.00	9.79	77.21		
		6649477.00	9.48	74.81		
	24.00	8483886.00	12.16	95.93	95.51	5.54
		7948705.00	11.38	89.77		
		8909604.00	12.78	100.83		
	32.00	9415003.00	13.52	106.65	103.40	2.94
		9066954.00	13.01	102.64		
		8916484.00	12.79	100.91		
48.00	9189424.00	13.19	104.05	105.21	1.23	
	9402055.00	13.50	106.50			
	9278313.00	13.32	105.08			

Table J6 Ethanol production of immobilized cell fermentation

Batch number	Fermentation time (hour)	Peak area	Ethanol (%v/v)	Ethanol (g/l)	Average	SD
3	8.00	3775678.00	5.29	41.72	41.79	0.90
		3863096.00	5.42	42.73		
		3706378.00	5.19	40.92		
	16.00	5367874.00	7.61	60.05	58.54	2.21
		5325788.00	7.55	59.57		
		5015723.00	7.10	56.00		
	24.00	6035349.00	8.59	67.74	66.85	0.88
		5958707.00	8.47	66.86		
		5881684.00	8.36	65.97		
	32.00	8916707.00	12.79	100.91	100.89	1.17
		8812697.00	12.64	99.72		
		9015873.00	12.93	102.06		
48.00	8973822.00	12.87	101.57	103.19	3.64	
	8892116.00	12.75	100.63			
	9476169.00	13.61	107.35			

Table J7 Ethanol production of immobilized cell fermentation

Batch number	Fermentation time (hour)	Peak area	Ethanol (%v/v)	Ethanol (g/l)	Average	SD
4	6915146.00	9.87	77.87	6915146.00	80.27	2.27
	7150515.00	10.21	80.58	7150515.00		
	7306834.00	10.44	82.38	7306834.00		
	8921862.00	12.80	100.97	8921862.00	100.54	0.38
	8861677.00	12.71	100.28	8861677.00		
	8870163.00	12.72	100.38	8870163.00		

Table J8 Ethanol production of immobilized cell fermentation

Batch number	Fermentation time (hour)	Peak area	Ethanol (%v/v)	Ethanol (g/l)	Average	SD
5	24	6700726.00	9.56	75.40	78.21	2.83
		6941560.00	9.91	78.17		
		7192587.00	10.27	81.06		
	48	8214155.00	11.76	92.82	91.83	0.86
		8087893.00	11.58	91.37		
		8081467.00	11.57	91.30		

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Proceedings:

1. Punyavardhana, V., Nithitanakul, M., and Rujiravanit, R. (2012) Preparation and Characterization of Cellulose Whiskers- Reinforced Silk Fibroin Sponge for Yeast Immobilization for Ethanol Production. Proceeding of the 3rd Research Symposium on Petrochemical and Materials Technology and The 18th PPC Symposium on Petroleum, Petrochemicals and Polymers, Bangkok, Thailand, 24 April 2012.

Presentations:

1. Punyavardhana, V., Nithitanakul, M., and Rujiravanit, R. (2011, August 23-25) Preparation and Characterization of Cellulose Whisker Sponges Containing Silk Fibroin for Cell Entrapment. Paper presented at the 6th International Symposium in Science and Technology at Kansai University 2011, Osaka, Japan.
2. Punyavardhana, V., Nithitanakul, M., and Rujiravanit, R. (2012, January 11-13) Preparation and Characterization of Cellulose Whiskers Reinforced Silk Fibroin Sponges for Yeast Cell Immobilization. Paper presented at the Pure and Applied Chemistry International Conference 2012 (PACCON 2012), Chiang Mai, Thailand.