Appendix A-Properties of adsorbents

Table A1: Properties of adsorbents PA-500 and PA-800

	PA-500	PA-800
Appearance	Translucent beads	Translucent beads
Matrix	Styrene divinylbenzene copolymer	Styrene divinylbenzene copolymer
Moisture holding capacity	62-69%	54-60%
Particle size range	0.3-0.85 mm	0.3-1.2 mm
Uniformity coefficient	1.8, maximum	1.8, maximum
Effective size	0.40-0.50 mm	0.40-0.50 mm
Surface area	$\geq$ 500 m^2/g	$\geq$ 800 m^2/g
Maximum operating temperature	250^oC	250^oC
Operating pH range	0 to 14	0 to 14
Resistance to reducing agents	Good	Good
Resistance to oxidizing agents	Generally good, chlorine should be absent	Generally good, chlorine should be absent

Appendix B: Adsorption-desorption data (system 1)

Table B1: Equilibrium data: Adsorption of naringin from fresh KPBW on the resin PA-500 (system 1)

S.No	Year	Wt of F.P.D$\times10^{-3}$ (kg)	Solid content	O.D.R $\times10^{-3}$ (kg)	Vol. of Solution $\times10^{-6}$ (m^3)	Initial Conc.C_o (kg/m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	2012	0.506	0.382	0.193	50	0.810	0.540	0.0698
2		0.751		0.287	50		0.470	0.0592
3		1.009		0.385	50		0.405	0.0525
4		1.504		0.575	50		0.290	0.0452
5		2.009		0.768	50		0.235	0.0374
6		0.606		0.231	100		0.660	0.0647
7		0.403		0.154	100		0.700	0.0714
8		0.307		0.117	100		0.715	0.0810
9	2013	0.501	0.316	0.158	50	0.780	0.570	0.0663
10		0.672		0.212	50		0.470	0.0729
11		0.912		0.288	50		0.385	0.0685
12		1.379		0.435	50		0.300	0.0550
13		1.862		0.588	50		0.245	0.0454
14		0.485		0.153	100		0.638	0.0926
15		0.289		0.091	100		0.700	0.0876
16		0.208		0.065	100		0.715	0.0988
17	2014	0.503	0.304	0.153	50	0.750	0.565	0.0604
18		0.751		0.228	50		0.475	0.0602
19		1.004		0.305	50		0.415	0.0548
20		1.501		0.456	50		0.320	0.0471
21		2.013		0.612	50		0.270	0.0392
22		0.613		0.186	100		0.620	0.0696
23		0.414		0.125	100		0.655	0.0754
24		0.308		0.093	100		0.690	0.0640

Table B2: Thermo dynamic data for adsorption of naringin from fresh KPBW on the resin PA-500

Initial naringin conc. = 0.800 kg/m^3

S.No	Temperature (K)	Wt of F.P.D×10^{-3} (kg)	Solid content	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-3} (m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	303	0.516	0.345	0.178	50	0.570	0.0728
2		0.761		0.263	50	0.495	0.0636
3		1.171		0.405	50	0.400	0.0530
4		1.501		0.518	50	0.310	0.0501
5		2.012		0.695	50	0.235	0.0427
6		0.301		0.104	100	0.750	0.0766
7		0.409		0.141	100	0.720	0.0776
8		0.601		0.207	100	0.685	0.0697
9	313	0.501	0.331	0.166	50	0.650	0.0541
10		0.756		0.251	50	0.595	0.0467
11		1.009		0.334	50	0.520	0.0462
12		1.531		0.508	50	0.430	0.0393
13		2.004		0.664	50	0.365	0.0349
14		0.309		0.102	100	0.770	0.0583
15		0.415		0.137	100	0.750	0.0580
16		0.608		0.201	100	0.720	0.0545
17	323	0.527	0.333	0.175	50	0.700	0.0369
18		0.750		0.249	50	0.655	0.0350
19		1.000		0.333	50	0.600	0.0345
20		1.500		0.500	50	0.520	0.0309
21		2.081		0.693	50	0.435	0.0284
22		0.329		0.109	100	0.790	0.0364
23		0.400		0.133	100	0.780	0.0375
24		0.608		0.202	100	0.755	0.0370

Table B3: Reproducibility test data for Kinetic studies (system 1)

Volume of KPBW= 0.450×10^{-3} m^3, Initial naringin conc. = 0.810 kg/m^3

S.No	Time (s)	Run 1	Run 2
		Wt. of F.P.D = 4.115×10^{-3} (kg) solid content = 0.363	Wt. of F.P.D =4.05×10^{-3} (kg) solid content = 0.373
		Naringin Conc. $C_t\,(kg/m^3)$	
1	0	0.810	0.810
2	450	0.770	0.765
3	900	0.740	0.750
4	1800	0.730	0.720
5	2700	0.695	0.690
6	3600	0.675	0.665
7	5400	0.665	0.650
8	7200	0.640	0.640
9	10800	0.640	0.635
10	14400	0.635	0.625
11	21600	0.610	0.615
12	36000	0.605	0.605
13	86400	0.600	0.595

Table B4 (a): Kinetic data: Adsorption of naringin from fresh KPBW on the resin PA-500 (system 1, year 2012)

Volume of KPBW= 0.450×10^{-3} m^3, Initial naringin conc. = 0.810 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 4.115×10^{-3} (kg) solid content = 0.365	Wt. of F.P.D = 5.980×10^{-3} (kg) solid content = 0.356	Wt. of F.P.D = 8.045×10^{-3} (kg) solid content = 0.341	Wt. of F.P.D = 10.01×10^{-3} (kg) solid content = 0.348
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.810	0.810	0.810	0.810
2	450	0.770	0.745	0.720	0.685
3	900	0.740	0.735	0.685	0.645
4	1800	0.730	0.685	0.680	0.585
5	2700	0.695	0.660	0.625	0.540
6	3600	0.675	0.640	0.600	0.540
7	5400	0.665	0.635	0.550	0.515
8	7200	0.640	0.600	0.550	0.500
9	10800	0.640	0.575	0.520	0.485
10	14400	0.635	0.570	0.515	0.465
11	21600	0.610	0.560	0.505	0.420
12	36000	0.605	0.550	0.495	0.415
13	86400	0.600	0.545	0.490	0.410

Table B4 (b): Kinetic data: Adsorption of naringin from fresh KPBW on the resin PA-500 (system 1, year 2013)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.780 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.004×10^{-3} (kg) solid content = 0.351	Wt. of F.P.D = 4.101×10^{-3} (kg) solid content = 0.365	Wt. of F.P.D = 6.109×10^{-3} (kg) solid content = 0.346	Wt. of F.P.D = 8.002×10^{-3} (kg) solid content = 0.346
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.780	0.780	0.780	0.780
2	450	0.765	0.750	0.740	0.725
3	900	0.750	0.735	0.710	0.690
4	1800	0.745	0.715	0.700	0.645
5	2700	0.730	0.710	0.685	0.640
6	3600	0.710	0.675	0.670	0.610
7	5400	0.705	0.665	0.630	0.595
8	7200	0.705	0.640	0.625	0.545
9	10800	0.695	0.615	0.590	0.545
10	14400	0.695	0.610	0.585	0.525
11	21600	0.685	0.605	0.570	0.505
12	36000	0.680	0.590	0.560	0.500
13	86400	0.675	0.585	0.555	0.495

Table B4 (c): Kinetic data: Adsorption of naringin from fresh KPBW on the resin PA-500 (system 1, year 2014)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.750 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.006×10^{-3} (kg) solid content = 0.387	Wt. of F.P.D = 4.007×10^{-3} (kg) solid content = 0.347	Wt. of F.P.D = 5.873×10^{-3} (kg) solid content = 0.388	Wt. of F.P.D = 8.117×10^{-3} (kg) solid content = 0.376
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.750	0.750	0.750	0.750
2	450	0.720	0.705	0.695	0.680
3	900	0.705	0.690	0.690	0.655
4	1800	0.705	0.675	0.650	0.610
5	2700	0.685	0.670	0.635	0.585
6	3600	0.675	0.650	0.615	0.580
7	5400	0.660	0.620	0.585	0.550
8	7200	0.655	0.615	0.580	0.54
9	10800	0.655	0.600	0.550	0.510
10	14400	0.645	0.595	0.540	0.515
11	21600	0.640	0.585	0.520	0.495
12	36000	0.635	0.580	0.515	0.475
13	86400	0.630	0.575	0.510	0.470

Table B5 (a): Adsorption of naringin from fresh KPBW on the resin PA-500: Fixed bed column data (Effect of flow rate)

Initial naringin conc. (C_o) =0.810 kg/m^3

S.No	Time (s)	Flow rate×10^{-8} m^3/s		
		3.3	6.6	10
		C_t / C_o		
1	0	0	0	0
2	3600	0	0.003	0.012
3	18000	0.008	0.030	0.067
4	32400	0.024	0.096	0.296
5	46800	0.037	0.241	0.469
6	61200	0.048	0.387	0.740
7	75600	0.083	0.543	0.864
8	90000	0.167	0.740	0.966
9	104400	0.246	0.867	
10	118800	0.345	0.934	
11	133200	0.407	0.981	
12	147600	0.487		
13	162000	0.579		
14	176400	0.688		
15	190800	0.775		
16	205200	0.858		
17	219600	0.907		
18	234000	0.929		
19	248400	0.944		
20	262800	0.958		
21	277200	0.974		
22	291600	0.987		
23	306000	0.992		

Table B5 (b): Adsorption of naringin from fresh KPBW on the resin PA-500: Fixed bed column data (Effect of height)

Initial naringin conc. (C_o) =0.810 kg/m^3

S.No	Time (s)	Height (m)	
		1.20	0.90
		C_t / C_o	
1	0	0	0
2	3600	0	0.001
3	18000	0.008	0.025
4	32400	0.024	0.044
5	46800	0.037	0.113
6	61200	0.048	0.246
7	75600	0.083	0.370
8	90000	0.167	0.477
9	104400	0.246	0.595
10	118800	0.345	0.692
11	133200	0.407	0.830
12	147600	0.487	0.864
13	162000	0.579	0.913
14	176400	0.688	0.940
15	190800	0.775	0.972
16	205200	0.858	0.987
17	219600	0.907	
18	234000	0.929	
19	248400	0.944	
20	262800	0.958	
21	277200	0.974	
22	291600	0.987	
23	298800	0.991	
24	306000	0.992	

Table B6 (a): Fixed bed column data: Adsorption of naringin from fresh KPBW on the resin PA-500 (system 1, year 2012)

Initial naringin conc. (C_o) =0.810 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	23	154800	0.527
2	3600	0	24	162000	0.579
3	10800	0.003	25	169200	0.632
4	18000	0.008	26	176400	0.688
5	25200	0.016	27	183600	0.740
6	32400	0.024	28	190800	0.775
7	39600	0.029	29	198000	0.813
8	46800	0.037	30	205200	0.858
9	54000	0.044	31	212400	0.890
10	61200	0.048	32	219600	0.907
11	68400	0.058	33	226800	0.923
12	75600	0.083	34	234000	0.929
13	82800	0.122	35	241200	0.938
14	90000	0.167	36	248400	0.944
15	97200	0.208	37	255600	0.949
16	104400	0.246	38	262800	0.958
17	111600	0.276	39	270000	0.967
18	118800	0.345	40	277200	0.974
19	126000	0.370	41	284400	0.982
20	133200	0.407	42	291600	0.987
21	140400	0.449	43	298800	0.991
22	147600	0.487			

Table B6 (b): Fixed bed column data: Adsorption of naringin from fresh KPBW on the resin PA-500 (system 1, year 2013)

Initial naringin conc. (C_o) =0.780 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	22	147600	0.682
2	3600	0	23	154800	0.705
3	10800	0.001	24	162000	0.741
4	18000	0.006	25	169200	0.771
5	25200	0.010	26	176400	0.787
6	32400	0.015	27	183600	0.804
7	39600	0.022	28	190800	0.844
8	46800	0.027	29	198000	0.860
9	54000	0.041	30	205200	0.887
10	61200	0.050	31	212400	0.908
11	68400	0.071	32	219600	0.913
12	75600	0.122	33	226800	0.924
13	82800	0.183	34	234000	0.931
14	90000	0.250	35	241200	0.936
15	97200	0.290	36	248400	0.944
16	104400	0.324	37	255600	0.949
17	111600	0.392	38	262800	0.956
18	118800	0.455	39	270000	0.965
19	126000	0.508	40	277200	0.979
20	133200	0.614	41	284400	0.988
21	140400	0.650	42	291600	0.997

Table B6 (c): Fixed bed column data: Adsorption of naringin from fresh KPBW on the resin PA-500 (system 1, year 2014)

Initial naringin conc. (C_o) =0.750 kg/m^3

S.No	Time (s)	C_t / C_o	S. No	Time (s)	C_t / C_o
1	0	0	22	147600	0.569
2	3600	0	23	154800	0.6
3	10800	0.003	24	162000	0.639
4	18000	0.007	25	169200	0.707
5	25200	0.012	26	176400	0.772
6	32400	0.02	27	183600	0.807
7	39600	0.033	28	190800	0.833
8	46800	0.037	29	198000	0.887
9	54000	0.044	30	205200	0.9
10	61200	0.055	31	212400	0.933
11	68400	0.067	32	219600	0.947
12	75600	0.099	33	226800	0.948
13	82800	0.16	34	234000	0.964
14	90000	0.213	35	241200	0.971
15	97200	0.265	36	248400	0.975
16	104400	0.293	37	255600	0.979
17	111600	0.356	38	262800	0.984
18	118800	0.435	39	270000	0.989
19	126000	0.473	40	277200	0.992
20	133200	0.516	41	284400	0.993
21	140400	0.533			

Table B7: Equilibrium data: Desorption studies with ethanol to recover naringin (system 1)

Initial naringin conc. in ethanol (C_{od}) = 0 kg/m^3

S.No	Year	Wt of F.P.D×10^{-3} (kg)	Solid content	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-6} (m^3)	q_{od} (kg/kg)	Final Conc. C_{ed} (kg/m^3)	q_{ed} (kg /kg)
1	2012	0.500	0.468	0.234	25	0.078	0.340	0.0417
2		0.750		0.351	25		0.405	0.0492
3		1.000		0.468	25		0.445	0.0543
4		1.500		0.703	25		0.500	0.0602
5		2.001		0.937	25		0.575	0.0627
6		0.609		0.285	50		0.245	0.0351
7		0.400		0.187	50		0.190	0.0273
8		0.304		0.142	50		0.140	0.0288
9	2013	0.500	0.471	0.236	25	0.072	0.285	0.0418
10		0.751		0.354	25		0.335	0.0483
11		1.032		0.487	25		0.395	0.0517
12		1.500		0.707	25		0.445	0.0563
13		2.005		0.945	25		0.480	0.0593
14		0.604		0.285	50		0.230	0.0316
15		0.404		0.191	50		0.170	0.0274
16		0.312		0.147	50		0.135	0.0261
17	2014	0.500	0.477	0.239	25	0.074	0.275	0.0452
18		0.751		0.359	25		0.340	0.0503
19		1.032		0.493	25		0.365	0.0555
20		1.500		0.716	25		0.395	0.0602
21		2.005		0.957	25		0.430	0.0628
22		0.604		0.288	50		0.210	0.0376
23		0.404		0.193	50		0.180	0.0274
24		0.3121		0.149	50		0.130	0.0304

Table B8 (a): Kinetic data: Desorption studies with ethanol to recover naringin in the year 2012 (system 1)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.003×10^{-3} (kg) solid content = 0.497	Wt. of F.P.D = 4.006×10^{-3} (kg) solid content = 0.473	Wt. of F.P.D = 6.001×10^{-3} (kg) solid content = 0.486
		Naringin Conc. $C_{td}\,(kg/m^3)$		
1	0	0	0	0
2	450	0.010	0.025	0.035
3	900	0.025	0.030	0.065
4	1800	0.030	0.065	0.095
5	2700	0.045	0.080	0.120
6	3600	0.050	0.120	0.135
7	5400	0.050	0.125	0.170
8	7200	0.075	0.150	0.225
9	10800	0.080	0.165	0.265
10	14400	0.095	0.175	0.295
11	21600	0.100	0.210	0.305
12	36000	0.120	0.200	0.305
13	86400	0.125	0.205	0.305

Table B8 (b): Kinetic data: Desorption studies with ethanol to recover naringin in the year 2013 (system 1)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.019×10^{-3} (kg) solid content = 0.487	Wt. of F.P.D = 4.000×10^{-3} (kg) solid content = 0.502	Wt. of F.P.D = 6.018×10^{-3} (kg) solid content = 0.487
		Naringin Conc. $C_{td}\,(kg/m^3)$		
1	0	0	0	0
2	450	0.010	0.020	0.040
3	900	0.020	0.050	0.045
4	1800	0.030	0.055	0.090
5	2700	0.035	0.070	0.125
6	3600	0.045	0.090	0.135
7	5400	0.055	0.115	0.160
8	7200	0.085	0.125	0.190
9	10800	0.085	0.14	0.200
10	14400	0.090	0.165	0.265
11	21600	0.100	0.200	0.280
12	36000	0.120	0.205	0.280
13	86400	0.125	0.210	0.290

Table B8 (c): Kinetic data: Desorption studies with ethanol to recover naringin in the year 2014 (system 1)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.009×10^{-3} (kg) solid content = 0.493	Wt. of F.P.D = 4.005×10^{-3} (kg) solid content = 0.517	Wt. of F.P.D = 6.048×10^{-3} (kg) solid content = 0.493
		Naringin Conc. $C_{td}\,(kg/m^3)$		
1	0	0	0	0
2	450	0.010	0.015	0.035
3	900	0.020	0.030	0.060
4	1800	0.025	0.045	0.075
5	2700	0.025	0.055	0.090
6	3600	0.035	0.080	0.110
7	5400	0.055	0.100	0.135
8	7200	0.065	0.120	0.190
9	10800	0.075	0.135	0.195
10	14400	0.080	0.165	0.250
11	21600	0.095	0.200	0.285
12	36000	0.100	0.205	0.290
13	86400	0.130	0.210	0.295

Table B9: Column studies data: Desorption studies with ethanol to recover naringin (system 1)

S.No	Time (s)	Naringin Conc. $C_{td}\,(kg/m^3)$		
		Year 2012	Year 2013	Year 2014
1	180	4.860	3.96	4.000
2	3600	4.185	3.330	3.550
3	10800	3.699	2.925	3.025
4	18000	2.943	2.632	2.500
5	25200	2.511	2.272	2.000
6	32400	2.052	1.912	1.625
7	39600	1.593	1.642	1.325
8	46800	1.161	1.305	1.075
9	54000	0.945	1.012	0.875
10	61200	0.729	0.742	0.700
11	68400	0.540	0.517	0.550
12	75600	0.432	0.427	0.425
13	82800	0.405	0.360	0.375
14	90000	0.297	0.270	0.325
15	97200	0.270	0.202	0.225
16	104400	0.081	0.180	0.200
17	111600	0.027	0.045	0.025
18	118800		0.027	

Appendix C: Adsorption-desorption data (system 2)

Table C1: Equilibrium data: Adsorption of naringin from fresh KPBW on the resin PA-800 (system 2)

S.No	Year	Wt of F.P.D$\times10^{-3}$ (kg)	Solid content	O.D.R $\times10^{-3}$ (kg)	Vol. of Solution $\times10^{-6}$ (m^3)	Initial Conc.C_o (kg/m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	2012	0.503	0.402	0.202	50	0.810	0.460	0.0863
2		0.754		0.302	50		0.405	0.0669
3		1.002		0.403	50		0.335	0.0588
4		1.499		0.604	50		0.250	0.0463
5		2.001		0.805	50		0.195	0.0381
6		0.304		0.122	100		0.710	0.0815
7		0.401		0.161	100		0.675	0.0835
8		0.602		0.242	100		0.630	0.0742
9	2013	0.500	0.417	0.208	50	0.780	0.430	0.0838
10		0.745		0.311	50		0.305	0.0763
11		1.004		0.419	50		0.235	0.0650
12		1.503		0.627	50		0.165	0.0490
13		2.027		0.846	50		0.135	0.0381
14		0.300		0.125	100		0.650	0.1037
15		0.412		0.172	100		0.620	0.0929
16		0.608		0.253	100		0.585	0.0768
17	2014	0.498	0.386	0.192	50	0.750	0.415	0.0870
18		0.754		0.291	50		0.330	0.0720
19		1.002		0.387	50		0.265	0.0626
20		1.508		0.582	50		0.220	0.0454
21		2.045		0.790	50		0.130	0.0392
22		0.304		0.117	100		0.655	0.0807
23		0.415		0.160	100		0.615	0.0841
24		0.601		0.232	100		0.555	0.0839

Table C2: Thermo dynamic data for Adsorption of naringin from fresh KPBW on the resin PA-800

Initial naringin conc. = 0.830 kg/m^3

S.No	Temperature (K)	Wt of F.P.D×10^{-3} (kg)	Solid content	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-3} (m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	303	0.516	0.345	0.178	50	0.570	0.0728
2		0.761		0.263	50	0.495	0.0636
3		1.171		0.405	50	0.400	0.0530
4		1.501		0.518	50	0.310	0.0501
5		2.012		0.695	50	0.235	0.0427
6		0.301		0.104	100	0.750	0.0766
7		0.409		0.141	100	0.720	0.0776
8		0.601		0.207	100	0.685	0.0697
9	313	0.501	0.331	0.166	50	0.650	0.0541
10		0.756		0.251	50	0.595	0.0467
11		1.009		0.334	50	0.520	0.0462
12		1.531		0.508	50	0.430	0.0393
13		2.004		0.664	50	0.365	0.0349
14		0.309		0.102	100	0.770	0.0583
15		0.415		0.137	100	0.750	0.0580
16		0.608		0.201	100	0.720	0.0545
17	323	0.527	0.333	0.175	50	0.700	0.0369
18		0.750		0.249	50	0.655	0.0350
19		1.000		0.333	50	0.600	0.0345
20		1.500		0.500	50	0.520	0.0309
21		2.081		0.693	50	0.435	0.0284
22		0.329		0.109	100	0.790	0.0364
23		0.400		0.133	100	0.780	0.0375
24		0.608		0.202	100	0.755	0.0370

Table C3 (a): Kinetic data: Adsorption of naringin from fresh KPBW on the resin PA-800 (system 2, year 2012)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.810 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4	Run 5
		Wt. of F.P.D = 2.112×10^{-3} (kg) solid content = 0.489	Wt. of F.P.D = 4.097×10^{-3} (kg) solid content = 0.432	Wt. of F.P.D = 6.000×10^{-3} (kg) solid content = 0.456	Wt. of F.P.D = 8.023×10^{-3} (kg) solid content = 0.476	Wt. of F.P.D = 10.05×10^{-3} (kg) solid content = 0.443
		Naringin Conc. $C_t\,(kg/m^3)$				
1	0	0.810	0.810	0.810	0.810	0.810
2	450	0.770	0.765	0.725	0.710	0.725
3	900	0.745	0.745	0.685	0.670	0.665
4	1800	0.740	0.720	0.675	0.655	0.600
5	2700	0.710	0.675	0.635	0.605	0.545
6	3600	0.675	0.645	0.600	0.575	0.535
7	5400	0.670	0.625	0.54	0.545	0.530
8	7200	0.660	0.610	0.530	0.510	0.470
9	10800	0.650	0.615	0.520	0.485	0.465
10	14400	0.645	0.610	0.515	0.480	0.450
11	21600	0.630	0.590	0.510	0.475	0.440
12	36000	0.620	0.565	0.505	0.465	0.435
13	86400	0.615	0.560	0.500	0.460	0.430

Table C3 (b): Kinetic data: Adsorption of naringin from fresh KPBW on the resin PA-800 (system 2, year 2013)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.780 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.098×10^{-3} (kg) solid content = 0.471	Wt. of F.P.D = 4.113×10^{-3} (kg) solid content = 0.439	Wt. of F.P.D = 6.012×10^{-3} (kg) solid content = 0.416	Wt. of F.P.D = 8.000×10^{-3} (kg) solid content = 0.427
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.780	0.780	0.780	0.780
2	450	0.750	0.745	0.710	0.665
3	900	0.725	0.700	0.680	0.625
4	1800	0.720	0.675	0.620	0.600
5	2700	0.700	0.670	0.645	0.590
6	3600	0.68	0.625	0.615	0.560
7	5400	0.675	0.625	0.585	0.535
8	7200	0.665	0.600	0.550	0.515
9	10800	0.650	0.580	0.545	0.455
10	14400	0.650	0.575	0.530	0.450
11	21600	0.615	0.550	0.515	0.435
12	36000	0.605	0.545	0.500	0.430
13	86400	0.600	0.540	0.495	0.425

Table C3 (c): Kinetic data: Adsorption of naringin from fresh KPBW on the resin PA-800 (system 2, year 2014)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.750 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.001×10^{-3} (kg) solid content = 0.456	Wt. of F.P.D = 4.012×10^{-3} (kg) solid content = 0.493	Wt. of F.P.D = 6.002×10^{-3} (kg) solid content = 0.458
		Naringin Conc. $C_t\,(kg/m^3)$		
1	0	0.750	0.750	0.750
2	450	0.720	0.700	0.700
3	900	0.710	0.685	0.655
4	1800	0.665	0.655	0.625
5	2700	0.660	0.630	0.600
6	3600	0.655	0.605	0.560
7	5400	0.655	0.600	0.570
8	7200	0.640	0.590	0.565
9	10800	0.635	0.565	0.540
10	14400	0.625	0.550	0.535
11	21600	0.600	0.540	0.510
12	36000	0.595	0.530	0.490
13	86400	0.590	0.525	0.485

Table C4 (a): Fixed bed column data: Adsorption of naringin from fresh KPBW on the resin PA 800 (system 1, year 2012)

Initial naringin conc. (C_o) =0.810 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	26	176400	0.551
2	3600	0	27	183600	0.570
3	10800	0	28	190800	0.620
4	18000	0.002	29	198000	0.644
5	25200	0.004	30	205200	0.675
6	32400	0.008	31	212400	0.707
7	39600	0.015	32	219600	0.747
8	46800	0.021	33	226800	0.783
9	54000	0.025	34	234000	0.839
10	61200	0.033	35	241200	0.880
11	68400	0.038	36	248400	0.899
12	75600	0.045	37	255600	0.918
13	82800	0.057	38	262800	0.929
14	90000	0.075	39	270000	0.938
15	97200	0.103	40	277200	0.949
16	104400	0.138	41	284400	0.956
17	111600	0.167	42	291600	0.962
18	118800	0.209	43	298800	0.967
19	126000	0.255	44	306000	0.971
20	133200	0.291	45	313200	0.973
21	140400	0.334	46	320400	0.977
22	147600	0.380	47	327600	0.981
23	154800	0.426	48	334800	0.982
24	162000	0.456	49	342000	0.989
25	169200	0.497	50	349200	0.991

Table C4 (b): Fixed bed column data: Adsorption of naringin from fresh KPBW on the resin PA-800 (system 2, year 2013)

Initial naringin conc. (C_o) =0.780 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	25	169200	0.592
2	3600	0	26	176400	0.630
3	10800	0.002	27	183600	0.648
4	18000	0.004	28	190800	0.663
5	25200	0.007	29	198000	0.703
6	32400	0.012	30	205200	0.734
7	39600	0.015	31	212400	0.761
8	46800	0.020	32	219600	0.774
9	54000	0.029	33	226800	0.809
10	61200	0.035	34	234000	0.885
11	68400	0.045	35	241200	0.911
12	75600	0.052	36	248400	0.924
13	82800	0.065	37	255600	0.939
14	90000	0.075	38	262800	0.949
15	97200	0.090	39	270000	0.958
16	104400	0.129	40	277200	0.970
17	111600	0.193	41	284400	0.974
18	118800	0.236	42	291600	0.979
19	126000	0.283	43	298800	0.983
20	133200	0.317	44	306000	0.989
21	140400	0.366	45	313200	0.992
22	147600	0.413	46	320400	0.994
23	154800	0.471	47	327600	0.994
24	162000	0.513			

Table C4 (c): Fixed bed column data: Adsorption of naringin from fresh KPBW on the resin PA-800 (system 2, year 2014)

Initial naringin conc. (C_o) =0.750 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	23	154800	0.534
2	3600	0	24	162000	0.588
3	10800	0.002	25	169200	0.643
4	18000	0.007	26	176400	0.679
5	25200	0.010	27	183600	0.722
6	32400	0.015	28	190800	0.794
7	39600	0.018	29	198000	0.830
8	46800	0.022	30	205200	0.870
9	54000	0.028	31	212400	0.892
10	61200	0.034	32	219600	0.900
11	68400	0.043	33	226800	0.923
12	75600	0.055	34	234000	0.922
13	82800	0.067	35	241200	0.943
14	90000	0.087	36	248400	0.952
15	97200	0.122	37	255600	0.964
16	104400	0.180	38	262800	0.970
17	111600	0.198	39	270000	0.974
18	118800	0.259	40	277200	0.975
19	126000	0.343	41	284400	0.982
20	133200	0.406	42	291600	0.987
21	140400	0.460	43	298800	0.991
22	147600	0.492	44	306000	0.995

Table C5: Equilibrium data: Desorption studies with ethanol to recover naringin (system 2)

Initial naringin conc. in ethanol (C_{od}) = 0 kg/m^3

S.No	Year	Wt of F.P.D×10^{-3} (kg)	Solid content	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-6} (m^3)	q_{od} (kg/kg)	Final Conc. C_{ed} (kg/m^3)	q_{ed} (kg /kg)
1	2012	0.5012	0.479	0.24	25	0.092	0.405	0.0499
2		0.7499		0.36	25		0.495	0.0576
3		1.0032		0.481	25		0.525	0.0647
4		1.5045		0.721	25		0.585	0.0717
5		2.0087		0.963	25		0.600	0.0764
6		0.6048		0.29	50		0.280	0.0437
7		0.4094		0.196	50		0.220	0.036
8		0.3003		0.144	50		0.160	0.0364
9	2013	0.5005	0.483	0.242	25	0.095	0.375	0.0563
10		0.7591		0.367	25		0.440	0.065
11		1.0073		0.487	25		0.490	0.0699
12		1.5109		0.731	25		0.555	0.076
13		2.0083		0.971	25		0.590	0.0798
14		0.6093		0.295	50		0.270	0.0492
15		0.4068		0.197	50		0.235	0.0353
16		0.3103		0.15	50		0.180	0.035
17	2014	0.5023	0.459	0.231	25	0.092	0.365	0.0525
18		0.7501		0.345	25		0.400	0.063
19		1.0281		0.473	25		0.445	0.0685
20		1.5081		0.694	25		0.485	0.0745
21		2.0021		0.921	25		0.520	0.0779
22		0.6082		0.28	50		0.265	0.0446
23		0.4067		0.187	50		0.220	0.0332
24		0.3042		0.14	50		0.165	0.0330

Table C6 (a): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2012 (system 2)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.009×10^{-3} (kg) solid content = 0.516	Wt. of F.P.D = 4.003×10^{-3} (kg) solid content = 0.464	Wt. of F.P.D = 6.018×10^{-3} (kg) solid content = 0.487
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.01	0.030	0.055
3	900	0.015	0.050	0.080
4	1800	0.035	0.050	0.090
5	2700	0.050	0.095	0.145
6	3600	0.055	0.115	0.175
7	5400	0.095	0.120	0.170
8	7200	0.095	0.165	0.215
9	10800	0.100	0.195	0.275
10	14400	0.125	0.210	0.340
11	21600	0.135	0.225	0.355
12	36000	0.135	0.230	0.390
13	86400	0.140	0.230	0.370

Table C6 (b): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2013 (system 2)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.010×10^{-3} (kg) solid content = 0.480	Wt. of F.P.D = 4.005×10^{-3} (kg) solid content = 0.486	Wt. of F.P.D = 6.002×10^{-3} (kg) solid content = 0.504
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.015	0.045	0.06
3	900	0.025	0.075	0.100
4	1800	0.025	0.100	0.165
5	2700	0.060	0.130	0.170
6	3600	0.080	0.115	0.205
7	5400	0.100	0.180	0.260
8	7200	0.105	0.185	0.265
9	10800	0.100	0.205	0.300
10	14400	0.130	0.240	0.345
11	21600	0.140	0.290	0.375
12	36000	0.145	0.295	0.380
13	86400	0.160	0.300	0.385

Table C6 (c): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2014 (system 2)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.100×10^{-3} (kg) solid content = 0.467	Wt. of F.P.D = 4.025×10^{-3} (kg) solid content = 0.471	Wt. of F.P.D = 6.021×10^{-3} (kg) solid content = 0.490
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.010	0.025	0.050
3	900	0.030	0.030	0.085
4	1800	0.045	0.060	0.120
5	2700	0.050	0.080	0.125
6	3600	0.070	0.105	0.180
7	5400	0.090	0.105	0.245
8	7200	0.090	0.155	0.225
9	10800	0.095	0.195	0.285
10	14400	0.120	0.200	0.330
11	21600	0.125	0.225	0.345
12	36000	0.130	0.225	0.350
13	86400	0.135	0.230	0.350

Table C7: Column studies data: Desorption studies with ethanol to recover naringin (system 2)

S.No	Time (s)	Naringin Conc. C_{td} (kg/m^3)		
		Year 2012	Year 2013	Year 2014
1	180	5.252	4.230	4.136
2	3600	3.932	3.219	3.125
3	7200	3.547	2.820	2.749
4	10800	3.107	2.467	2.397
5	14400	2.722	2.209	2.091
6	18000	2.392	1.927	1.856
7	21600	2.007	1.715	1.621
8	25200	1.622	1.551	1.386
9	28800	1.402	1.339	1.245
10	32400	0.962	1.128	1.104
11	36000	0.742	0.987	0.822
12	39600	0.522	0.799	0.681
13	43200	0.440	0.681	0.540
14	46800	0.412	0.540	0.399
15	50400	0.357	0.446	0.352
16	54000	0.275	0.399	0.329
17	57600	0.110	0.282	0.188
18	61200	0.055	0.141	0.023
19	64800	0.027	0.047	

Appendix D: Adsorption-desorption data (system 3)

Table D1: Equilibrium data: Adsorption of naringin from dropped KPBW on the resin PA-500 (system 3)

S.No	Year	Wt of F.P.D$\times10^{-3}$ (kg)	Solid content	O.D.R $\times10^{-3}$ (kg)	Vol. of Solution $\times10^{-6}$ (m^3)	Initial Conc.C_o (kg/m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	2012	0.500	0.347	0.174	50	0.890	0.58	0.0891
2		0.750		0.261	50		0.535	0.0681
3		1.005		0.349	50		0.435	0.0652
4		1.509		0.524	50		0.340	0.0525
5		2.006		0.697	50		0.255	0.0456
6		0.600		0.209	100		0.715	0.0839
7		0.400		0.139	100		0.765	0.0899
8		0.300		0.104	100		0.795	0.0911
9	2013	0.501	0.330	0.166	50	0.935	0.625	0.0936
10		0.754		0.249	50		0.535	0.0803
11		1.001		0.331	50		0.405	0.0801
12		1.512		0.500	50		0.295	0.064
13		2.002		0.662	50		0.215	0.0544
14		0.603		0.199	100		0.735	0.1004
15		0.405		0.134	100		0.805	0.0971
16		0.301		0.099	100		0.825	0.1106

Table D2 (a): Kinetic data: Adsorption of naringin from dropped KPBW on the resin PA-500 (system 3, year 2012)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.890 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.007×10^{-3} (kg) solid content = 0.436	Wt. of F.P.D = 4.009×10^{-3} (kg) solid content = 0.429	Wt. of F.P.D = 6.017×10^{-3} (kg) solid content = 0.377	Wt. of F.P.D = 8.009×10^{-3} (kg) solid content = 0.423
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.890	0.890	0.890	0.890
2	450	0.855	0.860	0.830	0.810
3	900	0.825	0.810	0.790	0.765
4	1800	0.810	0.765	0.775	0.740
5	2700	0.775	0.755	0.730	0.710
6	3600	0.755	0.735	0.730	0.670
7	5400	0.740	0.740	0.685	0.660
8	7200	0.710	0.700	0.645	0.645
9	10800	0.705	0.695	0.640	0.635
10	14400	0.700	0.655	0.620	0.620
11	21600	0.685	0.635	0.615	0.595
12	36000	0.680	0.630	0.610	0.590
13	86400	0.675	0.625	0.605	0.585

Table D2 (b): Kinetic data: Adsorption of naringin from dropped KPBW on the resin PA-500 (system 3, year 2013)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.935 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.006×10^{-3} (kg) solid content = 0.365	Wt. of F.P.D = 4.005×10^{-3} (kg) solid content = 0.373	Wt. of F.P.D = 6.007×10^{-3} (kg) solid content = 0.365	Wt. of F.P.D = 7.799×10^{-3} (kg) solid content = 0.373
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.935	0.935	0.935	0.935
2	450	0.910	0.875	0.860	0.840
3	900	0.885	0.840	0.825	0.800
4	1800	0.870	0.825	0.790	0.755
5	2700	0.840	0.810	0.765	0.700
6	3600	0.835	0.765	0.755	0.685
7	5400	0.820	0.745	0.715	0.685
8	7200	0.790	0.735	0.690	0.660
9	10800	0.765	0.720	0.675	0.620
10	14400	0.760	0.680	0.640	0.600
11	21600	0.750	0.665	0.635	0.590
12	36000	0.745	0.660	0.630	0.585
13	86400	0.74	0.655	0.625	0.580

Table D3 (a): Fixed bed column data: Adsorption of naringin from dropped KPBW on the resin PA 500 (system 3, year 2012)

Initial naringin conc. (C_o) =0.890 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	26	176400	0.503
2	3600	0	27	183600	0.547
3	10800	0.002	28	190800	0.612
4	18000	0.004	29	198000	0.649
5	25200	0.008	30	205200	0.676
6	32400	0.014	31	212400	0.708
7	39600	0.019	32	219600	0.738
8	46800	0.024	33	226800	0.777
9	54000	0.030	34	234000	0.796
10	61200	0.036	35	241200	0.822
11	68400	0.041	36	248400	0.847
12	75600	0.047	37	255600	0.871
13	82800	0.053	38	262800	0.882
14	90000	0.073	39	270000	0.906
15	97200	0.111	40	277200	0.928
16	104400	0.142	41	284400	0.938
17	111600	0.177	42	291600	0.948
18	118800	0.231	43	298800	0.955
19	126000	0.255	44	306000	0.961
20	133200	0.288	45	313200	0.975
21	140400	0.331	46	320400	0.979
22	147600	0.359	47	327600	0.987
23	154800	0.392	48	334800	0.989
24	162000	0.444	49	342000	0.992
25	169200	0.475			

Table D3 (b): Fixed bed column data: Adsorption of naringin from dropped KPBW on the resin PA-500 (system 3, year 2013)

Initial naringin conc. (C_o) =0.935 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	28	190800	0.495
2	3600	0	29	198000	0.532
3	10800	0	30	205200	0.575
4	18000	0.002	31	212400	0.646
5	25200	0.003	32	219600	0.671
6	32400	0.006	33	226800	0.699
7	39600	0.009	34	234000	0.753
8	46800	0.013	35	241200	0.803
9	54000	0.017	36	248400	0.835
10	61200	0.020	37	255600	0.824
11	68400	0.025	38	262800	0.863
12	75600	0.027	39	270000	0.888
13	82800	0.034	40	277200	0.906
14	90000	0.043	41	284400	0.913
15	97200	0.067	42	291600	0.925
16	104400	0.097	43	298800	0.933
17	111600	0.144	44	306000	0.942
18	118800	0.197	45	313200	0.949
19	126000	0.237	46	320400	0.958
20	133200	0.284	47	327600	0.960
21	140400	0.300	48	334800	0.971
22	147600	0.333	49	342000	0.968
23	154800	0.343	50	349200	0.977
24	162000	0.375	51	356400	0.980
25	169200	0.391	52	363600	0.988
26	176400	0.428	53	367200	0.993
27	183600	0.444	54	374400	0.995

Table D4: Equilibrium data: Desorption studies with ethanol to recover naringin (system 3)

Initial naringin conc. (C_{od}) = 0 kg/m^3

S.No	Year	Wt of F.P.D×10^{-3} (kg)	Solid content	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-6} (m^3)	q_{od} (kg/kg)	Final Conc. C_{ed} (kg/m^3)	q_{ed} (kg /kg)
1	2012	0.514	0.406	0.209	25	0.096	0.385	0.0499
2		0.751		0.305	25		0.430	0.0607
3		1.012		0.411	25		0.495	0.0658
4		1.531		0.622	25		0.555	0.0736
5		2.007		0.815	25		0.600	0.0776
6		0.602		0.245	50		0.255	0.0438
7		0.408		0.166	50		0.210	0.0326
8		0.299		0.121	50		0.150	0.0342
9	2013	0.509	0.396	0.202	25	0.106	0.410	0.0552
10		0.748		0.297	25		0.475	0.0660
11		1.075		0.426	25		0.530	0.0749
12		1.504		0.597	25		0.590	0.0813
13		2.001		0.794	25		0.620	0.0865
14		0.605		0.240	50		0.275	0.0487
15		0.416		0.165	50		0.200	0.0454
16		0.302		0.120	50		0.170	0.0351

Table D5 (a): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2012 (system 3)

Volume of ethanol = 0.450×10^{-3} m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.100×10^{-3} (kg) solid content = 0.495	Wt. of F.P.D = 4.111×10^{-3} (kg) solid content = 0.494	Wt. of F.P.D = 6.001×10^{-3} (kg) solid content = 0.500
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.030	0.015	0.060
3	900	0.035	0.065	0.140
4	1800	0.055	0.085	0.135
5	2700	0.060	0.080	0.165
6	3600	0.090	0.150	0.210
7	5400	0.090	0.135	0.215
8	7200	0.105	0.170	0.250
9	10800	0.135	0.230	0.315
10	14400	0.135	0.240	0.330
11	21600	0.145	0.275	0.365
12	36000	0.145	0.280	0.370
13	86400	0.150	0.285	0.375

Table D5 (b): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2013 (system 3)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.004×10^{-3} (kg) solid content = 0.493	Wt. of F.P.D = 4.001×10^{-3} (kg) solid content = 0.481	Wt. of F.P.D = 6.018×10^{-3} (kg) solid content = 0.499
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.015	0.045	0.070
3	900	0.030	0.050	0.115
4	1800	0.035	0.100	0.150
5	2700	0.055	0.105	0.210
6	3600	0.070	0.180	0.255
7	5400	0.105	0.185	0.250
8	7200	0.120	0.225	0.320
9	10800	0.120	0.220	0.335
10	14400	0.125	0.245	0.385
11	21600	0.160	0.300	0.400
12	36000	0.165	0.305	0.405
13	86400	0.170	0.310	0.410

Table D6: Column studies data: Desorption studies with ethanol to recover naringin (system 3)

S.No	Time (s)	Naringin Conc. C_{td} (kg/m^3)	
		Year 2012	Year 2013
1	180	5.000	5.880
2	3600	4.125	4.410
3	7200	3.550	3.846
4	10800	2.975	3.430
5	14400	2.550	3.038
6	18000	2.125	2.695
7	21600	1.750	2.131
8	25200	1.500	1.813
9	28800	1.200	1.568
10	32400	1.100	1.249
11	36000	0.925	0.980
12	39600	0.850	0.906
13	43200	0.825	0.588
14	46800	0.650	0.441
15	50400	0.550	0.367
16	54000	0.425	0.245
17	57600	0.325	0.171
18	61200	0.275	0.122
19	64800	0.225	0.073
20	68400	0.100	0.049
21	72000	0.075	0.024
22	75600	0.050	

Appendix E: Adsorption-desorption data (system 4)

Table E1: Equilibrium data: Adsorption of naringin from dropped KPBW on the resin PA-800 (system 4)

S.No	Year	Wt of F.P.D$\times10^{-3}$ (kg)	Solid content	O.D.R $\times10^{-3}$ (kg)	Vol. of Solution $\times10^{-6}$ (m^3)	Initial Conc.C_o (kg/m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	2012	0.510	0.439	0.224	50	0.890	0.475	0.0925
2		0.750		0.329	50		0.400	0.0743
3		1.003		0.440	50		0.245	0.0731
4		1.507		0.661	50		0.190	0.0528
5		2.011		0.883	50		0.155	0.0416
6		0.608		0.267	100		0.630	0.0972
7		0.400		0.175	100		0.710	0.1023
8		0.311		0.136	100		0.740	0.1098
9	2013	0.500	0.346	0.199	50	0.935	0.500	0.1088
10		0.752		0.300	50		0.385	0.0914
11		1.005		0.401	50		0.300	0.0790
12		1.506		0.601	50		0.195	0.0614
13		2.003		0.800	50		0.115	0.0512
14		0.600		0.239	100		0.640	0.1229
15		0.405		0.161	100		0.710	0.1389
16		0.300		0.119	100		0.775	0.1334

Table E2 (a): Kinetic data: Adsorption of naringin from dropped KPBW on the resin PA-800 (system 4, year 2012)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.890 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.112×10^{-3} (kg) solid content = 0.435	Wt. of F.P.D = 4.097×10^{-3} (kg) solid content = 0.426	Wt. of F.P.D = 6.000×10^{-3} (kg) solid content = 0.444	Wt. of F.P.D = 8.023×10^{-3} (kg) solid content = 0.434
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.890	0.890	0.890	0.890
2	450	0.850	0.810	0.780	0.755
3	900	0.815	0.770	0.700	0.700
4	1800	0.810	0.735	0.690	0.645
5	2700	0.765	0.695	0.640	0.625
6	3600	0.745	0.685	0.600	0.555
7	5400	0.710	0.630	0.595	0.495
8	7200	0.715	0.625	0.570	0.485
9	10800	0.705	0.620	0.540	0.450
10	14400	0.690	0.565	0.535	0.425
11	21600	0.685	0.555	0.495	0.410
12	36000	0.680	0.550	0.485	0.405
13	86400	0.675	0.545	0.480	0.400

Table E2 (b): Kinetic data: Adsorption of naringin from dropped KPBW on the resin PA-800 (system 4, year 2013)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.935 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.003×10^{-3} (kg) solid content = 0.434	Wt. of F.P.D = 4.085×10^{-3} (kg) solid content = 0.426	Wt. of F.P.D = 6.001×10^{-3} (kg) solid content = 0.418
		Naringin Conc. $C_t\,(kg/m^3)$		
1	0	0.935	0.935	0.935
2	450	0.895	0.860	0.850
3	900	0.860	0.840	0.750
4	1800	0.810	0.770	0.740
5	2700	0.820	0.710	0.655
6	3600	0.805	0.705	0.630
7	5400	0.770	0.680	0.535
8	7200	0.765	0.640	0.565
9	10800	0.755	0.635	0.545
10	14400	0.715	0.595	0.530
11	21600	0.705	0.590	0.485
12	36000	0.700	0.585	0.480
13	86400	0.695	0.58	0.475

Table E3 (a): Fixed bed column data: Adsorption of naringin from dropped KPBW on the resin PA 800 (system 4, year 2012)

Initial naringin conc. (C_o) =0.890 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	30	205200	0.503
2	3600	0	31	212400	0.537
3	10800	0	32	219600	0.572
4	18000	0.001	33	226800	0.612
5	25200	0.002	34	234000	0.639
6	32400	0.006	35	241200	0.670
7	39600	0.009	36	248400	0.732
8	46800	0.013	37	255600	0.750
9	54000	0.017	38	262800	0.785
10	61200	0.020	39	270000	0.822
11	68400	0.026	40	277200	0.872
12	75600	0.028	41	284400	0.886
13	82800	0.035	42	291600	0.898
14	90000	0.040	43	298800	0.909
15	97200	0.045	44	306000	0.923
16	104400	0.049	45	313200	0.944
17	111600	0.064	46	320400	0.947
18	118800	0.080	47	327600	0.954
19	126000	0.112	48	334800	0.961
20	133200	0.142	49	342000	0.965
21	140400	0.174	50	349200	0.972
22	147600	0.218	51	356400	0.978
23	154800	0.272	52	363600	0.983
24	162000	0.294	53	370800	0.987
25	169200	0.335	54	378000	0.988
26	176400	0.371	55	385200	0.989
27	183600	0.401	56	392400	0.989
28	190800	0.445	57	399600	0.990
29	198000	0.475	58	406800	0.991

Table E3 (b): Fixed bed column data: Adsorption of naringin from dropped KPBW on the resin PA-800 (system 4, year 2013)

Initial naringin conc. (C_o) =0.935 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	33	226800	0.505
2	3600	0	34	234000	0.535
3	10800	0	35	241200	0.568
4	18000	0	36	248400	0.594
5	25200	0.001	37	255600	0.635
6	32400	0.003	38	262800	0.663
7	39600	0.007	39	270000	0.695
8	46800	0.010	40	277200	0.736
9	54000	0.013	41	284400	0.765
10	61200	0.016	42	291600	0.775
11	68400	0.022	43	298800	0.807
12	75600	0.029	44	306000	0.829
13	82800	0.034	45	313200	0.866
14	90000	0.041	46	320400	0.880
15	97200	0.045	47	327600	0.892
16	104400	0.048	48	334800	0.910
17	111600	0.053	49	342000	0.920
18	118800	0.066	50	349200	0.927
19	126000	0.091	51	356400	0.936
20	133200	0.113	52	363600	0.938
21	140400	0.144	53	370800	0.948
22	147600	0.164	54	378000	0.955
23	154800	0.197	55	385200	0.958
24	162000	0.218	56	392400	0.961
25	169200	0.257	57	399600	0.967
26	176400	0.301	58	406800	0.975
27	183600	0.330	59	414000	0.983
28	190800	0.376	60	421200	0.989
29	198000	0.394	61	428400	0.991
30	205200	0.406	62	435600	0.995
31	212400	0.433	63	442800	0.996
32	219600	0.465			

Table E4: Equilibrium data: Desorption studies with ethanol to recover naringin (system 4)

Initial naringin conc. in ethanol (C_{od}) = 0 kg/m^3

S.No	Year	Wt of F.P.D×10^{-3} (kg)	Solid content	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-6} (m^3)	q_{od} (kg/kg)	Final Conc. C_{ed} (kg/m^3)	q_{ed} (kg /kg)
1	2012	0.507	0.427	0.216	25	0.116	0.415	0.0680
2		0.753		0.321	25		0.470	0.0794
3		1.001		0.427	25		0.545	0.0841
4		1.518		0.648	25		0.605	0.0926
5		2.006		0.856	25		0.660	0.0967
6		0.608		0.259	50		0.300	0.0582
7		0.399		0.170	50		0.255	0.0411
8		0.307		0.131	50		0.180	0.0473
9	2013	0.503	0.397	0.199	25	0.129	0.430	0.0752
10		0.754		0.299	25		0.495	0.0877
11		1.106		0.439	25		0.570	0.0965
12		1.508		0.599	25		0.650	0.1018
13		2.505		0.995	25		0.700	0.1114
14		0.604		0.240	50		0.325	0.0613
15		0.402		0.159	50		0.270	0.0445
16		0.308		0.122	50		0.215	0.0411

Table E5 (a): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2012 (system 4)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol. = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.005×10^{-3} (kg) solid content = 0.500	Wt. of F.P.D = 4.083×10^{-3} (kg) solid content = 0.498	Wt. of F.P.D = 6.001×10^{-3} (kg) solid content = 0.481
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.015	0.045	0.030
3	900	0.040	0.060	0.125
4	1800	0.045	0.085	0.165
5	2700	0.075	0.090	0.240
6	3600	0.080	0.145	0.235
7	5400	0.120	0.200	0.270
8	7200	0.125	0.205	0.315
9	10800	0.150	0.270	0.355
10	14400	0.150	0.300	0.410
11	21600	0.165	0.315	0.440
12	36000	0.175	0.285	0.420
13	86400	0.180	0.290	0.425

Table E5 (b): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2013 (system 4)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.010×10^{-3} (kg) solid content = 0.489	Wt. of F.P.D = 4.005×10^{-3} (kg) solid content = 0.482	Wt. of F.P.D = 6.002×10^{-3} (kg) solid content = 0.491
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.025	0.055	0.070
3	900	0.040	0.060	0.155
4	1800	0.040	0.125	0.165
5	2700	0.080	0.170	0.225
6	3600	0.095	0.175	0.265
7	5400	0.135	0.230	0.295
8	7200	0.135	0.220	0.360
9	10800	0.170	0.290	0.400
10	14400	0.175	0.355	0.445
11	21600	0.180	0.360	0.490
12	36000	0.200	0.390	0.495
13	86400	0.205	0.395	0.500

Table E6: Column studies data: Desorption studies with ethanol to recover naringin (system 4)

S.No	Time (s)	Naringin Conc. $C_{td}\ (kg/m^3)$	
		Year 2012	Year 2013
1	180	5.850	6.200
2	3600	3.915	4.000
3	7200	3.510	3.300
4	10800	3.240	3.020
5	14400	2.947	2.720
6	18000	2.610	2.500
7	21600	2.250	2.360
8	25200	1.867	2.080
9	28800	1.530	1.840
10	32400	1.350	1.520
11	36000	1.192	1.300
12	39600	0.967	1.100
13	43200	0.945	0.920
14	46800	0.787	0.780
15	50400	0.697	0.740
16	54000	0.562	0.580
17	57600	0.450	0.540
18	61200	0.382	0.440
19	64800	0.315	0.380
20	68400	0.292	0.280
21	72000	0.225	0.260
22	75600	0.045	0.160
23	79200		0.040
24	82800		0.020

Appendix F: Adsorption-desorption data (system 5)

Table F1: Equilibrium data: Adsorption of naringin from dry KPBW on the resin PA-500 (system 5)

S.No	Year	Wt of F.P.D$\times10^{-3}$ (kg)	Solid content	O.D.R $\times10^{-3}$ (kg)	Vol. of Solution $\times10^{-6}$ (m^3)	Initial Conc.C_o (kg/m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	2012	0.508	0.329	0.167	50	0.700	0.520	0.0536
2		0.750		0.247	50		0.450	0.0505
3		1.063		0.350	50		0.375	0.0463
4		1.505		0.496	50		0.315	0.0387
5		2.000		0.659	50		0.245	0.0344
6		0.600		0.19	100		0.595	0.0530
7		0.403		0.133	100		0.620	0.0600
8		0.299		0.098	100		0.645	0.0556
9	2013	0.501	0.324	0.162	50	0.650	0.465	0.0568
10		0.756		0.245	50		0.405	0.0499
11		1.063		0.344	50		0.325	0.0471
12		1.500		0.486	50		0.235	0.0426
13		2.026		0.657	50		0.200	0.0342
14		0.600		0.194	100		0.530	0.0616
15		0.416		0.135	100		0.570	0.0592
16		0.300		0.097	100		0.595	0.0564

Table F2 (a): Kinetic data: Adsorption of naringin from dry KPBW on the resin PA-500 (system 5, year 2012)

Volume of KPBW= 0.450×10^{-3} m^3, Initial naringin conc. = 0.700 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.001×10^{-3} (kg) solid content = 0.359	Wt. of F.P.D = 4.072×10^{-3} (kg) solid content = 0.333	Wt. of F.P.D = 6.006×10^{-3} (kg) solid content = 0.358	Wt. of F.P.D = 7.993×10^{-3} (kg) solid content = 0.348
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.700	0.700	0.700	0.700
2	450	0.675	0.655	0.650	0.625
3	900	0.665	0.635	0.610	0.595
4	1800	0.650	0.605	0.605	0.565
5	2700	0.645	0.600	0.575	0.525
6	3600	0.640	0.585	0.555	0.520
7	5400	0.625	0.580	0.550	0.500
8	7200	0.625	0.550	0.515	0.490
9	10800	0.615	0.545	0.495	0.455
10	14400	0.615	0.540	0.490	0.445
11	21600	0.605	0.530	0.485	0.440
12	36000	0.600	0.525	0.480	0.430
13	86400	0.595	0.520	0.475	0.425

Table F2 (b): Kinetic data: Adsorption of naringin from dry KPBW on the resin PA-500 (system 5, year 2013)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.650 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.036×10^{-3} (kg) solid content = 0.353	Wt. of F.P.D = 4.103×10^{-3} (kg) solid content = 0.346	Wt. of F.P.D = 6.003×10^{-3} (kg) solid content = 0.338	Wt. of F.P.D = 8.002×10^{-3} (kg) solid content = 0.376
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.650	0.650	0.650	0.650
2	450	0.630	0.615	0.600	0.555
3	900	0.615	0.610	0.600	0.550
4	1800	0.610	0.580	0.555	0.535
5	2700	0.595	0.565	0.530	0.485
6	3600	0.585	0.565	0.515	0.480
7	5400	0.580	0.540	0.480	0.450
8	7200	0.580	0.535	0.485	0.445
9	10800	0.570	0.515	0.475	0.435
10	14400	0.560	0.510	0.450	0.395
11	21600	0.560	0.490	0.445	0.400
12	36000	0.555	0.485	0.430	0.395
13	86400	0.550	0.480	0.425	0.390

Table F3 (a): Fixed bed column data: Adsorption of naringin from dry KPBW on the resin PA 500 (system 5, year 2012)

Initial naringin conc. (C_o) =0.700 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	19	126000	0.601
2	3600	0.001	20	133200	0.653
3	10800	0.006	21	140400	0.700
4	18000	0.014	22	147600	0.744
5	25200	0.021	23	154800	0.796
6	32400	0.031	24	162000	0.831
7	39600	0.040	25	169200	0.859
8	46800	0.046	26	176400	0.866
9	54000	0.071	27	183600	0.890
10	61200	0.121	28	190800	0.900
11	68400	0.204	29	198000	0.917
12	75600	0.240	30	205200	0.929
13	82800	0.334	31	212400	0.930
14	90000	0.373	32	219600	0.943
15	97200	0.426	33	226800	0.957
16	104400	0.463	34	234000	0.964
17	111600	0.509	35	241200	0.977
18	118800	0.566	36	248400	0.989

Table F3 (b): Fixed bed column data: Adsorption of naringin from dry KPBW on the resin PA-500 (system 5, year 2013)

Initial naringin conc. (C_o) =0.650 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	18	118800	0.602
2	3600	0	19	126000	0.685
3	10800	0.003	20	133200	0.725
4	18000	0.011	21	140400	0.757
5	25200	0.017	22	147600	0.772
6	32400	0.023	23	154800	0.840
7	39600	0.032	24	162000	0.882
8	46800	0.043	25	169200	0.908
9	54000	0.063	26	176400	0.923
10	61200	0.089	27	183600	0.932
11	68400	0.154	28	190800	0.943
12	75600	0.225	29	198000	0.954
13	82800	0.345	30	205200	0.962
14	90000	0.423	31	212400	0.969
15	97200	0.462	32	219600	0.980
16	104400	0.500	33	226800	0.985
17	111600	0.538	34	234000	0.992

Table F4: Equilibrium data: Desorption studies with ethanol to recover naringin (system 5)

Initial naringin conc. in ethanol (C_{od}) = 0 kg/m^3

S.No	Year	Wt of F.P.D×10^{-3} (kg)	Solid content	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-6} (m^3)	q_{od} (kg/kg)	Final Conc. C_{ed} (kg/m^3)	q_{ed} (kg /kg)
1	2012	0.518	0.449	0.232	25	0.060	0.23	0.0353
2		0.752		0.338	25		0.285	0.0389
3		1.004		0.451	25		0.33	0.0417
4		1.503		0.675	25		0.39	0.0455
5		2.007		0.902	25		0.44	0.0478
6		0.608		0.273	50		0.155	0.0316
7		0.413		0.185	50		0.12	0.0276
8		0.305		0.137	50		0.085	0.0290
9	2013	0.502	0.456	0.229	25	0.061	0.25	0.0337
10		0.752		0.343	25		0.315	0.0380
11		1.008		0.460	25		0.37	0.0408
12		1.507		0.687	25		0.42	0.0457
13		2.016		0.920	25		0.465	0.0483
14		0.598		0.272	50		0.165	0.0307
15		0.406		0.185	50		0.12	0.0286
16		0.301		0.137	50		0.11	0.0209

Table F5 (a): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2012 (system 5)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.002×10^{-3} (kg) solid content = 0.481	Wt. of F.P.D = 4.093×10^{-3} (kg) solid content = 0.483	Wt. of F.P.D = 6.004×10^{-3} (kg) solid content = 0.495
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.005	0.010	0.040
3	900	0.010	0.035	0.070
4	1800	0.015	0.050	0.075
5	2700	0.025	0.075	0.095
6	3600	0.035	0.085	0.100
7	5400	0.050	0.095	0.135
8	7200	0.055	0.110	0.135
9	10800	0.060	0.120	0.145
10	14400	0.065	0.13	0.200
11	21600	0.080	0.155	0.215
12	36000	0.090	0.160	0.215
13	86400	0.095	0.165	0.220

Table F5 (b): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2013 (system 5)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.004×10^{-3} (kg) solid content = 0.491	Wt. of F.P.D = 4.001×10^{-3} (kg) solid content = 0.477	Wt. of F.P.D = 6.018×10^{-3} (kg) solid content = 0.493
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.010	0.025	0.050
3	900	0.020	0.050	0.075
4	1800	0.030	0.065	0.090
5	2700	0.045	0.075	0.150
6	3600	0.050	0.090	0.135
7	5400	0.055	0.105	0.155
8	7200	0.060	0.125	0.18
9	10800	0.065	0.130	0.185
10	14400	0.070	0.155	0.200
11	21600	0.090	0.170	0.250
12	36000	0.095	0.175	0.255
13	86400	0.095	0.180	0.255

Table F6: Column studies data: Desorption studies with ethanol to recover naringin (system 5)

S.No	Time (s)	C_{td} (kg/m^3)	
		Year 2012	Year 2013
1	180	3.442	3.356
2	3600	3.060	2.817
3	7200	2.700	2.450
4	10800	2.295	1.935
5	14400	1.890	1.568
6	18000	1.575	1.298
7	21600	1.170	0.980
8	25200	0.877	0.686
9	28800	0.540	0.490
10	32400	0.360	0.269
11	36000	0.090	0.171
12	39600	0.022	0.073
13	43200		0.024

Appendix G: Adsorption-desorption data (system 6)

Table G1: Equilibrium data: Adsorption of naringin from dry KPBW on the resin PA-800 (system 6)

S.No	Year	Wt of F.P.D$\times10^{-3}$ (kg)	Solid content	O.D.R $\times10^{-3}$ (kg)	Vol. of Solution $\times10^{-6}$ (m^3)	Initial Conc.C_o (kg/m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	2012	0.500	0.414	0.207	50	0.700	0.425	0.0662
2		0.742		0.307	50		0.365	0.0543
3		1.038		0.430	50		0.290	0.0476
4		1.500		0.622	50		0.200	0.0401
5		2.000		0.829	50		0.145	0.0334
6		0.310		0.128	100		0.600	0.0776
7		0.406		0.168	100		0.575	0.0741
8		0.600		0.249	100		0.550	0.0602
9	2013	0.512	0.409	0.209	50	0.650	0.380	0.0643
10		0.760		0.311	50		0.330	0.0514
11		1.005		0.411	50		0.285	0.0443
12		1.510		0.618	50		0.220	0.0347
13		2.005		0.821	50		0.185	0.0283
14		0.300		0.123	100		0.570	0.0650
15		0.408		0.167	100		0.555	0.0568
16		0.599		0.245	100		0.525	0.0509

Table G2 (a): Kinetic data: Adsorption of naringin from dry KPBW on the resin PA-800 (system 6, year 2012)

Volume of KPBW= 0.450×10^{-3} m^3, Initial naringin conc. = 0.700 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.112×10^{-3} (kg) solid content = 0.464	Wt. of F.P.D = 4.097×10^{-3} (kg) solid content = 0.421	Wt. of F.P.D = 6.000×10^{-3} (kg) solid content = 0.442	Wt. of F.P.D = 8.023×10^{-3} (kg) solid content = 0.437
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.700	0.700	0.700	0.700
2	450	0.660	0.640	0.615	0.595
3	900	0.635	0.610	0.580	0.560
4	1800	0.615	0.575	0.545	0.535
5	2700	0.605	0.555	0.520	0.500
6	3600	0.595	0.530	0.495	0.470
7	5400	0.585	0.515	0.475	0.435
8	7200	0.570	0.495	0.455	0.410
9	10800	0.565	0.480	0.435	0.385
10	14400	0.550	0.465	0.405	0.360
11	21600	0.545	0.450	0.385	0.340
12	36000	0.540	0.445	0.380	0.335
13	86400	0.535	0.440	0.375	0.300

Table G2 (b): Kinetic data: Adsorption of naringin from dry KPBW on the resin PA-800 (system 6, year 2013)

Volume of KPBW= 0.450×10^{-3} m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.098×10^{-3} (kg) solid content = 0.438	Wt. of F.P.D = 4.113×10^{-3} (kg) solid content = 0.441	Wt. of F.P.D = 6.012×10^{-3} (kg) solid content = 0.436	Wt. of F.P.D = 8.000×10^{-3} (kg) solid content = 0.435
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.650	0.650	0.650	0.650
2	450	0.620	0.605	0.580	0.560
3	900	0.600	0.600	0.530	0.525
4	1800	0.585	0.565	0.525	0.510
5	2700	0.550	0.570	0.470	0.440
6	3600	0.565	0.525	0.435	0.415
7	5400	0.550	0.490	0.430	0.380
8	7200	0.540	0.485	0.395	0.335
9	10800	0.515	0.460	0.380	0.325
10	14400	0.525	0.455	0.360	0.320
11	21600	0.530	0.435	0.360	0.290
12	36000	0.515	0.435	0.355	0.285
13	86400	0.510	0.430	0.350	0.280

Table G3 (a): Fixed bed column data: Adsorption of naringin from dry KPBW on the resin PA 800 (system 6, year 2012)

Initial naringin conc. (C_o) =0.700 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	21	140400	0.559
2	3600	0	22	147600	0.609
3	10800	0.001	23	154800	0.647
4	18000	0.010	24	162000	0.700
5	25200	0.016	25	169200	0.729
6	32400	0.021	26	176400	0.749
7	39600	0.030	27	183600	0.800
8	46800	0.040	28	190800	0.813
9	54000	0.050	29	198000	0.849
10	61200	0.066	30	205200	0.861
11	68400	0.089	31	212400	0.890
12	75600	0.129	32	219600	0.914
13	82800	0.164	33	226800	0.923
14	90000	0.203	34	234000	0.934
15	97200	0.251	35	241200	0.949
16	104400	0.286	36	248400	0.960
17	111600	0.347	37	255600	0.971
18	118800	0.409	38	262800	0.983
19	126000	0.464	39	270000	0.991
20	133200	0.529			

Table G3 (b): Fixed bed column data: Adsorption of naringin from dry KPBW on the resin PA-800 (system 6, year 2013)

Initial naringin conc. (C_o) =0.650 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	19	126000	0.502
2	3600	0	20	133200	0.589
3	10800	0.003	21	140400	0.632
4	18000	0.011	22	147600	0.671
5	25200	0.017	23	154800	0.692
6	32400	0.023	24	162000	0.712
7	39600	0.032	25	169200	0.769
8	46800	0.043	26	176400	0.800
9	54000	0.063	27	183600	0.828
10	61200	0.089	28	190800	0.855
11	68400	0.131	29	198000	0.912
12	75600	0.189	30	205200	0.929
13	82800	0.240	31	212400	0.946
14	90000	0.283	32	219600	0.946
15	97200	0.342	33	226800	0.962
16	104400	0.378	34	234000	0.972
17	111600	0.406	35	241200	0.986
18	118800	0.443	36	248400	0.992

Table G4: Equilibrium data: Desorption studies with ethanol to recover naringin (system 6)

Initial naringin conc. (C_{od}) = 0 kg/m^3

S.No	Year	Wt of F.P.D×10^{-3} (kg)	Solid content	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-6} (m^3)	q_{od} (kg/kg)	Final Conc. C_{ed} (kg/m^3)	q_{ed} (kg /kg)
1	2012	0.517	0.438	0.226	25	0.074	0.345	0.0359
2		0.758		0.332	25		0.410	0.0431
3		1.027		0.449	25		0.460	0.0484
4		1.509		0.660	25		0.510	0.0547
5		2.008		0.879	25		0.555	0.0582
6		0.608		0.266	50		0.230	0.0308
7		0.402		0.176	50		0.20	0.0172
8		0.305		0.133	50		0.150	0.0178
9	2013	0.517	0.421	0.217	25	0.068	0.320	0.0312
10		0.756		0.318	25		0.385	0.0377
11		1.008		0.424	25		0.440	0.0420
12		1.508		0.634	25		0.500	0.0483
13		2.006		0.844	25		0.545	0.0518
14		0.607		0.255	50		0.220	0.0249
15		0.408		0.171	50		0.145	0.0257
16		0.316		0.133	50		0.135	0.0172

Table G5 (a): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2012 (system 6)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.001×10^{-3} (kg) solid content = 0.474	Wt. of F.P.D = 4.007×10^{-3} (kg) solid content = 0.456	Wt. of F.P.D = 6.015×10^{-3} (kg) solid content = 0.490
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.010	0.030	0.055
3	900	0.010	0.045	0.060
4	1800	0.035	0.075	0.105
5	2700	0.040	0.080	0.145
6	3600	0.060	0.095	0.140
7	5400	0.070	0.120	0.175
8	7200	0.080	0.140	0.235
9	10800	0.090	0.155	0.240
10	14400	0.095	0.185	0.270
11	21600	0.100	0.200	0.305
12	36000	0.115	0.210	0.315
13	86400	0.125	0.215	0.320

Table G5 (b): Kinetic data: Desorption studies with ethanol to recover naringin for the year 2013 (system 6)

Volume of ethanol = 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.010×10^{-3} (kg) solid content = 0.468	Wt. of F.P.D = 4.005×10^{-3} (kg) solid content = 0.463	Wt. of F.P.D = 6.002×10^{-3} (kg) solid content = 0.501
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.005	0.020	0.045
3	900	0.010	0.025	0.045
4	1800	0.035	0.050	0.090
5	2700	0.030	0.055	0.110
6	3600	0.055	0.080	0.130
7	5400	0.065	0.100	0.155
8	7200	0.075	0.120	0.170
9	10800	0.080	0.145	0.205
10	14400	0.085	0.170	0.270
11	21600	0.095	0.180	0.300
12	36000	0.10	0.190	0.305
13	86400	0.110	0.195	0.310

Table G6: Column studies data: Desorption studies with ethanol to recover naringin (system 6)

S.No	Time (s)	Naringin Conc. C_{td} (kg/m^3)	
		Year 2012	Year 2013
1	180	4.240	3.901
2	3600	3.630	3.391
3	7200	3.180	2.958
4	10800	2.650	2.422
5	14400	2.226	1.836
6	18000	1.828	1.453
7	21600	1.378	1.020
8	25200	1.007	0.841
9	28800	0.795	0.688
10	32400	0.477	0.357
11	36000	0.371	0.280
12	39600	0.185	0.127
13	43200	0.079	0.051
14	46800	0.026	

Appendix H: Adsorption-desorption data with regenerated resin (system 7 and 8)

Table H1 (a): Equilibrium data: Adsorption of naringin from fresh KPBW on the regenerated resin PA-500 (system 7)

Solid content (s) = 0.344, Initial naringin conc. = 0.800 kg/m^3

S.No	Wt of F.P.D $\times 10^{-3}$ (kg)	O.D.R $\times 10^{-3}$ (kg)	Vol. of Solution $\times 10^{-6}$ (m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	0.502	0.173	50	0.610	0.0548
2	0.750	0.258	50	0.545	0.0493
3	1.028	0.354	50	0.480	0.0451
4	1.508	0.519	50	0.365	0.0418
5	2.002	0.690	50	0.320	0.0347
6	0.612	0.211	100	0.685	0.0545
7	0.401	0.138	100	0.720	0.0578
8	0.309	0.106	100	0.740	0.0563

Table H1 (b): Equilibrium data: Adsorption of naringin from fresh KPBW on the regenerated resin PA-800 (system 8)

Solid content (s) = 0.422, Initial naringin conc. = 0.800 kg/m^3

S.No	Wt of F.P.D $\times 10^{-3}$ (kg)	O.D.R $\times 10^{-3}$ (kg)	Vol. of Solution $\times 10^{-6}$ (m^3)	Final Conc. C_e (kg/m^3)	q_e (kg /kg)
1	0.503	0.212	50	0.570	0.0541
2	0.759	0.320	50	0.495	0.0475
3	1.012	0.427	50	0.400	0.0467
4	1.504	0.635	50	0.315	0.0381
5	2.006	0.847	50	0.225	0.0339
6	0.302	0.127	100	0.705	0.0744
7	0.401	0.169	100	0.670	0.0767
8	0.599	0.253	100	0.640	0.0632

Table H2 (a): Kinetic data: Adsorption of naringin from fresh KPBW on the regenerated resin PA-500 (system 7)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.800 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.034×10^{-3} (kg) solid content = 0.395	Wt. of F.P.D = 4.021×10^{-3} (kg) solid content = 0.383	Wt. of F.P.D = 6.102×10^{-3} (kg) solid content = 0.371
		Naringin Conc. $C_t\,(kg/m^3)$		
1	0	0.800	0.800	0.800
2	450	0.785	0.775	0.755
3	900	0.775	0.745	0.710
4	1800	0.760	0.740	0.700
5	2700	0.755	0.730	0.685
6	3600	0.745	0.720	0.660
7	5400	0.740	0.715	0.650
8	7200	0.740	0.695	0.625
9	10800	0.725	0.690	0.630
10	14400	0.720	0.685	0.625
11	21600	0.715	0.675	0.615
12	36000	0.710	0.670	0.610
13	86400	0.705	0.665	0.610

Table H2 (b): Kinetic data: Adsorption of naringin from fresh KPBW on the regenerated resin PA-800 (system 8)

Volume of KPBW= 0.450 $\times 10^{-3}$ m^3, Initial naringin conc. = 0.800 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3	Run 4
		Wt. of F.P.D = 2.001×10^{-3} (kg) solid content = 0.452	Wt. of F.P.D = 4.012×10^{-3} (kg) solid content = 0.447	Wt. of F.P.D = 6.002×10^{-3} (kg) solid content = 0.462	Wt. of F.P.D = 8.091×10^{-3} (kg) solid content = 0.416
		Naringin Conc. $C_t\,(kg/m^3)$			
1	0	0.800	0.800	0.800	0.800
2	450	0.780	0.765	0.735	0.720
3	900	0.765	0.745	0.695	0.690
4	1800	0.750	0.720	0.665	0.610
5	2700	0.730	0.710	0.615	0.590
6	3600	0.725	0.675	0.610	0.545
7	5400	0.700	0.650	0.595	0.520
8	7200	0.680	0.645	0.560	0.505
9	10800	0.675	0.620	0.545	0.485
10	14400	0.660	0.590	0.530	0.445
11	21600	0.655	0.585	0.485	0.410
12	36000	0.650	0.570	0.470	0.400
13	86400	0.645	0.560	0.460	0.395

Table H3 (a): Fixed bed column data: Adsorption of naringin from fresh KPBW on the regenerated resin PA 500 (system 7)

Initial naringin conc. (C_o) =0.800 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	19	126000	0.62
2	3600	0	20	133200	0.664
3	10800	0.006	21	140400	0.722
4	18000	0.017	22	147600	0.767
5	25200	0.026	23	154800	0.788
6	32400	0.032	24	162000	0.806
7	39600	0.043	25	169200	0.817
8	46800	0.062	26	176400	0.865
9	54000	0.095	27	183600	0.879
10	61200	0.112	28	190800	0.891
11	68400	0.153	29	198000	0.898
12	75600	0.221	30	205200	0.914
13	82800	0.291	31	212400	0.928
14	90000	0.364	32	219600	0.944
15	97200	0.428	33	226800	0.957
16	104400	0.494	34	234000	0.965
17	111600	0.541	35	241200	0.979
18	118800	0.581			

Table H3 (b): Fixed bed column data: Adsorption of naringin from fresh KPBW on the regenerated resin PA-800 (system 8)

Initial naringin conc. (C_o) =0.800 kg/m^3

S.No	Time (s)	C_t / C_o	S.No	Time (s)	C_t / C_o
1	0	0	21	140400	0.578
2	3600	0	22	147600	0.611
3	10800	0.003	23	154800	0.658
4	18000	0.008	24	162000	0.704
5	25200	0.020	25	169200	0.750
6	32400	0.033	26	176400	0.781
7	39600	0.039	27	183600	0.823
8	46800	0.048	28	190800	0.875
9	54000	0.063	29	198000	0.881
10	61200	0.090	30	205200	0.901
11	68400	0.110	31	212400	0.923
12	75600	0.156	32	219600	0.940
13	82800	0.235	33	226800	0.960
14	90000	0.295	34	234000	0.973
15	97200	0.325	35	241200	0.978
16	104400	0.374	36	248400	0.986
17	111600	0.418	37	255600	0.989
18	118800	0.460	38	259200	0.991
19	126000	0.485	39	262800	0.991
20	133200	0.515			

Table H4 (a): Equilibrium data: Desorption studies with ethanol to recover naringin (system 7)

Initial naringin conc. in ethanol (C_{od}) = 0 kg/m^3, q_{od} = 0.058 kg/kg, solid content = 0.456

S.No	Wt of F.P.D×10^{-3} (kg)	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-6} (m^3)	Final Conc. C_{ed} (kg/m^3)	q_{ed} (kg /kg)
1	0.502	0.229	25	0.270	0.0292
2	0.754	0.344	25	0.325	0.0351
3	1.014	0.462	25	0.360	0.0392
4	1.505	0.687	25	0.410	0.0437
5	2.028	0.925	25	0.455	0.0464
6	0.601	0.274	50	0.210	0.0204
7	0.407	0.185	50	0.145	0.0196
8	0.302	0.137	50	0.135	0.0097

Table H4 (b): Equilibrium data: Desorption studies with alcohol to recover naringin (system 8)

Initial naringin conc. in ethanol (C_{od}) = 0 kg/m^3, q_{od} = 0.070 kg/kg, solid content = 0.467

S.No	Wt of F.P.D×10^{-3} (kg)	O.D.R ×10^{-3} (kg)	Vol. of Solution ×10^{-6} (m^3)	Final Conc. C_{ed} (kg/m^3)	q_{ed} (kg /kg)
1	0.514	0.240	25	0.300	0.0387
2	0.753	0.351	25	0.355	0.0447
3	1.007	0.470	25	0.410	0.0482
4	1.502	0.701	25	0.475	0.0530
5	2.001	0.934	25	0.510	0.0563
6	0.614	0.286	50	0.240	0.0281
7	0.405	0.189	50	0.195	0.0184
8	0.301	0.140	50	0.135	0.0219

Table H5 (a): Kinetic data: Desorption studies with ethanol to recover naringin (system 7)

Volume of ethanol = 0.450×10^{-3} m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.002×10^{-3} (kg) solid content = 0.484	Wt. of F.P.D = 4.005×10^{-3} (kg) solid content = 0.507	Wt. of F.P.D = 6.025×10^{-3} (kg) solid content = 0.474
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.005	0.015	0.035
3	900	0.010	0.030	0.060
4	1800	0.030	0.045	0.080
5	2700	0.040	0.070	0.100
6	3600	0.050	0.085	0.125
7	5400	0.050	0.115	0.145
8	7200	0.065	0.125	0.175
9	10800	0.075	0.145	0.230
10	14400	0.080	0.150	0.225
11	21600	0.085	0.175	0.230
12	36000	0.090	0.180	0.250
13	86400	0.090	0.185	0.255

Table H5 (b): Kinetic data: Desorption studies with ethanol to recover naringin (system 8)

Volume of ethanol = 0.450×10^{-3} m^3, Initial naringin conc. in ethanol = 0 kg/m^3

S.No	Time (s)	Run 1	Run 2	Run 3
		Wt. of F.P.D = 2.007×10^{-3} (kg) solid content = 0.478	Wt. of F.P.D = 4.001×10^{-3} (kg) solid content = 0.486	Wt. of F.P.D = 6.019×10^{-3} (kg) solid content = 0.455
		Naringin Conc. C_{td} (kg/m^3)		
1	0	0	0	0
2	450	0.015	0.040	0.060
3	900	0.025	0.050	0.080
4	1800	0.035	0.070	0.100
5	2700	0.050	0.090	0.125
6	3600	0.060	0.120	0.140
7	5400	0.075	0.125	0.170
8	7200	0.080	0.150	0.200
9	10800	0.085	0.175	0.230
10	14400	0.090	0.180	0.240
11	21600	0.095	0.190	0.255
12	36000	0.115	0.195	0.260
13	86400	0.120	0.200	0.265

Table H6 (a): Column studies data: Desorption studies with ethanol to recover naringin (system 7)

S.No	Time (s)	C_{td} (kg/m^3)
1	180	3.920
2	3600	3.388
3	7200	3.108
4	10800	2.436
5	14400	1.792
6	18000	1.484
7	21600	1.092
8	25200	0.812
9	28800	0.504
10	32400	0.336
11	36000	0.252
12	39600	0.056
13	43200	0.028

Table H6 (b): Column studies data: Desorption studies with ethanol to recover naringin (system 8)

S.No	Time (s)	C_{td} (kg/m^3)
1	180	4.482
2	3600	4.097
3	7200	3.630
4	10800	2.970
5	14400	2.282
6	18000	1.677
7	21600	1.017
8	25200	0.687
9	28800	0.412
10	32400	0.220
11	36000	0.055
12	39600	0.027

Appendix I1: Calculation of naringin adsorption equilibrium and kinetics

(A) Equilibrium studies: (Refer to observation no-1, Table B1**)**

Amount of naringin adsorbed by the rein PA-500 (system 1, year 2012) =

$$q_e = \frac{V(C_o - C_e)}{w} \qquad (3.1)$$

$$q_e = \frac{0.050\times10^{-3}(0.810-0.540)}{0.193\times10^{-3}} \quad = 0.0698 \text{ kg of naringin adsorbed/kg of dry resin}$$

(B) Kinetic studies:

Sample calculations for calculating q_t and u_t (for system 1, Run1, Table B4 (a))

Amount of naringin picked up by the resin PA-500 at time t =450 s

$$q_t = \frac{V(C_t - C_e)}{w}$$

$$q_t = \frac{0.450\times10^{-3}(0.810-0.770)}{1.504\times10^{-3}} \quad = 0.0119 \text{ kg of naringin adsorbed/kg of dry resin}$$

The fractional attainment of equilibrium at time t = 450 s

$$u_t = \frac{(C_o - C_t)}{(C_o - C_e)} \qquad (4.12)$$

$$u_t = \frac{(0.810-0.770)}{(0.810-0.600)} \quad = 0.258$$

Appendix I2

Sample calculations for calculating K , β and ψ (for system 1, year 2012, run 1)

C_o = 0.810 kg/m^3, q_e = 62.81 kg/m^3, from figure 5.15 Slope = 2.51×10^{-4}/s

$$Slope = \frac{2K\ D_P\ \varepsilon\ C_0}{5(1-\varepsilon)q_e R_P^2}$$

D_P = 1.032×10^{-10} m^2/s, R_P = 0.375×10^{-3} m and ε = 0.39

Substituting for the values for slope D_P , ε , C_0 , q_e , and R_P ; in equation

K = 103.84

Substituting value of K in relation

$$\log_{10} K = 1.357 \exp (0.207 \log_{10} \beta) \qquad (4.25)$$

β = 81.8

$$\psi = \beta \frac{C_0}{q_e} = 81.8 \times \frac{0.810}{62.81} = 1.05$$

Sample calculations for generation of C_t from value of ψ

C_o = 0.810 kg/m^3, C_e = 0.610 kg/m^3 and q_e = 62.81 kg/m^3

D_P = 1.032×10^{-10} m^2/s, R_P = 0.375×10^{-3} m and ε = 0.39

Taking representative value of $\psi = 1.57$

$$\beta = \psi \frac{q_e}{C_0} = 1.57 \times \frac{62.8}{0.81} = 122.3$$

Substituting this value of β in relation

$\log_{10} K = 1.357 \exp(0.207 \log_{10} \beta)$

$K = 123.18$

Substituting for the values K, D_P, ε, C_0, q_e, R_P and t in equation (4.13), the value of u_t at different times are calculated

$$u_t = 1 - \frac{1}{\left(1 + \frac{2}{5} \frac{KD_p \varepsilon C_0}{(1-\varepsilon)\, q_e R_p^2}\, t\right)^{3/2}} \qquad (4.30)$$

u_t at time 450 (s) = 0.172

The value of C_t calculated $\quad C_t = C_o^{\mathrm{I}} - u_t (C_o^{\mathrm{I}} - C_e)$ (4.32)

and $C_o^{\mathrm{I}} = C_o - \frac{kq_e w}{V}$ (4.34)

$= 0.810 - \frac{0.064 \times 0.078 \times 1.504 \times 10^{-3}}{0.450 \times 10^{-3}} = 0.801$

$C_t = 0.801 - 0.158(0.801 - 0.610) = 0.768$

Appendix I3

Fixed bed adsorption column studies:

Sample calculations for calculating t_t , q_{total} , q_s , H_{UNB} , **and** MTZ (system 1, year 2012)

The breakthrough time (t_b) = 66.6×10^3 s (from the fig.5.22)

Time equivalent to total or stoichiometric capacity is

$$t_t = \int_o^\infty \left(1-\frac{C_t}{C_o}\right) dt \qquad (4.35)$$

$$= \quad 157.6 \times 10^3 \text{ s}$$

$\int_o^\infty \left(1-\frac{C_t}{C_o}\right) dt$ = Area above the curve = 157.6×10^3 s (from the fig.5.18)

The total adsorbed naringin quantity q_{total} (g) in the column is calculated as follows

$$q_{total} = Q \times C_o \times \int_o^\infty \left(1-\frac{C_t}{C_o}\right) dt \qquad (4.38)$$

q_{total} = $3.3\times10^{-8} \times 0.810 \times 157.6 \times 10^3$ = 4.25 g

Saturation loading capacity of the adsorbent bed or equilibrium naringin uptake q_s (kg/kg) in the column

$$q_s = \frac{q_{total}}{w} \qquad (4.39)$$

q_s = 4.25/(158×0.349) = 0.077 kg/kg

The unused bed length (H_{UNB})

$$H_{UNB}=\left(1-\frac{t_u}{t_t}\right)H_T \tag{4.40}$$

$$H_{UNB}=\left(1-\frac{7.2\times10^3}{66.6\times10^3}\right)1.2 \ = 0.692 \text{ m}$$

Mass transfer zone (MTZ)

$$MTZ \ = \ \frac{H_T}{\left(\frac{t_t}{t_t-t_b}\right)-\gamma} \tag{4.41}$$

where $\gamma=\frac{t_u}{t_t}=\frac{7.2\times10^3}{157.6\times10^3}$ = 0.0.0456

$$MTZ \ = \ \frac{1.2}{\left(\frac{157.6\times10^3}{157.6\times10^3-66.6\times10^3}\right)-0.0456} \ = 0.711 \text{ m}$$

Appendix J: Calculation of naringin desorption equilibrium, kinetics and fixed bed column

(A) Equilibrium studies:

Amount of naringin desorbed from the rein PA-500 into ethanol (system 1, year 2012) =

$$W^{I}(q_{od} - q_{ed}) = V_e C_{ed} \quad (3.2)$$

$$q_{ed} = q_{od} - \left(\frac{V_e C_{ed}}{W^{I}}\right)$$

$$q_{ed} = 0.078 - \left(\frac{0.025\times10^{-3}\times0.340}{0.234\times10^{-3}}\right) = 0.0417 \text{ kg of naringin/kg of dry resin}$$

(B) Kinetic studies:

Sample calculations for calculating $C_{\max}$, u_d and D_{ed} (for system 1, Run1)

$$C_{\max} = \frac{q_{od} W^{I}}{V_e} \quad (4.44)$$

$$= \frac{0.078\times0.995\times10^{-3}}{0.45\times10^{-3}} = 0.172$$

$$u_d(t) = \frac{C_{td}}{C_{\max}} \quad (4.44)$$

= 0.057

From figure 5.29 Slope = 2.14×10^{-5}, $R_P = 0.375\times10^{-3}$ m

$$\text{Slope} = \frac{\pi^2 D_{ed} t}{R_p^2}$$

$D_{ed} = 9.60\times10^{-13}\ m^2 s^{-1}$

Sample calculations for generation of C_{td} from the average value of D_{ed}

Taking the average value of $D_{ed} = 9.75\times10^{-13}\ m^2 s^{-1}$ the value of $u_d(t)$ was calculated by the relation (4.43) $\ln\left(\frac{1}{1-u_d^2(t)}\right)=\frac{\pi^2 D_{ed} t}{R_p^2}$

$u_d(t)$ = 0.098 (t= 450 s)

From $u_d(t)$ the value of C_{td} calculated by the relation 4.44

C_{td} = 0.098×0.172 = 0.017

(C) Fixed bed adsorption column studies:

The total naringin desorbed from the column = $Q_e \times \int_o^t (C_{td})\, dt$ (4.45)

$= 3.3 \times 10^{-8} \times 86.617 \times 10^6$

= 2.88 g

$\int_o^t (C_{td})\, dt$ = Area below the curve = 95323.5 kg/m^3 s (from the fig.5.29)